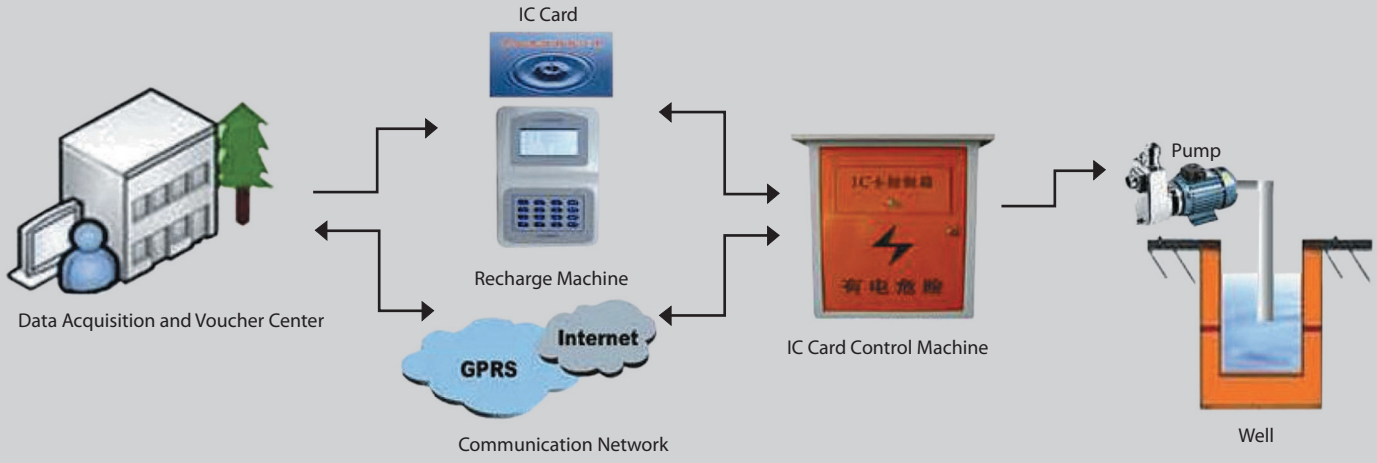
Food and Agriculture Organization of the United Nations

Case study on the use of Information and Communication Technology in the management of rural groundwater in China



FAO case study on ICT application for rural groundwater management
LoA/RAP/2016/18

Case study on the use of Information and Communication Technology in the management of rural groundwater in China

by

Jin Leshan
China Agricultural University

Li He
FAO Regional Office for Asia and the Pacific

Li Ying
China Agricultural University

Du Dan
China Agricultural University

Published by
Food and Agriculture Organization of the United Nations
China Agricultural University
Bangkok, 2017

ISBN 978-92-5-109723-6 (FAO)

Contents

Contents *(continued)*

Abbreviations and Acronyms

CI	cash inflow
CN¥	Chinese Yuan – Yuan is the name of a unit of the Renminbi currency introduced by the People's Republic of China in 1949
CO	cash outflow
COS	Chip Operating System
CPU	Central Processing Unit
CPC	Communist Party of China
GRM	groundwater resources management
GW	groundwater
IC	Intelligent Card
ICard	Intelligent Card
ICT	information and communication technology
IRR	internal rate of return
LoA	Letter of Agreement
Mu	the 市亩, as applied to agricultural land, = 666 ⅔ square metres (UN, *1966*). This = 60 square zhang, about 0.165 acre. (https://sizes.com/units/mu.htm)
NPV	net present value
RF	Radio Frequency
RTU	Remote Terminal Unit
WRM	water resources management

Summary

As an important precise measuring facility, the technology of the Intelligent Card (ICard) can effectively facilitate water resource management and collection and analysis of data and information on water services, which has great significance for the realization of agricultural structural transformation and the sustainable development of groundwater resources in rural areas. This research project looked at four townships in Sanhe City, Hebei Province, China as research sites and conducted fieldwork studying groundwater management in six villages using the ICard and two villages without ICard use. Employing household questionnaire surveys, interviews at village level and township level and literature reviews, we studied the technical compatibility, financial and economic feasibility and factors that affect household willingness to participate in the ICard system and analysed the specific impact on poor households, groundwater management in rural areas, rural development, agricultural society and other aspects. The research suggested that Information and Communication Technology (ICT) is promising with significant economic benefits when applied in the management of rural groundwater.

The study concludes that:

The ICard is compatible with other technical links when it is used for groundwater irrigation management. But some farmers reported problems using the ICard, including computer system failures that sometimes led to the phenomenon of "successful payment with unsuccessful recharge." The electric power required to start the ICard controller in some cases was not available in some villages and some households did not know how to use the card for irrigation. Some users did not know how to determine the electricity fees, or find the balance left on the ICard. Some problems were resolved by technological improvements and additional technical training could potentially overcome other issues. Many problems were caused because households were unfamiliar with the new system. In such cases more training is necessary.

However, the technology is still developing and needs to be better adapted to and coordinated with the original electricity grid and engineering system of each village. A mature fully functioning technical system is not expected to be available for two to three years.

The use of the ICard in groundwater irrigation management can bring significant economic benefits, mainly from saving maintenance costs and labour costs in fees and by reducing losses from electricity theft at some research sites. Cost benefit analysis showed that ICard use is financially and economically feasible in all six of the project villages that tested the ICard controller.

Using the ICard in groundwater irrigation management can also bring significant social benefits, such as increasing the transparency of water and electricity usage, thereby significantly reducing disputes over the use of water.

Field study showed that poor households have no technical or social barriers to the use of ICards. Regarding the economic barrier, it seems that government funding for the initial installation of the ICard system is essential if the poor are to use the ICard, otherwise installation costs would likely be a barrier for the poor to join the user group. Some poor households did not use the ICard because they do not have any irrigated land.

Most households were satisfied with the use of the ICard and will use it in the future. In addition, the use of the lCard in groundwater irrigation management has laid the foundation to reform water prices and water rights trading.

The benefits of saving water and energy and increasing agricultural production by using the IC card in groundwater irrigation management remain to be seen.

There are two major policy implications from the study results. The first is that technical training should be strengthened when this technology is extended in order for the farmers to quickly learn and adapt to the use of ICards. The benefits of using the ICard will only be known once the farmers learn how to use the cards. The second is that after-sales service of ICard technology should be improved to promptly solve ICard problems and prevent improper ICard operation.

1. Background on the application of ICards in groundwater irrigation management in China

1.1 Problems of groundwater table dropping and water shortage

China is a country with scarce per capita freshwater resources. Statistics show that China's per capita water resources are only a quarter of the world average. Ranked 110 in the world, China is one of the World's poorest countries in per capita water resources (ChinaNet, 2010). With the acceleration of population growth, urbanization and economic development, water shortages in China have become an increasingly serious problem.

The problem is particularly significant in North China. The region lacks water resources. For example, Hebei province has a serious shortage of water resources. The long-term average amount of total water resources in the province is 20.5 billion cubic metres, and per capita water resources amount to 307 cubic metres, which is one-seventh of the national average level and is well below 500 cubic metres, the internationally recognized level of severe lack of water (Hbzhan, 2015). Excessive exploitation of groundwater has brought a series of problems, such as a continuous drop in groundwater level, gradual depletion of groundwater resources and the formation of regional groundwater depression cones. Currently, even the level of shallow groundwater in North China is below 30 metres and as agricultural and industrial water demand increase, the groundwater level in North China has been dropping at an astonishing pace in recent years. The region is facing a serious water crisis. From the 1950s to the 1960s, groundwater levels in the region were about 2-3 metres, but now the levels have dropped to 20-30 metres (Xinhua, 2013). Statistics show that deep groundwater in the North China Plain has been severely overexploited and that the degree of exploitation has reached 177.2 percent (Hebwater, 2010). Due to years of excessive groundwater exploitation, the North China Plain has become the world's largest "depression cone." Currently, there are 25 groundwater depression cones in Hebei province, seven of which cover an area of some 1 000 square kilometres (Renmin, 2014).

1.2 Agricultural water use is facing competition from other sectors

Water use in agriculture in China accounted for 63 percent of total water withdrawal in the whole country in 2000 and the share decreased to 55 percent in 2013. Industrial water users and municipal water users are claiming more and more water use and so water users in the agricultural sector are facing competition for water from both industrial and municipal users. A unit of water use in agriculture produces less value per cubic meters of water compared with industrial and municipal water users. The government has urged increased water use efficiency in the agriculture sector (ChinaNet, 2014).

In April 2015, in order to effectively guarantee food security, the quality of agricultural products, the environmental security agriculture and in particular the security of the environment in production areas of China, as well as to promote the coordinated development of production, life and ecology in agriculture and rural areas, the Ministry of Agriculture developed and introduced the "Ministry of Agriculture's Implementation Opinions on Control and Prevention of Multiple Non-Point-Source-Pollution in Agriculture," which sets the goal of achieving "one control, two reductions and three basics" by 2020. The "one control" refers to controlling total agricultural water use and pollution of the agricultural water environment to ensure that the total amount of water used in agricultural irrigation

remains at 372 billion cubic metres while insuring that the quality of agricultural irrigation water meets the standards[1] (the State Council, 2015).

1.3 Water-saving agriculture

The application of ICards in agricultural irrigation conforms to the trend of scientific and careful management in agriculture. As two development directions in modern agriculture, scientific and careful management will become the choice for China's agricultural management. Gu Shugui et al (2008) analysed the social factors behind this choice. As urban industrialization has limited ability to absorb surplus labour in rural areas, China cannot indiscriminately copy the Lewis model to achieve agricultural modernization, but needs to open up a new field of employment to absorb surplus labour in rural areas. The new field of employment is special agriculture.

The development of agricultural water saving in China is lagging behind. Agricultural irrigation water use is inefficient. By the end of 2013, water-saving irrigation projects only covered 50 percent of the effective irrigated area. Flood irrigation still existed in some areas. Though water resources and irrigation water are scarce, irrigation water continues to be wasted. The area of sprinkling irrigation and micro-irrigation only accounted for 11 percent of the effective irrigated area. China's effective utilization coefficient of irrigation water was only 0.52, while Israel's was 0.8, and Australia's was 0.65. China was lagging far behind the world's advanced countries. The grain output per cubic metre of irrigation water was only 1.5 kg, equivalent to only about 60 percent of what the world's more advanced countries have achieved (Xinhua, 2014). The application of ICard measuring facilities in agricultural irrigation can help build a resource-conserving society and speed up the transformation of agricultural development. It will play an important role in promoting scientific and careful management of agriculture.

1.4 Advanced water management

Due to the lack of water supply measuring facilities, the problem of inaccurate agricultural irrigation water fees has persisted in China. The existing collection standard of agriculture water fees is based on the measurement of farmland. Such extensive management of water has led to a series of problems, such as water consumption that is not linked with irrigation water prices, difficulty in collecting agriculture water fees, farmers who are not aware of how much water is saved and how much is wasted.

In the current reform of agricultural water prices, the biggest problems are the difficulty in charging and collecting water fees, the drop in the collection rate of water fees and the sharp decrease in water revenues. Impacted by factors like households' out-dated views on water fees, farmers' limited disposable income and the poor quality of water supply services. Collection rates of agricultural water fees are low. Following the reform of taxes and fees in rural areas, many place waived irrigation water fees to alleviate the financial burden on farmers and this has resulted in making the collection of irrigation water fees more difficult. The difficulty collecting water fees and the low collection rate of water fees has led to further problems such as maintaining agricultural water equipment and serious waste of water resources (Meng Ge et al, 2012).

---

[1] China National Standards Code, GB5084-2005 *Standards for Irrigation Water Quality.* https://www.baidu.com/s?ie=utf-8&f=8&rsv_bp=0&rsv_idx=1&tn=baidu&wd=%E5%86%9C%E7%94%B0%E7%81%8C%E6%BA%89%E6%B0%B4%E8%B4%A8%E6%A0%87%E5%87%86&rsv_pq=ea401642000d0d3b&rsv_t=26b6kcbco6riAqAxG%2FDZD38KPDUE37PFodqRsKLJNST7uOBJvkhnGvTeA0s&rqlang=cn&rsv_enter=1&rsv_sug3=10&rsv_sug1=5&rsv_sug7=100

According to a survey, before the reform of taxes and fees in rural areas, the actual collection rate of agricultural water fees in Sichuan province was as high as 80.4 percent. After the reform, the collection rate of water fees fell some 15 percent to only 65.8 percent; in Henan province, the average collection rate of agricultural water fees was about 55 percent, a decrease of 20 to 30 percent; in Jilin province, the average rate decreased by 25 percent; in Guangdong province, the average rate has decreased by 40 percent; in Zhejiang province, the average rate has decreased by 23 percent. In addition, according to the operating statements of water management units in China, water supply revenues from state-owned water engineering in 19 out of 31 provincial administrative regions (including Xinjiang Production and Construction Corps, but excluding Tibet Autonomous Region) decreased in 2005 compared to the revenues collected in 2002 before the tax and fee reforms were implemented. The amount of revenue lost was CN¥123.023 million (Zheng Tonghan et al, 2006).

IC card measuring facilities are the basis for carrying out agricultural water rights trading. The water rights trading system is a water resources allocation system relying on the market. It can be divided into two parts, the internal trade and the external trade of agricultural water rights. In March 2016, the Hebei provincial government issued the "Measures for the Agricultural Water Rights Trade in Hebei Province," which said that water rights trading would apply to agricultural business entities with agricultural water rights, such as households, leading specialized households, family farms and specialized farmer cooperative organizations. There are four types of agricultural water rights trade in Hebei province: discretionary trade between agricultural water collecting and using households; trade through the platform of county-level property rights circulation trading centres, trade through farmer water use cooperative organizations and repurchases by the government.

Meanwhile, the precise measuring of water consumption and a market-based method of collecting water fees have also played an important role in easing water use conflicts and disputes in rural areas.

1.5 Advancement of ICT technology

The ICard technology has been continuously and rapidly developing since its inception. Before the year of 1996, ICard products were mainly in the form of storage cards. Logic encrypted cards were the high-end ICard product at that time. From 1996 to 2000, these cards were widely used, and non-telecom Computer Central Processing Unit (CPU) cards began to be applied in relevant fields, such as social security and banking (A CPU card is a printed circuit board (PCB) that contains the central processing unit (CPU) of a computer). Non-contact logic encrypted cards were promoted rapidly in the fields like public transportation. Dual interface cards also emerged. After the year 2000, logic encrypted cards gained popularity, the number of companies developing Chip Operating System (COS) increased, and CPU cards enjoyed rapid growth. New products like USB keys began to find a place in computer networks (Pan Lihua, 2005). At present, ICards are widely used in fields such as electronic payments, attendance management, mobile communication, anti-piracy for hardware and software, energy, identification, health and social security.

1.6 Encouraging policies from the governments

Facing the grim situation of over-exploitation of groundwater and the formation of groundwater depression cones in the North China Plain, the CPC Central Committee and local governments have introduced a series of policies in recent years, trying to change this situation. For example, agricultural water-saving technologies have been introduced; agricultural water prices and water rights trading were reformed. Irrigation measuring technology, the foundation of agricultural water price reform and water rights trade, has also been written into national and local policy documents.

The ICard measuring and control system is an advanced and important method for measuring water use. It applies computer and ICard automatic control technology to agricultural irrigation. With the ICard, individual water users can be archived and managed. Computers can be linked together the control effort. Each user is given a card with a username and password on it. When using the card, the user needs to prepay water fees on the card, then swipe the card and turn on the system to fetch water. The system automatically does the timing and charging, deducting the correct fees from the card. When the card runs out of money, the system automatically shuts down and the water is stopped. Introduction of the ICard technology to agricultural irrigation contributes a lot to building water-saving agriculture, increasing farmer awareness of the importance of saving water and solving problems like the lack of transparency in collecting water fees. It is also expected to make collecting water fees easier for the authorities, thereby becoming the foundation of the successful implementation of relevant government policies.

The ICard system is the basis for achieving precise measuring of water consumption, promoting household water conservation and realizing water price reforms and water rights trading. In the *Opinions on Promoting the Comprehensive Reform of Agricultural Water Price*, the first proposal in the section on "improving water measuring facilities" is to improve water supply measuring facilities. The *Opinions* proposes speeding up the construction of the water measuring system. Measures proposed in it include building measuring facilities for newly-built and reconstruction projects; rebuilding existing projects that are not equipped with measuring facilities; equipping complete sets of facilities within a definite time in areas with serious water shortages, or where groundwater has been over-exploited; achieving water supply with the measurement of all the outlets in all medium and large key projects in irrigation areas; refining units of measurement based on the requirements of management in small irrigation areas and end-canal systems. For places that use groundwater for irrigation, water consumption needs to be measured by wells and for places with suitable conditions, water consumption needs to be measured by households (gov.cn, 2016).

In 2014, Hebei Province issued the *Opinions on Comprehensive Reform of Agricultural Water Price in Pilot Areas Where Over-exploitation of Groundwater is Being Comprehensively Controlled*, which proposed to improve measurement facilities and promote measured charges. The *Opinions* proposed specifically that funding is to be achieved by installing ICard measuring facilities to all water-saving pressure recovery projects in pilot counties so as to achieve precise measurement of agricultural water use and to charge water fees based on actual water consumption by the user; in well irrigated areas in pilot counties, water consumption can be calculated by translating power consumption and charging according to the amount of power consumption; in surface water irrigated areas, water fees are charged according to the "(agricultural) outlet measurement by households and by time;" for areas where the system of cumulative pricing for consumption exceeds the quota, water fees should be reasonably charged with sensible and creative collecting methods (hebwater.gov.cn, 2014).

1.7 Local initiatives

At present, the ICard control system has been used in agricultural irrigation in parts of Xinjiang, Liaoning, Shandong, Shanxi, Hebei, Inner Mongolia, Tianjin and Beijing.

The water conservancy bureau of Qitai County, Xinjiang Autonomous Region has invested CN¥9 million in launching the ICard water fetching and measuring project for electromechanical wells. For all electromechanical wells throughout the county water is fetched by swiping ICards. One card is dedicated to one well or multiple wells. Water consumption is remotely managed and groundwater resources are effectively monitored. By 2014, wells had been electrified and households had been

given ICards in most parts of Qitai County. The county has also completed survey on the data of over 2 800 electromechanical wells. In 2014, it installed ICard water fetching and measuring devices on more than 1 700 electromechanical wells, achieving efficient electric power irrigation in an area of 291 square kilometres, accounting for more than 30 percent of the total cultivated land in the county (cj.xjkunlun.cn, 2014).

Tancheng County, Shandong Province has been implementing a highly efficient water-saving irrigation project since 2011. As of 2015, in areas where the water-saving irrigation project was implemented, over 400 new electromechanical wells were drilled, and over 400 sets of radio frequency ICard controllers were installed, achieving highly efficient water-saving irrigation on more than 33 square kilometres of farmland. The radio frequency ICard controller is an irrigation equipment controlling system that is installed next to an electromechanical well. It measures water and electricity consumption when the water pump is started, or switched off. Using the radio frequency ICard controllers in irrigation, farmers can save half the costs of the traditional irrigation method, as well as saving time and manpower (farmer.com.cn, 2015).

Since carrying out the project of small-scale farmland irrigation and water conservancy in key counties in 2009, Hebei Province has built over 12 000 intelligent well houses in over 30 counties (including cities or districts). The intelligent well house consists of a protective cover, an ICard module and related programmes. It can be used alone or connected to the control centre to form an intelligent control system for irrigation (hebnews.cn, 2013). During the "Eleventh Five-Year Program" period, Qianan City, Hebei Province invested a total of CN¥15.71 million to build water-saving irrigation facilities for 37 square kilometres of farmland, installing 307 sets of ICard facilities and laying 357 100 metres of pipelines. Effective irrigated area in the city reached 335 square kilometres (hebnews.cn, 2010).

Tianjin City has introduced and promoted the ICard control system. With one ICard for each household, users can prepay water fees and fetch water with the card. Water consumption is accurately measured and the system is easy to use. The city has installed 600 sets of ICard controllers, which measure irrigation for an area of 40 square metres. Implementation of total quantity control of agricultural irrigation water, quota management and efficient use has been improved (jwb.com.cn, 2014).

1.8 Problems occurring in the ICard application identified in the literature

Economic problems

Some villages have difficulties in allocating funds for the ICard system. Most villages that have installed the system are operating on borrowed money. For the power sector, the primary difficulty is the financial issue when conducting a large-scale installation of the IC card system because of the large scope of their business,. As for relevant government departments, they merely implement the ICard system to support electromechanical well projects. They think less about innovative management of the system.

Technical problems

The main component of ICard system is a control box, in which core components like electric meters, air switches and controllers. are installed. Due to long-term exposure in the natural environment outside, the control box will be seriously weathered and will need to be replaced every two or three years so as to avoid electrical leakage that could injure users. Therefore, the build quality of the control box is very important.

Problems of public acceptance

The ICard water pumping control system for electromechanical wells is a new water-saving monitoring and management measure that is vigorously promoted by the government, but passively accepted by farmers. Some farmers regard it as high-tech gear that is difficult to understand and use. They would rather use the old measuring system. As a consequence, the system is sometimes difficult to promote among some households (Feng Wenjun, 2013).

Cost differences

When using the ICard system, the farther away land parcels are from electromechanical wells, the more water permeates and evaporates from the land, resulting in some farmers paying less in electricity fees to irrigate their the land parcels; on the contrary, farmers pay less electricity fees. In addition, because clay soil has better water retention properties than sandy soil, clay soil needs less water per irrigation and holds the water for a longer time. Thus, clay soil requires fewer times of irrigation and costs much less in electricity fees. Under the new management method, the differences caused by land parcel location and soil texture become much more obvious. Some farmers are concerned that they might pay more than others do to irrigate the same amount of land (Zhang Lijuan et al, 2005).

1.9 Research objectives and methodologies

1.9.1 Research objectives

As defined in the Letter of Agreement (LoA), the objective of the proposed case study is to understand the application of Information and Communication Technologies (ICT) for rural groundwater management in China and its impact on the rural poor. Ultimately, this will help to understand the physical and policy context this technology has when applied and expanded, including its impact on resource management and changes in water delivery service to farmers. Understanding these impacts will help improve water management and provide data and information to replicate the system in other parts of Asia. In addition, it will also help to understand the capabilities of ICT within the water sector.

1.9.2 Research tasks

The above objectives will be achieved by the following key tasks as defined in the LoA:

Physical and policy context of ICT application in GW management

This analysis will be based primarily on a review of literature, feedback from experts and key interviews with informants. These will analyse the physical and institutional context of ICT application and adoption in China, exposing its opportunities and challenges. It will further explore what policy or institutional reform, or changes are essential to facilitate adoption of this technology.

Compatibility of technology: The adoption and implementation of ICT involves a range of hardware and software used by farmers, pump operators, field supervisors and by central monitoring systems. Currently, the arrangement involves smart cards, charging meters, volumetric distribution through buried pipe systems, data monitoring and transferring systems. This section would involve analyses of the compatibility of each component of hardware and software in use, identify issues, constraints and opportunities and make recommendations for necessary modifications and changes as required.

Cost and benefit: This will analyse the cost involved and benefits from the use of ICT. The cost should include all relevant expenses: additional physical investment, institutional requirements, operation and maintenance and replacement costs. The benefits should include relevant economic as well as environmental ones.

Water delivery service: The objective of this section is to understand the change in water delivery service to farmers with the application of ICT. It should also consider how the technology has helped, or not, in accountability mechanisms between service delivery and payment for services and include changes in water service collection rates.

Impact on GRM/WRM: This will analyse how the use of ICT helps in overall groundwater resource management. It will include the net effect of water withdrawal and application and explore how the result could be linked to broader GRM/WRM through mapping of water resources and early warning systems.

Synergy across water, energy and food: The study will also look at how emerging technologies like ICT can help balance water usage, energy needs and food production, which is of particular interest in country like China where water, energy and food production are tightly linked.

Scope for adoption and expansion in the region: This is the concluding part of the study. Based on the policy, institutional and physical context of the application of ICT and key findings from the above analysis, this section will draw conclusions about opportunities, constraints and challenges of this technology and look at the potential for adoption and extension this technology in other parts of the region.

1.9.3 Research methodology

Literature review: This involves review and analysis of physical and institutional context of GW management in China, opportunities and risks and the emergence and expansion of the ICT.

Field data collection and analysis: Six villages using the ICard and two villages that do not use the ICard to assist groundwater management are studied. More detailed information can be found in sections of 1.9.4 and 1.9.5.

Consultative workshops: Consultative workshops were conducted at the beginning and towards the end of the study. The purpose was to gather expert opinion and suggestions for methodological approaches, consolidation and validation of data and information and any other relevant suggestions and feedback. The workshops were organised by inviting local experts to contribute their views on the benefits of using the ICard GWM system.

1.9.4 Study area

Six villages that had applied the ICard system in agricultural irrigation with groundwater (hereafter referred to as project villages) and two villages that used traditional methods to measure agricultural irrigation hereafter referred to as non-project villages) in four towns in Sanhe City, Hebei Province are selected as study areas. The project villages are Dashigezhuang Village of Yanjiao Town, Nanzhaogezhuang Village, Xinjuntun Village and Fuxinzhuang Village of Yangzhuang Town, Xiaocuigezhuang Village of Gaolou Town and Nannie Village of Qixinzhuang Town. Non-project villages are Xiazhuang Village and Dacaozhuang Village of Yangzhuang Town.

1.9.5 Sample characteristics

Random sampling surveys were carried out in sample villages with the method of stratified random sampling. Leaders of each village were interviewed to understand the basic situation of the village. Random sampling surveys were then given to about 20 households for each village by means of face-to-face interviews between investigators and households interviewed. In total, 115 questionnaires for project villages were distributed and 113 valid questionnaires were collected. The effective rate of response was 98.3 percent. Fifty-one questionnaires were distributed for non-project villages and all of them were valid, bringing the effective response rate to 100 percent.

Characteristics of samples in project villages were analysed as follows: In terms of basic characteristics, females accounted for a higher proportion of the total respondents and most of them were more than 46 years old. About 92 percent of the respondents had junior high school, or lower level of education. Only 13.27 percent of the households had village officials in the family. Just over 14.16 percent of the households had members of CPC in the family.

In terms of family demographics, most households were composed of three to five persons. Just over 53 percent of the respondents had no elderly persons in the family, and similarly 53.10 percent of the respondents have no children less than 14 years of age in the family. Almost 56 percent of the respondents had three to four labourers in the family. Households having no persons working elsewhere accounted for 79.65 percent of interviewed households.

In terms of economic conditions, 96.46 percent of the interviewed households were not poor. Most households had an average annual household income of CN¥20 000-50 000. Households in the income category accounted for 42.48 percent of interviewed households. Just over 44 percent of the interviewed households earned less than 20 percent of their average annual household income from farming. In terms of the area of family farmland, 50.44 percent of the interviewed households had between 0.33 and 0.67 hectares of farmland. Table 1-1 shows the detailed basic characteristics of the households interviewed.

Following are the characteristics of samples in non-project villages. In terms of basic characteristics, female accounted for a higher proportion of the total respondents and most of them were over 60 years old. Just over 94 percent of the respondents had junior high school education or lower level of education. Only 13.73 percent of the households have village officials in the family. Just over 11 percent of the households have CPC members in the family. In terms of family demographics, most households consisted of three to five persons. Almost 50 percent of the respondents had no elderly persons in the family. Almost 50 percent of the respondents had no children under 14 years old in the family. Almost 50 percent of the respondents had three to four labourers in the family. Households having no persons working elsewhere accounted for 74.51 percent of the interviewed households. About 96 percent of the households interviewed were not poor. Most households had an average annual household income of between CN¥20 000 and CN¥50 000, accounting for 41.18 percent of the interviewed households. Almost 59 percent of the interviewed households earned less than 20 percent of average annual household income from farming. In terms of the area of family farmland, 72.55 percent of the interviewed households had between 5 and 10 hectares of farmland. Table 1-2 shows the detailed basic characteristics of the households interviewed in non-project villages.

Table 1-1 Characteristics of rural household respondents in project villages (ICard user)

	Category	Number of samples	Proportion (%)
Gender	Male	48	42.48
	Female	65	57.52
Age	Under 35 years old	1	0.89
	35-45 years old	7	6.19
	46-60 years old	65	57.52
	Over 60 years old	40	35.40
Level of education	Below primary school	15	13.27
	Primary school	55	48.67
	Junior high school	34	30.09
	High school and above	9	7.97
Are there any village officials in your family?	Yes	15	13.27
	No	98	86.73
Political identity of the head of household	Member of CPC	16	14.16
	Not a member of any parties	97	85.84
Number of family members	2 persons and below	18	15.93
	3-5 persons	61	53.98
	6 persons and above	34	30.09
Number of elderly persons	0	60	53.10
	1	31	27.43
	2	22	19.47
Number of children aged 14 years old	0	60	53.10
	1	32	28.32
	2 persons and above	21	18.58
Number of labourers	0-2 persons	45	39.82
	3-4 persons	63	55.75
	5-6 persons	5	4.43
Number of persons working elsewhere	0 persons	90	79.65
	1-2 persons	20	17.70
	3 persons	3	2.65
Is your family a poor household?	Yes, we are recognized as poor households.	1	0.89
	No	109	96.46
	We think we are, but we have not been recognized.	3	2.65
Average annual household income	Less than CN¥10 000	7	6.19
	CN¥10 000-2 000	16	14.16
	CN¥20 000-50 000	48	42.48
	More than CN¥50 000	42	37.17
Proportion of income from farming in average annual household income	Less than 20%	50	44.25
	20%-50%	43	38.05
	50%-80%	6	5.31
	More than 80%	14	12.39
Area of family farmland	Less than 0.33 hectares	41	36.28
	0.33-0.67 hectares	57	50.44
	0.67-1 hectares	11	9.73
	More than 1 hectare	4	3.55

Source: statistics of sample households in the field survey

Table 1-2 Characteristics of rural household respondents in non-project villages (non-users)

	Category	Number of samples	Proportion (%)
Gender	Male	20	39.22
	Female	31	60.78
Age	Under 35 years old	1	1.96
	35-45 years old	2	3.92
	46-60 years old	22	43.14
	Over 60 years old	26	50.98
Level of education	Below primary school	8	15.69
	Primary school	23	45.10
	Junior high school	17	33.33
	High school and above	3	5.88
Are there any village officials in your family?	Yes	7	13.73
	No	44	86.27
Political identity of the head of household	Member of CPC	6	11.76
	Not a member of any parties	45	88.24
Number of family members	2 persons and below	13	25.49
	3-5 persons	23	45.10
	6 persons and above	15	29.41
Number of elderly persons	0	25	49.02
	1	10	19.61
	2	16	31.37
Number of children aged 14 years old	0	29	56.86
	1	12	23.53
	2 persons and above	10	19.61
Number of labourers	0-2 persons	22	43.14
	3-4 persons	25	49.02
	5-6 persons	4	7.84
Number of persons working elsewhere	0 persons	38	74.51
	1-2 persons	11	21.57
	3 persons	2	3.92
Is your family a poor household?	Yes, we are recognized as poor households.	1	1.96
	No	49	96.08
	We think we are, but we have not been recognized.	1	1.96
Average annual household income	Less than CN¥10 000	6	11.76
	CN¥10 000-20 000	7	13.73
	CN¥20 000-50 000	21	41.18
	More than CN¥50 000	17	33.33
Proportion of income from farming in average annual household income	Less than 20%	30	58.82
	20%-50%	12	23.53
	50%-80%	2	3.92
	More than 80%	7	13.73
Area of family farmland	Less than 0.33 hectares	11	21.57
	0.33-0.67 hectares	37	72.55
	0.67-1 hectares	2	3.92
	More than 1 hectare	1	1.96

2. Compatibility of the ICard with related technologies

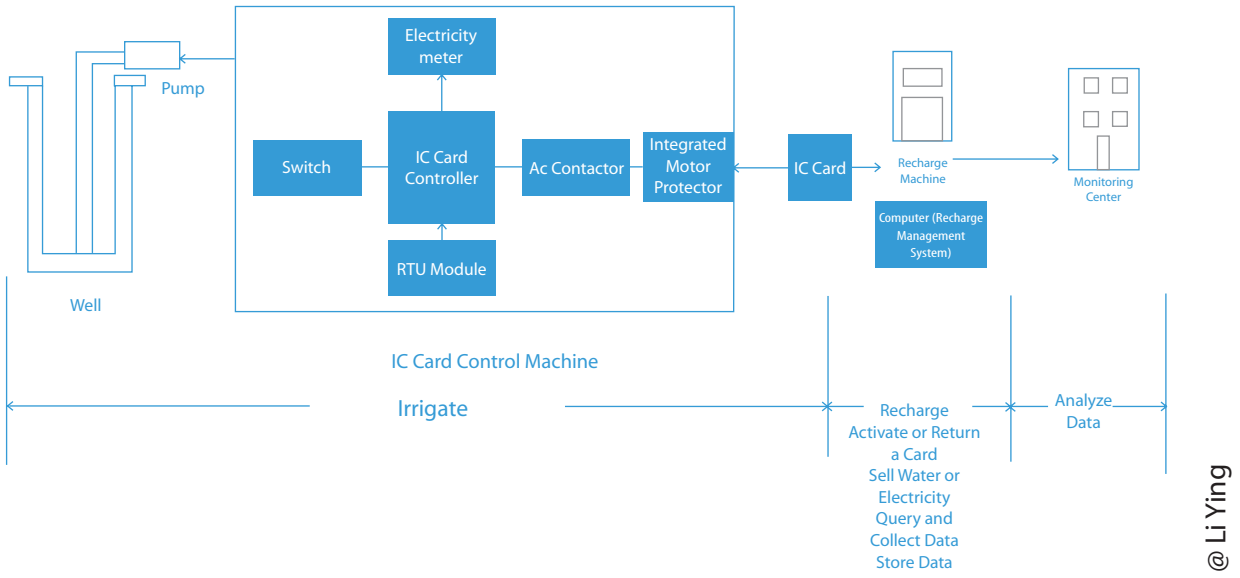
2.1 Technologies related to ICard application

The ICard Control System is an intelligent device system that aids water resource management by metering water resources and water resource fees. The system is energy efficient, self-protected and performs multiple functions, including water measurements and fee calculations. The system is based on microcomputer technology, sensing technology and ICard technology to achieve the goal of controlling intelligent motor pumps and maximally prolonging service and the life of the motors. Users can put their pre-paid card close to the ICard Controller to start irrigating crops as needed. The system can solve many major problems that existed in previous irrigation fee management by remotely metering water and charging irrigation fees. It is also characterized by disturbance resistance and lightning resistance, being suitable for operation in various outdoor environments.

The agricultural ICard well irrigation control system is composed of a well irrigation controller, Radio Frequency (RF) card (ICard), metering instruments (electricity meter and water meter) and a water resource user management platform.

A well irrigation control box is installed beside each well and a well irrigation fee charging management machine is set in each village (or each recharge site) to recharge the ICard for households in the local area. After installation, an ICard is issued to each household, which they can recharge at the ICard recharging site. The user can put the ICard near the controller to start irrigation and put it near the controller again to stop irrigation and turn off the pump. The amount of electricity and water used during each irrigation operation will be automatically deducted from the card and the pump will be automatically switched off once electricity and water volume on the card runs out. Several households can use each control box.

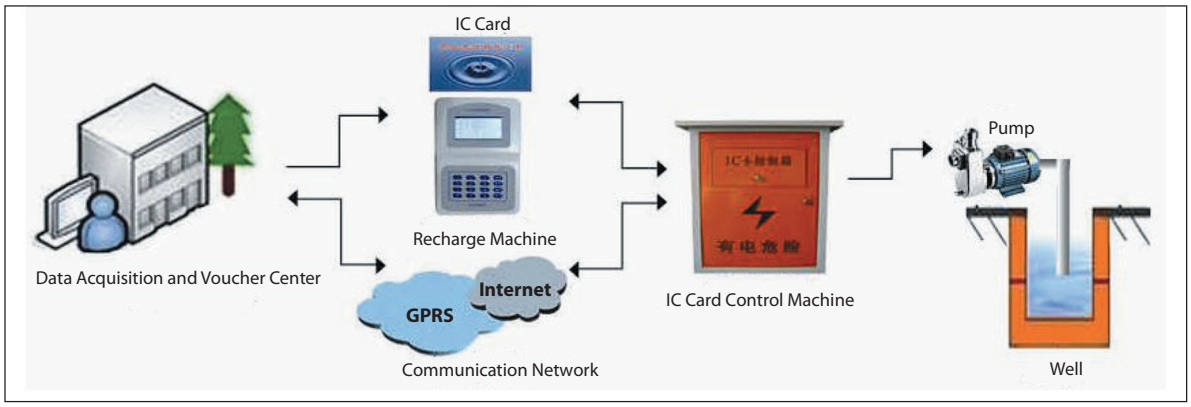
Figure 2-1 Technical flow chart



In real world situations, the ICard system has three work modes: on-line work mode, remote online work mode and comprehensive work mode.

The RF IC-based pump well irrigation control system also has an off-line work mode. Using the card as an information carrier, the system provides a card-based pre-paid management solution for agricultural irrigation.

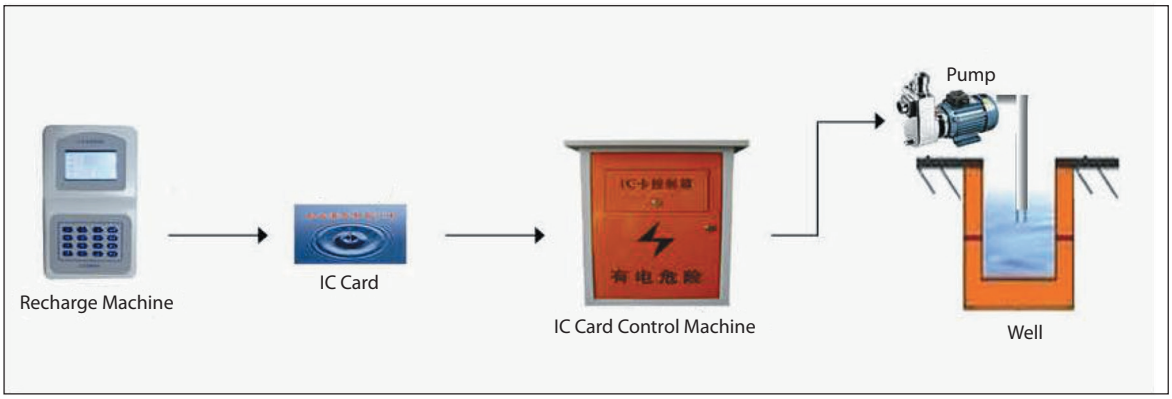
Figure 2-2 Off-line work mode



@Li Ying

Remote On-line Work Mode: The RF IC-based pumped well irrigation control system in remote on-line work mode, using a card as a pre-paid data carrier and general packet radio service (GPRS) as a carrier for site data acquisition, can provide card-based pre-paid management for agricultural irrigation and collection of statistics, analysis and management of well water usage information and data.

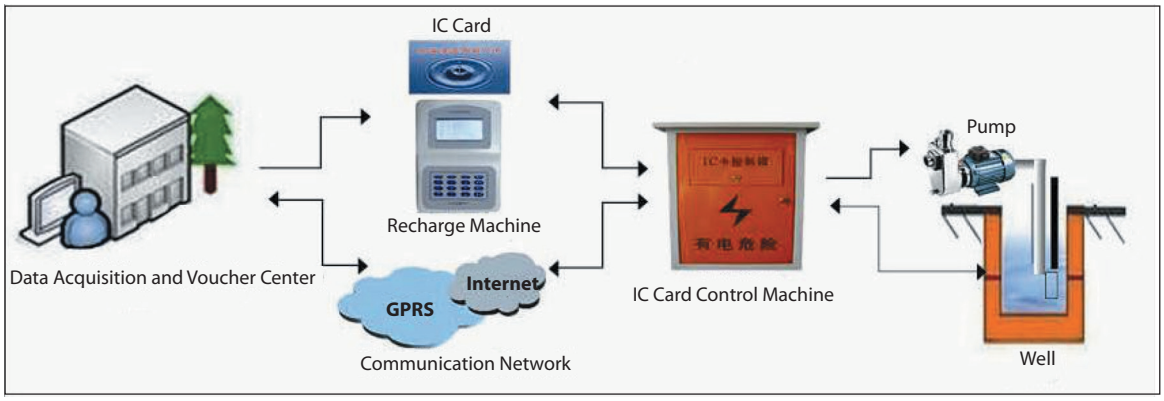
Figure 2-3 Remote online work mode



@Li Ying

Comprehensive work mode: The RF IC-based pumped well irrigation control system in the comprehensive work mode, using a card as a pre-paid carrier and GPRS as a carrier for site data acquisition, can provide a card-based pre-paid management for agricultural irrigation statistics collection, analysis and management of well water usage and data and other groundwater information.

Figure 2-4 Comprehensive work mode



@ Li Ying

Figure 2-5 Outdoor open-type and simple well-type ICard control box

@ Li Ying

Figure 2-6 The ICard and recharge of fees

@ Li Ying

2.2 Key Technology

Well irrigation control box is the key technology for IC card control system. The ICard and fee recharging-based pumped well irrigation control box is installed with RF-based pumped well irrigation controller, electricity meter, ac contactor and protection device. The in-built electricity meter can be used to calculate the electricity consumed when the household irrigates their crops. For water consumption to be calculated a remote water meter at the water outlet of the pumped well must be installed. Take the product of Beijing East Victoria Times Co., Ltd as an example. It is mainly composed of an ICard controller, electricity meter, a switch, an integrated motor protector, an alternating current (ac) contactor and a remote terminal unit (RTU) module.

ICard Controller: the controller is equipped with data writing and storage functions and is available for external reading under certain conditions. Specific functions can be divided into the following five parts: monitoring of well and water consumption by each household to encourage precise irrigation; household-rated water use management and pre-charge management; household electricity pre-charge management; control of water pumps at the site of the water source; and, remote transmission of data.

Electricity Meter: to realise precise metering of household electricity consumption.

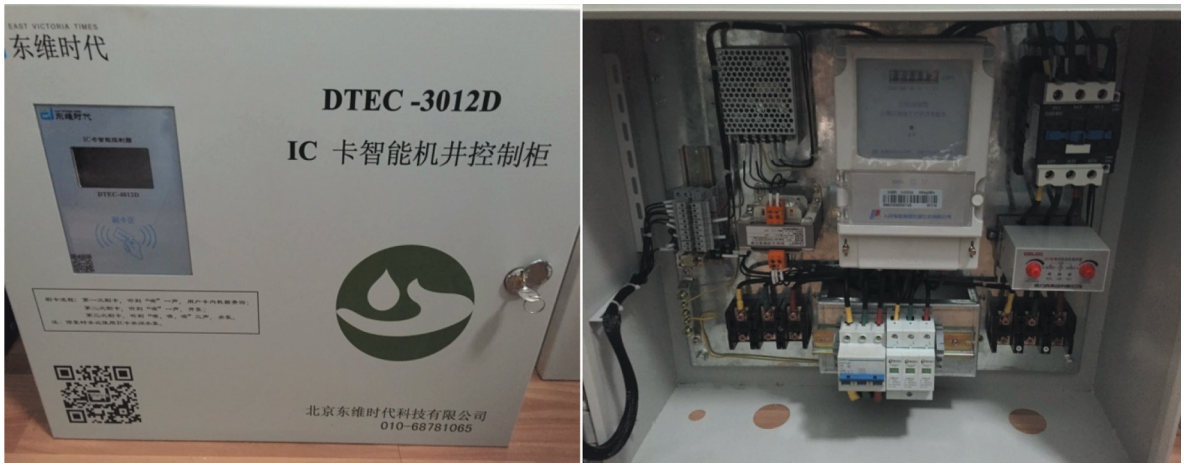
Switch: to supply power for the ICard controller or RTU module.

Integrated Motor Protector: to carry out comprehensive protection of the motor, mainly including electrical current fluctuation protection and phase-loss protection.

Ac Contactor: to turn the current for the motor on or off and to start and stop the motor.

RTU Module: to realize remote transmission of data and to transmit the onsite data to the data center.

Figure 2-7 External and internal look of the ICard intelligent well control box



@ Li Ying

2.3 Problems reported by ICard users in field surveys

During the survey, some households raised the following issues about ICard use

1. Product design and household experience

Design problems led some households to use the ICard system improperly at the very beginning. For example, some households did not know how to use the ICard to irrigate, or how to check data such as fees and the electricity balance. Villagers said that some of them at first forgot to use the card after irrigation, which resulted in a loss of electricity fees. Some villagers expressed their distrust of the ICard system at its current stage of development. They subjectively thought that electronic equipment metering is inaccurate and that fees may be charged at a higher rate than they should be. Such issues have been gradually solved by upgrades to ICard technology and because the villagers learned to adapt to the new technology.

2. Rated electrical current does not conform to the reality of rural electricity usage

The controller does not conform to actual situation found in the village. For example, the electric power required to start the IC controller does not conform to that in the village. Therefore, it is difficult to start the controller and parts and accessories of the controller tend to burn out. Electricians in Dashigezhuang Village said that the present rated current of the switch controller is 30 Amperes (Amp), but factors such as the starting current is three to five times that of the rated current, outdoor temperatures exceeded the maximum recommended operating temperature of the equipment, which is only suitable for use in temperatures between -45 degree centigrade and 45 degree centigrade. When equipment wear and tear are neglected, the problem of "small horse pulling a big cart" occurs. Theoretically the most suitable rated current should be 63 Amps. Because of this, electricians say that previously not much time needed to be spent on repairing the irrigation equipment all the year round, but now the new ICard system requires much more maintenance to keep it working properly.

3. Computer recharge system problem

Computer system crashes lead to the phenomenon of "successful payment unsuccessful recharge." Older electricians and accountants in some villages do not know how to use the computer to recharge the ICard; instead, they prefer to use traditional approaches.

4. The ICard has some safety defects and economic losses may occur if the card is lost

Currently, safety defects exist in the ICard. Once the card is lost, the balance on the card is also lost. The data in the card is unable to be stored at the current stage of development, therefore the card cannot be reissued and the previous balance cannot be restored. If another person finds the card, they could use for it for irrigation.

5. There are technical barriers to timely repairs

The ICard system is a high-tech project, unlike traditional electricity meter boxes. Therefore it is hard for village electricians to solve some problems that may develop. For example, when parts need to be replaced company engineers must be called and they live far away from villages where the ICard system is being trialled. This results in problems not being solved in a timely way.

6. Early control system design proved not to be sensitive enough

Early system programmes were not of good quality and sometimes failed to read the card or switch off. Because company maintenance personnel could not always come to the village to upgrade the system and make timely repairs, regular irrigation activities by the villagers may be occasionally delayed.

7. Balance on the card may "vanish all of a sudden"

Many villagers reported that after the card was used for irrigation, the balance on the card "vanished all of a sudden" when it was used to irrigate a second time; or, after recharging the balance on the card appears to be "zero," despite the fact that no irrigation was been carried out.

2.4 Compatibility

Different technical procedures in the ICard system are compatible with each other on the technical level and certain incompatibilities can be easily resolved technically. However, this technology is still in the preliminary development stage and needs to adapt to and coordinate with the original electricity grid and engineering system in the various villages. It is estimated that a comparatively mature technical system will not be realised for two to three more years.

Some problems identified by households using the ICard are basically not problems with the technology itself, but are problems of after-sales service by the company. Other problems are caused by a lack of familiarity with the new system, in which case more training should be offered.

3. Cost and benefit analysis of using ICard technology

3.1 Costs and benefits

3.1.1 Costs

According to a review of earlier literature, additional costs for using the ICard system can be broken down as follows:

Additional engineering costs of using the ICard. First is construction cost, including wages, materials, machinery use fees and new facilities acquisition costs for well house construction. Second is ICard measuring equipment acquisition cost, including computers, central management software, prepaid non-contact ICard water meter controllers, card readers, ICards, electric control and protection devices, water measuring devices and protective devices. Third is equipment installation costs.

Additional day-to-day operation and maintenance costs for using the ICard system include staff salaries and benefits, electricity expenses and management fees.

Additional major repair costs for using the ICard include, labour costs, equipment repairs, or replacement costs.

In the field survey, according to information obtained from the Agricultural Development Office of Sanhe City People's Government, the ICard well-pumping irrigation control project adopts a central bidding method. Equipment cost, equipment installation cost, operation cost, electrician training cost, after-sales service fees and so on are paid in lump sums. The investment for each well is CN¥2 550. In the following analysis, we will use CN¥2 550 as the project cost.

3.1.2 Economic benefits

According to earlier literature reviews, the economic benefits of using the ICard may be broken down as follows:

Manpower savings: We should consider household and water-keeper manpower savings and determine a price based on the price of manpower during the irrigation season.

Electricity savings: Electricity savings are made as a result of reducing irrigation time.

Water savings: Water savings are due to the use of facilities.

Equipment maintenance cost savings: The use of measuring facilities reduces the cost of maintenance for water pumps and other equipment.

Land savings: Land savings is realised because a reduced number of irrigation facilities are needed. Before the ICard, ponds and ditches for irrigation took up some areas of the farmland.

Crop yield increases

In the field survey, manpower savings mainly includes fee collection by accountants, maintenance by electricians and guarding water pumps by water keepers. Nearly 100 percent of households said that there was no change in irrigation time (including payment time) before and after use of the ICard. The ICard was more convenient, but the time cost savings accounted for only a small proportion in the

overall irrigation time, which meant little to the households. Therefore, time cost savings won't be discussed in the following analysis.

In terms of electricity and water savings, as households are more sensitive to irrigation costs, so long as electricity prices remain the same, the increase and decrease in irrigation cost directly reflects the degree of change in the quantity of irrigation electricity and water. About 82 percent of the villagers said that there was no change in irrigation costs before and after using of the ICard. Therefore we infer that the ICard temporarily does not result in electricity and water savings. The main reason for this is because the research area measured water costs according to electricity costs; the ICard device is a new measurement method, but currently Sanhe City has not yet implemented agricultural water price reforms, so there is no significant change in irrigation water and electricity quantity.

In terms of equipment maintenance cost savings, as the ICard device contains an integrated motor protector that can better prevent loss of the pump from electrical burning out.

In terms of land savings, as an ICard control box can be just installed in the old irrigation equipment, there is no land savings, so land savings will not be discussed in the following analysis.

In terms of crop yield increases, as the yield relates to comprehensive factors such as climate, technology and soil fertility, the crop yield change question is put to households as: "Do you think the ICard has effects on crop yield". The results show that nearly 100 percent of households think it makes no difference; therefore crop yield increases will not be discussed in the following analysis.

In addition to the above benefits, we find in the research that the ICard can prevent "electricity theft", so our analysis items of economic benefits are adjusted as: irrigation equipment maintenance cost savings, accountants fee-collection time cost savings, electricians maintenance-time cost savings, water keepers wage cost savings and "electricity theft" loss savings.

3.1.3 Cost benefit analysis framework

An investment project could be evaluated with the cost benefit analysis method, which compares the benefits with project costs in a time frame called "project life time." Benefits include both the monetary cash inflow and non-monetary items such as timesavings. Costs include both the monetary cash outflow and non-monetary items such as environmental costs. Both benefits and costs will be monetized and discounted in order to make benefits and costs in different years comparable.

A cash flow table will be prepared after benefits and costs are estimated. Comparison of benefits and costs will depend on the cash flow table with the indicators of net present value (NPV) and Inner Rate of Return (IRR). The investment project is economically viable if its NPV>0, or IRR>social discount rate. The bigger the NPV/IRR is, the better.

$$NPV = (CI - CO)_1 + \sum_{t=2}^{n} (CI - CO)_t (1 + r)^{-t+1}$$

$$\sum_{t=1}^{n} (CI - CO)_t (1 + IRR)^{-t} = 0$$

Where CI stands for cash inflow, CO stands for cash outflow, $(CI - CO)_t$ is the net cash flow in year t, n is year when CI or CO occurs, and r is discount rate.

3.2 Cost benefit analysis of ICard use in groundwater irrigation in project villages

As there are various situations in different project villages, we have adopted a one-by-one analysis. The research subjects are transformation projects based on old wells. We will research additional costs and economic benefits of single wells from the perspective of the national economy after implementing the ICard system. As an ICard controller has an average service life of up to 10 years or so, the project calculation period (n) for the financial analysis is set as 10 years; and as the project is ready to work after investment, we will not make any distinction between the construction period and the operation period. The discount rate (r) is set as 6.5 percent. The data comes from village-level interviews of village cadres, accountants and electricians.

3.2.1 Dashigezhuang Village, Yanjiao Township

The village has a total of seven wells and the ICard brings the following economic benefits:

In terms of irrigation equipment maintenance cost savings, a motor protection device at CN¥300 was installed in the past to achieve the same pump protection effect, so CN¥300 is set for this item.

In terms of accountant's fee-collection time cost savings, as there is no longer frequent collection and recovery, the accountant's work time is shortened to 15 days a year, and as the local labour cost is CN¥150 a day in the irrigation season, a single well can bring a benefit of CN¥321.43 per year.

In terms of electrician's maintenance time cost savings, as a motor protection device would be installed in the past, the pump's damage frequency was as low as it is now; so, there is no change in electrician's maintenance time cost.

The water keeper's wage cost savings and the electricity theft loss savings are both zero.

Table 3-1 is the Cash Flow Statement. According to the calculation results, the net present value (NPV) of the village's ICard project is CN¥210.90, and the inner rate of return (IRR) is 9 percent.

Table 3-1 Cash flow chart of Dashigezhuang Village, Yanjiao Township

Year	1	2~10
1. Cash inflow (CI)	621.43	321.43
1.1 Irrigation equipment maintenance cost saving	300.00	0.00
1.2 Accountant's fee-collection time cost saving	321.43	321.43
1.3 Electrician's maintenance time cost saving	0.00	0.00
1.4 Water keeper's wage cost saving	0.00	0.00
1.5 Electricity theft loss saving	0.00	0.00
2. Cash outflow (CO)	2 550.00	0.00
3. Net cash flow (CI-CO)	-1 928.57	321.43

3.2.2 Nanzhaogezhuang Village, Yangzhuang Township

The village has a total of seven wells and the ICard brings the following economic benefits:

In terms of irrigation equipment maintenance cost saving, the electrical box equipment in the past contained a three-phase disconnector type electricity meter, which was easily damaged. Now the controller contains a well-water pump protection device, which will automatically protect the water pump from burning. In the past, 10 water pumps might burn up each year. Each burn out would

require the labour of five workers costing CN¥500 to CN¥600 per water pump push-pull cost of CN¥300 yuan and a coil renewal cost of CN¥600 to CN¥1 400, with an average cost of CN¥900; average cost for each instance of pump repair was CN¥1 750 and the rebuild quality was not as good as the original. The ICard basically excludes such maintenance costs and the irrigation equipment maintenance cost savings is CN¥2 500 a year per well.

In terms of the accountant's fee-collection time cost savings, the accountant needed about 35 days in the past to collect and recover electricity fees, while now only about 15 days is needed. The time saved can be used for a part-time job with a wage of CN¥150/day. Therefore, the accountant's fee-collection time cost saving is CN¥428.57 a year per well.

In terms of the electrician's maintenance time cost savings, the electrician spent 90 days a year in the past on such work as electricity box opening and reading the meter to determine the agricultural irrigation charges. Now only about 15 days is needed. The time saved can be used for a part-time job, with a wage of CN¥200 per day. Therefore, the electrician's maintenance time cost saving is CN¥2 142.86 a year per well.

The water keeper's wage cost savings and the electricity theft loss savings are both zero.

Table 3-2 is the Cash Flow Statement. According to the calculation results, the net present value (NPV) of the village's ICard project is CN¥33 755.97.

Table 3-2 Cash flow statement of Nanzhaogezhuang Village, Yangzhuang Township

Year	1	2~10
1. Cash inflow (CI)	5 071.43	5 071.43
1.1 Irrigation equipment maintenance cost saving	2 500.00	2 500.00
1.2 Accountant's fee-collection time cost saving	428.57	428.57
1.3 Electrician's maintenance time cost saving	2 142.86	2 142.86
1.4 Water keeper's wage cost saving	0.00	0.00
1.5 Electricity theft loss saving	0.00	0.00
2. Cash outflow (CO)	2 550.00	0.00
3. Net cash flow (CI-CO)	2 521.43	5 071.43

3.2.3 Xinjuntun Village, Yangzhuang Township

The village has a total of seven wells and the ICard brings the following economic benefits:

In terms of irrigation equipment maintenance cost saving, seven water pumps might be burned a year in the past, each burning would take a labour cost of CN¥600, a water pump push-pull cost of CN¥300 and a coil renewal cost of CN¥800; average cost for each time of pump repair was CN¥1 800. Now the number of burned water pumps reduces by almost half to about 3.5, and average cost for each time of pump repair remains the same; the irrigation equipment maintenance cost saving is CN¥900 a year per well.

In terms of accountant's fee-collection time cost saving, the accountant's working days reduces from 30 to 15 a year; as the accountant is physically disabled and has no other part-time job, the accountant's fee-collection time cost saving is counted as 0.

In terms of electrician's maintenance time cost saving, the electrician spent 90 days a year in the past on related work, while now only 30 days is needed. The time saved can be used for maintenance of

electric poles and facilities of factories, gas stations and power supply systems, with a wage of CN¥200/day. Therefore, the electrician's maintenance time cost saving is CN¥1 714.28 a year per well.

In terms of the water keeper's wage cost savings, in the past a temporary worker had to be employed for each well to guard the pump, at a wage of CN¥50 a day for 16 days a year. The wage costs was split among the households using the well. Therefore, the water keeper's wage cost savings is CN¥800.

In terms of electricity theft loss savings, an overall average of 500-600 kilowatt-hours of electricity was stolen for one round of irrigation in the past; as there were six rounds of irrigation a year on average and the electricity tariff was CN¥0.7 per kilowatt-hour, the total loss was CN¥2 310, equivalent to CN¥330 per well.

Table 3-3 is the Cash Flow Statement. According to the calculation results, the net present value (NPV) of the village's ICard project is CN¥24 922.32.

Table 3-3 Cash flow statement of Xinjuntun Village, Yangzhuang Township

Year	1	2~10
1. Cash inflow (CI)	3 744.28	3 744.28
1.1 Irrigation equipment maintenance cost saving	900.00	900.00
1.2 Accountant's fee-collection time cost saving	0	0
1.3 Electrician's maintenance time cost saving	1 714.28	1 714.28
1.4 Water keeper's wage cost saving	800.00	800.00
1.5 Electricity theft loss saving	330.00	330.00
2. Cash outflow (CO)	2 550.00	0.00
3. Net cash flow (CI-CO)	1 194.28	3 744.28

3.2.4 Xiaocuigezhuang Village, Gaolou Township

The village has a total of 10 wells and the ICard brings the following economic benefits:

In terms of irrigation equipment maintenance cost savings, the ICard provides some protective aspects regarding the water pump; power will be automatically shut off in case of a short circuit or a phase failure, reducing the likelihood the pump will burn out. This reduces the overall maintenance costs. In the past, about some two to three pumps might burn out a year, resulting in a maintenance cost of about CN¥5 050 a year. Therefore, the irrigation equipment maintenance cost savings is CN¥505 per well.

In terms of the accountant's fee-collection time cost savings, the accountant does not need to collect electricity fees at a particular time, so the collection time becomes more flexible. However, as the village accountant has no other part-time job, the time saved fails to produce economic benefits. Therefore, the accountant's fee-collection time cost saving is counted as 0.

In terms of electrician's maintenance time cost savings, the electrician's working days are reduced from 90 days in the past to at most 30 days now, with a time cost of CN¥200 a day. We conservatively estimate that the electrician's maintenance time cost savings is CN¥1 200 a year per well.

The water keeper's wage cost savings and the electricity theft loss saving are both zero.

Table 3-4 is the Cash Flow Statement. According to the calculation results, the net present value (NPV) of the village's ICard project is CN¥11 348.66, and the internal rate of return (IRR) is 20.2 percent.

Table 3-4 Cash flow statement of Xiaocuigezhuang Village, Gaolou Township

Year	1	2~10
1. Cash inflow (CI)	1 705.00	1 705.00
1.1 Irrigation equipment maintenance cost saving	505.00	505.00
1.2 Accountant's fee-collection time cost saving	0	0
1.3 Electrician's maintenance time cost saving	1 200.00	1 200.00
1.4 Water keeper's wage cost saving	0.00	0.00
1.5 Electricity theft loss saving	0.00	0.00
2. Cash outflow (CO)	2 550.00	0.00
3. Net cash flow (CI-CO)	-845.00	1 705.00

3.2.5 Nannie Village, Qixinzhuang Township

The village has a total of 11 wells and the ICard brings the following economic benefits:

In terms of irrigation equipment maintenance cost savings, the ICard has a motor protection device; power will be automatically shut off in case of a short circuit or a phase failure, reducing the likelihood that the pump will burn out, thus reducing the maintenance costs. In the past, two to three pumps might burn out in a year. The maintenance cost for each time was about CN¥2 000. Therefore, if we set the number of burned pumps as 2.5 a year, the irrigation equipment maintenance cost savings is CN¥454.54 per well.

In terms of the accountant's fee-collection time cost savings, the accountant's work time and workload were reduced because the accountant no longer needs to go to the field for meter recording or to collect electricity fees from door to door. In the past, the accountant needed an average of 45 days for fee collection, while this now takes only 15 days. If we set the time cost as CN¥150 a day, the accountant's fee-collection time cost savings amounts to CN¥409.09 a year per well.

In terms of the electrician's maintenance time cost savings, the electrician's work days have been reduced from 90 days to 30 days at most, with a time cost of CN¥200 day. We conservatively estimate that the electrician's maintenance time cost savings is CN¥1 200 a year per well.

The water keeper's wage cost savings and the electricity theft loss savings are both zero

Table 3-5 is the Cash Flow Statement. According to the calculated results, the net present value (NPV) of the village's ICard project is CN¥13 735.74 and the internal rate of return (IRR) is 42.4 percent.

Table 3-5 Cash flow statement of Nannie Village, Qixinzhuang Township

Year	1	2~10
1. Cash inflow (CI)	2 063.63	2 063.63
1.1 Irrigation equipment maintenance cost saving	454.54	454.54
1.2 Accountant's fee collection time cost saving	409.09	409.09
1.3 Electrician's maintenance time cost saving	1 200.00	1 200.00
1.4 Water keeper's wage cost saving	0.00	0.00
1.5 Electricity theft loss saving	0.00	0.00
2. Cash outflow (CO)	2 550.00	0.00
3. Net cash flow (CI-CO)	-486.37	2 063.63

3.2.6 Fuxinzhuang Village, Yangzhuang Township

Not all project villages still use the ICard control system today; Fuxinzhuang Village, Yangzhuang Town is representative of villages that abandoned use of the ICard control system. Due to equipment damage and the fact that households were not accustomed to operating the system, the village abandoned using it for irrigation of one-season crops in 11 of its 12 wells in the spring of 2013. The village currently uses a push-button irrigation system where a green button is for water outlet and a red button is for water pause.

As the case is special, the project calculation period is counted as one year and the number of irrigations was counted as two. The irrigation equipment maintenance cost saving was put at CN¥400, equalling the cost of the push button irrigation system. There is no significant change in the savings of the accountant's fee-collection time, the electrician's maintenance time cost savings and electricity theft loss savings, so they are all counted as zero.

In terms of the water keeper's wage cost saving, there are now two workers guarding the pump and arranging the irrigation queue; they are also responsible for recording electricity metering from door to door and handing over all the electricity fees to the accountant. The two workers take care of six wells, taking 10 percent from the collected electricity fees as commission. When an ICard was used in the past, there was no such a specially trained worker. The electricity tariff is CN¥2 100 for one time irrigation per well on average; CN¥4 200 for two times; when the commission is 10 percent, the water keeper can receive an income of CN¥420 per well for guarding the pump. The net cash flow of the village project is -CN¥1 730.00 for year one, but there are a few positive cash flows in subsequent years.

Table 3-6 Cash flow statement of Fuxinzhuang Village, Yangzhuang Township

Year	1	2~10
1. Cash inflow (CI)	820.00	820
1.1 Irrigation equipment maintenance cost saving	400.00	400
1.2 Accountant's fee-collection time cost saving	0.00	0
1.3 Electrician's maintenance time cost saving	0.00	0
1.4 Water keeper's wage cost saving	420.00	420
1.5 Electricity theft loss saving	0.00	0
2. Cash outflow (CO)	2 550.00	0
3. Net cash flow (CI-CO)	-1 730.00	820

3.2.7 Cost benefit analysis summary

Based on the cost benefit analysis results, the project is feasible for the six project villages that trialled the ICard controller. In the project villages that used the ICard controller, the net value of single wells ranged from CN¥210.90 to CN¥48 164.30, with an average of CN¥16 794.72. On the whole, the project is financially feasible and it is of good input-output benefit. In 2013, when the ICard controller was used and the technology was not yet perfected, some villages abandoned its use. Now the technology was comparatively mature, after three years of development and it was unlikely that new project villages would abandon using the ICard controller for a similar reasons. Therefore we can conclude that the ICard well-pumping irrigation control project was financially feasible.

3.3 Further analysis

In addition to the above economic benefits, the ICard well-pumping irrigation control project can bring great environmental and social benefits.

3.3.1 Environmental benefits

Environmental benefits mainly refer to water savings after using the ICard; especially considering the potential water savings after agricultural water price reforms, The ICard well-pumping irrigation control project will play a positive role in reducing the on-going decline in groundwater levels.

We learn from village-level interviews that there have been cases in the past when the fuse blew and the circuit breaker tripped in halfway through irrigation and electricians had to be frequently called for timely repair, which wasted time as irrigation had to be repeated. The village adopted flood irrigation water flowing from one side to the other side. But, often the water supplied leaked and the irrigation had to start over, resulting in a lot of water wasted. An ICard can save irrigation time and improve well efficiency, resulting in water savings.

In order to estimate the potential water savings after agricultural water price reforms, we put such a question in the household questionnaire: "If on the existing basis, the agricultural water fee was CN¥0.2/m^3, will you reduce the number of irrigations and the quantity of irrigation water and by how much will you reduce it?" According to the results of 164 questionnaires, 53 people said they would save water, accounting for 32.32 percent of the total, and they said they could save on average 15.10 percent on water. One hundred eleven people said they would not save water, accounting for 67.68 percent. Therefore we can estimate that agricultural reform can save 4.88 percent of water. Although there may be some deviation between the actual household behaviour and the estimate, the figure still has a certain reference value.

3.3.2 Social benefits

Irrigation was more convenient for households. The convenience was embodied in the following: They don't have to call electricians to install wiring for well openings as before and they can now independently irrigate; card swiping was more convenient than electrical brake push-pull irrigation; they don't have to queue up for irrigation some two days ahead as before and they can now swipe the card for irrigation at any time as long as the irrigation facilities are available in the field, saving queue time; irrigation times are more flexible; payment of electricity bills was more convenient as they can increase the amount they prepay to reduce payment times; they do not have to suffer high irrigation equipment failure rates and low well utilization ratios as before.

Water disputes are reduced. In the past, household electricity meters were read for electricity consumption and there would be some disputes in determining the range of irrigation, electricity quantity, such as meter recording errors, or the meter readings of one villager might by wrongly attributed to the wrong account, which easily caused conflicts.

Security was higher. In the past, the electricity brake had to be pulled and there would be sometimes electricity leakages when it was raining, which was frightening to old people and women in the village. The ICard makes safe and convenient irrigation possible with just a swipe.

3.4 Summary

Research shows that the ICard can bring good economic benefits to households. Good economic benefits mainly include maintenance cost savings and labour cost savings. Given reduced water disputes and other social benefits that are difficult to quantify, the ICard will show a more obvious overall benefit compared to previous irrigation methods.

4. The impact of ICard technology on rural households

4.1 An analysis of the willingness of households to participate in the use of the ICard in GW management: household satisfaction and descriptive statistics

Field surveys show that 73.46 percent of households in the project villages were completely, or relatively more willing to participate in the ICard policy; 12.39 percent were neutral; and the remaining 14.15 percent were not quite willing, or completely unwilling to participate in the policy. In terms of satisfaction, 79.65 percent of households had a positive evaluation; 7.08 percent of households had a neutral attitude; and 13.27 percent were completely dissatisfied, or not very satisfied. In terms of the willingness to participate in the ICard trials in non-project villages, 43.14 percent of households had a neutral attitude; 27.45 percent were completely or relatively more willing; and 29.41 percent were not quite willing, or completely unwilling.

Table 4-1 Willingness to participate and satisfaction of households in the project villages

	Categories	Amount of Samples	Proportion (%)
Policy participation willingness	Completely unwilling	9	7.96
	Not quite willing	7	6.19
	Neutral	14	12.39
	Relatively more willing	18	15.93
	Completely willing	65	57.53
Policy satisfaction	Completely dissatisfied	2	1.77
	Not quite satisfied	13	11.50
	Neutral	8	7.08
	Relatively more satisfied	30	26.55
	Completely satisfied	60	53.10

Table 4-2 Willingness to participate among households in the non-project villages

	Categories	Amount of Samples	Proportion (%)
Policy participation willingness	Completely unwilling	6	11.76
	Not quite willing	9	17.65
	Neutral	22	43.14
	Relatively more willing	6	5.31
	Completely willing	8	22.14

On the whole, households in the project villages have a high degree of willingness to participate in the ICard trials and there was also a high degree of satisfaction among those who participated in the evaluation of the ICard technology in agricultural irrigation. The willingness of households to participate in non-project villages was obviously lower than that of the project villages and they mainly held a neutral attitude. As shown by the survey of villagers, the major reason for their neutral attitude was that they had never learned about the technology and thus were not familiar with the benefits of ICards; moreover, they were satisfied with the current status of agricultural irrigation, so they were not quite willing to try new technology. As shown by the results of the questionnaire, nearly 30 percent of households in the non-project villages were not willing to use the ICard technology, mainly because they worried about their ability to use the technology due to their old age and, in some cases, limited degree of education.

The difference seen between the non-project village households and the project village households regarding their willingness to accept and appreciate the ICard technology derives from the benefits the project village households saw in the practical application of the ICard which was widely welcomed by the trialled ICard. Moreover, about 70 percent of respondents in the non-project villages held a neutral or positive attitude towards ICard technology, so it is meaningful for the promotion and application of the ICard project.

4.2 Analysis of the factors affecting project village household willingness to participate in the use of ICard technology in GW irrigation

4.2.1 Econometric model

According to the relevant literature and the specific circumstances of the research site, the following model needs to be established to reflect the impact of different factors on the willingness (y) of households in the project villages to accept ICard technology.

$$y = (PC, AR, PB, PC, GO) + v \quad (1)$$

In equation (1), v is a random disturbance term, which reflects other influence factors, which cannot be observed. Y stands for the willingness of households to accept the ICard technology application and its method of taking value is as follows: 0 stands for completely unwilling, 1 stands for not quite willing, 2 stands for neutral, 3 stands for a little willing, 4 stands for completely willing.

In the project villages, the willingness of households accepting the ICard technology application (Y) is mainly affected by the following five categories of factors including:

1. Fundamental characteristics of households (FC) including age (x1), gender (x2), degree of education in the households (x3), whether the head of household is a village cadre (x4), political status of the head of household (x5), total number of family members (x6), number of elderly above 65 years of age (x7), quantity of labour force (x8) and annual family total income (x9);
2. Agricultural irrigation status (AR), including family arable land area (x10), family arable land blocks (x11) and annual times of irrigation (x12);
3. Household evaluation of project benefits (PB), including whether irrigation is more convenient and timely (x13), whether electrical safety is increased during irrigation (x14), whether water disputes and conflicts are reduced, (x15), whether water allocation is fairer and more reasonable (x16), whether water fee collection is more open and transparent (x17) and, whther the frequency of damage to irrigation equipment is reduced (x18);
4. Household recognition of project characteristics (PC) including the degree of familiarity with the operating principles (x19), whether operation is convenient (x20), system quality evaluation (x21) and, evaluation of the accuracy of measurements (x22);
5. Characteristics of government support (GO) including, government support evaluation (x23).

4.2.2 Model and variables

Because the explanatory variables in this paper are graded variables, we use the multivariate and orderly logistic model for analysis. The equation of this model is as follows:

$$\ln\left[\frac{p(y\le j)}{1-p(y\le j)}\right]=\alpha_j+\sum_{i=1}^{k}\beta_i x_i, j=1,2,3,4 \quad (2)$$

Is equivalent to the following equation:

$$p\left(y\le j|x_i\right)=\exp\left(\alpha_j+\sum_{i=1}^{k}\beta_i x_i\right)\Big/\left[1+\exp\left(\alpha_j+\sum_{i=1}^{k}\beta_i x_i\right)\right] \quad (3)$$

In the above two equations, y refers to the participation willingness of the application of the ICard in agricultural irrigation policy. It is divided into five levels represented by 0, 1, 2, 3, and 4. x_i refers to k independent variables of explaining variables; α_j refers to intercept parameter and β_i refers to regression coefficient. Specific variables, major statistics and effect expectation of various influencing factors of the project villages in the model are given in table 4-3.

Table 4-3 Illustration of explaining variables of the model for project villages

Variable name	Variable definition	Average value	Standard value	Expected direction
Fundamental characteristics (FC)				
Age of households (*x1*)	Below 35 years old = 1; 35 to 45 years old = 2; 46 to 60 years old = 3; above 60 years old = 4	3.27	0.61	+/–
Gender of households (*x*2)	Male = 0; Female = 1	0.58	0.49	+/–
	Below primary school = 1; primary school = 2; junior high school = 3; senior high school and above = 4	2.33	0.80	+
Degree of education of households (*x*3)	No = 0; Yes = 1	0.13	0.34	+
Whether the head of household is a village cadre (*x*4)				
Political status of the head of household (*x*5)				
Total number of family members (*x*6)	The masses = 0; Party member = 1	0.14	0.35	+
Number of elderly above 65 years old (*x*7)	No more than two persons = 1; 3 to 5 persons = 2; no less than six persons = 3	2.14	0.66	+/–
Quantity of labour force (*x*8)	Calculated according to the actual situation	0.66	0.78	+/–
	0~2 persons = 1; 3 to 4 persons = 2; 5~6 persons = 3	1.65	0.56	+/–
	Less than CN¥10,000 = 1; CN¥10,000 yuan – CN¥20,000 = 2; CN¥20,000 yuan – CN¥50,000 = 3; more than CN¥50,0004	3.11	0.87	+/–
Annual family total income (*x*9)				
Agricultural irrigation status (AR)				
Family arable land area (*x*10)	Less than 5 mu = 1; 5~10 mu = 2; 10~15 mu = 3; more than 15 mu = 4	1.82	0.74	+/–
Family arable land blocks (*x*11)	1-2 blocks = 1; 3-4 blocks = 2; 5-6 blocks = 3	1.29	0.51	+/–
Annual times of irrigation (*x*12)	Less than 2 times = 1; 2-3 times = 2; 3-5 times = 3; more than 5 times = 4	2.75	0.93	+

Table 4-3 *(continued)*

Variable name	Variable definition	Average value	Standard value	Expected direction
Household evaluation of project benefits (PB)				
Is irrigation more convenient and timely? (x13)	No = 1; no change = 2; yes = 3	2.68	0.61	+
Is electrical safety of irrigation increased? (x14)	No = 1; no change = 2; Yes = 3	2.83	0.37	+
Are water disputes and conflicts reduced? (*x*15)	Decreased = 1; no change = 2; increased = 3	1.51	0.53	-
Is water allocation more fair and reasonable (*x*16)	No = 1; no change = 2; Yes = 3	2.36	0.50	+
Is water fee collection more open and transparent (x17)	No = 1; no change = 2; Yes = 3	2.25	0.62	+
Is the frequency of irrigation equipment damage reduced (x18)	Decreased = 1; no change = 2; increased = 3	1.71	0.69	-
Household recognition of project characteristics (PC)				
Degree of being familiar with the operating principle (x19)	Completely unfamiliar = 1; not quite familiar = 2; average = 3; very familiar = 4; Completely familiar = 5	1.92	0.96	+
Is operation convenient (x20)	Very difficult = 1; difficult = 2; average = 3; convenient = 4; very convenient = 5	4.83	0.53	+
System quality evaluation (x21)	Very poor quality = 1; poor quality = 2; average quality = 3; good quality = 4; Very good quality = 5	3.80	0.81	+
Evaluation on the accuracy of measurement (x22)	Completely inaccurate = 1; not accurate = 2; average = 3; accurate = 4; very accurate = 5	4.47	1.30	+
Government support characteristics (GO)				
Government support evaluation (x23)	Not support = 0; not clear = 1; support = 2	1.50	0.55	+

4.2.3 Estimated result and analysis of the participation willingness of households in the project villages for the ICard use

This section uses software Eviews 5.0 to carry out the multivariate and orderly Logistic model handling of 113 samples in the project villages. The result estimated by the model is shown in the following table 4-4 the largest likelihood value of the model is 112.5226. The significant height shows good imitative effects of the model. The hypothesis of regression coefficient being 0 shall be rejected.

Table 4-4 Regression result for the project villages

Variable name	Regression coefficient	z-statistic
Age of households (*x1*)	-0.488742	-0.786221
Gender of households (x2)	-1.435969**	-2.427938
Degree of education of households (x3)	-0.393422	-0.937107
Whether the head of household is a village cadre (x4)	0.24025	0.23854
Political status of the head of household (*x*5)	-0.841883	-0.88099
Total number of family members (*x*6)	-0.458205	-0.782646
Number of elderly above 65 years old (*x7*)	0.180683	0.525087
Quantity of labour force (x8)	-0.865652	-1.559408
Annual family total income (x9)	1.185806**	2.427602
Family arable land area (x10)	0.35211	0.727281
Family arable land blocks (x11)	-1.360502**	-2.342254
Annual times of irrigation (x12)	-0.287894	-1.039439
Is irrigation more convenient and timely? (x13)	1.294147***	2.759021
Is electrical safety of irrigation increased? (x14)	1.493075**	2.045921
Are water disputes and conflicts reduced? (*x*15)	-0.926994*	-1.66599
Is water allocation more fair and reasonable (*x*16)	-0.180344	-0.294849
Is water fee collection more open and transparent (x17)	0.924931*	1.77258
Is the frequency of irrigation equipment damage reduced (x18)	-1.210808***	-2.80144
Degree of being familiar with the operating principle (x19)	0.567984	1.611033
Is operation convenient (x20)	2.729786***	3.311049
System quality evaluation (x21)	0.336169	0.836169
Evaluation on the accuracy of measurement (x22)	0.155093	0.684839
Government support evaluation (x23)	0.191123	0.346265
LR statistic	112.5226***	
Pseudo R-squared	0.400466	

1. **The impact of fundamental characteristics on the willingness of policy participation.** Among the explanatory variables of fundamental characteristics, the gender of people in the households in the regression model passes the significance test at the level of 5 percent and its coefficient is negative, indicating that males are more willing to participate in the ICard trial possibly because they are more willing to try new technology and more sensitive about scientific and technological progress. Total annual family income is significantly above the level of 5 percent and its coefficient is positive, meaning stronger willingness of policy participation for higher family incomes. The possible reason for this is that families with higher incomes tend to have broader vision and thinking and thus a higher willingness to accept new technology. Factors such as the degree of household education, whether the head of household is a village cadre, political status of the head of household, total number of family members, number of elderly people above 65 years of age and the quantity of the labour force do not pass the significance test and do not have a significant impact on the willingness of households to participate in the trials.

2. **The impact of the status of agricultural irrigation on the willingness of policy participation.** Among the explanatory variables of agricultural irrigation, the number of arable family land blocks passes the significance test at the level of 5 percent and its coefficient is negative, indicating that

households with more arable land blocks have a lower willingness to participate. The possible reason for thsi is that they have to invest more time and energy on the whole for more arable land blocks, so they do not feel the obvious benefits brought by the new technology. The two factors of arable family land area and annual times of irrigation are not significant factors and did not pass the significance test.

3. **The impact of household evaluation of project benefits on the willingness of policy participation.** Among six factors involved in benefit evaluation, five pass the significance test, indicating that the household evaluation of project benefits is the key affecting the willingness of households to participate in the ICard project. The factor of "is irrigation convenient and timely" significantly affects the participation willingness of households at the level of 1 percent and its coefficient is positive, indicating that households, who have used ICards and felt that irrigation becomes more convenient and timely, tend to be more willing to participate in the programme. The factor of "is electrical safety of irrigation increased" passes the significance test at the level of 5 percent and its coefficient is positive, indicating that households who have used ICards and felt that electrical safety of irrigation is increased, tend to be more willing to participate in the ICard programme. The factor of "are water disputes and conflicts reduced" passes the significance test at the level of 10 percent and its coefficient is negative, indicating that households, who have used ICards and felt that water disputes and conflicts reduced, tend to be more willing to participate in the programme. The factor of "is water fee collection more open and transparent" passes the significance test at the level of 10 percent and its coefficient is positive, indicating that households who have used ICards and felt that water fee collection becomes more open and transparent, tend to be more willing to participate in the programme. The factor of "is the frequency of irrigation equipment damage reduced" significantly affects the participation willingness of households at the level of 1 percent and its coefficient is negative, indicating that households, who have used ICards and felt that the frequency of irrigation equipment damage is reduced, tend to be more willing to participate in the programme. The factor of "is water allocation more fair and reasonable" did not pass the significance test.

4. **The impact of household recognition of project characteristics on household willingness to participate in the ICard trials.** The factor of "is operation convenient" significantly affects the participation willingness of households at the level of 1 percent and its coefficient is positive, indicating that households are more willing to participate in the policy if the evaluation of operational convenience is higher. The system quality evaluation and evaluation of the degree of measurement accuracy did not pass the significance test.

5. **The impact of government support characteristics on the willingness of participation.** Government support evaluation did not pass the significance test. One possible reason may be that the organizational capability of village cadres, accountants, electricians and other nearby grass-roots management persons directly affects the experience of households using the ICards, but the government is seen as being relatively more removed from agricultural irrigation by households, so they are not sensitive.

4.3 Impacts of IC technology application on poor households

As shown by numerous studies, government investment in rural public facilities plays an important role in reducing rural poverty. The application of the ICard technology in rural well irrigation is an important government investment project for rural irrigation facilities. It is worthy of study to determine whether the project can influence rural poverty reduction, whether rural poor people can

use the ICards equally, whether they can benefit from the application of the ICard technology and other issues.

The survey also carried out a case study of poor household A in Dashigezhuang village in Yanjiao Town, poor household B in Nanniezhuang Village in Qixinzhuang Town and poor households C and D in Xinjuntun Village in Yangzhuang Town in Sanhe City to study the impact of ICard technology use on poor households.

4.3.1 Household one: Poor household A in Dashigezhuang Village in Yanjiao Town

Dashigezhuang Village in Yanjiao Town is a key village in Hebei Province and a refined municipal village with a renovated appearance. Households in the village generally plant pear trees and have high incomes per capita. According to interviews, there was only one household in the village, which engages in agricultural production, but does not use the ICard. The head of the household was 72 years old with a primary school education. He did not act as a village cadre or hold other posts before. There are only two people living together in the household. The head of household was mainly responsible for planting and irrigation at home and his 65-year-old wife was mostly responsible for daily housework. The family has an annual total income of more than CN¥10 000, which mainly comes from planting 3.3 mu of corn and 1.7 mu of pear trees and a government subsidy for military service earned by the head of household in the past. The plantation income provided more than 90 percent of their total income. Although they were not considered a low-income family at the time by national standards, CN¥10 000 was a low household income in their village.

All other households in the village have changed from pulling electric switches to using ICards for irrigation, with only this household not participating in the project, because he has not irrigated land since moving back to the village in 2007. His land that was planted with corn is adjacent to the land of his brother, so his brother helps irrigate his land at the time of corn planting. At other times, corn irrigation relies on rain. His pear trees rely completely on natural conditions for growth and no artificial irrigation was carried out, because in his opinion, over-irrigation causes pears to lose their flavour and become less sweet. Moreover, the household thinks that he was very old and not very healthy and that he plants the land unevenly, because it was difficult for him to do the physical work of irrigation and plugging pipelines. It is extremely dangerous work, because people may easily fall into the mud during irrigation. In addition, the household sold pears for more than CN¥7 000 last year and the harvested corn yield was more than 650 kilogrammes per mu, which was only 150 to 200 kilogrammes less than the yield of those from irrigated land. The difference was in his range of acceptability and the money he made was enough for their daily needs.

The household had heard of the ICard technology for irrigation from others in the village. In his opinion, although the ICard technology can improve the convenience of irrigation to a certain extent and reduce the trouble of recording digits from an electricity meter, the actual irrigation itself was difficult considering his age and health and the fact that his living conditions and his expenses will not be affected whether or not he irrigates his land. He did abandon irrigation because he could not afford the cost of irrigation with the ICard.

4.3.2 Household two: Poor household B in Nanniezhuang Village in Qixinzhuang Town

Nanniezhuang Village in Qixinzhuang Town has the total arable land area of 1 300 mu. More than one-third of the land has been contracted out and only about 800 mu is left for local residents. Currently, there are five poor households in the village enjoying a national low-income subsidy, because they have no land, or they have given up land cultivation for various reasons.

The person interviewed in poor household B was a 70-year-old man whose son and daughter do not live with him. He lives alone in the village. His income mainly comes from the government subsidy for low-income people and money provided by his children. He has six mu of land, but has not planted any crops on the land, which has been abandoned for many years. According to this man's interview, he had cerebral thrombosis in 2000. Although he recovered, his health is still fragile, making it difficult for him to cultivate his land. He did not give up farming completely before the year 2010. He had his children help him to plant and irrigate his land during peak agricultural seasons. However, his children were also busy and could not look after the land much of the time. Because he was poor and not very healthy and had no relatives or friends to help him, there were always some people in the village who bullied him and stole his corn. Moreover, he was in poor health due to old age, so he abandoned his land and was looking to contract it out.

As for ICard use for irrigation, he had not used it and was not familiar with it because he had not cultivated and irrigated his land for many years.

4.3.3 Household three: Poor household C in Xinjuntun Village in Yangzhuang Town

Xinjuntun Village in Yangzhuang Town mainly plants corn and wheat and currently owns more than 700 mu of arable land. Most of the villagers have gone away to work, so there was a severe aging problem within the village. Poor household C in the village enjoys national subsistence allowances for low-income households. The head of household C was 68 years old with a primary school education. He was never married and has no children. He lives alone. His income mainly comes from planting corn on 1.5 mu of land and from the low-income subsidy from the government.

In a normal year, household C irrigates corn twice every year at a cost of about CN¥40 each time. Because a person in poor health and without any relatives heads household C, villagers with land nearby help him irrigate his land. In 2014, the government and village collectives launched a drive to encourage the village to use of the ICard for the irrigation of agricultural crops. Household C was included in the drive. Although a fee was required to charge the ICard before irrigation, household C did not think it was an economic burden for him. On one hand, the use of the ICard does not increase the fees for irrigation. Although the government did not offer a subsidy for irrigation, household C considered the fee for irrigation was affordable considering his income. In addition, household C considered that the payment used to charge the card, remains on the card and will not be lost. So, there was not much difference between the pre-payment method and the previous payment method of paying after irrigation as far as household C was concerned.

After the using the ICard, household C said that the greatest benefit was that irrigation was more convenient, which was mainly reflected in the fact that water can be used directly if there was remaining credit on the card. So, he no longer needs to go to pay the electricity bill in the village brigade every month. In addition, before he needed to pull the electricity switch before irrigation and then record the number on the power meter. Now, he only needs to swipe the ICard to automatically start and stop the flow of water for irrigation and to record the cost of the water.

4.3.4 Household four: Poor household D in Xinjuntun village in Yangzhuang town

Poor household D in Xinjuntun Village was also a low-income household enjoying the national subsistence allowance. A 70-year-old man who used to act as a brigade director for five years and a production team leader for 10 years headed household D. He is an old cadre in the village. Now, he lives with his wife who was mentally ill. They had no registered permanent residence in the village. He

cared for his 90-year-old mother with help from his brothers and sisters. With less than three mu of land and no labour force, he planted corn for only one season every year. Last year, he sold corn for more than CN¥2 000 and there was basically no money left after deducting the cost of seeds, fertilizer and others farming inputs. All of his income basically came from his government subsidy. In addition to the monthly government subsidy of CN¥570 to CN¥580, the civil affairs bureau also provided a subsidy of CN¥500 and CN¥500 for coal during the Spring Festival. However, the government does not provide any subsidy for poor households to irrigate their farmland.

Under normal circumstances, household C irrigates corn three times a year at the cost of about CN¥70 each time, bringing the irrigation fee to more than CN¥200 every year. Usually, his relatives helped with irrigation, but it was still difficult for him to irrigate the corn because of his advanced age. After adopting the ICard in 2014, payment needed to be made before irrigation.

On the whole, the household was very satisfied with the ICard, although he was not able to use it. He asked others how to use it and felt it was easy to learn. Moreover, he considered it much more convenient to use the ICard for irrigation than the previous way of irrigation. On one hand, he needed to record the amount of electricity consumption in a notebook, using a flashlight to see to write the number down when ended at night. Previously irrigation was problematic because he might have to ask others for help, when he could not see clearly to record the number. But, with the function of automatic recording when the card is swiped, irrigation became much more convenient. On the other hand, safety was also significantly improved. Because of his old age, he was reluctant to pull the electrical switch before, particularly in the evening. Just swiping the ICard proved to be much safer.

4.3.5 Summary

As for the impact of the ICard technology on poor households, interviews reveal there are two kinds of common situations. Most of the poor households are older people who have lost the ability to plant and irrigate agricultural crops. Many have contracted their land to others, or abandoned the land, or at least stopped irrigating the land. These poor households have not used ICards yet. Other poor households are able to plant and irrigate and used the ICard for daily irrigation. On the whole, they were quite satisfied with the use of the ICard and thought that the new system enhances the convenience and safety of irrigation. Poor households choose not to plant wheat, which requires many rounds of irrigation and much more investment. Instead, they choose to plant corn, which requires much less water and investment. As a result, they are able to afford the irrigation fee.

However, Sanhe City has not implemented water fee reforms yet. The city still applies the irrigation charge method of a fee for the electricity, but no water fee. Should the irrigation fee be reformed in the future, it would be worth studying whether some poor households will find that they cannot afford the pre-paid fees charged to the ICard.

5. Impact of ICard technology use on water management

5.1 Impact on irrigation water service

5.1.1 Convenient water for households

As for whether the ICard makes irrigation more convenient for households or not, this survey explores this in two aspects, i.e. "the changes that took place in irrigation from before ICard use and after ICard use in the project villages that trialled the card" and a "comparison of current irrigation use between the project villages and the non-project villages." On the whole, after using the ICard, households thought that irrigation becomes more convenient and less time consuming.

As shown by the statistics from the survey of the project villages (please see table 5-1), 76.1 percent of households thought that irrigation becomes more convenient and less time consuming when using the ICard and 15.9 percent of households thought that there was no big change. According to the investigation and statistics of the current irrigation methods in the project villages and the non-project villages, 73.5 percent of households in the project villages thought that irrigation was very convenient after using the ICard; Just over 14 percent of households thought that it was convenient; no household thought that it was completely inconvenient. In the non-project villages, 64.7 percent of households thought that current irrigation was very convenient; 21.6 percent of households thought that it was convenient; and one household thought that it was completely inconvenient (please see table 5-2).

Table 5-1 Whether irrigation is more convenient and timely after using the ICard in the project villages or not

Option	Frequency (persons)	Percentage (%)
Yes, it's more convenient	86	76.1
No big change	18	15.9
No, it's less convenient	9	8.0
Total	113	100.0

Table 5-2 The situation of irrigation convenience and timeliness in the project villages and non-project villages

Do you think the irrigation water in the village is convenient and timely		Completely inconvenient	inconvenient	Average	Convenient	Very convenient	Total
Project village	Frequency (persons)	–	9.0	5.0	16.0	83.0	113.0
Non-project village	Percentage (%)	–	8.0	4.4	14.2	73.5	100.0
	Frequency (persons)	1.0	2.0	4.0	11.0	33.0	51.0
	Percentage (%)	2.0	3.9	7.8	21.6	64.7	100.0

5.1.2 Irrigation guarantee for households

Statistics from households regarding "the change of irrigation safety in the project villages before and after using the ICard", found that 83.2 percent of households thought that irrigation was safer after using the ICard (please see table 5-3). After comparing and analysing "current irrigation safety in the

project villages and non-project villages," it was found that 94.6 percent of households in the project villages thought that irrigation was relatively safer or completely safe, while only 52.9 percent of households in the non-project villages thought so. In addition, 29.4 percent of households in the non-project villages thought that irrigation was not quite safe or completely unsafe, while no household in the non-project villages thought so (please see table 5-4).

Table 5-3 In the project villages is irrigation safer with the ICard than it was before?

Option	Frequency (persons)	Percentage (%)
Yes, it's safer	94	83.2
No big change	19	16.8
Total	113	100.0

Table 5-4 Situation of irrigation safety in the project villages and non-project villages

Do you think current irrigation water in the village is safe?		Completely unsafe	Unsafe	Average	Safe	Very safe	Total
Project village	Frequency (persons)	–	–	6.0	17.0	90.0	113.0
Non-project village	Percentage (%)	–	–	5.3	15.0	79.6	100.0
	Frequency (persons)	4.0	11.0	9.0	17.0	10.0	51.0
	Percentage (%)	7.8	21.6	17.6	33.3	19.6	100.0

5.2 Impact on water resource management

Since Sanhe City, Hebei Province had not carried out water price reforms when this study was conducted, traditional irrigation fees were being charged based on the amount of electricity used. No water fee was being charged at the time. Farmers were not sensitive about water consumption for irrigation. Therefore, households were not sure whether the irrigation water consumption per mu changed when using the ICard.

In addition, after asking households in the project villages "whether the use of the ICard helped reduce the decline in groundwater levels," it was found that 93.8 percent of households do not think that the use of the ICard helped to reduce the decline in groundwater levels (see table 5-5). Moreover, during the investigation, it became clear that households think that using the ICard only changes the irrigation method of pulling the electric switch as in the past. They do not think that it had any significant impact on water resource management.

Table 5-5 Does the use of the ICard help to easing the decline of ground water levels?

Option	Frequency (persons)	Percentage (%)
It helps with easing the situation	7	6.2
No help	106	93.8
Total	113	100.0

5.3 Impact on management of water users

5.3.1 Water disputes among households

From the questionnaire that households in the project villages and non-project villages responded to, we are able to determine "whether the situation of conflicts or disputes arising from irrigation has changed after using the ICard" and what was "the difference in the number of irrigation disputes seen by households in the project villages and non-project villages."

After asking about "the change in the number of irrigation conflicts, or disputes, after using the ICard in the project villages," it was found that 50.4 percent of households think that the number of conflicts and disputes arising from irrigation has been reduced after using the ICard (see table 5-6). It was found after comparing and analysing "whether households in the project villages and non-project villages see water conflicts and disputes" that 89.4 percent of households and 58.8 percent of households in the non-project villages did not see water conflicts or disputes. Eight percent of households in the project villages and 33.3 percent in the non-project villages sometimes see water conflicts or disputes. On the whole, the use of the ICard reduced the number of irrigation conflicts and disputes among households.

Table 5-6 Change in water conflicts or disputes in project villages after using the ICard

Option	Frequency (persons)	Percentage (%)
Reduced	57	50.4
Increased	2	1.8
No change	54	47.8
Total	113	100.0

Table 5-7 Water conflicts or disputes in the project villages and non-project villages

Do you see conflicts or disputes arising from irrigation		Always	Sometimes	No	Not clear	Total
Project village	Frequency (persons)	1.0	9.0	101.0	2.0	113.0
Non-project village	Percentage (%)	0.9	8.0	89.4	1.8	100.0
	Frequency (persons)	4.0	17.0	30.0	–	51.0
	Percentage (%)	7.8	33.3	58.8	–	100.0

5.3.2 Fairness and reasonability of water allocation

It was found after questioning the households about "the change in the degree of fairness and reasonability of water allocation when using the ICard in the project villages" that 61.9 percent of households thought that there is no big change of irrigation water allocation after using the ICard, but 94.3 percent of them thought that current water allocation was still somewhat fair and very fair. More than 32 percent of households thought that water allocation became fairer after using the ICard (see table 5-8).

It was found after comparing "whether water allocation in the project villages and non-project villages was fair and reasonable or not" that 96.4 percent of households in the project villages and 84.3 percent in the non-project villages thought that water allocation was somewhat fair and very fair; while 13.6 percent of households in the non-project villages and only 0.9 percent in the project villages

thought that current water allocation is very unfair or not quite fair (refer to table 5-9). On the whole, more households using the ICard in the project villages thought that water allocation was fairer and more reasonable than those in the non-project villages.

Table 5-8 Situation and comparison of fairness and reasonability of water allocation after the use of the ICard in the project villages

			Whether water allocation was fairer and more reasonable after using the ICard			Total
			Fairer	No big change	Even less fair	
Degree of fairness and reasonability of current water allocation	Very unfair	Frequency	–	–	–	–
		(persons)	–	–		–
		Percentage (%)			–	
	Not quite fair	Frequency	–	1.0	–	1.0
		(persons)	–	1.4		0.9
		Percentage (%)			–	
	Average	Frequency	–	3.0	–	3.0
		(persons)	–	4.3		2.7
		Percentage (%)			–	
	Fair	Frequency	7.0	29.0	1.0	37.0
		(persons)	16.7	41.4		32.7
		Percentage (%)			100.0	
	Very fair	Frequency	35.0	37.0	–	72.0
		(persons)	83.3	52.9		63.7
		Percentage (%)			–	
Total		Frequency	42.0	70.0	1.0	113.0
		(persons)	37.2	61.9	0.9	100.0

Table 5-9 Whether water allocation in the project villages and non-project villages was fair and reasonable or not

Do you think current water allocation is fair and reasonable		Very unfair	Not quite fair	Average	Fair	Very fair	Total
Project village	Frequency (persons)	–	1.0	3.0	37.0	72.0	113.0
Non-project village	Percentage (%)	–	0.9	2.7	32.7	63.7	100.0
	Frequency (persons)	2.0	5.0	1.0	20.0	23.0	51.0
	Percentage (%)	3.9	9.8	2.0	39.2	45.1	100.0

5.3.3 Water fee collection rate

It was learned after the interview with village cadres from six project villages that water fee collection rates had been significantly increased after using the ICard for agricultural irrigation in the villages. Currently, the villages in Sanhe City still apply the model of charging an electricity tariff instead of water fees for irrigation. Before using the ICard, there were mainly two methods of charging agricultural water fees. In one method, a village selects one day in each month to be the payment day in the irrigation season and the large loudspeaker in the village will notify villagers to go to the village brigade to pay the irrigation fee in advance; in another method, the accountant, electrician or plumber in a village goes door-to-door to villagers homes to collect the fee. However, there are cases of non-

payment, under-payment, or late payments of irrigation fees using these two methods and village cadre must eventually recover the full payment. After using the ICard, the method of charging before irrigation makes villagers actively pay the irrigation fee so as it greatly improves the irrigation water fee collection rate.

5.3.4 Rural steal of electricity (unpaid use) for irrigation

It was learned from the interview with a village cadre in Xinjuntun Village in Yangzhuang Town that electricity theft was a severe problem before using the ICard. In the past, the village used power meters to measure the electricity used for irrigation and some villagers, who had some knowledge about power meters, would tamper with power meter to make it stop running and still normally supply power for irrigation. According to the description of the village cadre, large-scale irrigation might lose 500 to 600 kilowatt hours (kwh) of electricity in the past. Irrigating six times a year would cost the village a huge amount of income every year. However, with the ICard system specifically and scientifically controls water supply for irrigation, shuts off water and accurately measures water and electricity consumption so that electricity theft is eliminated, which is beneficial for the village and improves the management of irrigation.

However, households in other villages did not report any theft of electricity.

5.4 Impact on the water management mechanism

5.4.1 The frequency of irrigation equipment maintenance

Taking into account the difference of wells, electrical voltage within the village and other real-world situations among project villages and non-project villages, this paper will only explain the "change in frequency of irrigation equipment damage within the village after using the ICard". It can be seen in table 5-10 that 42.5 percent of households thought that the damage to irrigation equipment within the village was reduced after using the ICard.

Table 5-10 The change of frequency of irrigation equipment damage in the project village after using the ICard

Option	Frequency (persons)	Percentage (%)
Reduced	48	42.5
Increased	15	13.3
No change	50	44.2
Total	113	100.0

According to interviews in the villages, when the electric switch method was used in the past, fuses frequently burned out, which caused a power cut in the middle of the irrigation process, requiring frequent visits by electricians to replace the blown fuses. It wasted everyone's time, because the irrigation process had to be repeated. After using the ICard, it was no longer necessary to get electricians to come to replace the fuse. In addition, because villagers did not understand the complexities of motor-pumped wells, they often on pulled the electrical switch to begin irrigation at times when the electrical voltage was too low, causing a short circuit, which severely damaged the pumps. Because the ICard has integrated motor protection built into the system, it automatically cuts off power before a short circuit can occur, reducing pump burn-outs and labour and maintenance costs for the village collectives.

5.4.2 Management time and costs for the village communities

Through interviews with village cadres in the six project villages, we learned that before the ICard was introduced the following methods of irrigation management were in use. In the first method, the village did not arrange for a water keeper and the villagers would look at the pump to record electricity usage on their own at the time of irrigation. The accountant was responsible for recording the power consumption of the villagers and collecting the electricity fees; the village electrician earned his salary by maintaining and installing the power source box before irrigation and uninstalling it after irrigation. In the second method, the village would arrange a special water keeper to be responsible for the pump, opening the electricity box, lining up the villagers for turns at irrigating their fields, recording power consumption and collecting electricity fees to hand over to the accountant. The water keeper received 10 percent of the electricity fees as his income. In the third method, all issues related to irrigation in the village were the responsibility of the electrician, who had a monthly salary of CN¥800 for the whole year. The electrician was mainly responsible for installing and unloading the transformer, opening the electricity box, daily irrigation maintenance and collecting and handing in the electricity fees to the authorities.

After using the ICard, households no longer need to get the key from the electrician or water keeper to open the electricity box before irrigation. They also no longer need to record the number on the power meter. In addition, the frequency of maintenance in daily irrigation has been reduced and the number of cases of under payment, no payment and delayed payment in the village has also been reduced. All this has led to a reduction in working time for electrician, water keeper and accountant. Moreover, in the past, there used to be professional management personnel who charged a small fee for collecting electricity fees. Using the ICard, such economic expenses are reduced for village collectives.

5.4.3 The fairness and transparency of water fee collection

After households responded to the questionnaires about "the change in the degree of openness and transparency of water fee collection after using the ICard in the project villages," it was found that 55.8 percent of households thought that there was no big change in the transparency of water fee collection after using the ICard and 34.5 percent of households thought that water fee collection was more transparent after using the ICard (see table 5-11).

After studying the opinions of households in project villages and non-project villages regarding the transparency of water fee collection, it was found that 79.7 percent of households in the project villages thought that the irrigation fee collection after the use of the ICard was somewhat transparent and very transparent and 20.3 percent of households thought that the irrigation fee collection after the use of the ICard is not quite transparent or average. On the other hand, 82.4 percent of households in the non-project villages thought that the irrigation fee collection after the use of the ICard was somewhat transparent and very transparent and 17.6 percent thought that it was not quite transparent or average (see table 5-12). On the whole, there was no significant difference on the matter of transparency in water fee collection between the project villages and non-project villages.

Table 5-11 The change of water fee collection transparency in the project village after using the ICard

Option	Frequency (persons)	Percentage (%)
More transparent	39	34.5
No change	63	55.8
Less transparent	11	9.7
Total	113	100.0

Table 5-12 Whether water fee collection in the project village and non-project village open and transparent

Do you think current irrigation fee collection open and transparent		Quite not transparent	Not transparent	Average	Transparent	Very transparent	Total
Project village	Frequency (persons)	–	14.0	9.0	35.0	55.0	113.0
	Percentage (%)	–	12.3	8.0	31.0	48.7	100.0
Non-project village	Frequency (persons)	2.0	6.0	1.0	21.0	21.0	51.0
	Percentage (%)	3.9	11.8	2.0	41.2	41.2	100.0

5.4.4 The measurement basis of water rights transaction and water price reforms

In March 2016, the government of Hebei Province issued *Measures on agricultural water rights transaction in Hebei Province* to make water rights a floating resource based on market value, which would be beneficial for promoting the rational allocation and efficient use of water resources. On April 21, 2016, the office of people's government of Hebei Province introduced *Implementation opinion on promoting comprehensive reform of agricultural water prices* to specifically propose improving facilities for water supply measurement and the gradual promotion of "one power meter for one well (pump) and one Icard for one household" in areas. It also proposed to gradually establish a system of agricultural water rights transaction to encourage users to transfer saved water, or carry it over for next year.

To achieve tradability of agricultural water rights and reform the water price ladder, an important prerequisite was to form improved irrigation measurement facilities to accurately measure water consumption and effectively record the total water consumption of households, so as to clarify water rights. The ICard system, which is a professional agricultural irrigation water measurement facility, provides an effective measurement basis to achieve water rights transactions and reform of water pricing, so as to realize conservation, protection and rational optimization of water.

5.5 Summary

After surveying the households in six project villages and two non-project villages and interviewing people in the project villages, it was found that the application of ICT in rural well irrigation areas has had a big impact on groundwater management.

5.5.1 Impact on irrigation water delivery

On one hand, it makes water use for households more convenient, which is mainly reflected in the fact that households no longer need to record numbers on the power meter and only need to swipe the card for automatic measurement and water supply; they no longer need to ask an electrician for help with wiring and opening the electrical box shortening the procedures of irrigation; they no longer need to line up for irrigation two or three days ahead, but only need to irrigate when the facility is idle to make the irrigation time more flexible; and they can charge the electricity fee on their card ahead of time so they do not need to go to the brigade to pay for the fee every month.

On the other hand, the irrigation safety of households was enhanced. In the past, villagers carried out farmland irrigation by pulling an electric switch to pump the irrigation water and the damage resulted over time to the electric switch because of heavy use by the villagers. On rainy days, the power unit often leaked, causing fear, particularly for the elderly and women in the village. However, after using the ICard, households only need to swipe the card to complete irrigation, which is both safer and more convenient.

5.5.2 Impact on water resource management

On the whole, the use of ICards in rural well irrigation areas neither reduces water consumption per mu nor does it ease the trend of declining of groundwater levels.

5.5.3 Impact on management of water users

The ICard reduces water disputes and conflicts. On one hand, because households recorded their own electricity amount for irrigation before, there were inevitably cases where the amounts recorded were in dispute. Villagers might inevitably also have disputes while determining their own electricity consumption. But after using the ICards and implementing the rule of one card for one household, the IC system automatically measures amount of electricity remaining and the remaining amount of money, thus reducing conflicts and disputes arising from manual recording. In addition, households needed to make oral agreements, or find the water keeper to line people up for irrigation in the past and sometimes people jumped the queue, or pulled the electric switch before others finished their irrigation. All this often resulted in water conflicts and disputes. However, after using the ICard, the irrigation time became more flexible and irrigation could not be stopped before swiping the card to shut off the water supply, effectively reducing opportunities for disputes to arise.

Water allocation is fairer with the ICard. It is mainly reflected in the fact that, after using the ICard, there are far fewer cases than in the past, of people who do not pay for irrigation water and power. Also queuing is eliminated and that stops some people from using personal relationships to gain a better position in the queue.

The collection rate of water fees is improved. The ICard system of charging fees before the actural irrigation reduces the number of villagers who fail to pay for irrigation, greatly improving the water fee collection rate to the benefit of rural water management.

5.5.4 Impact on management mechanisms

The ICard reduces the amount of maintenance the irrigation equipment requires. It reduces the frequency of minor repairs such as replacing burnt-out fuses. Moreover, because the control box of the ICard system is equipped with comprehensive motor protection equipment, it reduces the frequency of burnt-out pumps.

It reduces the management time and cost for village collectives. ICard reduces the workload of the accountant, electrician and water keeper in the village.

Collection of the water fees is not open and transparent. The change in the transparency of water fee collection when using the ICard in the project villages and non-project villages was not transparent to most villagers. In addition, the survey of households in the project villages revealed that some households did not look at the amount of electricity that remained on the box of the ICard system. Therefore they thought that tariff collection was not very transparent.

The ICard can accurately measure water consumption and effectively record the total water consumption of households, so it becomes the basis for on which to measure water rights transactions and water price reforms.

6. Other impacts of using ICard technology

6.1 Impact on the relationship among water, energy and food

For northern rural areas of well irrigation, groundwater is the major source of their water supply and groundwater irrigation plays a very important role in agricultural and grain production. Being an important grain production region in China, Hebei Province faces severe problems of groundwater overdraft and waste due to the shortage of water resources, weak awareness levels among farmers about water conservation and the excessive way irrigation water is used. A large number of "ground funnels" have formed, which seriously restrict basic agricultural irrigation and are not conducive to grain production. These irrigation challenges are threatening China's grain security.

We learned from interviews with villager and from the household questionnaires that the application of the ICard system in agricultural irrigation could save water. After using the ICard for agricultural irrigation in the village, it reduced cases of irrigation suspension caused by blown fuses on the electric switch, reducing repeat irrigation caused by maintenance during the middle of irrigation. So, it can save water to some extent. This could be of great significance for the sustainable use of China's rural groundwater resources and energy. However, according to village interviews and household surveys, the application of the ICard system in rural well irrigation areas played a positive role in energy conservation and enhanced grain production.

6.2 Impact on rural development

Industrialization and urbanization have produced the unstoppable trend of young people going away to work in the city, while the elderly are left behind in villages where they become the major force supporting agricultural production. However, elderly people face the problems of declining physical fitness that impedes their ability to do rigorous agricultural labour. Moreover, they are generally not highly educated, so they are unable to adopt modern trends in rural development and this is restraining agricultural development in China.

However, the ICard eases agricultural problems such as long irrigation times and heavy workloads for rural elderly people. They can complete farmland irrigation by inserting and removing their ICard. With advantages like convenient operation and easy to understand usage the ICard allows the elderly to better adapt to the technical requirements of agricultural information and mechanization, so they can contribute to the progress of agricultural modernization. In addition, the application of the ICard in farmland irrigation can help the left-behind elderly reduce the burden of their own labour, so that they can more easily complete the activities of household agricultural production. Then young people working in urban areas can be less worried, which is beneficial to the flow of rural labour to cities where their labour can contribute to the country's overall economic development.

6.3 Impact on rural communities

Rural contradiction is an important problem affecting rural harmony and hindering rural economic development. Agricultural irrigation occupies a crucial position in rural living, but it is also an important issue prone to causing conflicts. In the past, during peak agricultural irrigation seasons, there were water resource shortages and the water keeper did not have appropriate tools to ensure fair water use for all households, so households always had conflicts and disputes about grabbing well water, which severely harmed rural relationships, social stability and harmony.

After applying ICard technology to agricultural irrigation, households could consciously control and allocate irrigation time to reduce the "irrigation difficulties" they faced before the card. Moreover, the ICard made the process of water use among households more transparent and therefor fairer, reducing the number of conflicts and disputes arising from irrigation. This is helping to maintain rural social stability and development and it has great significance for new rural construction.

7. Conclusions and recommendations

By conducting fieldwork on a total of 164 households in six villages using the ICard in GW irrigation and two villages not yet using the ICard in GW irrigation, our research led to the following conclusions:

1. The ICard is compatible with other technical links when used for groundwater irrigation management. Most of the problems that occur in actual ICard application can be solved through technical training.
2. The application of the ICard in groundwater irrigation management can bring significant economic benefits, which are mainly reflected in reduced maintenance and labour costs; in fee collection and reduced losses from electricity theft in some research sites.
3. The application of the ICard in groundwater irrigation management can also bring significant social benefits, such as increasing the transparency of water use and electricity use and significantly reducing water use disputes.
4. All poor households that are willing to irrigate can participate in the use of the ICard reducing their marginalization.
5. Most of the households are satisfied with the ICard and are willing to use it.
6. In addition, the application of the ICard in groundwater irrigation management has laid foundation for water price reforms and water rights trading.
7. The benefits of water savings, energy savings and increasing agricultural production from the application of the ICard in groundwater irrigation management remain to be seen.

Policy recommendations are to:

1. Strengthen the education and training when promoting ICard technology so as to help households quickly learn and adapt to the use of ICards;
2. Improve the after sales service of the ICard technology so as to promptly eliminate any technical barriers caused by improper operation by village households.

References

ChinaNet, 2014. China.com.cn http://news.china.com.cn/2014-09/29/content_33646038.htm

ChinaNet, 2015. http://www.china.com.cn/node_7064072/content_19634796.htm
http://cj.xjkunlun.cn/xncjs/xncjs/2014/4238491.htm
http://www.farmer.com.cn/ywzt/wcg/jx/201504/t20150421_1027330.htm

Feng Wenjun. Application of ICard System in Electromechanical Well Irrigation in Rural Areas [j]. Hunan Agricultural Machinery, 2013, 01:103-104.

gov.cn http://www.gov.cn/zhengce/content/2016-01/29/content_5037340.htm

Gu Shugui, Pan Mingzhong. Large-scale and Refined Farming is the Basic Direction of Agricultural Development in China [J]. Economic Review, 2008 (9):67-69.

hebnews.cn http://hebei.hebnews.cn/2010-09/28/content_788491.htm 2010

hebnews.cn http://hebei.hebnews.cn/2013-11/05/content_3586986.htm 2013

Hebwater, 2010. hbzhan.com http://www.hbzhan.com/news/detail/94631.html

hebwater.gov.cn http://www.hebwater.gov.cn/a/2014/10/29/1414552593995.html

jwb.com.cn http://news.jwb.com.cn/art/2014/11/20/art_179_5076967.html

Meng Ge, Shen Zhen. Present Situation and Countermeasure Research of the Collection of Irrigation Water Fees [J]. Economic Research Guide, 2012 (24):213-214.

Pan Lihua. On the Development of ICard Industry in China from the Perspective of ICard Application [J]. Information Technology & Standardization, 2005 (7):4-6.

Renming, 2014. People's Daily Online http://politics.people.com.cn/n/2014/0507/c1001-24984953.html

The State Council of the People's Republic of China http://www.gov.cn/2015-04/14/content_2846156.htm

Wang Tong, et al. Deep groundwater in North China Plain has been over exploited by more than 70 percent. Hebei Geology, 2010, (3):26-26

Xinhua, 2013. Xinhua http://news.xinhuanet.com/fortune/2013-09/19/c_117428735.htm

Xinhua, 2014 (b). Xinhua http://news.xinhuanet.com/fortune/2014-08/27/c_1112248453.htm

Zhang Lijuan, Wang Jinxia. Application of Intelligent ICard System in Electromechanical Well Irrigation and Its Effect [j]. Journal of Economics of Water Resources, 2005, 02:42-44.

Zheng Tonghan, Zhang Bin, Wang Xiwen. Current Problems in the Reform of Agricultural Water Price, Their Impact and Countermeasures [J]. China Water Resources, 2006, 16:17-20.

Appendix

Appendix 1: Household questionnaire (project village)

Questionnaire on intelligent card application in groundwater irrigation areas in China

Questionnaire Number:
Answered by:
Time:
Location: **Village** **County (Town)**

Dear Madam/Sir:

Hello! We are students from College of Humanities and Development Studies of China Agricultural University. We are now conducting a study about ICard application in groundwater irrigation areas in China. Your support is needed to answer this questionnaire. Please give your answers based on facts and there is no right or wrong to your answers. All of the information collected from this study will be used for academic purposes only and your personal information will be kept highly confidential. Thank you very much for your cooperation!

A. Basic household conditions

A01	Age (Full Year):
A02	Gender: **[**0**]** Male **[**1**]** Female
A03	Education: **[**1**]** Below Primary School **[**2**]** Primary School **[**3**]** Junior Middle School **[**4**]** Senior Middle School
A04	Is (was) any household member a village/town cadre: **[**0**]** No **[**1**]** Yes
A05	Political Status of the Head of Household: **[**0**]** The Masses **[**1**]** Communist Party Member **[**2**]** Probationary Party Member **[**3**]** Communist Youth League Member **[**4**]** Others
A06	Total Number of Household Members _____ person(s)
A07	Number of Senior Citizens Aged 65 and Older _____ person(s)
A08	Number of Labour Force _____
A09	Are you poor households? **[**0**]** No **[**1**]** We think so, but not acknowledged **[**2**]** Yes, we are acknowledged poor household
A10	Annual Household Income: _____ **[**1**]** Less than CN¥10 000 **[**2**]** CN¥10 000 – CN¥20 000 **[**3**]** CN¥20 000 – CN¥50 000 **[**4**]** More than CN¥50 000
A11	Percentage of agricultural income in total household income: _____**[**1**]** Below 20% **[**2**]** 20%-50% **[**3**]** 50%-80% **[**4**]** More than 80%

B. Household Irrigation Water Status

B01	Area of Arable Land is _____ acre(s)
B02	Groundwater irrigation frequency in one crop season? Corn _____ Wheat _____
B03	Arable land is divided into _____part(s). How far is the biggest land away from the source of irrigation water (the irrigation station or pumping station in the village)? **[**1**]** Nearby **[**2**]** A little bit far **[**3**]** Very far

C. Application and Efficiency of Irrigation Water Management

Social Efficiency	
C01 In your opinion, has irrigation in your village become more convenient and timely after using intelligent water card?	**[1]** Not convenient at all **[2]** Not very convenient **[3]** Just so so **[4]** Convenient **[5]** Very Convenient
C02 Is it more convenient compared with the situation before using the ICard?	**[0]** Less convenient **[1]** No change **[2]** More convenient
C03 Have you ever seen any disputes or conflicts over irrigation after using the IC card?	**[1]** Often **[2]** Sometimes **[3]** Never **[4]** No idea
C04 How is the frequency of disputes and conflicts compared with the situation before using the ICard?	**[0]** Increased _____ **[1]** No change **[2]** Reduced _____
C05 How do you think of the safety of irrigation electricity after using the ICard?	**[1]** Not safe at all **[2]** Not very safe **[3]** Just so so **[4]** Safe **[5]** Very safe
C06 How is the safety compared with the situation before using the ICard?	**[0]** Less safe **[1]** No change **[2]** Much safer
C07 Is water allocation fair and reasonable after using the ICard?	**[1]** Quite unfair **[2]** Not very fair **[3]** Just so so **[4]** Fair **[5]** Very fair
C08 How is water allocation compared with the situation before using the ICard?	**[0]** Less fair **[1]** No change **[2]** More fair
C09 How do you think of the transparency of irrigation charge after using the ICard?	**[1]** Not transparent at all **[2]** Not very transparent **[3]** Just so so **[4]** Transparent **[5]** Very transparent
C10 How is the transparency compared with the situation before using the ICard?	**[0]** Less transparent **[1]** No change **[2]** More transparent
C11 How often does irrigation facility failure happen after using ICard?	**[1]** Quite often **[2]** Often **[3]** Just so so **[4]** Not very often **[5]** Seldom
C12 How is the frequency of irrigation facility compared with the situation before using the ICard?	**[0]** More frequent _____ **[1]** No change **[2]** Less frequent _____
Eco-Efficiency	
C13 Do you think the use of the ICard helps to slow down groundwater level recession?	**[0]** No **[1]** Helps in some way **[2]** Helps a lot

Your Opinion on the Use of Intelligent IC Card						
C14	Do you have any idea on the concept of operations of ICard?	**[1]** No idea at all	**[2]** Very limited	**[3]** Just so so	**[4]** Know a lot	**[5]** Know everything
C15	Are you willing to be involved in policy-making regarding the application of ICard technology in agricultural irrigation?	**[1]** Unwilling	**[2]** Not very willing	**[3]** Neutral	**[4]** Willing	**[5]** Totally willing
C16	Are you satisfied with the use of the ICard in your village?	**[1]** Totally unsatisfied	**[2]** Not very satisfied	**[3]** Neutral	**[4]** Satisfied	**[5]** Totally satisfied
C17	Do you think ICard is easy to use?	**[1]** Very difficult	**[2]** Difficult	**[3]** Just so so	**[4]** Easy	**[5]** Very easy
C18	How do you think of the quality of ICard system?	**[1]** Very poor	**[2]** Poor	**[3]** Just so so	**[4]** Good	**[5]** Very good
C19	Do you think measurement with ICard is accurate?	**[1]** Totally inaccurate	**[2]** Not very accurate	**[3]** Just so so	**[4]** Accurate	**[5]** Totally accurate	**[6]** No idea
C20	Does the government support ICard in terms of investment, technology, etc.?	**[0]** No	**[1]** No idea	**[2]** Yes		
C21	Assuming that agricultural water fee is charged at CN¥0.2/m^3, will you reduce irrigation frequency or quantity?	**[0]** Yes	**[1]** No			
C22	What is the biggest problem at present in using the ICard in your opinion?					

Appendix 2: Household questionnaire (non-project village)

Questionnaire on ICard application in groundwater irrigation areas in China

Questionnaire Number:
Answered by:
Time:
Location: **Village** **County (Town)**

Dear Madam/Sir:

Hello! We are students from the College of Humanities and Development Studies of China Agricultural University. We are now conducting a study about ICard application in groundwater irrigation areas in China. Your support is needed to answer this questionnaire. Please give your answers based on facts and there is no right or wrong to your answers. All of the information collected from this study will be used for academic purposes only and your personal information will be kept highly confidential. Thank you very much for your cooperation!

D. Basic Household Conditions

A01	Age (Full Year):
A02	Gender: **[0]** Male **[1]** Female
A03	Education: **[1]** Below Primary School **[2]** Primary School **[3]** Junior Middle School **[4]** Senior Middle School
A04	Is (was) any household member a village/town cadre: **[0]** No **[1]** Yes
A05	Political Status of the Head of Household: **[0]** The Masses **[1]** Communist Party Member **[2]** Probationary Party Member **[3]** Communist Youth League Member **[4]** Others
A06	Total Number of Household Members _____ person(s)
A07	Number of Senior Citizens Aged 65 and Older _____ person(s)
A08	Number of Labour Force _____
A09	Are you poor households? **[0]** No **[1]** We think so, but not acknowledged **[2]** Yes, we are acknowledged poor household
A10	Annual Household Income: _____ **[1]** Less than CN¥10 000 **[2]** CN¥10 000–CN¥20 000 **[3]** CN¥20 000–CN¥50 000 **[4]** More than CN¥50 000
A11	Percentage of agricultural income in total household income: _____ **[1]** Below 20% **[2]** 20%-50% **[3]** 50%-80% **[4]** More than 80%

E. Status of Household Irrigation Water

B01	Area of Arable Land is _____ acre(s)
B02	Groundwater irrigation frequency in one crop season? Corn _____ Wheat _____
B03	Arable land is divided into _____ part(s). How far is the biggest land away from the source of irrigation water (the irrigation station or pumping station in the village)? **[1]** Nearby **[2]** A little bit far **[3]** Very far

F. Application and Efficiency of Irrigation Water Management

Socia l Efficiency						
C01	Do you think irrigation in your village is convenient and timely?	**[1]** Not convenient at all **[2]** Not very convenient **[3]** Just so so **[4]** Convenient **[5]** Very Convenient				
C02	Have you ever seen any disputes or conflicts over irrigation?	**[1]** Often **[2]** Sometimes **[3]** Never **[4]** No idea				
C03	How do you think of the safety of irrigation electricity in your village?	**[1]** Not safe at all **[2]** Not very safe **[3]** Just so so **[4]** Safe **[5]** Very safe				
C04	Is water allocation fair and reasonable at present?	**[1]** Quite unfair **[2]** Not very fair **[3]** Just so so **[4]** Fair **[5]** Very fair				
C05	How do you think of the transparency of irrigation charge at present?	**[1]** Not transparent at all **[2]** Not very transparent **[3]** Just so so **[4]** Transparent **[5]** Very transparent				
C06	How often does irrigation facility failure happen at present?	**[1]** Quite often **[2]** Often **[3]** Just so so **[4]** Not very often **[5]** Seldom				
Your Opinion on the Use of Intelligent ICard						
C07	Are you willing to be involved in the policy making regarding the application of ICard technology in agricultural irrigation?	**[1]** Unwilling	**[2]** Not very willing	**[3]** Neutral	**[4]** Willing	**[5]** Totally willing
C08	Assuming that agricultural water fee is charged at CN¥0.2/m^3, will you reduce irrigation frequency or quantity?	**[0]** Yes **[1]** No				

Appendix 3: Outline for village-level interview

1. Fundamental Conditions of the Village

Facts and Figures	
Total Land Area	
Total Arable Area	
Total Number of Households and Population of the Village	
Annual Per-Capita Income in the Village	
Number of Low-Income Families in the Village	
Major Irrigation Method	
Major Crops	
Number of Pumping Stations in the Village	
Electricity Price in the Village	

2. Status of the ICard Project

Project Status	
Sponsor of the ICard Project and Number of Years in Use	
Percentage of Coverage in the Village	
How does the government support this project?	
Follow-up maintenance of the ICard system (the responsible department, maintenance frequency and method, cost, etc.)	
Has your village ever popularized the knowledge of intelligent ICard? If yes, how was it conducted?	

3. Benefits and Problems of the Project

Benefits and Problems	
Has water fee collection been improved?	
How was irrigation (such as repair and fee collection, etc.) managed in your village before using the ICard? How about the salary and working time of the irrigation manager, accountant and electrician?	
How about the irrigation management (repair, top-up, etc.) as well as the salary and working time of the irrigation manager, accountant and electrician after using the ICard? Will their salary be increased and workload reduced?	

Have disputes and conflicts over irrigation reduced after using the ICard in your village and why?	
Has the use of the ICard helped for water and energy saving as well as production increase and why?	
How frequently were irrigation facilities repaired before using the ICard in your village? How much did it cost every time (labour plus material cost)?	
Has the repair of irrigation facility happened less after the use of the ICard and why? How much is the repair fee now?	
How do the villagers queue for irrigation before and after the use of the ICard? Is it fairer now?	
Is there any change in the irrigation procedure for the villagers now after the use of the ICard? Has the irrigation procedure become simplified and more convenient?	
Are there any other notable benefits after using the ICard?	
Are there any problems in the course of using the ICard system?	

Appendix 4: Outline for county-level interview

1. How long has the ICard system been implemented? Can you give more information on the background and target?
2. Basic conditions of the city (economic level, rainfall and basic agricultural situation).
3. Do you have policies in place regarding water price, water rights allocation and water fee management, etc.?
4. The regulations and provisions (detailed rules) for the implementation of intelligent IC water card, how to roll out the project (the selection of villages for wave I and II).
5. Current status of the project.
6. The difficulties encountered during the implementation.
7. Are there extra policy compensations for poor households?
8. How to popularize the application of the ICard system?
9. The current status of technical maintenance for the ICard system and how to do maintenance after the warranty period?
10. How much is the investment in the ICard project? How is the investment allocated?
11. What are the benefits generated by the implementation of the ICard project?

ISBN 978-92-5-109723-6

I7082EN/1/04.17