# Securing Water for Wetland Conservation: A Comparative Analysis of Policy Options to Protect a National Nature Reserve in China

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## Abstract

This study evaluates four policy options to secure the water supply needed for wetland conservation in Qixinghe—a national wetland nature reserve in China—using four criteria: cost effectiveness, probability of success in achieving the water-saving goal, political feasibility, and farmer acceptance. This multi-criteria analysis framework reveals the ecological, economic, and socio-political trade-offs for policymakers when choosing among the four policy options. Results suggest that upgrading irrigation infrastructure in the area surrounding the wetland (Option I) is the most politically feasible option, but it is the second best option in terms of cost effectiveness. Constructing a dam to store and control floodwater (Option II) is the most reliable for achieving the water-saving goal. It is also the farmers' most favored strategy. But this option is the least cost effective and receives little support from local governments. Promoting farmers' adoption of water-saving practices (Option III) is the most cost effective, but it is less reliable for achieving the water-saving goal than Options I or II. Converting paddy crops to dry-land crops (Option IV) is politically infeasible and least reliable for achieving the water-saving goal. The overall ranking of the four options is determined using the policymakers' revealed weights on the four criteria. Option I is ranked first, followed by Options II, III, and IV.

*Key words:* agricultural water use, cost effectiveness, multi-criteria decision making, water resource management, wetland conservation

## 1. Introduction

Water shortage—insufficient water for human use and ecological functions—has been identified as the primary cause of wetlands loss on a global scale (Millennium Ecosystem Assessment, 2005; Mitsch and Gosselink, 2007). Approaches to resolve the water use conflicts to meet the basic ecological water requirement of wetlands has attracted increased attention (Hirji and Davis, 2009; Lemly, 2000). China owns about 10% of the total wetland area in the world (State Forestry Bureau, 2000) but faces serious water conflicts in wetland conservation (State Forestry Bureau, 2005). This paper addresses this issue by evaluating an array of policy options to secure water for wetland conservation using the Qixinghe wetland—a national wetland nature reserve in the Sanjiang Plain, north-east of China—as a case study.

Wetlands in the Sanjiang Plain have high ecological significance regionally, nationally, and globally. They are the most important breeding grounds of migratory waterfowl in Northeastern Asia. Thirty-seven vertebrate wildlife species listed by the World Conservation Union (IUCN) as globally threatened are found in these wetlands. Three wetland nature reserves in the Sanjiang Plain are listed by the Ramsar Convention as internationally significant wetlands (Asian Development Bank, 2004).

The Sanjiang wetlands are rapidly disappearing, however. The total area of the wetlands decreased from 3.7 million hectares in the 1950s to 0.92 million hectares in 2005 (Li, 2008). A major cause of the wetland loss is agricultural development. The high-quality soils and favorable climate for grain production in the region have attracted major attention from the central government, which has encouraged settlement and reclamation of wetlands and development of large-scale farming in the region since the early 1950s. The government policy has no doubt exacerbated the water conflicts between ecological conservation and agricultural development. According to the Heilongjiang Provincial Institute of Hydraulic and Hydropower Reconnaissance and Design (2005), agricultural use accounts for more than 80% of total water use in the Sanjiang Plain and is expected to continue to increase in the future because the irrigated paddy acreage is expected to double in the next 15 years. The situation in the Sanjiang Plain presents some of the typical wetland conservation issues in China: wetland ecosystems are increasingly threatened by water use throughout the entire basin, driven by the government's overall development strategy, including agricultural development, urbanization, and industrialization.

Resolving such water use conflicts requires striking a balance between wetland conservation and socio-economic development. Many previous studies have examined the relationship between water allocation and wetland conservation (Birol et al., 2008; Dietrich and Grossmann, 2005; Jogo and Hassan, 2010; Li et al., 2009). Some of these studies focused on exploring ways to preserve wetlands through agricultural water management. For example, De Voogt et al. (2000) modeled the water allocation between wetland and irrigated agriculture using an engineering approach. Others (e.g., Varela-Ortega, 2003; Mejias et al., 2004) examined the effect of water pricing policies for wetland conservation on agricultural water use, farm income, and government revenue. Those previous studies tended to focus on a single type of policy without comparing it to other policy options.

In recent years, the systems approach has been used increasingly to analyze water resource management issues. This approach emphasizes the importance of active stakeholder involvement in resolving resource conflicts and developing mutually acceptable solutions (Mostert, 1998; Yang et al., 2008; Nijkamp, 1989; Janssen, 1992; Olewiler, 2007; Corsair et al., 2009). Several studies have developed concepts and methods for integrated policy analysis of wetland conservation, which combine economic efficiency, stakeholder analysis and multi-criteria evaluation to achieve policy consistency (Turner et al., 2000； Brouwer et al., 2003; Van den Bergh et al., 1999; Herath, 2004). Multi-Criteria Decision Making (MCDM) and Multi-Objective Programming (MOP) methods have also been used to analyze water allocation among conflicting stakeholders (Nandalal and Simonovic, 2003; Srdjevic et al., 2004). Relatively few studies, however—especially in China—have evaluated policies for solving water conflicts in wetland conservation using an integrated research approach.

The purpose of this study is to explore ways of securing the water supply needed for wetland conservation in the Sanjiang Plain of China. Our specific objectives are: 1) to identify water problems encountered in wetland conservation and the associated water-use patterns in the study region; 2) to propose policy options for securing wetland water supply through multiple channels; 3) to compare the proposed policy options using four criteria: cost effectiveness, probability of achieving the water-saving goal, political feasibility, and farmer acceptance; and 4) to perform a multi-criteria analysis to rank the policy options. The results of this study should inform the design of strategies to achieve conservation targets by considering the ecological, economic, and socio-political trade-offs of alternative policies in the study region.

This paper is organized as follows. Section 2 describes the study region, its conservation challenges, and the policy options to meet the challenges. Section 3 presents the methods and data for comparing the policy options. Section 4 discusses the results. Conclusions and policy suggestions are summarized in Section 5.

## 2. The Study Region, Conservation Challenges, and Policy Options

Our study region includes the Qixinghe wetland and its surrounding area (see Figure 1). The Qixinghe wetland is a typical freshwater wetland located at the hinterland of the Sanjiang Plain, along the southern bank of Qixinghe River. Qixinghe wetland is surrounded by one county (Baoqing County) and two State Farms (Wujiuqi State Farm and Youyi State Farm). The surrounding areas is dominated by agricultural activities.

The Qixinghe wetland is facing a serious water loss problem. The water table decreased by as much as 12 meters in some wells in the surrounding area between 1997 and 2005, with an average annual decrease of 2.5 meters (Xia and Wen, 2007). Water-use conflicts intensify during the irrigation season.

Water shortages are expected to increase in the future for several reasons. First, according to Baoqing County's development plan, there will be a huge increase in water demand in the next few years; the estimated total water demand in 2010 was 73% higher than that in 2006. Second, agricultural expansion along the river will accelerate water drainage in the region, as the water diversion systems are more fully developed. Third, the water inflow from upstream is expected to continue to decrease due to increased water diversion, lower precipitation, and reduced floodwater volume entering the wetland.

To preserve the wetland ecosystems, the Qixinghe National Wetland Nature Reserve was designated in 2000. The designation prohibits on-site activities that directly affect the wetland, such as expansion of farming, fishing, and the harvesting of reed and other raw materials (State Council of Government of China, 1994). However, off-site activities that indirectly affect the wetland remain, of which competing water use is the largest threat. Consequently, even if all the conservation measures were fully implemented inside the Nature Reserve, without policies to combat the threat from the outside, the wetland cannot be saved, and the conservation goal cannot be achieved. Policy interventions are therefore needed to meet the basic ecological water requirement of the wetland.

This basic requirement refers to the minimum flow level needed to maintain the components, functions, processes, and resilience of aquatic ecosystems (Acreman and Dunbar, 2004). Several previous studies have estimated the Qixinghe wetland's basic ecological water requirement (Cui et al., 2005; Xia and Wen, 2007).

The most recent estimate suggests Qixinghe's basic ecological water requirement is approximately 38.17 million $m^3$ (Xia and Wen, 2007). According to satellite images and data collected by the Qixinghe Wetland Management Bureau, about 20% of the total environmental water requirement, or 8 million $m^3$, needs to be recharged annually, which therefore is set as the amount of water that needs to be recharged into the wetland through policy intervention in this study.

To achieve the water-saving goal of 8 million $m^3$, this study examines water uses by various industries and sectors in the surrounding area, including industrial, agricultural, and urban water use, and identifies agriculture as the key sector for policy targeting. The emphasis on agriculture is based on the following reasoning:

First, agriculture is the largest water user, accounting for more than 80% of total water use in the study region. Agriculture has expanded drastically in recent years and is expected to continue to expand in the future. Policies encouraging agricultural development, along with high rice prices, have led to an increase in the total area of paddy fields since 1995, by 111%, 105%, and 248% in Baoqing County, Wujiuqi State Farm, and Youyi State Farm, respectively, according to statistics from the Heilongjiang State Farm Bureau (1996–2006) and the Baoqing Statistics Bureau (1996–2006).

Second, there is an inherent and severe water-use conflict between agriculture and wetland ecosystems. Agricultural water use concentrates in spring, which is also the most water-demanding season for the wetland. Along with the development of paddy fields, irrigation and drainage systems have greatly accelerated water draining from the wetland. Embankments for flood control and drainage canals have also prevented floodwater from entering the wetland.

Third, agriculture has the highest potential for saving water. According to the estimates of the local water affairs bureaus, water use for rice production is 13,500 $m^3$/ha in the rural area of Baoqing and 12,000 $m^3$/ha in the two state farms, whereas the average water use in Heilongjiang is only 6,750 $m^3$/ha. In addition, local water affairs bureaus have already implemented strong controls on industrial water intake, while controls on agricultural water intake are still very weak. Until very recently, there has been no control on agricultural water use, and the current water fee applies only to paddy field irrigation and is based on acreage (rather than on the amount of water used), charged at 300 CNY/ha, which covers only 54.3% of the water supply cost (Heilongjiang Provincial Bureau of Commodity Price, 1997).

Finally, the cost of saving water is lower in agriculture than in other sectors. Calculated with data from Baoqing Statistics Yearbook (Baoqing Statistics Bureau, 2007), the agricultural output value of water is 11.56 CNY/$m^3$, while the industrial output value is 27.32 CNY/$m^3$ in 2006.

Through our field investigation, we identified and formulated four policy options that could achieve the 8.00 million $m^3$ water-saving goal. Among the four policy options, two are engineering projects, one is technology dependent, and one addresses farming methods. The four policy options are described briefly below. The specific details about each option are discussed in Section 3.

*Option I. Upgrading irrigation networks*

This option aims to save water by modernizing irrigation networks in the region. The specific measures include: (i) completing the canal system to enhance water-delivery capacity; (ii) adding an under-layer to the canals to improve the water-delivery efficiency; and (iii) installing water-measurement devices and control gates to measure and control water use. These measures could save water by improving the efficiency of the canal system. Higher efficiency could be achieved by reducing water loss in the delivery process. This option would also make the irrigation infrastructure ready for implementing water-saving practices and other management policies, such as water pricing based on the amount of water use. Part of the capital investment for irrigation infrastructure upgrades can be obtained from the National Small Agricultural Hydraulic Project Funding. Operation and maintenance costs could be covered by water users and farmers through water charges based on volume. The first step for this option, of course, is to identify the appropriate sites for infrastructure upgrades.

*Option II. Constructing a small dam to store and control floodwater*

This option proposes construction of a low dam to address the inefficient use of snowmelt and floodwater. The design of this dam is based on a proposal put forth by the local water resource management bureau in 2002 (Water Affairs Bureau of Baoqing County, 2005), in which a dam with a Hennessy capacity of 6.94 million $m^3$ would be constructed in the middle upstream area of the Qixinghe River to store and control floodwater. The proposed site falls within the study area. As the designed height of the dam is to be only 15 meters, it would exert a minimal impact on the local ecological systems.

*Option III. Adopting water-saving irrigation practices*

This option encourages farmers to adopt water-saving practices, but it requires local governmental support. Specifically, the responsible party would be the Agricultural Technology Promotion Center (ATPC) of Baoqing County, which would provide water-saving irrigation training for farmers and monitor and evaluate the actual practice by the farmers. The training would be provided on a yearly basis, and each session could accept 20 trainees. The ultimate goal would be to guarantee farmers' implementation of water-saving practices.

*Option IV. Converting paddy fields to dry-land crops to reduce water use*

In the study area, dry-land crops rely completely on rainfall and do not require irrigation. Thus, converting paddy fields to dry-land crops could save a large amount of water. Since both wet- and dry-land farming are traditionally carried out in the local areas, the conversion is technically feasible for farmers. However, because there is a significant price difference between rice and dry-land crops, such a move would likely reduce farmers' net income, making them reluctant to make the change. The role of government is to promote the conversion of paddy fields to dry-land crops by providing information, subsidies, and technical assistance to farmers.

The proposed policy options would be implemented in the region where agriculture directly competes with the wetland for water. Based on our field investigations and experts' advice, we identified six irrigation districts surrounding the Qixinghe wetland as the region for possible policy implementation. Two districts belong to Baoqing County (Qixinghe town, Qixingpao town), two to the Wujiuqi State Farm (Wujiuqi-4, Wujiuqi-5), and two to Youyi State Farm (Youyi-6, Youyi-8). The characteristics of the implementation region appear in Table 1.

Among the four policy options, water pricing was not included in the final implementation because there are institutional barriers and physical infrastructure shortcomings that limit the flexibility of water pricing in the local area (Wu et al., 2009). As the Songliao Water Resources Commission (2005) has pointed out, administrative mechanisms, such as water resources planning and corresponding engineering projects, are still the dominant instruments for water resource allocation in the Sanjiang Plain.

## 3. Method and Data for Evaluating the Policy Options

The four policy options were evaluated based on a set of criteria, including cost effectiveness, probability of achieving the water-saving goal, political feasibility, and farmer acceptance. Previous studies tended to focus on cost effectiveness (Blanco-Gutiérrez, 2011; Trepel, 2007), but cost effectiveness is only one consideration when making policy choices. Political feasibility, farmer acceptance, and the probability of achieving the water-saving goal are also important considerations, as we discovered when interviewing local officials. Each of the policy evaluation criteria is discussed below.

*3.1 Cost effectiveness*

In the context of the current study, cost effectiveness (CE) is measured by the average cost per unit of water saved. One complexity in evaluating CE is that the costs and the effects (water saved) occur at different points in time. The standard approach to addressing this issue is discounting. Specifically, let $C_{it}$ be the cost for implementing Option *i* in year *t*, the present value of all costs for implementing Option *i* during the evaluation period is calculated by Equation (1).

(1) $$TC_i = \sum_{t=0}^{N} \frac{C_{it}}{(1+r)^t} - \frac{C_{iR}}{(1+r)^{N+1}},$$

where $r$ is the discount rate, $N$ is the number of years evaluated, and $C_{iR}$ is the residual or salvage value of the investment at the end of the evaluation period. The costs incurred during the evaluation period may include the initial investment and the annual operating costs.

The total effect can be calculated in a similar fashion. Let $W_{it}$ be the amount of water saved in year *t* from implementing Option *i*, then the "present value" of the total effects (Warford, 2003) can be calculated by Equation (2).

(2) $$TE_i = \sum_{t=0}^{N} \frac{W_{it}}{(1+r)^t}.$$

Water saved in the future is discounted, because even if the value of water saved remains the same at different points in time, current saving is still preferred to that in the future because it generates ecological and economic values immediately. In addition, delaying water-saving actions can lead to irreversible ecological degradation.

The cost effectiveness of Option *i* is defined as the ratio of the present value of total costs to the present value of total effects, as shown in Equation (3).

$$CE_i = \frac{TC_i}{TE_i}. \quad (3)$$

Equation (3) suggests that to evaluate the cost effectiveness of the options, we need to choose the evaluation period and the discount rate. We also need information about the initial investment, the annual operating costs, and water saved each year during the evaluation period.

The evaluation period for the four options is from 2008 to 2037 (i.e., N = 30). The discount rate is set at 5%, following China's Construction Project Economic Evaluation Methods and Parameters (National Development and Reform Commission and Ministry of Construction, 2006), which suggests a discount rate of 5 to 8%. To test the sensitivity of the results to the discount rate, we also calculated the results using 2% and 8% as the lower and upper bounds of the discount rate. Other data used to calculate the cost effectiveness of the options are discussed below.

Option I involves improving irrigation systems in the surrounding area where agriculture competes for water with wetland. The initial investment includes both the cost of modifying the canal system and the cost of installing water measurement devices and control gates. The annual operating costs include the costs of maintaining and operating the canal system.

The initial investment for improving the irrigation system in Option I was estimated by local experts at 27,750 CNY/ha for the irrigation districts in the rural area of Baoqing County, and 15,000 CNY/ha for the irrigation systems in the state farms.[1] According to the Heilongjiang Provincial Bureau of Commodity Pricing (1997), the average annual operating cost of the irrigation systems was 580 CNY/ha per year. The residual values of the initial investment were estimated using the methods presented in Appendix A.

Option I would save water by improving the delivery efficiency of the canal system. The annual amount of water saved under this option is calculated by Equation (4).

(4) $$W_i = \sum_{k=1}^{6} \left\{ A^k w_i^k \left( \frac{1}{V_0^k} - \frac{1}{V_1^k} \right) \right\},$$

where $A^k$ is the area of irrigated land in district $k$; $w_i^k$ is the amount of water applied to one unit of irrigated land ($m^3$/ha), and $V_0^k$ and $V_1^k$ are the delivery efficiencies of the canal system before and after the construction, which represent the amount of water delivered to the fields compared to the total amount of water withdrawn from the river. The water consumption per hectare ($w_i^k$) is 13,500 $m^3$/ha in rural areas, and 12,000 $m^3$/ha in the state farms, as estimated by the Baoqing Water Affairs Bureau. The data on irrigation efficiency ($V_0^k$, $V_1^k$) were provided by local experts based on the irrigation system design. The parameter values are listed in Table 1.

[1] All cost estimates are in the 2007 CNY, adjusted using the industrial products price index (PPI), if needed.

Since the irrigation districts have different potentials to improve water-delivery efficiency, the selection of districts for implementation will determine the overall effectiveness of Option I. To decide where the upgrades should be implemented, we first calculated the cost effectiveness for each district. Among the six irrigation districts, upgrades were determined to be the most cost effective in the Qixingpao Irrigation District. This, therefore, was the first district considered for implementing Option I, which could save 11,250 $m^3$/ha of water after construction, as reported in Table 1. Thus, to save 8 million $m^3$ of water, irrigation systems on 711 ha of land (8,000,000/11,250=711) would need upgrading. Since Qixingpao Irrigation District has more than 711 ha of irrigated land, Option I would be implemented only in the Qixingpao Irrigation District. The results are shown in Table 2.

Option II involves constructing a dam to store and control floodwater and reduce seasonal water scarcity. Initial investments include the cost of constructing the dam and the reservoir and the compensation to landowners dwelling in the inundation area of the reservoir. The annual operating costs would include the cost of maintaining and operating the dam and the reservoir.

Based on the design of the dam and reservoir, the total initial investment would be 67.7 million CNY. The compensation cost would be 19.4 million CNY. We estimated the annual operating costs based on the operating cost of a reservoir with the identical function but smaller capacity in another watershed of the same region (the Lishugou Reservoir with a Hennessy capacity of 0.88 million $m^3$).

According to the Water Affairs Bureau of Baoqing County (2005), the annual operating cost of the Lishugou Reservoir is 215,600 CNY. Hence, the annual operating cost of the designed reservoir (with a Hennessy capacity of 6.94 million $m^3$) is estimated at 1.9 million CNY. The residual value of the reservoir at the end of the evaluation period is 29.36 million CNY, calculated using the method discussed in Appendix A.

The amount of water to be saved by Option II was estimated based on the Hennessy capacity of the reservoir, which is 6.94 million $m^3$. The amount of water saved is assumed to be constant perennially, without considering any extreme variation in climate conditions.

In Option III, the government would organize training classes for farmers to learn water-saving skills. The cost of this option includes providing training classes, and monitoring and evaluating the implementation of the program to ensure its effective implementation. The total number of households that need to be trained to achieve the 8 million $m^3$ water-saving goal was determined based on the estimated water-saving potential of this option. The total training cost was then estimated by multiplying the total number of households trained by the cost per household.

Three assumptions were made when calculating the cost effectiveness for Option III: 1) all farmers trained for water-saving irrigation practices would be able to apply them successfully and could achieve the expected water-saving amounts; 2) it is unnecessary for ATPC to employ new staff or require current staff to work overtime to provide the training (thus, salary changes can be neglected); 3) only real materials or financial input are to be included in the costs: non-monetary input, such as time spent by farmers to learn about the water-saving practices, was ignored.

Option III has no initial investment. The governments, however, must pay the annual training and management costs throughout the 30-year period. Our methodology requires an estimation of the land area that must adopt the water-saving practices to achieve the 8 million $m^3$ water-saving goal and the number of households that must be trained. According to the estimation of the ATPC in Baoqing County, the water-saving potential after adopting conservation practices is 10% over the current amount. Annual costs include the cost to run training courses, which is estimated at 70 CNY per household (including 20 CNY training cost, 10 CNY for training materials, 20 CNY for continuous support services, and 20 CNY for organizing costs), and the management cost for tracking and evaluating, which is estimated at 20 CNY per household. Based on our survey in the implementation area, each household owns, on average, 8.86 ha of paddy land. The average water consumption in the implementation area is 12,179 $m^3$/ha, weighted by the acreage of paddy fields in the rural area and the state farms. Based on these values, the number of households that must be trained to achieve the water-saving goal was calculated at 742 households (8,000,000/12,179/10%/8.86=742).

Option IV is to convert paddy fields to dry-land crops to reduce water use. The total cost of this option can be divided into two categories: the initial cost and the annual costs starting in the second year. The initial cost would occur in the first year of conversion and would include the productivity loss due to lowered temperatures in the newly converted land and the cost of preparing the land for dry-land crop production. The annual costs include the reduction in profit when paddy crops are converted to dry-land crops.

According to our household survey, the cost to prepare land for conversion was estimated at 500 CNY/ha, and the productivity loss due to the lower temperature of newly converted land in the first year of conversion was estimated at 50%. Using data from the National Bureau of Statistics of China (1997–2007), we calculated the net income per hectare and net income differences between rice and corn or soybeans. The average difference in net returns between rice and corn or soybeans from 1996 to 2006 was used to calculate the annual income loss, which was estimated at 997.99 CNY/ha reduction from rice to soybeans and 1,123.53 CNY/ha reduction from rice to corn. The income loss in the first year would be larger, and was estimated at 1,812.03 CNY/ha for conversion from rice to soybeans and 1,874.79 CNY/ha for conversion from rice to corn.

Because dry-land crops in this area rely on natural precipitation and do not need additional irrigation, we assume that all the water used for irrigating a paddy field would be saved if it were converted to dry-land production. Thus, the total area of paddy crops that must be converted to dry crops to achieve the water saving target equals (8,000,000/12,179)=656.89 ha, where 12,179 is the average water application per hectare in the region). Since there is enough paddy cropland in the region to achieve the water-saving goal, the annual water-saving amount would in fact reach the target water-saving goal.

*3.2 Probability of Success in Achieving the Water-saving Goal*

Some of the options save water through engineering approaches; others rely on farmers' adoption of water-saving practices. Because of the nature of the water-saving approaches, some options would be more reliable for achieving the water-saving goal than others. Since the ultimate goal of any policy intervention is to meet the environmental water requirement of the wetland, the probability of achieving the goal is an important consideration for policy choice. The four options were ranked from high to low according to their probability of achieving the water-saving goal based on the information we collected through interviews with local experts.

Local experts were identified following the suggestions of the Baoqing Water Affairs Bureau and were selected based on their local project or management experiences and affiliations. Five experts from three of the most relevant research institutes were interviewed, including two experts on water resources, one hydraulic engineer, and two agricultural experts. The design of each policy option was described to these experts, who were then asked to assess the probability of success of each of the options based on their professional judgments. All interviews were semi-structured. We used a questionnaire, but we allowed the interviewees to express their opinions freely. The interviews were recorded to help verify their judgments.

*3.3 Political Feasibility*

The political feasibility of an option is defined as the extent to which the involved government agencies are willing to accept and support the option. Political feasibility is only one criterion, but it is arguably the most critical criterion. If not politically feasible, a policy option will not be implemented in China.

Stakeholder analysis was used to evaluate the attitudes of different government agencies toward the four policy options. Different government agencies play different roles and, therefore, would be affected differently by the four policy options. They also exert different influences in the decision-making process. The government agencies at the local level include the Water Affairs Bureau (WAB), the Agricultural Development Commission (ADC), and the Wetland Management Bureau (WMB). Public enterprises, such as State Farm Bureaus (SFB) and Water Supply Enterprises (WSE), traditionally have close relationships with or are part of the government agencies. Although they now attempt to maximize their own profits, they are not fully independent of the government and can directly or indirectly affect government decisions. Therefore, we considered these enterprises as part of government agencies.

Through interviews with government officials, the interests and concerns of government agencies were identified. Because the agencies play different roles in the four options, some agencies would be more important and influential than others. *Importance* refers to the degree to which an agency would be the focal point of the decision. *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. More attention should be paid to the attitude of the more important and influential agencies (De Groot et al., 2006). An option is more politically feasible if it is preferred by more influential and important agencies. Based on these principles, the political feasibility of the four options was determined through an analysis of the functions of the government agencies and interviews with government officials. The four options were then ranked from high to low according to their political feasibility.

Among the local governmental agencies involved, the Water Affairs Bureau (WAB) is responsible for implementing water policies and managing water affairs. Specific responsibilities include collecting water fees, issuing water use permits, and conducting water resources planning and engineering projects. The Agricultural Development Commission (ADC) oversees the implementation of agricultural development policies, including agricultural development planning, agricultural technology promotion, and public investment in agriculture (including infrastructure investment). The WAB makes decisions about agro-hydraulic projects, but the ADC is closely involved in the decision process because agro-hydraulic projects traditionally serve the purpose of agricultural development. The main function of the State Farm Bureaus (SFBs) is to organize agricultural production by means of planning and infrastructure development, to promote agricultural technology adoption, and to provide information services. SFBs generally make decisions about agro-hydraulic projects in cooperation with local and higher-level WABs, and they care more about agricultural production than about wetland conservation. Water Supply Enterprises (WSEs) do not make investment decisions about agricultural projects, but they are crucial in the operation of those projects. The WSEs are highly motivated to seek profit from the operation of the projects. The Wetland Management Bureau (WMB) has no formal function in the proposed options but would benefit most from the options.

In Option I, the WAB would be the most important agency, followed by the ADC and the SFBs. In Option II, the WAB would be the most important. In Option III, the ADC would be the key decision-maker. In Option IV, both the ADC and the SFBs would be very important. Based on this understanding of relative importance, a semi-structured interview was conducted with six executive officials from the WAB, SFBs, ADC, WSE, and WMB, and their attitudes toward each policy option were recorded.

*3.4 Farmer Acceptance*

Farmers include those who have land tenure in this area, as well as those who rent land for farming. Farmers will inevitably be affected, either directly or indirectly, regardless of which option is adopted, so they are the most important stakeholders. Under the slogan “Constructing New Socialist Villages” proposed by the central government, farmer acceptance has become an important consideration in policy decisions.

A household survey was conducted to measure the farmer's acceptance of the four options. Considering the differences between the villages and the state farms, a stratified sampling method was used. The first stratum consisted of irrigation districts in the rural area, and the second stratum, those in the state farms. The samples were allocated based on the total area of paddy fields in the two strata. About 30% of the samples were allocated to the rural area of Baoqing County and about 70% to the state farms. Within each stratum, a simple random sampling method was used to select households for the survey.

Our sample consisted of 201 households. The sample represented about 14% of the total households in the implementation zone (margin of error 6.5%), and the surveyed households own about 16% of the total paddy acreage of the implementation area. Structured interviews were conducted to collect the data, and 189 households expressed their attitudes toward the four options.

After a clear description of each option, each farmer surveyed was asked whether he or she would vote for or against the option. Based on the survey, we calculated the farmer support rate for each option. However, we did not rank the options according to the support rates. Instead, we asked the farmers to rank the options directly. To avoid the problem that farmers might have difficulty ranking all four options, we asked the farmers to pick only their first and second choices from among the four options. If an option was chosen as the best, it received a score of 2; if it was chosen as the second best, it received a score of 1. The options that were not chosen as the first or second best received a score of zero. Thus, a higher score means that the option was chosen as the first or second best more often.

*3.5 Multi-criteria assessments*

This study adopts a multi-criteria decision-making framework to rank the options. Specifically, an option's overall score is calculated using the weights given to the four criteria, as in Equation (5).

(5) $$S_i = \sum_{j=1}^{4} w_j r_{ij} \ ,$$

where $r_{ij}$ represents option $i$'s score on criterion $j$, which equals 4 if it is ranked first, 3 if second, 2 if third, and 1 if fourth; and $w_j$ is the weight of criterion $j$, which reflects the importance and priority the decision maker puts on criterion $j$. This framework ensures that the decision process is balanced and systematic and reflects the stakeholders' values.

Like other multi-criteria analyses, this study also faced the challenge of choosing the appropriate weights for policy ranking. To avoid the problem of choosing weights subjectively, this study conducted focus group discussions with local government officials to reveal the weights they would put on each criterion in a real situation.[2] Specifically, for any two criteria $j$ and $k$, they were asked to assign a weight to criterion $j$ relative to criterion $k$, $w_{jk}$, and a weight to criterion $k$ relative to criterion $j$, $w_{kj}$, where $w_{jk}+w_{kj}=1$. Table 3 reports on $w_{jk}$ for $j$, $k$ = 1, 2, 3, 4, averaged

[2] Although this approach reduces the subjectivity problem to some extent, it does not completely avoid it. Further research is needed to explore the ways of determining the weights appropriately for multi-criteria analysis.

over all the participants in the focus group. Using the data, the overall weight for each criterion is calculated using Equation (6).

(6)
$$w_j = \frac{\sum_{k=1}^{4} w_{jk}}{\sum_{j=1}^{4}\sum_{k=1}^{4} w_{jk}}.$$

The results are reported in the last row of Table 3. Overall, the focus group put the most weight on political feasibility, followed by probability of success and farmer acceptance. The smallest weight was put on cost effectiveness.

## 4. Results and Discussion

The four options were evaluated based on their cost effectiveness, probability of success in achieving the water-saving goal, political feasibility, and farmer acceptance. The results are discussed below for each of the four criteria.

### *4.1 Cost effectiveness*

Table 4 presents the estimates of the cost effectiveness of the four options. The first column shows the present value of the total costs, and the second column shows the present value of the total effects. The ratio of the present value of total costs to the present value of total effects gives the cost effectiveness measures, which are shown in column 3.

Option III is the most cost effective among the four options, followed by Options IV and I. Option II is the least cost effective among the four options. The reasoning behind these results is straightforward: Option III saves water wasted in the production process by changing water-using behavior while maintaining the current planting pattern, so it is the cheapest way; Option IV frees up water by changing planting patterns. Options I and II are engineering measures that require a large amount of capital investment, hence they are more costly. The ranking of the four options is not affected by the choice of discount rate, as can be seen in Figure 2. The higher the discount rate, the larger the comparative advantage of Option III.

### *4.2 Probability of Success in Achieving the Water-saving Goal*

Options I and II are engineering projects. Once the irrigation systems and the dam are constructed as planned, they will probably be able to save the amount of water needed for wetland conservation. Although the effectiveness of the two options depends upon the operation of the irrigation systems and the dam, which may require a good management system to support, the probability that Options I and II can achieve the water-saving goal is higher relative to the other two options. Option II was deemed to have a higher probability of success than Option I because low dam projects that use current technology have been shown to achieve their designed capacity with a high degree of certainty.

The success of Option III for achieving the water-saving goal depends on farmers' willingness to take the training classes and to adopt the water-saving practices. Since farmers are not charged based on the amount of water used, they have little incentive to adopt water-saving practices in their rice production.

Option IV saves water by converting paddy fields to dry-land crops. Although converting rice to dry-land crops is not unusual in the region, its success depends on many factors, such as commodity prices, land quality, and government subsidies. Because some of these factors are out of the control of the local government or farmers, the area of land that would be converted from paddy crops to dry-land crops is uncertain in the long term.

In sum, Option II is most reliable for achieving the water-saving goal, followed by Options I and III. Option IV is least reliable for achieving the water-saving goal because the effectiveness of this option depends on many factors out of the control of the government.

### *4.3 Political Feasibility*

The Water Affairs Bureau (WAB) believes that Option I is the key measure for saving water from agriculture for several reasons. First, modernizing irrigation systems can improve irrigation services and enhance the capacity for regulating and measuring water. Without such investment, management measures such as water permitting or pricing would be impossible. Second, there is no political obstacle to Option I from any level of government because it is consistent with the current agricultural development strategy of the central government. Third, the central government provides strong financial support for improving irrigation systems and takes it as one of the concrete measures for “Constructing New Socialist Villages.” Finally, this project can be implemented stage by stage, which would help relieve the initial financial burden. Local governments can play an important role in initiating such projects. The agricultural sector (e.g. ADC and SFBs) also supports this option because it improves agricultural infrastructure. Water Supply Enterprises (WSEs) do not have a high motivation to encourage water saving from their customers, but they welcome this option because, with improved irrigation infrastructure, they can provide better services and therefore can charge farmers a higher fee for water delivery.

The Water Affairs Bureau (WAB) is a key stakeholder in Option II. It believes that building a dam will bring new water sources, which are the most welcomed solution to the water shortage problems in the Qixinghe River basin. But the Bureau also has a major concern about this option because it must get approval from the provincial government as part of hydraulic planning, and local governments do not have a big say in initiating this process. Also, due to the budget constraints of local governments, this option will face financial obstacles, since it requires a large initial investment. The Wetland Management Bureau (WMB) likes this option because it seems to have been designed specifically for wetland water supply and will not hurt any existing water users. In reality, though, water in the reservoir could be diverted to other commercial users rather than to the wetland nature reserve, unless some special budget is created to cover the operating cost of the reservoir.

Option III would be implemented by the Agricultural Technology Promotion Centre (ATPC) under the Agricultural Development Commission (ADC). Although this option shows excellent cost effectiveness, it can be effective only if Option I has been implemented so that farmers can be charged based on the amount of water used or saved.

The most influential stakeholders for Option IV are ADC and SFB. Both of the agencies have strong concerns over the option. They have doubts about its feasibility in the current political and economic situation because: 1) the option is not in line with the current agricultural development plan promoted by the central government, which, for example, provides subsidies for farmers who develop paddy fields; 2) rice prices are increasing and net returns from rice production are better than ever before; 3) as the most important rice producers in the country, the state farms are expected to increase production to stabilize rice prices.

Based on the above analysis, we conclude that Option I is the most politically feasible, followed by Option III and Option II. Option IV is the government's least favored strategy.

*4.4 Farmer Acceptance*

Farmers' support for each of the four options were assessed using the survey described in the last section. The results are reported in Table 5. The scores in the last column reveal that Option II was the farmers' most preferred option, with 87.4% of farmers in support and only 8% opposed, followed by Option I, with 82% supporting it and only 9% opposing it. These results are easy to understand because Option II would not impose any financial burden on farmers. A few farmers expressed concerns over option I because they would be charged based on the amount of water used after the implementation and were unsure how it would affect their profits.

The support rate for Option III is also quite high: 86.9% of those surveyed supported this option, with only 7.5% opposing it. Although farmers are generally supportive of this option, our interviews with the farmers revealed their ambivalence toward this option. On the one hand, farmers support it because it imposes no cost on them; on the other hand, they are not sure whether the option can actually achieve the water-saving goals it claims.

The survey results showed that only 48.7% of farmers surveyed supported Option IV, while 36.7% opposed it. This option is the only one with a support rate below 50%. This result is easy to understand because farmers have to take a risk in converting paddy crops to dry-land crops—a move which could reduce their incomes.

### *4.5 Overall Ranking of the Policy Options*

As shown in Table 6, Option I is the most politically feasible and the second best in terms of probability of success and farmer acceptance. This option, however, is not cost effective. Option II is the most reliable for achieving the water-saving goal. It is also the farmers' most favored strategy. But it is the least cost effective and does not receive strong support from the local governments because it imposes a heavy financial burden on them. Option III is the most cost effective, but it ranked third in terms of probability of success and farmer acceptance. Option IV ranked last by all criteria except cost effectiveness.

Using the weights placed by the focus group on the four evaluation criteria, we calculated the overall scores for each option. Based on the scores, Option I ranked first, followed by Options II, III, and IV. Option I ranked first because it is the most politically feasible (with the largest weight) and second best in terms of probability of success and farmer acceptance. Although Option II is the least cost effective (with the smallest weight), it still ranked second because it was judged the most reliable option for achieving the water-saving goal and gained the strongest support from farmers.

## 5. Conclusions

A primary cause of wetland loss in China is water withdrawal for agricultural, industrial, and urban uses in the surrounding areas. This study evaluated four policy options to secure the water supply needed for wetland conservation in Qixinghe, a national wetland nature reserve in China, based on four criteria: cost effectiveness, probability of success in achieving the water-saving goal, political feasibility, and farmer acceptance. This multi-criteria analysis framework revealed the ecological, economic, and socio-political trade-offs that policymakers faced when choosing among the four policy options. In addition, a focus group discussion was conducted with local government officials to elicit the weight that they would put on each of the four criteria. Based on these weights, the overall ranking of the four options was determined. Option I (upgrading irrigation infrastructure in the surrounding area of the wetland) ranked first, followed by Option II (dam construction) and Option III (adoption of water-saving practices). Option IV (converting paddy crops to dry-land production) was the least preferred strategy.

Our results suggest that to protect the Qixinghe national wetland nature reserve, local governments should invest in irrigation network improvements in the surrounding area as early as possible and prohibit or at least discourage further expansion of paddy fields in the river basin. At the same time, governments should encourage farmers to adopt water-saving practices through regular training and public education. Governments must also establish water pricing policies to create economic incentives for farmers to save water. The irrigation district management system must be reformed to create the appropriate institutional context for implementing water pricing policies and other incentive measures. Mechanisms are required to ensure that the water saved is devoted to wetland conservation and ecological benefits, rather than being sold to the highest bidders. In particular, a funding mechanism for the supply of water to wetland is needed to make wetland a competitive water user.

Water scarcity is certainly a global issue. Some of the options identified in this study to save water could be applicable to other water-stressed regions in the world. One important conclusion of this study is that upgrading irrigation infrastructure, including the ability to track water flows, is the most effective policy for water conservation. From an economic perspective, low water prices cause excessive water use. The ability to track water use can allow an efficient price to be established, which could help curtail water scarcity. With the improved irrigation infrastructure, the amount of water each farmer uses can be measured accurately, and farmers can then be charged for water according to the amount they actually use. This provides motivation for farmers to adopt water-saving practices. Public investment in irrigation infrastructure, coupled with public education to raise the awareness of the ecological consequences of water overuse and ways to prevent it, is likely to be a viable option for solving water scarcity problems in many parts of the world.

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Appendix A

**The Method to Calculate the Residual Value of the Projects**

Residual value or salvage value is the value of a project at the end of the evaluation period. It is estimated by using the straight-line depreciation method, as expressed in equation (A1).

(A1) $$C_{residual} = C_{investment} * \frac{T - N}{T} ,$$

where $T$ is the expected lifetime of the project. $T$ is calculated by $T=T_0/(1-R_0)$, where $T_0$ represents the Expected Working Life, and $R_0$ is the rate of residual value over total investment. At the end of year $T$, the residual value diminishes to zero.

According to the *Water Conservancy Construction Project Economic Evaluation Norms (SL72-94)* (Ministry of Water Resources, 1995), the Expected Working Life of the irrigation project is 30~50 years. Thus, $T_0$=40 years is set for Option I. Since the Expected Working Life of the reservoir project is 50 years, $T_0$=50 is set for Option II. According to the *Economic Evaluation Code for Small Hydropower Projects (SL 16-95)* (Ministry of Water Resources, 1996), the salvage value is 3%~5% of the initial investment. We set $R_0$=5%. Thus, $T$ equals 42 years for Option I and 53 years for Option II.

**List of Figures**