Measures and Efficiency of Groundwater Overdraft Governance in North China Plain Based on Community Appraisal

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Abstract: Research on groundwater over-exploited comprehensive governance in North China Plain has great significance for Jing-Jin-Ji water security and agricultural sustainable development. Farmers' evaluation is an important reference for improving the measures of groundwater over-exploited governance. Based on the survey of 270 farmers in Hengshui City of Heibei Province in 2016, this paper evaluated the18 measures of groundwater over-exploited governance from the farmer's perspective, which can be classified into five categories. The evaluation results indicated that farmers were more aware of the three types of measures, including construction of water conservancy facilities, adjustment of planting structure and agronomic water-saving technology, while less clear about the other two types of measures, which were reform of agricultural water right & water price and construction of service system. Farmers believed that construction of water conservancy facilities and adjustment of planting structure were good measures, agronomic water-saving technology and construction of service system were general measures, and reform of agricultural water right & water price was poor measures. Measures' relevance with agricultural production was the main factor to determine whether farmers were clear about the governance measures. The closer the relevance was, the better the farmers understood the governance measures. Measures' water-saving mechanism and farmers' participatory motivation were two main factors to determine how farmers evaluated the governance measures. The more direct and explicit the measures' water-saving mechanism was, the better the farmers would evaluate the governance measures. The stronger the farmers' participatory motivation was, the better the farmers would evaluate the governance measures. To improve the effectiveness of groundwater over-exploited comprehensive governance, direct and explicit water-saving mechanism should be designed, and farmers' participatory motivation should be fully considered.

Key Words: North China Plain; groundwater over-exploited; farmers' evaluation; Hengshui City

1. Introduction

Use of groundwater has been widely developed in the world, and disorder of groundwater exploitation and management has resulted in overdraft and its consequent environmental problems, like land subsidence, seawater flowing in, ground fissures. Groundwater, as a typical commons, existed widespread overuse, how to governance groundwater resources in a sustainable manner is a global challenge.

Much research has been undertaken, from both technical and managerial perspectives, to

address groundwater issues. Because of the open-access nature of the resource and the political economy of water management, particularly with regard to agriculture, governing groundwater is very difficult.

China has some unique lessons in groundwater overdraft governance to share with the world. In North China Plain, increasing water demand since the 1970s, in which agricultural irrigation water was main, has resulted in severe groundwater overdraft, water level decline, water quality degradation, and North China Plain has became world's largest groundwater funnel area. In recent years, groundwater overdraft got wide attention by the society, and central government put forward implementing groundwater overdraft governance since 2014.

China's groundwater overdraft governance had at least three characteristics. Firstly, comprehensive use of many policies and measures, which mainly included increasing the supply of surface water to replace the use of groundwater, farmland protective retirement, agricultural water rights &water pricing reform and promoting water-saving agricultural technology. Secondly, mode of collective action was mainly a type of top-down institution supply based on China's hierarchical authoritarian system. Thirdly, all of these measures were closely related to farmers' agricultural production, understanding farmers' participatory mechanism and self-governance was crucial to guarantee effective implementation of these measures.

In August of 2016, we conducted field investigation based on community appraisal in Hengshui City located in North China Plain. In the implementation of groundwater overdraft governance, of all these measures, some were effective, some were not, and what caused some measures ineffective? In this paper, we will systematically comb those existing measures, evaluate their efficiency, analyze their problems and provide some implications in theory and practice.

2. Collective action of China's groundwater governance

2.1 governance measures

As shown in table 1, China's groundwater overdraft governance has implemented 18 specific measures, which can be classified into five categories. All the groundwater overdraft governance measures are closely related to farmers' agricultural production. Construction of water conservancy facilities increase farmers' irrigation water supply and change the irrigation mode of farmers. Adjustment of planting structure changes the planting structure of farmers. Reform of agricultural water right & water price uses market mechanisms to affect the farmers' irrigation behavior. Agronomic water-saving technologies are related to planting, farming, irrigation, fertilizer, etc. Construction of services system provides technical support for farmers' agricultural production

Tab.1 Measures of groundwater over-exploited comprehensive governance in North China Plain and relevance analysis with farmers' agricultural production

Classification of measures	Specific measures	relevance with farmers' agricultural production
construction of water conservancy facilities	Water diversion project Restoration of surface water irrigation well prohibited Water-saving irrigation project	Increase farmers' irrigation water supply, change the irrigation mode of farmers
adjustment of planting structure	Fallow Returning farmland to forest	Change the planting structure of farmers

reform of agricultural water right & water price	Installation of agricultural water metering facilities Agricultural water right Agricultural water price	Use market mechanisms to affect the farmers' irrigation behavior
agronomic water-saving technologies	Drought resistant winter wheat Protective cultivation Water & fertilizer integration	Related to planting, farming, irrigation, fertilizer, etc
construction of services system	Small farmland water conservancy projects Groundwater monitoring Agro-technical popularization Water users association Irrigation forecast Artificial rainfall	Provide technical support for farmers' agricultural production

2.2 Evaluation methods

The evaluation methods were studied by the following:

1) Ask farmers to evaluate all 18 specific measures. Two main questions were asked, one was "do you clear this governance measures", the other was "if clear, how effective is this governance measure", very poor, poor, general, good or very good.
2) Construct two indicators to characterize the evaluation results, which were farmers' unclear proportion and farmers' good evaluation proportion.
3) Cluster analyze based on two indicators. All 18 specific measures could be classified into four categories, which included "clear and good", "clear and general", "unclear and general" and "unclear and not good".
4) Conduct in-depth analysis and discussion.

2.3 Data

The data collected by field survey of 270 farmers in Hengshui City of Heibei Province in 2016.

Tab.2 Farmers' evaluation of groundwater over-exploited comprehensive governance measures and cluster analysis results

Classification of measures	Specific measures	very poor	poor	general	good	very good	not clear	Unclear proportion (%)	Good evaluation proportion (%)	clear and good	clear and general	unclear and general	unclear and not good	overall evaluation
construction of water conservancy facilities	Water diversion project	1	2	13	39	176	39	15	93	√				clear and good
	Restoration of surface water irrigation	1	3	19	44	154	49	18	90	√				
	well prohibited	3	43	31	38	81	74	27	61		√			
	Water-saving irrigation project	3	19	22	62	80	84	31	76	√				
adjustment of planting structure	Fallow	0	5	23	60	162	20	7	89	√				clear and good
	Returning farmland to forest	6	30	41	74	68	51	19	65		√			
reform of agricultural water right & water price	Installation of agricultural water metering facilities	13	36	52	36	10	123	46	31				√	unclear and not good
	Agricultural water right	2	13	31	20	4	200	75	34				√	
	Agricultural water price	0	27	57	38	22	126	47	42				√	
agronomic water-saving technologies	Drought resistant winter wheat	1	27	37	96	46	63	23	69		√			clear and general
	Protective cultivation	2	39	58	69	37	65	24	52		√			
	Water & fertilizer integration	1	10	31	43	23	162	60	61			√		
construction of services system	Small farmland water conservancy projects	1	15	30	45	6	173	64	53			√		unclear and general
	Groundwater monitoring	1	14	35	30	13	177	66	46			√		
	Agro-technical popularization	0	7	37	75	27	124	46	70			√		
	Water users association	4	11	27	21	16	191	71	47			√		
	Irrigation forecast	1	5	23	61	104	76	28	85	√				
	Artificial rainfall	0	1	17	61	148	43	16	92	√				

3. Results

Farmers' evaluation of groundwater over-exploited comprehensive governance measures and cluster analysis results were shown in table 2.

According to the indicator of unclear proportion, farmers were more aware of the three types of measures, including construction of water conservancy facilities, adjustment of planting structure and agronomic water-saving technology, while less clear about the other two types of measures, which were reform of agricultural water right & water price and construction of service system. Sorted results of farmers' unclear proportion (%) of groundwater over-exploited governance measures were shown in Fig.1. The five clearest measures included fallow, water diversion project, artificial rainfall, restoration of surface water irrigation and returning farmland to forest. The five most unknown measures were agricultural water right, water users association, agro-technical popularization, small farmland water conservancy projects and water and fertilizer integration.

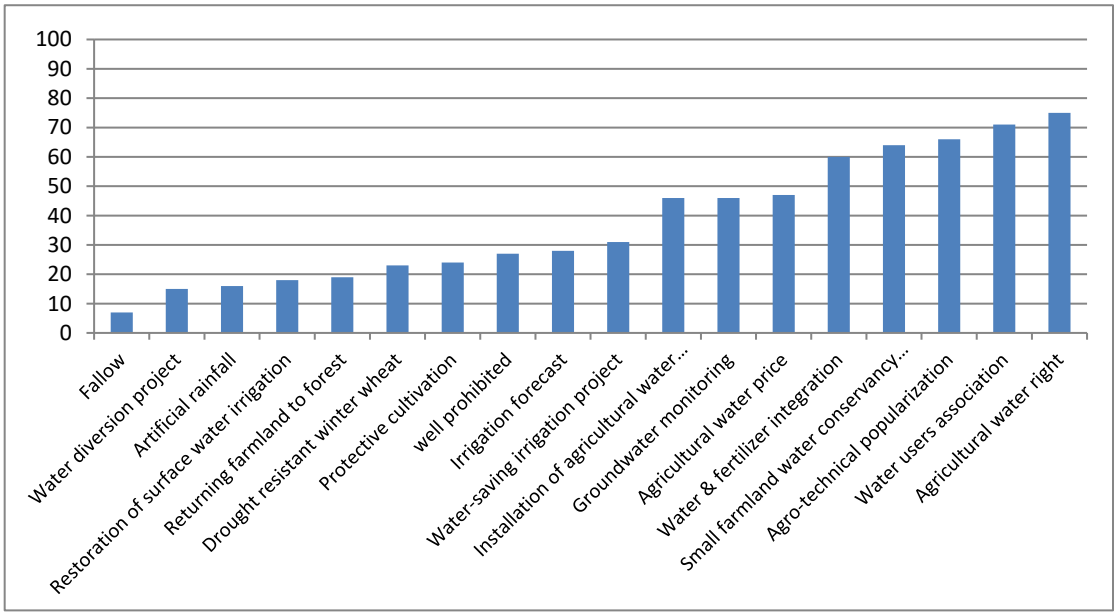

Fig.1 Sorted results of farmers' unclear proportion (%) of groundwater over-exploited governance measures

Based on the indicator of good evaluation proportion, farmers believed that construction of water conservancy facilities and adjustment of planting structure were good measures, agronomic water-saving technology and construction of service system were general measures, and reform of agricultural water right & water price was poor measures. Sorted results of farmers' good evaluation proportion (%) of groundwater over-exploited governance measures were shown in Fig.2. The five best evaluation measures were water diversion project, artificial rainfall, restoration of surface water irrigation, fallow and irrigation forecast. The five poorest evaluation measures were installation of agricultural water metering facilities, agricultural water right, agricultural water price, water users association and groundwater monitoring.

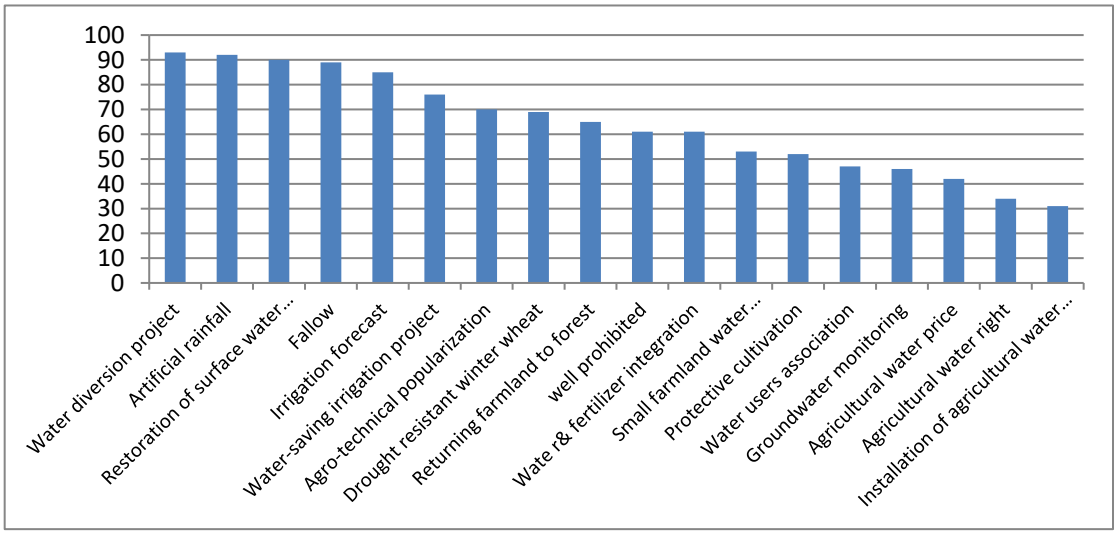

Fig.2 Sorted results of farmers' good evaluation proportion (%) of groundwater over-exploited governance measures

Using SPSS software, cluster analysis results of 18 specific measures results were presented in Tab. 3. It had six "clear and good" measures, which respectively were water diversion project, restoration of surface water irrigation, water-saving irrigation project fallow, irrigation forecast and artificial rainfall. Four "clear and general" measures included well prohibited, returning farmland to forest, drought resistant winter wheat and protective cultivation. Five "unclear and general" measures were made up of small farmland water conservancy projects, water & fertilizer integration, groundwater monitoring, agro-technical popularization, and water users association. At last, it had three "unclear and not good" measures, including installation of agricultural water metering facilities, agricultural water right and agricultural water price.

4. Discussion

4.1 Water-saving mechanism

Measures' water-saving mechanism was one of the main factors to determine how farmers evaluated the governance measures. As shown in Tab.4, the more direct and explicit the measures' water-saving mechanism was, the better the farmers would evaluate the governance measures.

Tab.4 measures 'water-saving mechanism and farmers' overall evaluation of groundwater over-exploited governance measures

Classification of measures	water-saving mechanism (WSM)	Qualitative evaluation of WSM	overall evaluation results
construction of water conservancy facilities	Increase the supply of surface water; improve the coefficient of water resources effective utilization	direct and explicit	Good
adjustment of planting structure	Reduce irrigation or no irrigation	direct and explicit	Good
reform of agricultural water right & water price	Use market mechanisms to affect the farmers' irrigation behavior	indirect and not explicit	Not good

agronomic water-saving technologies	Reduce crops' irrigation need	direct and not explicit	General
construction of services system	Provide technical support for other governance measures	Partly indirect and not explicit, Partly direct and explicit	General

Water-saving mechanism of "construction of water conservancy facilities", which appeared direct and explicit, was increasing the supply of surface water and improving the coefficient of water resources effective utilization.

Water-saving mechanism of "adjustment of planting structure", which appeared direct and explicit, was reducing irrigation or no irrigation.

Water-saving mechanism of "reform of agricultural water right & water price", which appeared indirect and not explicit, was using market mechanisms to affect the farmers' irrigation behavior.

Water-saving mechanism of "agronomic water-saving technologies", which appeared direct and not explicit, was reducing crops' irrigation need.

Water-saving mechanism of "construction of services system", which appeared partly indirect and not explicit, partly direct and explicit, was providing technical support for other governance measures.

4.2 Farmers' participatory motivation

Farmers' participatory motivation was another factor to determine how farmers evaluated the governance measures. As shown in Tab.5, The stronger the farmers' participatory motivation was, the better the farmers would evaluate the governance measures.

Tab.5 Farmers' participatory motivation and farmers' overall evaluation of groundwater over-exploited governance measures

Classification of measures	Farmers' participatory motivation (FPM)	Qualitative evaluation of FPM	overall evaluation results
construction of water conservancy facilities	Channel irrigation has a great advantage over well irrigation	strong	Good
adjustment of planting structure	The incentive for farmers to grow agriculture is declining; A certain benefit compensation mechanism	Strong	Good
reform of agricultural water right & water price	Barriers to the installation of agricultural water metering facilities; difficulties in collecting agricultural water fees; farmers are not sensitive to water price	weak	Not good
agronomic water-saving technologies	expected yield reduction by reducing irrigation	general	General
construction of services system	farmers' degree of demand and recognition of technical services	General or strong	General

Farmers' participatory motivation of "construction of water conservancy facilities" was strong, which appeared that channel irrigation had a great advantage over well irrigation.

Farmers' participatory motivation of "adjustment of planting structure" was strong, which appeared that the incentive for farmers to grow agriculture was declining and it exited a certain benefit compensation mechanism.

Farmers' participatory motivation of "reform of agricultural water right & water price" was weak, because it had barriers to the installation of agricultural water metering facilities and difficulties in collecting agricultural water fees, meanwhile, farmers were not sensitive to water price.

Farmers' participatory motivation of "agronomic water-saving technologies" was general, mainly due to expected yield reduction by reducing irrigation.

Farmers' participatory motivation of "construction of services system" was general or strong, depending on farmers' degree of demand and recognition of technical services.

5. Conclusion and implication

Research on groundwater over-exploited comprehensive governance in North China Plain has great significance for Jing-Jin-Ji water security and agricultural sustainable development. Farmers' evaluation is an important reference for improving the measures of groundwater over-exploited governance.

Based on the survey of 270 farmers in Hengshui City of Heibei Province in 2016, this paper evaluated the18 measures of groundwater over-exploited governance from the farmer's perspective, which can be classified into five categories. The evaluation results indicated that farmers were more aware of the three types of measures, including construction of water conservancy facilities, adjustment of planting structure and agronomic water-saving technology, while less clear about the other two types of measures, which were reform of agricultural water right & water price and construction of service system. Farmers believed that construction of water conservancy facilities and adjustment of planting structure were good measures, agronomic water-saving technology and construction of service system were general measures, and reform of agricultural water right & water price was poor measures. Measures' relevance with agricultural production was the main factor to determine whether farmers were clear about the governance measures. The closer the relevance was, the better the farmers understood the governance measures. Measures' water-saving mechanism and farmers' participatory motivation were two main factors to determine how farmers evaluated the governance measures. The more direct and explicit the measures' water-saving mechanism was, the better the farmers would evaluate the governance measures. The stronger the farmers' participatory motivation was, the better the farmers would evaluate the governance measures.

To improve the effectiveness of groundwater over-exploited comprehensive governance, direct and explicit water-saving mechanism should be designed, and farmers' participatory motivation should be fully considered.

Acknowledgements

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