Economy and Environment Program
for Southeast Asia
22 Cross Street
#02-55 South Bridge Court
Singapore 048421
Tel: (65) 6438 7877
Fax: (65) 6438 4844
E-mail: eepsea@idrc.org.sg
Web site: www.eepsea.org

RESEARCH REPORT

No. 2009-RR6

Cost-Effectiveness of Policy Options for Sustainable Wetland Conservation: A Case Study of Qixinghe Wetland, China

Wu Jian, Wang Xiaoxia, Niu Kunyu, and Li Shushan
School of Environment & Natural Resources
Renmin University of China
Research Bldg A-803,
No 59 Zhongguancun St, Haidian District
Beijing 100872 PR China
Phone: 86 10 6251 1939
Email: zhxwj@263.net; jianwu@ruc.edu.cn

This EEPSEA study from China assesses a number of potential policy options that could help protect the Qixinghe Wetlands which lie in the country's Sanjiang Plain. The region's wetlands are the most important breeding ground and migration route for waterfowls in Northeastern Asia, and provide a habitat for numerous species of wildlife. They face many challenges, one of the most significant being the disruption of the water supplies that feed them. Agriculture is the main cause of this problem, accounting for more than 75% of the total water use in the area. As the flow of water entering the wetlands is diverted, its ecosystem is damaged. This problem affects many wetland areas in China.

The study is the work of a team of researchers from Renmin University of China, led by Wu Jian. It assesses the best way to reduce the conflict between wetland water needs and off-site water use. Its overall aim is to help policy makers decide how best to balance economic development with wetland conservation. The study recommends that the local government should reconstruct the irrigation system in the area surrounding the Qixinghe Wetlands as soon as possible. At the same time, training on water saving practices should be promoted amongst farmers. The study also suggests how these two key policies could be supported by improvements in conservation funding and management.

Published by the Economy and Environment Program for Southeast Asia (EEPSEA)
Tanglin PO Box 101, Singapore 912404 (www.eepsea.org)
tel: +65-6235-1344, fax: +65-6235-1849, email: eepsea@idrc.org.sg

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ISBN: **978-981-08-4768-5**

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November, 2009

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ACKNOWLEDGEMENTS

This study was supported by a research grant from the Economy and Environment Program for Southeast Asia (EEPSEA). We thank Dr. Herminia Francisco, Ms. Catherine Ndiaye and other EEPSEA staff for their support; they made this study possible.

We gratefully acknowledge the valuable guidance and continuous encouragement from Dr. David James throughout this research study. Our thanks also go to Prof. Zhang Shiqiu and Prof. Ma Zhong for encouraging us to initiate this study. We further gratefully acknowledge all the other resource persons for their precious comments.

Last but not least, I wish to sincerely thank the Baoqing Water Affairs Bureau and Qixinghe National Wetland Nature Reserve Bureau for their generous support during our field work.

COST-EFFECTIVENESS OF POLICY OPTIONS TO REDUCE OFF-SITE WATER USE FOR SUSTAINABLE WETLAND CONSERVATION: A CASE STUDY OF QIXINGHE WETLAND, CHINA

Wu Jian, Wang Xiaoxia, Niu Kunyu, and Li Shushan

EXECUTIVE SUMMARY

A primary cause of the loss of wetlands in China is the competition for water between the wetlands and their surrounding areas. The purpose of this study was to explore cost-effective policy options to reduce off-site water use to support the sustainable conservation of the Qixinghe Wetland in Sanjiang Plain. This study calculated the cost-effectiveness of four policy options and compared their trade-offs by using the multi-criteria method. Option I was to reconstruct the irrigation systems in the surrounding areas of the wetland where agriculture competed with the wetland for water. This option was the government's most favored strategy, but was only the third most cost-effective. Option II was to construct a dam to store and control floodwaters to relieve seasonal water scarcity. This option was the most reliable in terms of saving water. It was also the farmers' most favored strategy, but it imposed a high cost on the local government and therefore did not receive strong support from the authorities. Option III was to promote the adoption of water-saving practices by providing farmers with training courses. This strategy was the most cost-effective, but was less effective in saving water. This option also did not receive strong support from the farmers and government and, was therefore not likely to be selected. In Option IV, water saving was achieved by converting some paddy fields to dryland crops. This option turned out to be politically unfeasible because it was the least preferred strategy of the government and farmers. It was also the least effective in saving water. If equal weights were given to all four criteria, Option I would have the best overall performance while Option IV would be the least preferred strategy. Based on these conclusions, we made suggestions on how the the local government should tackle the wetland's water shortage problem and how the central and provincial governments could solve such a problem at the macro level.

1. INTRODUCTION

1.1 Problem Statement

Sanjiang Plain is a vast, low-lying alluvial floodplain in the northeastern segment of Heilongjiang Province. It is situated at the confluence of three rivers: the Heilong (Amur), the Wusuli (Ussuri), and the Songhua.

The plain has high ecological significance nationally, regionally, and globally. The wetlands perform crucial ecological functions, maintaining the hydrological balance, regulating water flow, mitigating floods, and purifying the water and air. The Sanjiang Wetlands are the most important breeding grounds and migration routes of migratory waterfowls in northeastern Asia and provide habitats for numerous species of wildlife. Thirty-seven wildlife vertebrate species ranked by the World Conservation Union (IUCN) as globally threatened are found in these wetlands, 20 of which are wetland birds. For some of these wetland birds, the plain represents a significant portion of their remaining global habitat area (ADB 2004).

However, these wetlands have been dramatically reduced by agricultural development during the last 50 years (Figure 1.) The Sanjiang Plain’s high-quality soil and favorable climate for grain production has made it the focus of government agricultural development programs beginning from the early 1950s. The central government has strongly encouraged settlement in and reclamation of the wetlands, and the development of large-scale farming in the plain. This long-term focus on agricultural production in the plain has exacerbated the conflict between ecological conservation and agricultural development.

Water is the key factor affecting the value of wetlands. Recent statistics show that agriculture has consumed more than 75% of the water resources in the plain and it is predicted that its irrigated acreage under paddy will be doubled in the next 15 years which will require—under current farming practices—increasing quantities of irrigation water, leading to a sharp drop in the water table in the wetlands (Wang et al. 2005).

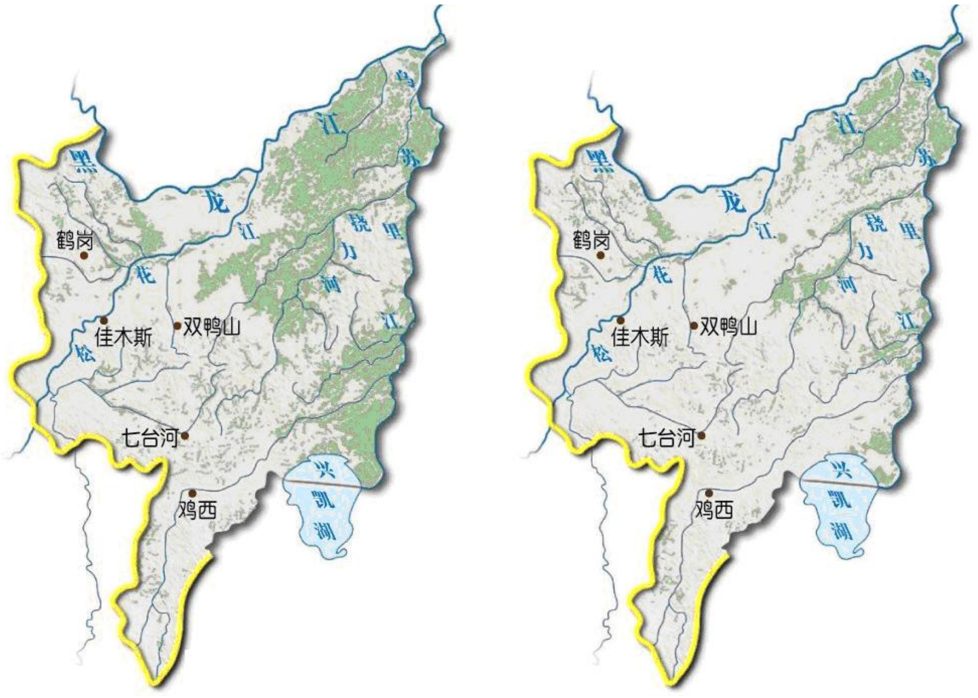

Figure 1. Decrease in wetland area in Sanjiang Plain from the 1950s to 2005

Source: Li (2008)

Note: The wetland area was 3.7 million ha in 1950’s (left) and 0.92 million ha in 2005 (right).

The conservation of the Sanjiang wetlands raises typical conservation issues in China. Wetland ecosystems have traditionally encountered threats from the direct consumption of their precious resources by local residents, but the more important and indirect threats come from the water demands driven by the overall development strategy of the country, including agricultural development, urbanization and industrialization.

This study explored policy options to reduce the off-site water use in the Qixinghe Wetland in Sanjiang Plain to support better policy decisions to achieve the multiple objectives of wetland conservation, agricultural development, and water resource management. We chose the Qixinghe Wetland and its surrounding area as our case study site in order to collect strong evidence to understand the real water conflict issues and explore concrete cost-effective ways of reducing off-site water use for sustainable wetland conservation.

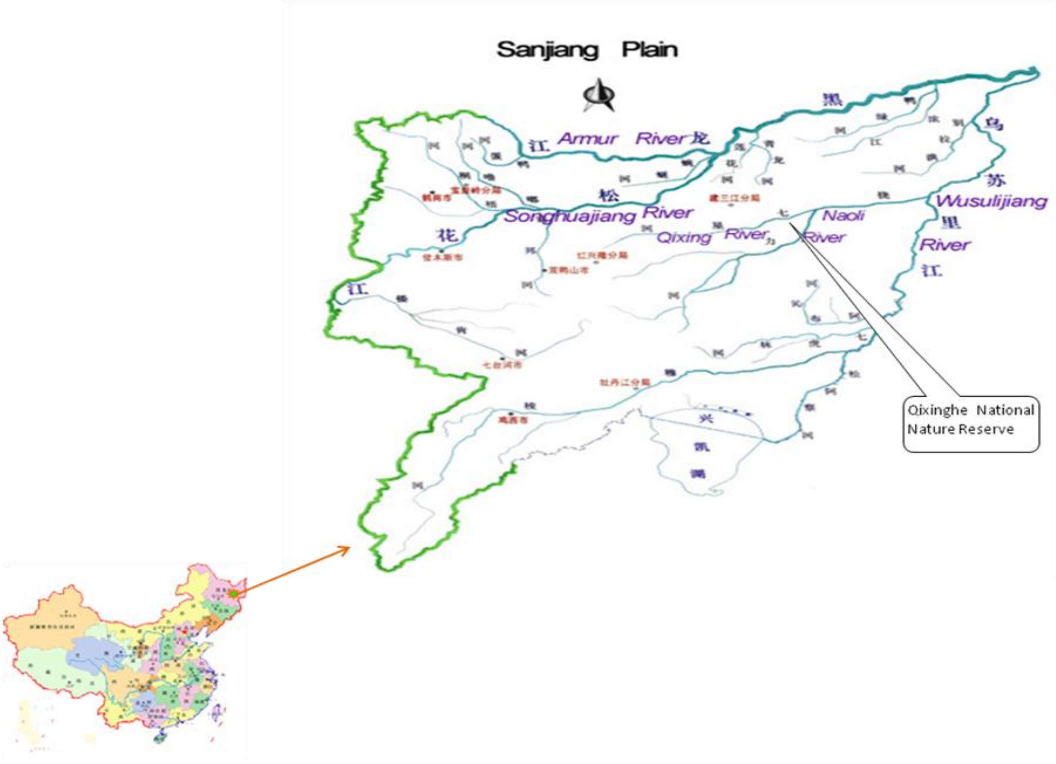

Figure 2. Geographical location of the Qixinghe National Nature Reserve in Sanjiang Plain

The Qixinghe Wetland, on the right bank of the Qixinghe River with a total area of 200 sq. km, is a typical inland freshwater wetland in Sanjiang Plain, Heilongjiang Province, northeast China, performing crucial ecological functions (Figure 2). For the purpose of wetland ecosystem conservation, the Qixinghe National Nature Reserve (QNNR) was founded in the year 2000. Since then, according to the China Nature Reserves Regulation (1994), activities that directly affected the Qixinghe Wetland have been prohibited, such as the expansion of farming and fishing, and the harvesting of the reefs and other raw materials, while activities that indirectly affect the wetland still remain, among which competing water use is the most important. There have not been any measures taken to deal with the water supply issue for the wetland. Therefore, although all conservation efforts within the QNNR have been fully implemented, without policies or plans to confront the threats from outside the wetland, the Qixinghe Wetland will not be saved.

The Qixinghe Wetland is already suffering from water shortage. Data collected on surrounding wells show that the water table in the Inner Qixinghe Watershed has dropped by 2.5 meters from 1997-2005; some wells even had a decrease of 7-12 meters (Xia and Wen 2007). Water conflicts arise especially during the irrigation season.

In order to mitigate the water conflict between wetland conservation and off-site water use, a detailed assessment of policy options was done through a cost-effectiveness analysis (CEA) to help policy-makers make better decisions on how to balance economic development and wetland conservation.

1.2 Research Objectives

The overall objective of the study was to explore cost-effective approaches in reducing off-site water use for sustainable wetland conservation under the real policy and institutional context in China.

The specific objectives were:

a) To establish a profile of water problems encountered in wetland conservation and associated water use patterns.

b) To explore and propose alternative policy options to manage off-site water uses for the purpose of wetland conservation.

c) To analyze and assess the impacts of these options in terms of their ecological effects and economic implications on different stakeholders.

d) To provide recommendations on how to implement the policy options with acceptable and properly distributed costs of conservation.

1.3 Research Sites

The geographical scope of this study included the Qixinghe Wetland and its surrounding areas where there were users competing directly with the wetland for water. To be exact, the research sites were: the Qixinghe National Nature Reserve, Baoqing County, the WuJiuQi (WJQ) state-owned farm on the right bank of the Qixinghe River, and the Youyi state-owned farm on the left bank, as shown in Figure 3.

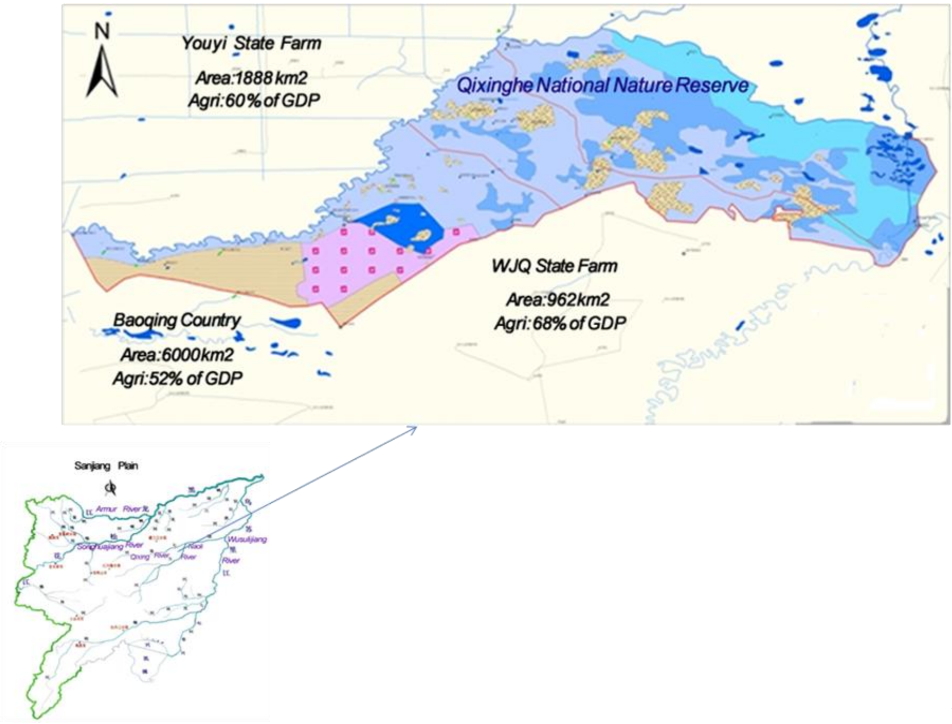

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Figure 3. The research sites

The areas surrounding the wetland comprised an agricultural township, a village and state-owned farms. Baoqing County had a economic structure of 54% : 22% : 24% among the agriculture, industry and service sectors in 2007 while the two state-owned farms were dominated by agriculture. In 2007, the farmers in Baoqing County had a net annual income of 4,799 RMB (over 90% of which came from agriculture), higher than the national average of 4,140 RMB. Urban citizens had a dispensable income of 9,602 RMB in 2007, lower than the national average of 13,786 RMB. The two state farms had even higher agricultural productivity than Baoqing County. The basic economic data of Baoqing County, the WJQ state farm, and the Youyi state farm are shown in Table 1.

Table 1. Socio-economic indices of the research sites (2004)

Research site	**Area (sq. km)**	**Total population (1,000)**	**Gross Domestic Product (in 10,000 RMB)**				**Farmland utilization (hectare)**	
			Total	**Primary industry**	**Second industry**	**Tertiary industry**	**Plantation**	**Paddy**
WJQ State Farm	962.05	30.4	39,360	26,670	4,193	8,497	26,714	10,680
Youyi State Farm	1,888.12	102.9	85,837	51,568	12,822	21,447	59,037	14,530
Baoqing County	6,003.05	302.0	282,196	146,477	63,342	72,377	157,448	1,1707
Total	8,853.22	435.3	371,969	224,715	80,357	102,321	243,199	36,917

Sources: Baoqing Statistics Bureau 2005; Heilongjiang State Farm Bureau 2005

2.0 WATER DEMAND FOR WETLAND CONSERVATION

2.1 Water Resources and Utilization of the Watershed

2.1.1 Amount of water resources

In the Inner Qixinghe Watershed (where the QNNR is located), the long-term average annual surface water quantity is 351 million m^3 while the groundwater quantity is 246 million m^3. Neglecting the double-counting between them, the total long-term average annual water quantity in the watershed is 597 million m^3. The average water resource is about 4,650 m^3 per capita and 5,550 m^3/ha, much higher than the country average (Xia and Wen 2007).

The average surface water resource quantity of the QNNR is 42.9 million m^3 while the average groundwater resources amount to 13.9 million m^3. The long-term average water quantity of the reserve is 56.8 million m^3. The surface water resources of the QNNR come from upstream of the Inner Qixinghe River and from precipitation and its runoff while the groundwater is recharged mainly by rainfall (Xia and Wen 2007).

The interaction between groundwater and surface water is very complicated and difficult to assess due to the lack of essential hydrographic and geological records. In this study, we presumed that the impact of surface water and groundwater usage were the same. This assumption is reasonable from a long-run hydrological perspective.

2.1.2 Water utilization

The overall water utilization amount of the whole Qixinghe Watershed is 540 million m^3 in which the surface water utilization amount is about 92 million m^3 with a utilization rate of 18.8% and the groundwater utilization amount is about 448 million m^3 with a utilization rate of 81.4% (Xia and Wen 2007). Generally, water supply can meet economic demand, but the ecological water demand has not been taken into account in these calculations.

As for the distribution of water among water-using sectors, taking Baoqing County as an example, in 2007, the total amount of water use in the county was 141 million m^3 in which agriculture used 105 million m^3 of water (74.6% of total use); industries used 32.7million m^3 (23.1% of total use); and households used 3.2 million m^3 (2.3% of total use) (personal communication with the Water Affairs Bureau of Baoqing Country in January, 2008). Since the WJQ and Youyi state farms are dominated by agriculture, the overall water utilization level for the whole study area is expected to be more than that of just Baoqing County.

2.2 Factors Influencing Wetland Water Shortage

As mentioned in Section 1 of this report, the Qixinghe Wetland has been suffering from a water shortage problem. According to the ADB (2007), the factors that contribute to reduced water level in the wetland are as follows in order of importance:

a) Increasing off-site water use.

b) Figure 3 shows that surrounding areas of the QNNR compete with it for water. According to the Baoqing County's planning estimation (Water Affairs Bureau of Baoqing County 2005), from 2006-2010, the total water demand is expected to increase from 119 million m^3 to 206 million m^3, in which agricultural usage will increase from 92 million m^3 to 153 million m^3. The more important but indirect effect is the development of the drainage and irrigation system driven by agricultural expansion.

c) Irrigation and drainage systems. There is no large hydrological project in the upstream part of the Inner Qixinghe River, but the development of the drainage system along with the expansion of paddy fields has damaged the wetland's capacity to retain water. The wetland is situated in a low-lying area where water resources converge at a slow flow rate. With the expansion of agriculture along the river, however, the water drainage system was fully developed. The system accelerates the rate at which water is drained from this region and then irrigation systems divert the water according to various economic uses.

d) Reduced water inflow. First, water inflow from upstream and precipitation are the only two sources of water supply, but the natural water supply or water inflow from upstream and precipitation have reduced in recent years. Secondly, the flood control banks or dams which were constructed to protect economic projects prevent small and medium-scale flood waters from entering the wetland and this contributes a lot to the water shortage in the wetland.

2.3 Estimation of the Water Demand of the QNNR

In general, the water shortage in the Qixinghe Wetland has been recognized. However, authoritative quantitative estimations of the situation and the wetland water demand are yet unavailable.

In Sanjiang Plain, some researchers have calculated the ecological water demand based on the geographical and ecological situation of the plain (Guo et al. 2004; Cui et al. 2005; SongLiao Water Resources Commission 2005). Based on their findings, the land types that should be involved in calculating the ecological water demand of the wetland are reservoirs/lakes, water swamps, marshes, and reed wet soil. By using the methodology developed by the study on the Zhalong Wetland (SongLiao Water Resources Commission 2005), and taking into account the rainfall, evaporation rate, soil infiltration capability and other factors of the Qixinghe River Basin, Xia and Wen (2007) found that the depth of water in the core zone of the wetland should be kept at about 20-25 cm while the depth of water in the buffer zone should be 15-20 cm in order to protect the QNNR and the basin wetland habitat from degradation. According to these requirements and deducting the existing water surface area, the total ecological water demand for the QNNR was estimated to be 38.17 million m^3 (Xia and Wen 2007).

According to satellite images and the QNNR Management Bureau, the amount of water that needs to be recharged to maintain the wetland is 20% of the total ecological water demand. So this study set 8 million m^3 as the target amount of water to be recharged to the wetland through policy intervention.

3.0 KEY SECTOR FOR REDUCING OFF-SITE WATER USE

3.1 Agriculture as the Key Sector in Water Saving

This study made a comparative analysis of various sectors closely related to water use. The three major sectors were industry, agriculture and urban livelihoods. Agriculture was identified to be the key sector based on the following reasons.

a) Compared with industry and urban livelihoods, agriculture was the largest water user, accounting for more than 75% of total water use in the research area.

b) There were severe conflicts between agricultural water use and wetland ecological water demands. Firstly, agricultural water demand was highest in spring, which is also the most ‘water-demanding’ season for the wetland. Secondly, along with the development of paddy fields, the irrigation and drainage systems have greatly accelerated the rate that water is drained from the wetland. Embankments built for flood control and drainage canals prevent flood waters from recharging the wetland.

c) There is a lot of room left for water-saving from agriculture. According to the Water Affairs Bureau of Baoqing County, the water consumption for paddy growing is about 12,000-13,500 m^3/ha in the county whereas the standard for Heilongjiang Province is only 6,750 m^3/ha. While the bureau has implemented strong controls over industrial water consumption, the control over agricultural water use is still very weak.

d) Water-saving from the agricultural sector has a much lower opportunity cost. Calculated with the statistics data of 2006 (Baoqing Statistics Bureau 2007), the agricultural output value is 11.56 RMB/m^3 of water consumed and the industrial output value is 27.32 RMB/m^3 of water.

3.2 Water Utilization in the Agricultural Sector

This section focuses on farmers’ awareness, attitudes, and behavior, and their preferences in water resource utilization and management which were measured by two indicators: behavior and consciousness. The findings of our survey are given in the following sub-sections according to the questions in the survey.

All the data cited in this report comes from the household survey conducted by research team in July 2008 through focus group discussions and structured interviews with farmers in Baoqing County and the WJQ state-owned farm, and officials of the Heilongjiang Provincial Hydraulic Design Institute, Baoqing Agriculture Technology Promotion Center, Baoqing Water Affairs Bureau, and the Qixinghe National Nature Reserve Management Bureau. Two hundred and one (201) households were interviewed in the survey. It should be noted that the survey did not include the Youyi state-owned farm due to feasibility constraints. Given that the overall conditions of the two state-owned farms were quite similar, the WJQ farm could be taken as being representative of both. The sample of 201 households represented about 14% of the overall number of households (margin of error of 6.5%) and about 16% of the total in terms of the paddy acreage.

As for the sample method, considering the differences in paddy production between the villages and the state farms, the stratified sampling method was applied. The first stratum consisted of irrigation districts in the rural areas in Baoqing County and the second stratum comprised the WJQ state farm. The samples were allocated based on the area of paddy fields; about 30% of the samples were from the rural areas and 70% from the state farm. In each stratum, the simple random sampling method was applied.

3.2.1 Water-use behavior

(a) How have the paddy field areas changed in the last 10 years?

The paddy fields in the surrounding areas of QNNR have developed rapidly in the past 10 years. Since 1995, paddy field areas in Baoqing County, WJQ state farm and Youyi state farm have significantly increased by 111%, 105% and 248%, respectively, mainly due to policies encouraging their development and the high market price of rice (Table 2).

Table 2. Growth rate of paddy field areas (1995-2005)

	Area(ha)		**Growth Rate**
	1995	**2005**	
Baoqing County	5,644	11,933	**111%**
WJQ SF	3,067	10,680	**248%**
Youyi SF	9,096	18,667	**105%**

Source: Baoqing Statistics Bureau (1996, 2006); Heilongjiang State Farm Bureau (1996, 2006)

(b) Where do the farmers get water for rice production from?

Our survey found that 28% of the people (56/200 households) completely relied on surface water (from rivers and/or the wetland), 31.5% (63/200 households) only used groundwater, and 40.5% (81/200 households) used both surface water and groundwater. Generally, the farmers tended to use suface water when it was available because the higher temperature of the surface water was more favorable for rice cultivation.

(c) What has encouraged the development of paddy fields?

Generally, local agricultural professionals have found that a farmer’s choice of planting will depend on factors like resource availability (particularly land and water), the market price of crops, planting experience, etc.

The survey results indicated that there existed differences between the rural areas in Baoqing County and the WJQ state farm as Table 3 shows. In the rural areas, interviewees put land conditions and water resources as the two most important factors which affected their planting choices. This means paddy growing in rural areas was significantly affected by the natural environment. On the other hand, the WJQ farm interviewees were significantly more concerned about the state farm's collective planting plan and market prices.

Table 3. Factors having an impact on farmers' planting choices

Ranking	Baoqing County	Scores	Ranking	WJQ Farm	Scores
1	Land suitable for rice planting	128	1	Farm plan of plantation	194
2	Abundant water resources	60	2	Better returns	155
3	Lower natural risks, stable output	53	3	Land suitable for rice planting	138
4	Better returns	45	4	Planting experience and capability	130

Note: The subjective weighting method was applied to assess the importance of the factors. If the factor ranked the first, it got a score of 4; if it ranked second, it would get a score of 3; third ranking scored 2 and fourth ranking scored 1. The gap between the total scores indicated the differences in the importance of the factors.

3.2.2 Water-saving consciousness

(a) How do farmers understand and feel towards the change in local water resources?

Our survey showed that about 54% (107/198 households) of the people were concerned about the decrease in water resources. Over 24% (24.2% or 48/198 households) did not think that there was really a scarcity; 21.2% (42/198 households) was not clear about the water situation, and 0.5% (1/198 households) was not concerned at all. This indicated that there was no consensus among the farmers on the local water situation. One possible reason was that they lived in a low area around the wetland and it was relatively easy to get water as compared to other areas.

(b) What do farmers believe is contributing to the decrease in water resources?

Decreased inflow from upstream and precipitation, and the rapid increase in water demand from agriculture and industry were cited as the two major reasons for the decrease in water resources.

(c) Do farmers consider it necessary to undertake water-saving practices?

The survey showed that the local farmers had low water-saving skills and many did not think water-saving was necessary. About 36.8% of the respondents (67/182 households) thought that local water use was efficient, 48.4% (88/182 households) thought it was normal, and only 14.8% (27/182 households) thought it is not efficient. About 61% of the respondents (111/182 households) thought it was necessary to undertake water-saving practices; 31.9% (58/182 households) thought such practices were unnecessary because there was no water wastage; and 7.1% (13/182 households) said it was hard to say whether water-saving was necessary or unnecessary. Most of the interviewees (80.6% or 112/139 households) had never done any trials on water-saving practices while 89% (178/200 households) had never had the opportunity to get water-saving training.

(d) What kind of factors influence the efficiency of water use?

The factors influencing the efficiency of water use were identified through a pretest. Tables 4 and 5 show the results. The poor hydrological system and land features were the two top factors leading to low efficiency in water use.

Table 4. Factors affecting water-use efficiency in the rural areas of Baoqing County

Ranking	Factors	Scores
1	Poor hydrological system, which makes it impossible to apply water-saving techniques	111
2	Land has low water-holding capacity	105
3	Lacking water-saving skills	64
4	Because they need more inputs of money and labor, farmers are unwilling to undertake water-saving practices	57
5	Lack of economic incentives	46
6	Others	7

Table 5. Factors affecting water-use efficiency in the WJQ state farm

Ranking	Factors	Scores
1	Poor hydrological system, which makes it impossible to apply water-saving techniques	153
2	Land has low water-holding capacity	142
3	Lack of economic incentives	79
4	Lacking water-saving skills	68
5	Others	63
6	Because they need more inputs of money and labor, farmers are unwilling to undertake water-saving practices	50

Note: The Subjective Weighting Method was applied to assess the importance of the factors. If the factor ranked the first, it got a score of 4; if it ranked second, it would get a score of 3; third ranking scored 2 and fourth ranking scored 1. The scores indicate the importance of the factor.

There were only few differences on these two factors between the rural areas of Baoqing County and the WJQ state farm. Farmers in the latter were more sensitive to economic incentives because they ranked “Lack of economic incentives” as the third most important factor while the farmers in Baoqing County ranked it as the fifth. The lack of water-saving techniques was also one of the reasons for not being able to save water.

(e) Farmers’ attitudes towards the hydrological system of the paddy fields

In the survey, only about 25% of the respondents were satisfied with the hydrological services provided (Table 6). A higher percentage of the farmers in Baoqing County was dissatisfied with the system. However, the difference between Baoqing County and the WJQ farm was not statistically significant. In all, 71.5% (133/186 households) hoped that the hydrological system would be improved.

Table 6. Assessment of the hydrological system

Area	Good	Not bad	Bad
Baoqing County	24.2%	27.3%	48.5%
WJQ State Farm	25.0%	37.0%	38.0%
Total	**24.8%**	**40.6%**	**34.6%**

Note: Only 133 interviewees (including 33 households in Baoqing County and 100 households in the WJQ state farm) evaluated the service quality.

(f) Farmers' awareness of the wetland and their relationship to it and their relative willingness to save water for the wetland's protection

Majority (86.3%) of the farmers (170/197 households) knew that the QNNR was a wetland. About 46% (91/198 households) agreed that their livelihoods were related to the wetland while 41.4% (82/198 households) denied such a relationship, and 12.7% (25/198 households) of the people did not know if there was a relationship.

About 64% (63.8% or 125/196 households) clearly expressed that they were willing to save water for the wetland while 17.3% (40/196 households) said that they were not willing to do so.

Through the above findings and other information obtained from the survey, we found that some of the local people already had some environmental awareness and recognized that the quality of the environment was linked to their livelihoods. However, the awareness was still too limited to be turned into water-saving behavior.

4.0 WATER RESOURCE MANAGEMENT IN HEILONGJIANG PROVINCE

4.1 Institutional Arrangement for Water Resource Management

Figure 4 shows the overall institutional arrangement for water resource management in Heilongjiang Province. This is a multi-sectoral water administration management system in which the Provincial Department of Water Resources (PDWR) plays the core role. Generally, the PDWR and Heilongjiang State Farm Bureau (HSFB) oversee the management of water resources in Heilongjiang Province. The PDWR manages provincial water issues for the Heilongjiang government and guides the Water Affairs Bureaus in the cities and counties. The Water Affairs Bureaus under the HSFB manage water issues within the state-owned farm areas and implement water administration policies. Water conservation plans in state farms need approval from the PDWR. At the provincial level, there is also the Provincial Agriculture Development Office (ADO) that provides guidance on water-saving practices in agriculture but this office has no strong role at the county level. At county level, it is the Agriculture Development Commission (ADC) of the county that provides education on how to save water.

Under such an institutional framework, water issues are controlled by different agencies and jurisdictions. Agriculture plays a big role in the management of water resources. The Forestry Bureau which controls the QNNR and is supposed to see to the wetland's water needs is, however, not sufficiently involved in the institutional arrangement.

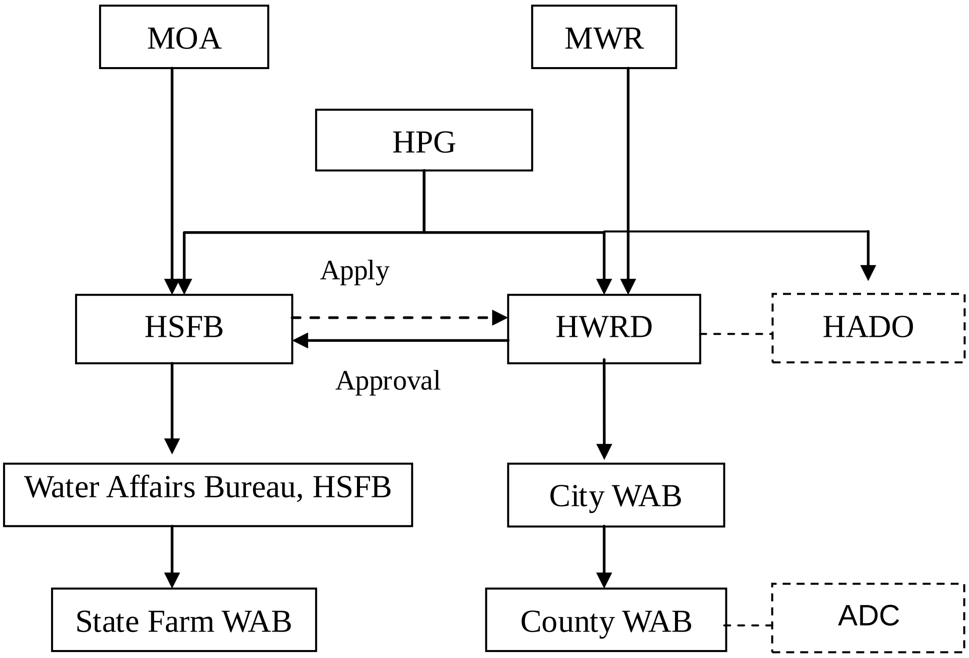

Figure 4. Institutional water management framework in Heilongjiang Province

Notes:

MOA = MINISTRY OF AGRICULTURE

HPG = HEILONGJIANG PROVINCE GOVERNMENT

MWR = MINISTRY OF WATER RESOURCES

HSFB = HEILONGJIANG STATE-OWNED FARM MANAGEMENT BUREAU

HWRD = HEILONGJIANG WATER RESOUCES DEPARTMENT

HADO = HEILONGJIANG AGRICULTURAL DEVELOPMENT OFFICE

WAB = WATER AFFAIRS BUREAU

ADB = ASIAN DEVELOPMENT BANK

ADO = AGRICULTURE DEVELOPMENT COMMISSION

4.2 Major Policies in Water Resource Management

Policies and regulations related to water management have been developed at the national and provincial levels to form an overall policy framework which covers water intake permits, water resource plans, water resource fees, water pricing policies, water resource assessments of construction projects, discharge fees, and other issues. In 2006, China issued a regulation on water permits and water resource fees, which required all water users in the various sectors to pay for water resources via the application of a water permit. That delivered a clear signal of the move towards gradually increasing water use efficiency by strengthening water resource management and charging the use of water resources. In general, however, these policies mainly focused on industrial water users.

4.2.1 Water resource plan

Since the Qixinghe River, and even its tributary, the Inner Qixinghe River, are only small rivers in Heilongjiang Province, there has never been a separate water resource plan for this river basin. Baoqing County and the two state farms (Youyi and WJQ) do their own water resource planning separately. Obviously, with the increased competition for water in the Qixinghe River basin, there should be a specific river basin water resource plan to coordinate the water demands from the different regions and sectors. Such a plan should be made by the PDWR.

4.2.2 Water permits

It is already 15 years since China issued the first administrative document on water permits which aimed at strengthening the management of water users. However, it was not until 2007 that a water permit policy came into force in Baoqing County. To date, the Water Resource Management Office in Baoqing County (under the Water Affairs Bureau) has issued 136 permits to water users, mainly industrial users. This has not yet been implemented in the agricultural sector.

4.2.3 Water fees for various users

(a) Water resource fees

As the most important grain production area in China, Heilongjiang Province consistently places high priority on meeting its agricultural water needs. In 1995, the “Provisions of Heilongjiang Province on the Management and Use of Water Resource Fees (1995-01-01)” regulated the amount of the water resource fees. The charge for agricultural irrigation was set at 0.003 RMB/m^3 for surface water and 0.006 RMB/m^3 for groundwater, much lower than the rates for industries (0.10 RMB/m^3 for surface water and 0.30 RMB/m^3 for groundwater).

In 2006, following the issue of national regulations on water permits and water resource fees, Heilongjiang Province issued two provincial regulations/notices namely, No.58 and No.8 administrative documents. These two provincial documents exempted and significantly decreased the water fees for agricultural production and stipulated that agricultural water users did not need to pay for water use within the "water-use quotas of HLJ Province" (DB23/T727-2003); they only needed to pay water fees for consumption beyond the quotas.

Almost all the provincial and lower level governments have taken advantage of the loopholes in the regulations and have generally postponed the implementation of water permits and water fees for the agriculture sector. Baoqing County, like many other counties, has not begun to levy water resource fees for agricultural production.

(b) Water supply fees

The water supply fee is a fee charged in irrigation districts. It was not until 1987 that Heilongjiang Province charged farmers for water supply services. Since then, the price of water has gradually increased.

In 1995, the Heilongjiang PDWR, Water Price Bureau, Agriculture Committee and Financial Department jointly issued a new water fee standard: the charges for paddy field irrigation were increased to 300 RMB/ha from 150 RMB/ha i.e., 2.4 cents/m^3 from 1 cent/m^3. The new charges made up 54.3% of the water supply cost, 7.4% of the production costs of agriculture, and 2.8% of the unit output value of agriculture.

In 2001, the National Planning Commission and Ministry of Finance declared that it was "*changing the water supply fee to an operating charge from an administrative charge*". There were two key elements in this reform; one was to charge by volume instead of by acreage and the other was to increase the water fee to offset the water supply cost. Four irrigation districts were chosen to test the water price reform.

As irrigation system and measurement devices have not yet been put in place, Baoqing County still calculates the water fees by acreage. For irrigation via water engineering projects, the water fee is 300 RMB/ha for paddy fields.

4.3 The Current Situation and Prospects of Economic Instruments Application in the Agricultural Sector

Some studies have discussed mechanisms for water resource allocation, including water pricing mechanisms and water rights markets (Randall 1981; Shen et al. 2001; Jiang 2003; Dietrich and Grossmann 2005). Many researchers have also focused on agricultural water use efficiency. Amir and Fisher (1999) analyzes the demand for water from agriculture under various price scenarios. Bazzani (2005), applied the DSIRR (Decision Support System for Irrigated Agriculture) model to analyze the impact of a water-pricing policy on water consumption at the catchment level. Gómez-Limón and Riesgo (2004) developed a methodology to evaluate alternative irrigation water pricing policies while Varela-Ortega (2003) and Mejias, and Varela-Ortega and Flichman (2004) examined the effect of different policy senarios for wetland conservation (mainly water pricing policies) on agricultural water use, farmers' incomes and government revenue. Fu et al. (2002) developed an agricultural production function with water as a factor input for setting up irrigation water quota targets in Sanjiang Plain. Guo and Wang (2004); Mao (2005); Wei, Chen and Li (2007); and Su

(2003) discussed the effectiveness of a water pricing policy in enhancing agricultural water efficiency in China. Wang and Zhou (1987); Liu, Huang and Zhang (2005); and Zhao (2006) applied an agricultural water-saving decision support model for western China, where water scarcity is a major issue.

Generally speaking, administrative mechanisms, such as water resources plans and engineering projects, are still the dominant instruments in water resource allocation in Sanjiang Plain (Songliao Water Resources Commission 2005). The use of market mechanisms in water resource allocation is still rare in the region, and we realized that the existing system, which lacks economic incentives to adjust water use, is unsustainable. The water supply program for Zhalong National Nature Reserve (ZNNR) is a case in point (see the box below). The ZNNR is in Song-nen Plain, which is adjacent to Sanjiang Plain. There are some fundamental limitations that keep its water pricing policy from being fully effective.

Water Supply Program for Zhalong National Nature Reserve

The Zhalong National Nature Reserve (ZNNR) is a freshwater wetland nature reserve in Song-nen Plain. It has an area of 2,100 sq. km and was declared a RAMSAR wetland in 1992.

Due to the rapid development of the area, the ZNNR has been facing a serious water shortage, which may threaten its reputation as a RAMSAR wetland. To solve this problem, the Chinese government made a water resource plan for the wetland and set up a water supply project in 2001 to transfer water from the Nen River to recharge the wetland in case of an emergency.

This is a typical case of supplying water for ecological requirements by administrative command and has been a successful model in the past few years. However, the sustainability of the model is doubtful since the reserve does not make any compensation for water consumption and the water authorities are reluctant to allocate enough water for the wetland without compensation.

4.3.1 The limitations of a water pricing policy

According to national and local policy, water fees should be linked to water quantity and charged by volume, but the implementation of such policy needs corresponding measurement devices which most irrigation districts do not have at present. Charging based on acerage rather than volume cannot form a connection between the quantity of water used and the water fee, so the water pricing policy will not induce water saving.

Under the current irrigation infrastructure, water supply cannot be guaranteed. Farmers cannot get water in a timely manner according to crop growth needs so they try to get as much water as they can whenever there is water available without considering water saving. Thus, in high water-use seasons, there is a tussle for water. Many irrigation districts get into a vicious circle of "poor service quality of the irrigation system→farmers don't pay water fees→water fees collected cannot support operations→even worse irrigation services→leading to low water efficiency rates". The bottom line is: if there is no good water supply service or no water measurement, a water pricing policy by itself will never be an adequate solution.

4.3.2 Agricultural water use and water pricing

People have been expecting a water price reform in agriculture to improve the efficiency of agricultural water consumption. In order to discover the relationship between agricultural water consumption and the existing water prices, this study adopted a Price–Field Water Demand Elasticity Model to predict farmers' water saving behavior at different water prices. See Appendix 2 for the model and calculations.

According to the results, when agricultural water prices meet the supply cost of 0.04 RMB/m^3, the water saving amount is just 135 m^3/ha and the ratio of saved water is just 0.9% Thus, the water price has little impact in terms of encouraging farmers to save water. As the water price goes up, however, the amount of irrigation water used by the farmers begins to decrease. When the water price reaches 0.08 RMB/m^3, the water saved is 270 m^3/ha resulting from the change in the farmers' irrigation behavior.

When the water price is 0.04 RMB/m^3, the percentage of the water fee against the total production input is 6.2%. Some surveys (e.g. Li 2007) suggest that when agricultural water fees are 10-12% and 8-10% of agricultural input and agricultural output, respectively, they are acceptable to farmers. Therefore, the water price at 0.08 RMB/m^3 is reasonable.

4.3.3 Water fee management system and policy

The water fee collection system and situation are very different in the rural areas in Baoqing County and the WJQ state farm. According to our interview with the Baoqing County Water Affairs Bureau, in the rural areas, the present water fee levy system is as follows: the farmers or the whole village pay water fees to the town's fiscal department which then hands over the fees to the county's fiscal department. The county hands over about 60% of the water fees collected to the city authorities and keeps about 40%. The water fee for surface water is 300 RMB/ ha in Baoqing County, but there is no charge for well water. The county or town provides grants from its budget for the maintenance of the local reservoir. We found that the fee collection rate was very low, below 30%, showing that the water fee management system was inefficient.

On the WJQ state farm, the Water Affairs Bureau levies water fees for each working district and the collected fees are handed over to the Management Bureau of the farm. The management bureau from each branch farm buys water from the reservoir (government owned and run by the Reservoir Management Bureau). In practice, the water fees are handed over together with the land taxes i.e., the water fees are bundled together with land contract fees and collected in advance when farmers rent land. The levy collection rate is as high as 100%. The water fee standard for surface water is 300 RMB/ha while well water costs 75 RMB/ha.

Because land property rights belong to the nation, farmers have to rent land for farming and including the water fees into the land rental agreements for state farms guarantees a high collection rate. However, the water fee system and policy implementation in the rural areas is weak.

At present, only the Youyi state farm has a water-user association (WUA), but its main function is to regulate water-use disputes among farmers. It is not organized well enough to fully play an effective role. This is partly due to the poor irrigation infrastructure and lack of water measurement devices.

4.3.4 Agriculture water pricing policy and institutional reform

In China, the direction of agricultural water price reform has been as follows: first, improving the measurement devices; second, charging on volume instead of acreage; and third, increasing the water price to cover the water supply cost. The goal of the first two is to promote water saving while the last one is maintain the operation and management of the irrigation services.

There are problems that cannot be solved by a water pricing policy alone, for example, the low willingness to pay of farmers; difficulty in collecting water fees; water fee cuts and embezzlement by the fee-collectors; and the poor management and maintenance of the irrigation canals, especially the end-parts, the maintenance of which is not funded by the government. These problems must be addressed by a proper reform of the irrigation district management system.

A water-user association (WUA) is one aspect of management system reform. A WUA can be organized for a village or canal district and comprise water-user representatives. The advantages of a WUA include encouraging water saving, self-management to reduce management expenses, relieving the burdens of water-users, and resolving disputes effectively.

As our household survey showed, the farmers had a rather high support rate (60%) for the charging-by-volume policy, that is to say, farmers can accept the rule of paying according to usage as long as good water supply services are provided. So, improving irrigation engineering and measurement devices, and introducing water pricing and institutional reforms are urgent tasks for irrigation district authorities.

5.0 DESIGNING POLICY OPTIONS

5.1 Policy Goal

With the above analysis, in targeting meeting the water conservation demands of the Qixinghe Wetland, the policy goal is to reduce off-site water use by about 8 million m^3 water (which accounts for about 20% of the ecological water demand of the wetland) to increase water supply to the wetland without diminshing the socio-economic growth of the surrounding areas. The conservation of the wetland will ultimately improve the water resources and climate in the watershed and support its sustainable development.

5.2 Potential Policy Options

In China, most reforms in water allocation have been initiated by the upper-level government authorities rather than at the local/county levels, so in our policy design in this study, we focused on what the local measures were and what could be implemented at the local level without too much political or bureaucratic complexity.

Through consultation with local officials and experts, policy options for the QNNR to reduce off-site water use should include water-saving measures through agro-hydraulic engineering, better agricultural skills, and water management reforms. Specific recommendations are as follows:

a) Reconstructing the irrigation network for better water conservation by improving the irrigation system for better supply and regulation of water flow, covering the underlayer of the irrigation channel to reduce leakage during water transfer, and ensuring that the diverted water is measurable and controllable.

b) Promoting water-saving irrigation practices, devices and technologies.

c) Encouraging a shift away from water-intensive crops like rice to “dry” crops like corn and soybean.

d) Strengthening the water management system using water permits and water fees.

e) Imposing limits on rice production directly e.g. imposing a cap for paddy land.

f) Building weirs or dams to store flood water or melted snow water.

g) Carrying out afforestation in upstream areas of the Qixinghe River.

5.3 Assessing Potential Policy Options

Before designing policy options for solving the water scarcity problem in the wetland, we did a preliminary screening of all potential policy options, mainly based on the general feasibility of the options, including the legal and political feasibility. Our assessment is shown in Table 7.

Table 7. Logical framework for policy options selection

Problem	**Factors contributing to the problem**	**Strategy**	**Options**
Decreasing water table in wetland	Competitive water use in surrounding area	Reducing off-site agriculture water use	(1) Reconstructing the irrigation system for water conservation
			(2) Water-saving planting practices
			(3) Change from paddy to dry crops
			(4) Management measures like water permits and water fees
	Accelerated water drainage in whole watersheds	Increasing the amount of stored water	(5) Restricting the expansion of paddy fields
			(6) Building new facilities to retain water
	Reduced water inflow	Securing water inflow (by improving the water cycle in the watershed)	(7) Afforestation in upstream areas

- Option (1) is fundamental for any kind of management or control on water flow. It was proposed by the farmers, government officials and experts. As some experts mentioned, without a good irrigation system to secure a good water supply to the farmers, the fight over water would not cease.
- Option (2) would be welcomed if there were more stringent control over water intake.
- Option (3) could be effective because both wet and dry planting are traditionally carried out in the local areas, but this option requires a good compensation mechanism to be designed.
- Option (4) is fundamental for water saving, but it is not an independent option as water experts argued that it will not be effective without improving the irrigation system.
- Option (5) will most likely not be welcomed from the local perspective under the background of "Constructing New Socialist Villages"[1] because there is still a

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[1] "Constructing New Socialist Villages" is a national slogan and policy priority of the government of China. It involves the central government providing subsidies to support agricultural development.

strong push for agricultural expansion. However, according to the central government's planning, Sanjiang Plain should be a restricted development zone. So the feasibility of this option also depends on how the central and local governments work out this issue.

- Option (6) is to keep water for the QNNR. The officials we interviewed included those from the Water Affairs Bureau and Wetland Nature Reserve Management Bureau. They thought that this option was politically feasible and welcomed it because it was a local decision. We proposed two different possible options: (i) to build a small dam downstream from the water outflow point of the QNNR to enhance the water level in the reserve, and (ii) to build a small reservoir upstream along the Qixinghe River near the reserve to store flood water or melted snow water. Of course, the first choice was preferred by the QNNR Management Bureau, but both its officials and as well as those from the Water Affairs Bureau admitted that there was no suitable geographical site for the dam to be built at a viable cost. The second alternative was also acceptable because there was already a preliminary draft plan for a similar project in the watershed.
- Option (7) was important for the whole river basin, but the linkage between the afforestation activities and their effects would be difficult to measure.

5.4 Selecting and Designing the Most Feasible Policy Options

Based on the above preliminary screening, we selected the most feasible options and reconstructed them as follows:

Option I. Reconstructing the irrigation network for water-saving purposes

Option II. Constructing a small dam to store and control flood water to increase the water supply and relieve seasonal water scarcity

Option III. Introducing water-saving practices to reduce water usage for paddy planting

Option IV. Changing from paddy to dry crops to reduce water use in paddy planting

5.5 Stakeholders of the Policy Options

Generally speaking, the stakeholders of the policy options at the local level included the government (Water Affairs Bureau, Agriculture Development Commission, Wetland Management Bureau, etc.); enterprises (state-owned farms, water supply enterprises, etc.), and the farmers.

For enterprises, there was no private enterprise involved. The state-owned farms were normally categorized as enterprises, but they actually functioned as government units and run according to government procedures. Water supply enterprises (such as reservoir and irrigation district enterprises) were not pure enterprises but part of the Water Affairs Bureau. They had to keep financially viable in terms of their operational costs by providing water supply services and charging water fees, just like some public service sectors. So in our analysis, we preferred to treat state-owned farms and water supply enterprises as part of the government and referred to their specific interests in each policy option.

For each policy option, the stakeholders may have different roles and be affected in different ways or to different degrees. They may have different degrees of importance attached to the options or varying levels of influence on the decision-making and implementation processes. A stakeholder analysis is discussed in Section 7.

5.6 Identifying the Zones for Policy Option Implementation

This study proposed the implementation of policy options in a region where external water use directly competed with wetland water requirements. Based on our local investigation and experts' advice, we chose six zones round the QNNR in which to implement the four policy options: two small towns in Baoqing County in the rural areas (Qixinghe town (QHT) and Qixingpao town (QPT)), and four branch farms of the WJQ state farm and the Youyi Farm. The two WJQ branch farms directly adjacent to the wetland are labeled below as WJQ-4 and WJQ-5 and the two Youyi branch farms directly adjacent to the wetland are labeled as Youyi-8 and Youyi-6. These six zones (Table 8) represent the major agricultural water use areas around the QNNR and directly compete with the wetland for water (Figure 5).

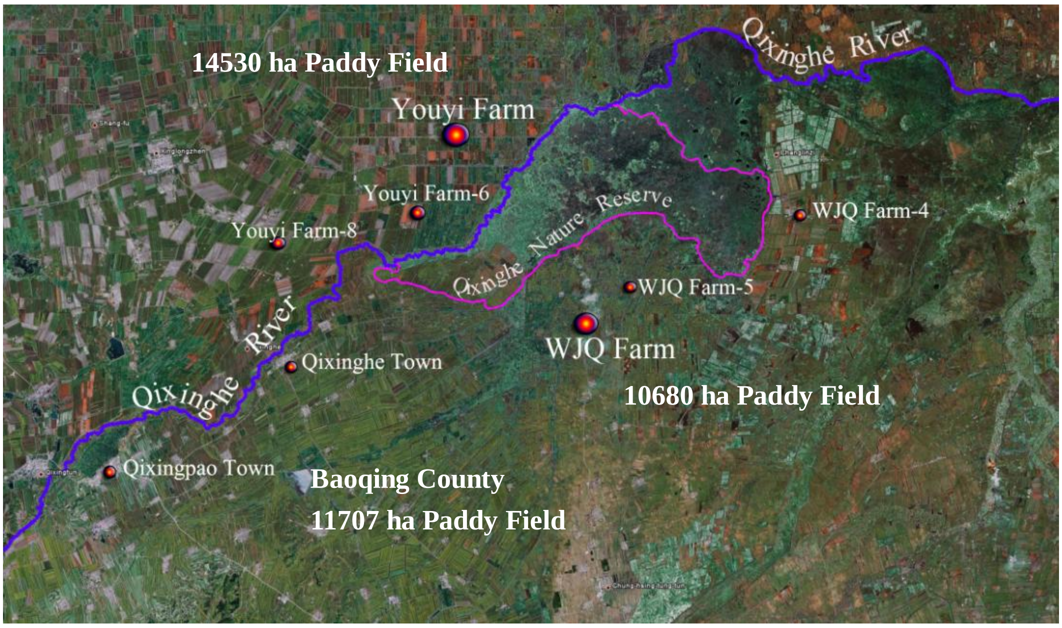

Figure 5. Geographical distribution of major agricultural water users

Table 8. Policy option implementation zones

Zone	Area（km^2）	Population	Farmland (ha）	Paddy (ha）
1. QHT	1,004	13,400	10,739	198
2. QPT	1,269	71,000	28,258	1,253
3. WJQ-4	274.7	4,800	14,000	6,667
4. WJQ-5	55.61	-	3,200	1,733
5. Youyi-8	145.83	9,700	6,960	1,333
6.Youyi-6	91.62	5,100	5,460	1,000
Total	2,840.76	-	68,617	12,185

Sources:

(1) The data on Qixinghe Town and Qixingpao Town is from the Baoqing Civil Administration and Baoqing Water Resource Authority.

(2) The data on the WJQ farms was collected through interviews.

(3) The data on the Youyi farms was collected from the Youyi Agriculture Committee and Youyi Farm interviews.

5.7 Variables to be measured for each policy option

The variables measured were: (a) cost (10^4 RMB/year); (b) effects: water saved (m^3/year); (c) farmers' income loss; and (d) government revenue and expenditure.

6.0 EVALUATING THE ECONOMIC AND ECOLOGICAL IMPACTS OF THE POLICY OPTIONS[2]

6.1 Option I: Irrigation System Reconstruction (ISR）

6.1.1 Option description

In order to save water to meet the ecological water demand of the wetland, the option was for the reconstruction of the irrigation system in the surrounding areas which were in competition with the wetland for water by among other things, sharing the same water source as the wetland. The specific measures were as follows:

(a) to complete the canal system (to enhance water delivery capacity)

(b) to cover the underlying layer of the canal (to improve water delivery efficiency)

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[2] 2007 was the base year for all cost data presented in this chapter.

(c) to install water measurement devices and control gates (for a measurable and controllable canal system)

These measures would more efficiently ensure the supply of water for agriculture, improve the efficiency of the water canal system, and lay the foundation for implementing field water-saving practices and water pricing policies. The option included choosing an appropriate irrigation system for the reconstruction for the purpose of saving 8 million m^3 of water to meet the wetland's ecological water needs.

The capital investment of this project could be supported by the National Small Agricultural-Hydraulic Project Fund[3]. Matching funds from the state and local governments would be required. In order to guarantee the irrigation services, operation and maintenance fees would be collected from the water users /farmers who benefited from the improved system. This option would achieve water-saving by improving the water delivery efficiency of the canal which would reduce water loss.

6.1.2 Cost-effectiveness calculations

(a) Methodology

The cost-effectiveness (C/E) of the option was measured by the average cost per unit of water saved. One complication was that the costs and effects (water-saving) occurred at different points in time. The standard approach in addressing this sort of problem is to use discounting.

$$C / E = TC_{ISR} / TE_{ISR} \qquad (1)$$

where

TC_{ISR} is the present value of the total infrastructure cost, including the initial investment and annual running costs; and

TE_{ISR} is similarly discounted as the total amount of water saved over the study period (Warford 2003).

In this option, we had to choose several irrigation districts for the proposed construction to achieve the target water volume. The cost for each district was likely to be different, so the total cost would be the sum of the costs for each irrigation district i .

$$TC_{ISR} = \sum_{i=1}^{6} C_{ISR}^{i} A^{i} \qquad (2)$$

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[3] The National Small Agricultural-Hydraulic Project Fund is a central government fund.

where

C^i_{ISR} is the present value of the total infrastructure cost per hectare in district *i*;

A^i is the area of the irrigation district *i*; and

i = 1,2…,6; there are altogether 6 irrigation districts in this option.

The costs incurred during the evaluation period include the initital investment and annual running costs. Since this is an engineering project, there could be residual value at the end of the evaluated period, so the residual value should be deducted from the real cost in each irrigation district.

$$C^i_{ISR} = \sum_{t=1}^{6}\left[C^i_{investment} + \sum_{t=1}^{N} C^{t,i}_{running}/(1+r)^t - C^i_{residual}\right] \qquad (t = 1, 2, \ldots, N) \qquad (3)$$

where

$C^i_{investment}$ is the construction cost per hectare (RMB/ha) of irrigation district *i*;

$C_{running}$ is the running cost per hectare (RMB/ha) of irrigation district *i* in the year *t*;

$C^i_{residual}$ is the residual value of the irrigation project in irrigation district *i*, which can be estimated using the “straight-line” depreciation method as shown in Figure 6;

A^i is the area of the irrigation district *i* in hectares;

r is the discount rate; and

N is the evaluation time period of the options. In order to compare the cost-effectivness of all the options on a consistent basis, this study set N = 30 for all options, from 2008-2037.

$$C_{residual} = C_{investme} * \frac{T-N}{T} \qquad (4)$$

T is the expected overall lifespan of the irrigation system. This means that at the end of year T, the residue value becomes zero. T is calculated as: T = $T_0/(1-R_0)$, in which T_0 represents the expected working lifespan and R_0 is the residual value over total investment. According to the “Water Conservation Construction Project Economic

Evaluation Norms (SL72-94)", the T_0 of the irrigation project should be 30-50 years (Ministry of Water Resources 1994). We selected $T_0 = 40$ years here. According to the "Economic Evaluation Code for Small Hydropower Projects(SL 16-95)" (Ministry of Water Resources 1995). the rate of residual value was 3-5%, so we set $R_0 = 5\%$. So T was 42 years using Equation (4) above.

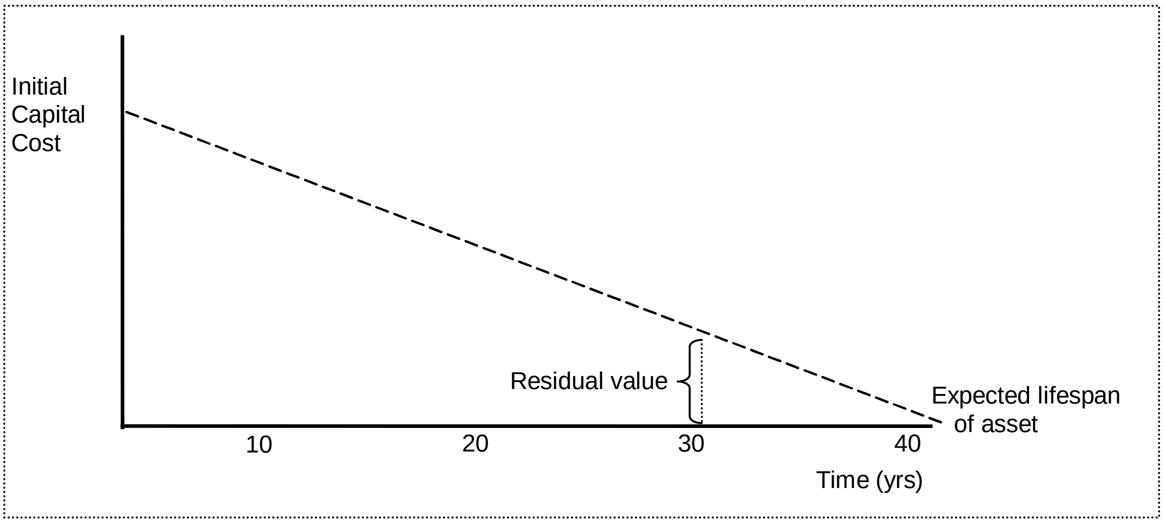

Figure 6. Depreciation of the irrigation system over time

$$TE_{ISR} = \sum_{i=1}^{6} E_{ISR}^{i} A^{i} \qquad (5)$$

where

E_{ISR}^{i} is the discounted water-saving amount per hectare (m^3/ha) in irrigation district *i*; and

A^{i} is the area of irrigation district *i* in hectares;

E_{ISR}^{i} can be calculated for each irrigation district and be discounted in a similar fashion as the cost.

$$E_{ISR}^{i} = \sum_{t=1}^{N} E_{ISR}^{i,t} / (1+r)^{t} = \sum_{t=1}^{N} W^{i} (1/V_0^{i} - 1/V_1^{i}) / (1+r)^{t} \qquad (6)$$

where

$E_{ISR}^{i,t}$ is the water-saving amount per hectare in irrigation district *i* in the year *t;*

W^i is the water use quantity per hectare (m^3/ha) in irrigation district *i*, which is actually the reduced water intake amount by irrigation district *i* from the water source due to increased water delivery efficiency in the district;

V_0^i is the water utilization coefficient before reconstruction of the irrigation system; and

V_1^i is the water utilization coefficient after reconstruction of the irrigation system.

(b) Valuing the parameters

$C_{investment}^i$: According to our interviews with the local Water Affairs Bureau and experts, without the consideration of the distance between the irrigation area and water source, the construction cost would be 27,750 RMB/ha for an irrigation district in the rural area and 15,000 RMB/ha for a state farm irrigation system.

$C_{running}^i$ **:** According to the "Provincial Notice on Changing the Charge Standard of Agricultural Water Supplied by the Hydraulic Project in Heilongjiang Province" (Heilongjiang Provincial Bureau of Commodity Pricing 1997), the running cost would be about 552 RMB/ha per year on average.

r**:** This is the discount rate. Three rates were used: 2%, 5%, and 8%[4] so as to be able to compare different results under high, medium and low discount rates.

$C_{residual}^i$ **:** Using Equation (4), the residual values would be 7,929 RMB/ha in the rural area, and 4,285.5 RMB/ha for a state farm.

The values of the major parameters are given in Table 9.

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[4] According to the"Construction Project Economic Evaluation Methods and Parameters" (Third edition) (National Development and Reform Commission and the Ministry of Construction 2006), the discounted rate was between 6-8%. As 5% was the discount rate most widely used in environmental economic analyses, we selected this, and in order to assess the sensitivity of the results to the discount rate, we also selected 2%.

Table 9. Values of the major parameters in Option I

Area	i	A_i (10^3ha)	W^i (m^3/ha)	V_0^i	V_1^i	$E_{ISR}^{i,t}$ (m^3/ha)	$C_{investment}^i$ (RMB/ha)	$C_{running}^i$ (RMB/ha/yr)	$C_{residual}^i$ (RMB/ha)
Rural areas	1	198	13,500	0.50	0.70	7,710	27,750	552	7,929
	2	1,253		0.40	0.60	11,250	27,750		
State Farm	3	6,667	1,200	0.60	0.80	4,995	15,000		4285.50
	4	1,733		0.60	0.80	4,995	15,000		
	5	1,333		0.65	0.85	4,350	15,000		
	6	1,000		0.65	0.85	4,350	15,000		

(c) Calculating the results

Using Equations (2), (3) and (4), the water-saving volume per hectare, total water-saving volumes and cost-effectiveness of this option for the six different irrigation districts were calculated under diferent discount rates. The cost-effectiveness results are shown in Table 10.

Table 10. Cost-effectiveness by irrigation district (at the discount rate of 5%)

i	C_{ISR}^i **(RMB/ha)**	E_{ISR}^i **(m^3/ha)**	C/E **(RMB/m^3)**
1	28,305	118,522	0.239
2	28,305	172,940	0.164
3	19,200	76,785	0.250
4	19,200	76,785	0.250
5	19,200	66,870	0.287
6	19,200	66,870	0.287

From the table above, we can see that Qixingpao irrigation district (i = 2) is the most cost-effective, so the reconstruction in Qixingpao should be considered first. An area of 711 ha would have to be reconstructed in order to save 8 million m^3 of water and the initial investment cost would have to be:

27,750 RMB/ha*711 ha = 19.74 million RMB

The results of using Equations (1), (4) and (5) are given in Table 11.

Table 11. Cost-effectiveness analysis of Option I (at different discount rates)

r	$E_{ISR}{}^{t}$ **(10^6 m^3/yr)**	TC_{ISR} **(10^6 RMB)**	TE_{ISR} **(10^6 m^3)**	C/E **(RMB/ m^3)**
2%	8.00	22.89	179.17	0.128
5%	8.00	20.14	122.98	0.164
8%	8.00	18.52	90.06	0.206

6.1.3 Distributional effects

In order to understand how the stakeholders would contribute to or gain from Option I, we compared how the costs and effects would be distributed among them (Table 12).

Table 12. Distribution of the costs and effects of Option I

Stakeholder	Costs	Effects
Farmers	The operation and maintenance of the irrigation system needs to be covered by the water fees paid by the farmers i.e., 552 RMB/ha.	-
Government	Irrigation reconstruction investment cost: 19.74 million RMB.	Saving 8 million cubic meters of water per year

6.2 Option II: Ecological Water Control Reservoir (EWC)

6.2.1 Option description

This option was to build a small dam to store and control flood water in a suitable place in upstream areas. We found that there was no engineering project to regulate the water quantity in upstream areas, so the water from melted snow or floods has never been fully utilized.

A proposal to construct a small dam to store and control flood waters in a suitable place upstream was raised by the local government years ago. Preliminary investigations were also conducted. We used the same proposal here. With the aim of retaining flood waters and the excess water of the Jinshahe River for irrigation, it was proposed to build a reservoir midstream along Qixinghe's first branch, the Jinshahe River. The reservoir was designed to be located in Qixingpao town in BaoQing County, with a water-catchment area of 102 km^2. It was to be medium-sized reservoir which was expected to provide 6.94 million m^3 of water. The total compensation paid by the government to the owners of the land taken for the reservoir was estimated to be 18.34 million RMB in which the land occupation compensation fee would be 2.14 million RMB and compensation for the inundated area would be 16.20 million RMB. The capital investment for the main reservoir construction was estimated at 64.18 million RMB (2002 prices) (Water Affairs Bureau of Baoqing County 2005).

Considering the potential ecological impacts of the dam, the height of the dam was designed to be 15 meters in this preliminary design, so it would be a low dam and the potential ecological impact would be moderate. Of course, the project would have to go through the environmental impact assessment process.

6.2.2 Cost-effectiveness calculations

(a) Methodology

The cost-effectiveness (C/E) of the option was measured by the average cost per unit of water saved. The estimations followed the same methodology as for Option I.

$$C/E = TC_{EWC} / TE_{EWC} \tag{7}$$

where

TC_{EWC} is the present value of the total infrastructure cost, including the investment and running costs; and

TE_{EWC} is the present value of the total water-saving amount.

$$TC_{EWC} = C_{investment} + C_{compensation} + \sum_{t=1}^{N} C^t_{running} / (1+r)^t - C_{residual} \quad (t=1,2,\ldots,N) \tag{8}$$

where

$C_{investment}$ is the construction cost of the designed reservior;

$C_{compensation}$ is the total compensation for the inundated area of the reservoir;

$C^t_{running}$ is the running cost of the designed reservior in the year t;

$C_{residual}$ is the residual value of the hydraulic engineering project in irrigation district i, which can be estimated using the “straight-line” depreciation method as in Option I;

r is the discount rate which represents the future investment preferences of the investor in this environment-friendly project; and

N is the time horizon. As in all other options, the time period is 30 years, from 2008-2037.

$$C_{residual} = C_{investment} * \frac{T-N}{T} \qquad (9)$$

T is the expected overall lifespan of the irrigation system. At the end of year T, the residue value becomes zero. T is calculated as: $T = T_0/(1-R_0)$, in which T_0 represents the expected working lifespan and R_0 is the rate of residual value over total investment. According to the “Water Conservancy Construction Project Economic Evaluation Norms (SL72-94)” (Ministry of Water Resource 1994), the T_0 of the reservoir project should be 50 years, so we selected $T_0 = 50$ years. According to the “Economic Evaluation Code for Small Hydropower Projects (SL 16-95)” (Ministry of Water Resource, 1995), the rate of residual value was 3-5%, so we set $R_0 = 5\%$. So T was 53 years using Equation (9) above.

$$TE_{ECW} = \sum_{t=1}^{N} E_{ECW}^{t} / (1+r)^{t} \qquad (10)$$

where E_{ECW}^{t} is the water-saving amount of the designed reservior in year t, which was found to be 6.94 million m^3 according to the project plan.

(b) Valuing the parameters

$C_{investment}$: the total investment was 64.2 million RMB estimated at 2002 prices, adjusted using the industrial price index (PPI) to eliminate the effects of price change over the years by converting the investment to 2007 prices (Table 13). The total investment was found to be 67.7 million RMB at 2007 prices.

$C_{compensation}$: the total compensation cost was 18.3 million RMB estimated at 2002 prices. The total compensation cost was 19.4 million RMB adjusted according to the consumer price index (CPI) at 2007 prices (Table 13).

Table 13. PPI and CPI for China (2002-2007)

Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
PPI	97.8	102.3	106.1	104.9	103	103.1
CPI	99.2	101.2	103.9	101.8	101.5	104.8

Source: National Bureau of Statistics of China (2008)

N was set at 30 years, the same as for the other options; and

r was 2%, 5%, and 8% for the same reason above.

$C_{running}$: According to "The 11th Five-Year Plan Report of Baoqing County on Water Conservation Development" (Water Affairs Bureau of Baoqing County 2005), the running cost of a resevoir in a different watershed in Sanjiang Plain (named as "Lishugou Reservoir") was estimated to be 215,600 RMB per year, and it had the same function as the new reservoir, but with a smaller capacity of 0.88 million m^3. Based on this, the running cost of the designed reservoir was estimated to be 1.9 million RMB/year.

$C_{residual}$: Using Equation (9) above, the residual value was found to be 29.4 million RMB.

The values of the major parameters are given in Table 14 below.

Table 14. Values of the major parameters in Option II

Parameter	$C_{investment}$ (million RMB)	$C_{compensation}$ (million RMB)	$C_{residual}$ (million RMB)	E^t_{ECW} (million m^3)	$C_{running}$ (million RMB)		
					r = 2%	r = 5%	r = 8%
Value	67.655	19.38	29.36	6.94	43.29	29.71	21.76

(c) Results

Using Equation (10), the TE_{EWC} was found to be 155.4, 106.7, and 78.1 million m^3 under the different discount rates of 2%, 5%, and 8%.

Using Equation (7), a cost-effectiveness analysis for Option II was carried out and the results are given in Table 15.

Table 15. Cost-effectiveness analysis of Option II (at different discount rates)

r	TC_{ISR} **(10^6RMB)**	TE_{ISR} **(10^6 m^3)**	C/E **(RMB/ m^3)**
2%	100.97	155.43	0.650
5%	87.39	106.68	0.819
8%	79.44	78.13	1.017

6.2.3 Distributional effects

The investment for this project would be mainly funded by the government. The water-saving is mainly for the purpose of supplying water to the wetland to create ecological benefits but there is no direct economic benefit. Therefore, the government should bear the running costs.

There will be no direct costs and effects on the famers as there would be no direct effect on the farmer's yields and water-use methods, but an indirect benefit could be a yield increase through improving local environmental conditions (Table 16).

Table 16. Distribution of the costs and effects of Option II

Distribution	**Costs**	**Effects**
Farmers	-	-
Government	Investment cost: 67.55 million RMB Compensation cost: 19.38 million RMB Running cost: 1.93 million RMB / year	Water saving of 6.94 million m^3/year

6.3 Option III: Water-saving Planting Practices (WSP)

6.3.1 Option description

In this option, the government will provide training in water-saving planting skills to farmers by organizing classes and promoting the implementation of the skills. The Agricultural Techniques Promotion Center (ATPC) of Baoqing County would be the appropriate implementing agency, responsible for getting agricultural professionals to give water-saving training to farmers at the village level. The training would be held every year during the project period of 30 years. Each class was estimated to have 20 trainees. The ATPC would provide the trainers, training materials and support services until the farmers could successfully implement the water-saving practices. The ATPC would also monitor and evaluate the implementation of the program. So, for the government, the costs of this option consisted of the training and management costs, including monitoring and evaluation.

On the farmers' side, this option involved learning costs, mainly in terms of time, but the benefits would be saving on water fees, water and energy, and increasing productivity.

We made three assumptions in calculating the cost-effectiveness of Option III. These were as follows:

(i) All the farmers trained in water-saving practices could apply their new skills successfully and achieve the expected water-saving targets.

(ii) It would not be necessary for the ATPC to employ new agricultural professionals as trainers and there will be no additional working hours for current staff. Thus, we could rule out any changes in salary costs.

(iii) Only real material or financial input would be calculated as costs while non-monetary time input, for example, more working hours spent by the farmers during their learning period, will be neglected.

6.3.2 Cost-effectiveness calculations

(a) Methodology

The cost-effectiveness (C/E) of the option was measured using the average cost per unit of water saved over the evaluated period. The total cost was calculated based on the sum of the training costs for each household. The number of households (N_h) that were to join the training program was determined based on the farm land area that required water-saving practices to achieve the target water-saving amount, while land areas that needed water-saving practices were affected by the current water consumption (W_a) and water-saving potential of the techniques (defined as water-saving coefficient, f_s). The water saving amount for each year was set by the target of 8 million m^3. The total water-saving effect was the sum of the present value of the amout of water saved each year over the evaluated period of 30 years.

$$C/E = TC_{WSP}/TE_{WSP} \tag{11}$$

$$TC_{WSP} = \sum_{t=1}^{N} (C^t_{training} + C^t_{management}) * N_h / (1+r)^t \quad (t=1,2,\ldots,N) \tag{12}$$

$$N_h = A_l / A_{HH} \tag{13}$$

$$\mathrm{A}_l = \mathrm{TE}_{WSP} / (\mathrm{Wa} * \mathrm{fs}) \tag{14}$$

$$TE_{WSP} = \sum_{t=1}^{N} \frac{E_{WSP}^{t}}{(1+r)^{t}} \qquad (15)$$

where

TC_{WSP} is the present value of the total cost of water-saving irrigation practices;

TE_{WSP} is the total amount of the reduction in water consumption (in m^3);

$C_{training}^{t}$ is the training cost in year *t*, which is calculated by the sum of training costs for each household;

$C_{management}^{t}$ is the cost of ensuring the effectiveness of the training in year *t* (mainly monitoring and evaluation costs);

N_h is the number of households that needs to be involved in the option;

r is the discount rate of 2%, 5%, and 8%, as for all other options (however, as Equations (11), (12) and (15) indicate, the cost-effectiveness will be independent of the discount rate);

N is 30 years (2008-2037);

A_l is the farm land area needed to achieve the water-saving objectives;

A_{HH} is the weighted average paddy area per household in the policy option implementation zones[5];

Wa is the weighted average of water consumption per hectare in the policy option implementation zones[6]; and

fs is the water-saving coefficient.

(b) Valuing the parameters

$C_{training}^{t}$ includes 20 RMB/household for training costs, 10 RMB/household for training materials, 20 RMB/household for continuous support services, and 20 RMB/household for organizing costs. All the above costs were estimated by professionals of the ATPC, Baoqing County.

$C_{training}^{t}$ includes monitoring and evaluation costs, equal to 20 RMB/household as estimated by the ATPC professionals of Baoqing County.

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[5] According to the survey results, the average paddy area per household was 4.73 ha/HH in the rural areas which had 60 samples and 9.42 ha/HH in the farms which had 141 samples. (HH = household)

[6] According to the survey results, the average water consumption amount was 13,500 m^3/ha in the rural areas (with 1451.33 ha of paddy fields) and 12,000 m^3/ha in the farms (10,733.33 ha of paddy fields).

A_{HH} was calculated to be 8.9 ha/household.

Wa was calculated to be 12,178.7 m^3/ha. See Table 17.

fs was estimated to be 10% by the ATPC professionals of Baoqing County.

Table 17. Average water consumption in the implementation areas

Implementation zone	**Water consumption (m^3/ha)**	**Paddy area (ha)**	**W_a(m^3/ha)**
Baoqing County	13,500	1,451	12,178.7
WJQ State Farm	12,000	8,400	
Youyi State Farm	12,000	2,333	

Table 18 shows the values of the major parameters for Option III.

Table 18. Values of the major parameters in Option III

Parameter	**W_a** (m^3/ha)	**f_s**	**A_I**(ha)	**$C_{training}$** (RMB/HH)	**$C_{management}$** (RMB/HH)	**Nh** (HH)	**C_{WSP}** (RMB)
Value	12,178.766	10%	6,568.986	70	20	742	6,6780

(c) Results

The costs-effectiveness analysis results of this option are shown in Table 19.

Table 19. Cost-effectiveness analysis of Option III (at different discount rates)

R	**TC_{WSP} (10^6RMB)**	**TE_{WSP}（10^6m^3）**	**C/E (RMB/ m^3)**
2%	1.50	179.17	0.008
5%	1.03	122.98	
8%	0.75	90.06	

6.3.3 Distributional effects

The proposal was designed so that the government would provide the water-saving training for free, which means that the government would bear the cost (Table 20).

Table 20. Distribution of the costs and effects of Option III

Stakeholder	Costs (10^3RMB)	Effects (10^6m^3)
Farmers	-	-
Government	Training cost: 51,940 RMB/year Management cost: 14,840 RMB/year	Saving 8 million m^3 of water per year

Although the cost-effectiveness of this option seems ideal, it cannot be achieved without meetign some prerequisites such as irrigation system improvement, installation of water measurement devices, and economic incentives. A high water price will act as an economic incentive for farmers to implement water-saving practices.

6.4 Option IV: Switching from Paddy to Dry Crops (PTD)

6.4.1 Option description

Switching from paddy to dry (or dryland) crops is another potential choice to achieve water-saving. In the targeted policy implementation areas, dry crops are completely reliant on rainfall and do not require irrigation. Thus, switching from paddy to dry crops is expected to save a large amount of water.

Changing from rice to dry crops is not unusual in local areas. In our survey, we found that farmers chose to change crops due to many reasons such as crop price fluctuation and conditions of land and water resources.

The roles of the government in this option included being the provider of information, helping farmers identify appropriate farm land, and promoting the change from paddy to dry crops.

Farmers are the most important actors in this option. Changing from paddy to dry crops will impact the farmers' net incomes. Significant price gaps between paddy and drp crops will definitely decrease farmers' willingness to switch so the net income change caused by this option should be carefully considered.

6.4.2 Cost-effectiveness calculations

(a) Methodology

The costs can be divided into two parts: **short-term costs** which will happen in first year[7] and **long-term costs** which will happen in the second year (Equation 17).

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[7] According to our survey and interview, it is very likely that productivity loss will happen in the first year of switching from paddy to dry crops.

In the first phase (the first year), there will be short-term losses due to productivity loss and the cost of levelling the land (Equation 18). The long-term costs are the farmers' income losses due to the conversion from paddy to dry crops because there is a significant price gap between rice and dry crops (Equation 19).

The water-saving effect each year (E_{PTD}) was determined by the target water-saving amount (8 million m^3). According to local experience, dry crops rely only on precipitation, so farmers do not have to water them. Therefore, all the irrigation water used in the paddy fields can be released after the conversion to dry crops. The land area that needs to be converted can be calculated and the short-term transition cost and long-term income loss due to the conversion can also be calculated using Equation (21).

$$C/E = TC_{PTD}/TE_{PTD} \tag{16}$$

$$TC_{PTD} = TC_{shortterm} / (1+r) + \sum_{t=2}^{30} C_{income}^{t} * A_l / (1+r)^t \tag{17}$$

$$TC_{shortterm} = (C_{levelland} + C_{productivity}) * A_l \tag{18}$$

$$C_{income} = C_{riceincome} - \lambda C_{soy(corn)income} \tag{19}$$

$$TE_{PTD} = \sum_{t=1}^{N} \frac{E_{PTD}^{t}}{(1+r)^t} \tag{20}$$

$$A_l = E_{PTD}/W_a \tag{21}$$

where

TC_{PTD} is the present value of the total cost of Option IV;

TE_{PTD} is the present value of the total reduction volume of water consumption (in m^3);

$C_{levelland}$ is the cost per hectare for levelling the land during the first year;

$C_{productivity}$ is the income loss per hectare caused by less production in the first year of transition;

λ is the rate of production; for the first transitional year, $\lambda = 0.5$, which means that production in the first year is only half the production in normal years, and

$\lambda = 1$ in later years means that there is no production reduction in subsequent years;

C_{income} is the net income difference per hectare between paddy and corn/soy bean in year *t* from the second year to the end of the 30th year;

E_{PTD} is the reduced volume of water consumption each year, which is determined by the water-saving target;

A_l is the paddy land areas that need to be changed to dry crop land to achieve the water-saving objective; and

Wa is the average water consumption of paddy per hectare[8].

(b) Valuing the parameters

$C_{levelland}$ was estimated to be 500 RMB/ha according to the household survey in 2008.

C_{income} was calculated as the simple average of all the net income differences between paddy and dry crops (corn and soybean) from 1996-2006. The data on net income per hectare for paddy, corn and soybean was sourced from the China Rural Statistical Yearbooks (1997-2007). The results are shown in Table 21.

$C_{productivity}$ was calculated as the simple average of the net income differences between paddy and dry crops (corn and soybean) from 1996-2006, taking the production reduction of the first year into consideration. The sources of the data on net income per hectare for paddy, corn and soybean were the China Rural Statistical Yearbooks (1997-2007). The results are shown in Table 21.

$$A_l = E_{PTD}/W_a = 8{,}000{,}000/12178.7 = 656.9 \text{ ha}$$

Table 21 shows the values of the major parameters for Option IV.

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[8] It is the same as in the Option III.

Table 21. Values of the major parameters in Option IV

Parameter	A_l(ha)	$C_{levelland}$	$C_{productivity}$	C_{income}
Value	656.9	500 RMB/ha	Paddy to soybean: 1,812 RMB/ha Paddy to corn: 1,874.8 RMB/ha	Paddy to soybean: 998 RMB/ha Paddy to corn: 1,123.5 RMB/ha

(c) Results

A cost-effectiveness analysis for Option IV was carried out and the results are given in Tables 22 and 23.

Table 22. Cost-effectiveness analysis of the switch from paddy to soybean (at different discount rates)

Paddy to soy	TC_{PTD} **(10^6RMB)**	TE_{PTD} **(10^6m^3)**	C/E **(RMB/ m^3)**
2%	15.53	179.17	0.087
5%	10.90	122.98	0.089
8%	8.18	90.06	0.091

Table 23. Cost-effectiveness analysis of the switch from paddy to corn (at different discount rates)

Paddy to corn	TC_{PTD} **(10^6RMB)**	TE_{PTD} **(10^6m^3)**	C/E **(RMB/ m^3)**
2%	17.34	179.17	0.097
5%	12.13	122.98	0.097
8%	9.07	90.06	0.101

The cost of changing from paddy to corn is a little bit higher than that of changing from paddy to soybean and we took the higher one to compare with the cost-effectiveness of the other three options.

6.4.3 Distributional effects

Table 24 shows how farmers absorb all the costs i.e., both short-term and long-term costs of Option IV. As the representative of public welfare, the government can be said to be the recipient of the effect of achieving the water-saving target.

Table 24. Distribution of the costs and effects of Option IV

Stakeholder	**Costs**		**Effects**
	Paddy to soybean	**Paddy to corn**	
Farmers	Short-term cost: 1,518,055.8 RMB in the first year; Long-term cost: 655,569.75 RMB/year	Short-term cost: 1,559,975.8 RMB in the first year; Long-term cost: 738,035.6 RMB/year	
Government			Saving 8 million m^3 of water per year

6.5 Comparing the Cost-effectiveness and Distributional Effects of the Options

The overall results of the option analysis are shown in Table 25. Option III is the most cost-effective followed by Option IV and then Option I. Option II is the most costly or the least cost-effective. Regarding the distribution of costs, Option I shares out costs between the farmers and government while Option II will lay a high cost on the government. Option III will lay a low cost on the government while Option IV has a medium cost, but which will be borne by the farmers.

Table 25. Comparison of the cost-effectiveness and distributional cost effects among options (at the discount rate of 5%)

Options	**Costs (10^6 RMB)**	**Effects (10^6 m^3)**	**C/E (RMB /m^3)**	**Distributional Cost Effects**	
				Government revenue and expenditure	**Farmers' income**
I (ISR)	20.14	122.98	0.164	19.7 million RMB for irrigation reconstruction – a one-off investment cost	552 RMB/ha/year for the running cost of the irrigation system
II (SDC)	87.39	106.68	0.819	67.7 million RMB one-off investment cost; 19.4 million RMB compensation cost; 1.9 million RMB running cost per year	-
III (WSP)	1.03	122.98	0.008	51,940 RMB/year training cost; 14,840 RMB/year management cost	-
IV (PTD)	10.90	122.98	0.089	-	Paddy to soybean as example: Short-term cost = 1.52 million RMB in the first year; Long-term cost = 0.66 million RMB/year

As for the sensitivity of the cost-effectiveness (C/E) ratio to different discount rates, Figure 7 shows that Option II is the most sensitive, followed by Option I and Option IV. Option III is not sensitive to the discount rate. The comparative relationship between the four options does not change under different discount rates from 2%-8%; only the comparative relationship between Option I and Option IV changes under very low discount rates.

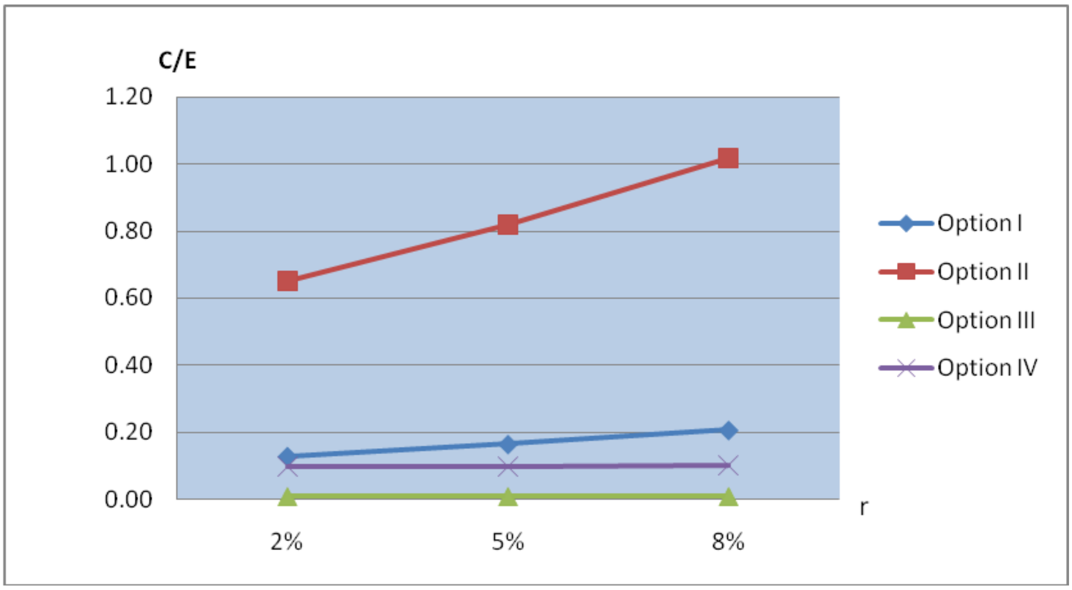

Figure 7. Cost-effectiveness of the four policy options under different discount rates

7.0 ANALYSIS AND DISCUSSION: COMPARING THE TRADE-OFFS BETWEEN THE DIFFERENT POLICY OPTIONS

7.1 Criteria for Comparing Different Policy Options

In Section 6, we calculated the cost-effectiveness of the different policy options. Yet this kind of economic analysis is only one of the ways environmental economics can support real decision-making. Based on our consultations with the local officials, we chose four different criteria to compare the trade-offs between the four options (Table 26). A stakeholder analysis was integrated into this exercise.

Table 26. Criteria for comparing the four policy options

Criteria	Description	Measurement
Cost-effectiveness	Economic performance	RMB/ha
Reliability in achieving the effect	Certainty in achieving the policy purpose	High to low (Scale:1-4)
Government's attitude		Support to oppose (Scale:1-4)
Acceptance by farmers		Support to oppose (Scale:1-4)

Criteria 1: Cost-effectiveness

For this policy study, the objective is very clear i.e., to save a certain amount of water for wetland conservation. Cost-effectiveness is a very useful and appropriate parameter to measure the economic viability of each policy option. The cost-effectiveness of each option was measured in RMB per cubic meter of water saved through the respective policy.

Criteria 2: Reliability in achieving the effect

Since the ultimate purpose is to release some water to meet the ecological water demand for wetland conservation, we basically measured the water-saving effect of each policy option. Some of the options were more reliable in achieving the desired effect than others.

Criteria 3: Government's attitude

The government includes the Water Affairs Bureau, Wetland Management Bureau, Reservoir/Irrigation District Management Bureau, State-owned Farm Bureaus, and Agriculture Development Commission. Because the agencies play different roles in the four options, some agencies are more important and influential than others. *Importance* refers to the degree to which an agency is the focal point of the decision to be made. *Influence* refers to the level of power an agency has to control the outcome of the decision. Influence is dictated by an agency's control of or access to power and resources (De Groot et al. 2006). More attention should be paid to the attitude of the most important and influential agencies.

Criteria 4: Acceptance by farmers

Farmers have land tenure in the area or rent land for a living. For all policy options, the farmers are inevitably affected directly or indirectly, so they are the most important stakeholders. Under the government plan for "Constructing New Socialist Villages", the acceptance by farmers of any proposed option is especially important.

7.2 Option I: Irrigation System Reconstruction (ISR)

Criteria 1: Cost-effectiveness

The cost-effectiveness result of 0.164 RMB/m^3 is acceptable ranking the option as the third most cost-effective among the four. In our calculation, we did not quantify the benefits of improved agricultural productivity which would have made the cost-effectiveness better.

Criteria 2: Reliability in achieving the effect

If the irrigation system is reconstructed as planned, this will surely save the targeted amount of water. In other words, the reliability is very high technically, but it is dependent on the proper running and operation of the irrigation system which requires a better management system.

Criteria 3:. Government's attitude

The Water Affairs Bureau, Agriculture Development Commission and State-owned Farm Bureau are the key government stakeholders in this policy option. The Water Affairs Bureau thinks that Option I is the key solution to reducing water use by the agriculture sector, without which no other hard or soft measures would work. The bureau officials think that the option is feasible for several reasons. Firstly, it is consistent with the current agricultural development strategy of the central government so there is no political obstacle from any level of government. Secondly, funding will be easy to raise as the central government is providing strong financial support for improving irrigations systems under the "Constructing New Socialist Villages" Program. Thirdly, the project can be carried out stage by stage to spread out the initial financial cost and the local government can play an important role in initiating this project. The Agriculture Development Commission and State-owned Farm Bureau also support this option because it is good for agricultural development.

One concern of the Wetland Management Bureau is that in order for this project to be successful, there needs to be a mechanism in place to ensure that the saved water really goes to the wetland. This raises two water management issues: one is the coordination of water allocation in the Qixinghe River basin by higher level government authorities and the other is the interests of the Reservoir/Irrigation District Management Bureau in the implementation of the water allocation plan.

The Reservoir/Irrigation District Management Bureau was originally under the government. This has changed; they are now expected to run like businesses. This makes it put profits as the primary objective and there is no incentive to encourage water saving because this would mean less fees collected. The bureau takes charge of the water supply and the running and maintenance of the irrigation system. Because it charges based on water used in the main irrigation canal, there is no incentive for it to maintain the end-parts of the canal or the capillary canals.

Since there is no proper maintenance of the end canals, low water transfer efficiency results and many farmers do not pay their water fees because of the poor service. This in turn results in a deficit for the bureau. Even assuming that that water is saved through the reconstruction of the irrigation system, the profit-first policy of the bureau may result in the saved water being diverted to rich users rather than the wetland.

Criteria 4: Acceptance by Farmers

Our rural household survey showed a relatively high vote for Option I (82.9%). Farmers ranked this option as their second preferred choice (score of 111) after Option II (EWC) (score of 221) (Table 27). One possible reason for this result is that the farmers could not judge whether they needed to pay more or less for the service they received.

Table 27. Farmers' attitudes towards the four policy options

Option	Support (%)	Unclear (%)	Oppose (%)	Score
I - ISR	82.9	8.0	9.0	111
II - EWC	87.4	4.5	8.0	221
III - WSP	86.9	5.5	7.5	49
IV - PTD	48.7	14.6	36.7	59

Notes:
(1) The response rate was 199 out of 201.
(2) We used the subjective weighting method with score indices to assess the farmers' attitudes. In our survey, the farmers were required to choose only two preferred options from the four. A higher score means the options were chosen as the best two more often.

7.3 Option II: Ecological Water Control Reservoir (EWC)

Criteria 1: Cost-effectiveness

At 0.819 RMB/m^3, this option is the least cost-effective among the four. One explanation for this is that in our calculations, we did not calculate benefits other than supplying water to the wetland, such as flood control for downstream areas and fishery improvement in the reservoir, which could greatly mitigate the investment cost and improve the cost-effectiveness of this policy option.

Criteria 2: Reliability in achieving the effect

If the reservoir is built, it is sure to save the amount of water the wetland requires. The only risk lies in the running efficiency of the reservoir, which means there needs a mechanism to guarantee that the water retained by the reservoir will be diverted to the wetland rather to commercial uses.

Criteria 3: Government's attitude

The Water Affairs Bureau is the key stakeholder in this policy option. The bureau officials believe that it is the key to solving the water problem in the Qixinghe River basin. The county Agriculture Development Commission agrees with this proposal because it will not hurt agriculture and the Wetland Management Bureau is also very supportive because it considers that this option would meet the wetland's water needs.

The Water Affairs Bureau expressed the need for approval and financial support from upper level government. This concern is understandable given that it is a local and low level government body with a limited budget and no big say in such high-budget decisions. Also, the project has to fit into the river basin water resources plan which is controlled by the Heilongjiang Provincial Water Resources Department although in reality, there has never been a serious water resources plan for the Qixinghe River basin. Although the bureau officials expressed that they would apply for approval for the project, this policy would face financial obstacles because it required a big lump-sum investment.

Besides the capital investment, the running cost is a more fundamental problem. As the purpose of this construction is to supply water to the wetland, the Wetland Management Bureau should be the beneficiary. However, the benefits of wetland conservation are externalized, and under current regulations on nature reserves, there might be no or low profits from the conservation of the wetland to cover the running costs of the reservoir. So although this policy option suggests that the government cover the construction and running costs, there is still a need to set up a financial mechanism to solve the problem of financing.

Criteria 4: Acceptance by farmers

Our household survey revealed that a very high percentage (87.4%) of farmers supported this option, while only 8% opposed it. We also asked the respondents to rank their most preferred option, and found that this option got the highest score among the four. This is completely understandable as this option would not bring the farmers any financial burden whilst benefiting them indirectly.

7.4 Option III: Water-Saving Practices (WSP)

Criteria 1: Cost-effectiveness

This option is the most cost-effective at 0.008 RMB/m^3.

Criteria 2: Reliability in achieving the effect

Regarding the reliability of this option, the main concern centers around the farmers’ willingness to learn and apply the water-saving practices. Many new techniques promoted in the rural areas faced such a challenge. In general, farmers do not like taking risks and are not very sensitive to limited incentives, particularly in Heilongjiang Province which has relatively large areas of farm land. Thus, the potential difficulties in organizing and implementing this option cannot be ignored and how to encourage farmers to learn and apply the practices in paddy cultivation should be prioritized. Supplementary policies such as water permits and high water fees or water-saving incentives/subsidies should be considered.

Criteria 3: Government's attitude

This option has to be implemented by the government with the participation of the farmers. Although the cost-effectiveness analysis of this option seems ideal and efficient, it cannot succeed in isolation. Officials from the water and agricultural bureaus stressed that the water-saving practices would only be effective if the irrigation system was improved. They also emphasized the importance of supplementary policies for improved water pricing, increasing water charges, and the installation of water measurement devices.

Criteria 4: Acceptance by farmers

The survey results showed that a very high percentage of farmers (86.9%) supported this option. However, although the support rate was very high, farmers preferred Options I and II more. Combining with the findings of the survey, this reveals the ambivalent feeling of farmers towards the practices. On one hand, farmers support the practices because of they inflict no cost on them; on the other hand, they actually question whether the practices can make difference.

7.5 Option IV: Switching from Paddy to Dry Crops (PTD)

Criteria 1: Cost-effectiveness

The cost-effectiveness of this option is 0.089 RMB/m^3, ranking as the second most cost-effective among the four options. The farmers will have to bear most of the cost.

Criteria 2: Reliability in achieving the effect

The study found that this option would not be sustainable in the long term. Since the choice is dependent on the farmers' willingness to switch, fluctuations in the prices of paddy and dry crops will either encourage or discourage the change.

Criteria 3: Government's attitude

The most important and influential government agencies include the county's Agricultural Development Commission and the State-farm Management Bureaus which expressed strong concern about the option; they did not think the option was feasible due to three major reasons.

a) Ensuring food security is a political task for the local government. It is not possible to decrease the area under paddy fields as the current proportion of paddy fields was not high in Baoqing County.

b) In the 11th Five-Year Plan (2006-2010) for Agriculture in Baoqing County, the areas under rice and corn are to be increased.

c) The price of rice is increasing and the returns from rice production are better than before.

In fact, the most important reason is that the option is not in line with the current agricultural development plan promoted by the central government nation-wide. Compared with agricultural development, wetland ecological protection is perceived as less important. Moreover, as the most important rice producers in the nation, the state-owned farms get direct pressure to produce more rice to stabilize the price.

The affected area of paddy fields is also quite limited. According to the survey findings, the estimated local rice output per hectare can reach 7.5 tonnes. The implementation of this option will lead to a rice production loss of 4,927 tonnes from 656.9 hectares.

Criteria 4: Acceptance by farmers

As farmers are the most important group in this option, their acceptance is very crucial. The survey results showed that 48.7% supported switching from paddy to dry crops while 36.7% opposed the idea. This option is the only one with a support rate lower than 50%. This is perfectly understandable as the farmers have to bear the risks of the change involved and the level of uncertainty is high.

Considering the farmer’s attitudes, supplementary policies are required to encourage the switch from paddy to dry crops, for example, providing a subsidy to cover any losses suffered by the farmers.

7.6 Summary

Based on the analysis above, the results can be summarized as shown in Table 28.

Table 28. Trade-offs between the four policy options

Criteria	**Option I: ISR**	**Option II: EWC**	**Option III: WSP**	**Option IV: PTD**
Water saved	8 million m^3	6.94 million m^3	8 million m^3	8 million m^3
Cost -effectiveness	0.164 RMB/m^3	0.819 RMB/m^3	0.008 RMB/m^3	0.089 RMB/m^3
Reliability in achieving the effect	- high - needs good management - needs mechanism to guarantee supply to wetland	- high - needs mechanism to guarantee supply to wetland	- medium - needs incentive	- low - needs incentive - unsustainable in the long-run
Government's attitude	- high - matches policy priority and funding mechanism	- medium - has technical support but no financial capacity	- high - not independent	- low
Acceptance by farmers	- high - not sure about cost burden	- high - no cost	- medium	- low

Note: For cost-effectiveness; the lower the value, the more cost-effective the option.

Based on each criterion, we gave a score to each option. Specifically, if an option ranked first, it got a score of 10. If it ranked second, third and fourth, it got a score of 8; 5 and 0, respectively. The results are listed in Table 29.

Table 29. Ranking of the four policy options

Criteria	**Option I: ISR**	**Option II: EWC**	**Option III: WSP**	**Option IV: PTD**
Cost-effectiveness	5 (3)	0 (4)	10 (1)	8 (2)
Reliability in achieving the effect	8 (2)	10 (1)	5 (3)	0 (4)
Government's attitude	10 (1)	5 (3)	8 (2)	0 (4)
Acceptance by farmers	8 (2)	10 (1)	5 (3)	0 (4)
Total Score (Ranking)	31 (1)	25 (3)	28 (2)	8 (4)

Note: The rank of the options is given in parenthesis (1 = best option; 4 = worst option)

We can see that each of the options have pros and cons. Option III is the most cost-effective while Option II has the highest reliability in terms of water saving and is the most supported by the farmers, but the cost is extremely high for the local government. Option I, on the other hand, has the government's greatest support. Given the same weighting for all four criteria, Option I is the best overall policy while Option III ranks second, Option II ranks third, and Option IV is the least feasible.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The target wetland in this study, the Qixinghe Wetland, is surrounded by large agricultural water users, which compete with it for water. This has led to a severe water shortage for wetland conservation. It is important to reduce agricultural water use for both wetland conservation and sustainable development of the economy.

Among the four policy options designed at the local level to manage the off-site agricultural water use, taking consideration of the reliability of supplying water to the wetland, cost effectiveness, and the attitudes of the government and farmers, we concluded that Option I (Irrigation System Reconstruction or ISR) was the optimal option and Option III (the promotion of water-saving planting practices or WPP) was the second best and could in fact be complementary to Option I. As for the implementation, both the ISR and WPP options require a reform of the water pricing policy and the improvement of the irrigation district management system.

As mentioned above, the current water pricing system (charged on acerage and having a low charge rate) has brought about the low collection of water fees so much so the water fees collected are insufficient to cover the running costs of the irrigation system. This has created a vicious circle: Irrigation project not well-functioning → poor irrigation service → low payment of water fees → lack of maintenance of the project. Even if the irrigation project were to be put in place, if we do not strengthen the implementation of the water pricing policy, it will still result in an ineffective irrigation system.

The same is the case for water-saving planting practices. Under the low water pricing policy, there is no incentive for farmers to take water-saving action, so even if the irrigation project is put in place, there still needs to be incentives to encourage farmer to take up these practices to create real water-saving.

Therefore, in order to ensure the effectiveness of the proposed measures, we must establish an effective pricing policy that will provide economic incentives to ensure implementation, and increasing the water price is a logical first step in this direction. The irrigation district management system should also be reformed in order to create a conducive institutional environment to support the new water pricing policy.

Other mechanisms are required to ensure that the water-saving effects are converted to ecological benefits in terms of wetland conservation. The options above presume that the water saved will not be diverted to other water users and will go to the wetland. However, our analysis revealed that whether the water saved will be allocated to the wetland depended on the water resource management authorities. As water becomes a more and more scarce resource, the decision to distribute the saved water freely to the wetland faces competition from commerical uses that promise greater financial returns to the water providers. Just as in the case of the Zhalong Wetland (see box in Section 4.3), the irrigation district bureau will have no economic incentive to ensure that the water goes to the wetland. Therefore, the answer lies in establishing a funding mechanism to make the wetland a *competitive* water user.

8.2 Recommendations

In light of the results of this study, several policy recommendations are made.

a) In order to tackle the wetland water shortage problem, we suggest that the local government reconstruct the irrigation system in the surrounding area of the Qixinghe Wetland for water-saving purposes as early as possible while restricting further expansion of paddy fields in the Qixinghe River basin. In order to implement the irrigation system reconstruction project, the Water Affairs Bureau should take the initiative to solve its bottleneck problem which is finance. There already exists an available funding source i.e., the national budget, so the local government can apply for National Funding for Neo-village Construction, in which agriculture water-saving is one of the priorities.

b) Water-saving practices should be continually promoted by providing regular training to farmers. The option of water-saving planting practices was found to be the most cost-effective, so it should be applied as much as possible. The training is also very necessary because this study found that the local farmers had quite low openness to water saving.

c) Speeding up water pricing reforms and irrigation district management system reforms is important. The implementation of hard measures needs to be strengthened by using economic incentives.

d) Actually, reconstucting the irrigation system and promoting water-saving planting practices should be conducted at the same time as irrigation management and water pricing reforms to accelerate the whole process. The direction of agricultural water pricing reform should be to make economic benefits play a role in water resource allocation. The irrigation management system should be based on the "Irrigation District Management Bureau + Water Users Association + water households" partnership model to ensure participatory irrigation management and stimulate the collective action of farmers in water-saving when the water price goes up.

e) Making the wetland a competitive water user, by arranging for funding for reliable water supply under the National Wetland Protection Program is necessary. The key constraint for wetlands in competing with other water users is the lack of funding. In view of the wetland's spill-over benefits, such funds should be guaranteed by the government. However, the current funding mechanism for wetland conservation does not take full consideration of the wetland's water resource demands. So we suggest that the central government set up a special budget for dealing with the problem of water shortage in wetland conservation.

f) For the provincial government, we suggest that a water resource plan of the whole Qixinghe River basin be made as early as possible, taking account of the real ecological water demands of the wetland.

g) Appropriate institutional arrangements should also be made at the provincial level by involving representative wetland departments in the water allocation and agricultural development decision-making process.

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APPENDICES

Appendix 1. Farmers' Water-Saving Behavior at Different Water Prices

We predicted the farmers' water saving behavior at different water prices by applying the Price –Field Water Demand Elasticity Model.

(a) Research assumption and methodology

Maximum profit is the only criteria in the farmers' water consumption choice. The water production function of crop yields and irrigation water amount can be illustrated as a quadratic curve.

$$Y = a + bX^{2} + \qquad \text{(A1)}$$

where

Y = crop yield (kg/ha)

X = water consumption (mm)

a, b, c = empirical coefficients

According to the principle of maximum profit, farmers would choose the level of water application to maximize their profit, so the target function is:

$$MaxB = YP - C = (a + {}^{2}bX + c \qquad \text{(A2)}$$

where

Pc = unit price of crop

Pi = price of water (RMB/mm)

L = other cost of planting, other cost associated with production e.g. pesticides, fertilizers, labor, and farmland.

The first order condition for this profit maximization problem defines the optimal level of water application. So the relationship between water consumption and price is:

$$X = \frac{w}{2Pc} - \frac{b}{2c} \qquad \text{(A3)}$$

Under this relationship, the amount of water saved under various prices can be estimated.

We can also calculate the farmers' welfare loss caused by water price changes. As Equation (A4) shows, the farmers' welfare loss is caused by yield reduction and water price increases.

$$C_{FBL} = C_{YD} + C \qquad \text{(A4)}$$

where

C_{FBL} is the farmers' welfare loss;

C_{YD} is the welfare loss caused by yield reduction; and

C_{WPI} is the welfare loss caused by water price increases.

(b) Evaluating the parameters

Taking rice production in WJQ Farm as an example, the value of parameters a, b, and c in Equation (A1) can be calculated using the confirmed relationship between water consumption and crop yields throughout the whole growth period in northeast China (where the research sites are located) as shown in Table A1.

The value of parameters a, b, and c in Equation (A1) is provided by the China information database on irrigation experiment stations, which reflects the actual relationship between paddy yields and water consumption throughout the whole growth period under the current production technology in northeast China (Xiao and Liu 2008). The prices of crops and costs of other inputs L, including the fixed capital investment, are obtained from the WJQ-5 farm which reflects the general situation in the study area (Li 2007). The data and parameters are summarized in Table A1.

Table A1. Values of the parameters

Parameter	**c**	**b**	**a**	**Pc(RMB/kg)**	**L(RMB/ha)**
Value	-0.0102	29.332	-11645	1.45	8645

(c) Results of the model

The predicted effects at the different prices are shown in Table A2.

Table A2. Effects at different water prices

Water price (RMB/ m^3)	**Water saved (m^3/ha)**	**Ratio of saved water**	**Loss of social welfare**	**Ratio of production reduction**	**Benefits to farmers**	**Ratio of lost benefits**	**Ratio of water fees to total costs**
0.04	135	0.90%	1.87	0.02%	272.7	1.99%	6.2%
0.05	169	1.18%	2.92	0.03%	415.1	3.03%	7.6%
0.06	203	1.41%	4.20	0.04%	557.0	4.07%	8.96%
0.08	270	1.88%	7.47	0.08%	840.0	6.14%	11.6%
0.09	305	2.12%	9.45	0.10%	981	7.17%	12.8%
0.1	338	2.35%	11.67	0.12%	1121.6	8.20%	13.87%

From the above table, when the agricultural water price meets the supply cost of 0.04 RMB/m^3, the water saved is just 135 m^3/ha and the ratio of saved water is just 0.9% of the total amount of water consumed. Thus, the water price has trivial impact on encouraging farmers to save water. As the water price increases, farmers begin to use less water for irrigation. When the water price reaches 0.08 RMB/m^3, the water saved is 270 m^3/ha and the ratio of saved water is 1.88%. Thus, the amount of water saved for the whole implementation region (12,185 ha of paddy fields) is about 3.29 million m^3/yr.

When the price is 0.04 RMB/m^3, the ratio of water fees to total production input is 6.2%. Some surveys suggest that when agricultural water fees are 10%-12% of agricultural input and 8%-10% of agricultural output, it is acceptable to farmers (Li et al. 2007). Therefore, the water price is reasonable at 0.08 RMB/m^3.

(d) Discussion

The model assumes that the maximum profit is the only factor determining farmers’ choices. However, there are other factors affecting the farmers’ irrigation behavior, such as traditional irrigation practices, maximum yields, neighbors’ irrigation behavior, risk-avoidance, and advice from related government agents. All of these factors could have an effect on water-saving and production reduction.