www.water-alternatives.org
Volume 14 | Issue 2

Deng, H.; Guan, B.; Wang, J.; Zuo, A.; Wang, Z. and Sun, T. 2021.
Seasonal land fallowing policy in response to groundwater overdraft in the north China Plain.
Water Alternatives 14(2): 371-394

Seasonal Land Fallowing Policy in Response to Groundwater Overdraft in the North China Plain

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ABSTRACT: The Seasonal Land Fallowing Policy (SLFP), designed to mitigate serious groundwater overdraft in the North China Plain, was introduced in Hebei Province in 2014. This paper offers a comprehensive review and assessment of its implementation status, effectiveness and challenges. Based on data at both macro and micro levels, we witnessed the rapid expansion of the SLFP from 2014 to 2019. With a high targeting efficiency, the SLFP reduced groundwater consumption and contributed to real water saving. However, further analysis is needed on the influence of the SLFP on water levels. As a means of payment for ecosystem services, the current subsidy offered by the SLFP is not sufficiently flexible to reflect the heterogeneity in farmers' opportunity cost. Obstacles to the effective and sustainable implementation of the SLFP include unstable and ineligible participants, insufficient incentive for farmers to shift surplus labour to off-farm jobs, and underuse of fallowed land. Based on these challenges, this paper offers policy suggestions to further aid the SLFP's effective and sustainable implementation in the future.

KEYWORDS: Seasonal Land Fallowing Policy, Implementation, Groundwater Overdraft, Conservation of Groundwater Irrigation, North China Plain

INTRODUCTION

The North China Plain (NCP) is one of the most important agricultural production regions in China, where five of China's 13 major grain production provinces are located – Hebei, Henan, Shandong, Anhui and Jiangsu. The NCP is home to 24% of China's population and contributes more than 30% of the country's grain production (NSBC, 2019). Due to low precipitation, agricultural production in the NCP is heavily dependent on irrigation, particularly groundwater irrigation (Wang et al., 2019). As a result, the NCP is renowned for suffering the most serious groundwater overdraft[1] in the world (Famiglietti, 2014), which has resulted in numerous environmental problems and threatens sustainable socioeconomic development in the NCP.

In order to tackle groundwater overdraft and promote the sustainable use of water in agriculture, the Chinese government launched the Comprehensive Control of Groundwater Overdraft (CCGO) programme in the NCP in 2014. Hebei Province was selected as the pilot province because it experiences the most serious groundwater overdraft issues and is of key importance in supplying agricultural products in the NCP. The CCGO pilot programme began in 49 counties in 2014 and was expanded to 116 counties in 2020, covering all groundwater cones of depression in Hebei Province. In 2017 the CCGO programme was rolled out in three further provinces – Shandong, Shanxi and Henan – and by 2020 there were plans to introduce it in 13 provinces in the near future.

The CCGO proposed a suite of measures on both the supply and demand sides to resolve groundwater overdraft issues. On the supply side it encourages water users to replace groundwater pumped for household and industrial use by surface water delivered by the South-North Water Transfer project. An important demand-side measure of the CCGO is the Seasonal Land Fallowing Policy (SLFP). It is different from other traditional demand-side measures, such as water pricing, water-rights reforms or the provision of water-saving technologies, as it is expected to deliver real water savings. Although land fallowing has been widely implemented in countries such as the USA (Miao et al., 2016), it was tried on a large scale for the first time by the Chinese government in Hebei Province in 2014. The SLFP requires farmers to fallow their winter wheat land, compensating them for the financial loss. The need to reduce evapotranspiration largely translates into a need to reduce the total cropping area and water-thirsty crops. Land fallowing is becoming recognised as a straightforward way to reduce water use (most examples are from the US, but there are examples in Spain and southern Europe in general) (O'Connell et al., 1995; Moret et al., 2006; Rao and Yang, 2010). Compared with other demand-side measures which mainly reduce water application through increasing irrigation efficiency, the SLFP directly reduces water consumption by not growing winter wheat and is expected to achieve real water savings in the long term.

Given that the SLFP has been extended to other provinces since 2017, the experience in Hebei is important. However, only a few studies have so far focused on this programme, almost all of which were based mainly on secondary data or small-scale field surveys (Wang et al., 2016; Xie et al., 2017). And current studies pay more attention to farmers' willingness to participate in the SLFP and the appropriate level of compensation (Wang et al., 2016; Wang and Li, 2018; Xie, et al., 2017; Xie, et al., 2018). Other research has evaluated the impact of the CCGO, particularly groundwater recovery and the restriction of groundwater exploitation (Shao, et al., 2017; Xu, et al., 2018; Zhao, et al., 2020). In these assessments, the SLFP caused more concern than any other CCGO policy. In order to effectively implement the SLFP in more regions its timely and comprehensive review and evaluation are needed. This study seeks to

[1] Groundwater overdraft is defined as the prolonged (multi-annual) withdrawal of groundwater from an aquifer in quantities exceeding average annual natural recharge, leading to a persistent decline in water levels and reduction of groundwater volumes (Bierkens and Wada, 2019). According to Hao et al. (2018), the groundwater recharge rate is 16.81 cm/yr in the North China Plain, meaning that when local water extraction exceeds this value there will be groundwater overdraft in this area. The rate of groundwater depletion in North China based on GRACE was 2.2 cm/yr from 2003 to 2010, which equates to a volume of 8.3 km^3/yr. The groundwater depletion rate estimated from the monitoring of well stations over the same period was between 2.0 and 2.8 cm/yr, which is consistent with the GRACE-based result (Feng et al., 2013).

document and analyse the latest implementation status, effectiveness and challenges of the SLFP in Hebei Province in order to assist its future implementation in wider areas.

The remainder of the paper is organised as follows. Firstly it presents a brief overview of groundwater management in China and the theoretical foundation for the SLFP, before introducing the research site and the data. The implementation, effectiveness and challenges of the SLFP are discussed in the following three sections. The final section summarises the key findings and provides corresponding policy suggestions.

GROUNDWATER MANAGEMENT IN CHINA AND THE THEORETICAL FOUNDATION FOR THE LAND-FALLOWING POLICY

The development of groundwater irrigation in China

Groundwater irrigation did not develop in China until the 1970s. Since the 1950s, in order to increase agricultural productivity and deal with serious natural disasters, the Chinese government invested heavily in establishing surface irrigation systems, and there was almost no groundwater irrigation at the time (Wang et al., 2020). Government efforts saw the share of cultivated land equipped with irrigation facilities increase from 16% in 1950 to 48% in 1978. However, extensive surface irrigation caused serious salinity issues in many districts of Northern China. In addition, some rivers (such as Yellow River and Haihe River) began to periodically dry up and failed to satisfy the increasing water demand, leading the government to invest in groundwater irrigation from the early 1970s. While the share of land irrigated with groundwater increased to 30% during the 1970s in Northern China, conjunctive water use became a common pattern in most regions (see Wang and Cao, This Issue). From the 1980s, with urbanisation, growing industry and increasing water competition, groundwater irrigation further accelerated, and by 2016 nearly 70% of irrigated land depended on groundwater supply. Significantly, in Northern China reliance on groundwater alone became the dominant pattern of irrigation.

Since the early 1980s the primary investors in groundwater irrigation have shifted from the government and village collectives to individual farmers, whose contribution had previously been their labour (Wang et al., 2020). Prior to the 1980s, since land property rights belonged to village collectives, there was no incentive for individual farmers to invest in irrigation infrastructure, which, in any case, was not permitted. Following rural reforms in the early 1980s government investment considerably declined, not only for groundwater irrigation, but also for surface irrigation (Wang and Cao, This Issue). Meanwhile, continuous excessive groundwater extraction led to falling water levels, as well as deteriorated or dysfunctional tubewells (it was common for them to be unusable or without groundwater). Since the collective organisations had no money it was down to individual farmers with the contract rights of cultivated land to invest their own money into tubewells in order to increase crop productivity and financial profits. By 1995 the share of private tubewells over total tubewells in Northern China paid for by individual farmers had risen to 63% and continued to grow, reaching 83% by the mid-2000s (Wang et al., 2020). Over the past decade, however, the government increased its investment in irrigation facilities, with large amounts coming directly from central government grants. As a consequence, the share of tubewells over total tubewells in the region invested by farmers had reduced to 62% by 2016.

Groundwater management in China

Owing to neglect over time China lacks distinct groundwater management systems, and groundwater has been separately managed by various agencies (Wang et al., 2019). In 1998 the Ministry of Water Resources (MWR) was endowed with the administrative power to manage water resources (including groundwater) in China, while the Ministry of Housing and Urban-Rural Development is responsible for urban groundwater management; the Ministry of Environmental Protection is responsible for groundwater quality management; and the Ministry of Land Resources (MLR)[2] is responsible for groundwater monitoring and information collection. Sharing the MLR's groundwater information remains a major barrier to integrated groundwater management. Thus, it is of no surprise to find a lack of national coordination on groundwater management. Despite national legislation on 'Groundwater Law' having been drafted and put through several rounds of corrections since 2014, it has still not reached the implementation phase. Groundwater management has therefore generally followed a similar management framework to surface water resources.

For the past two decades China's government has put greater effort into dealing with the issue of groundwater management. In 2003 the MWR enacted the '*Notice on the Delimitation of Groundwater Overdraft Regions*'. In 2004 it published a bulletin on groundwater resources and has begun to make some of the information public. In addition, the central and local governments have adopted some formal and informal policy measures to deal with increasing groundwater challenges. These include reforming irrigation pricing and water rights, pushing the implementation of well-drilling permits and well-spacing policies, implementing quota management and water resource fees, adopting IC card operation of tubewells, and investing in water-saving technology (such as canal lining, underground pipes, sprinklers, drip irrigation). These are being implemented in a growing number of villages, yet their reach remains limited (Wang et al., 2019).

The '*Three Red-Lines*' policy announced in 2011 aimed to establish clear and binding limits on water withdrawal to arrest the decline in water levels, to increase the efficiency of irrigation using groundwater, and to preserve and improve groundwater quality. The successful implementation of this policy not only required the government to establish an integrated water management institution and improve the legal system but also the use of market-oriented policy instruments to harness the water-saving potential of water users (Wang et al., 2017).

Under the umbrella of the 'Three Red-Lines' policy, and in the face of increasingly serious groundwater overdraft issues, the CCGO programme was launched recently. In order to deal with land subsidence resulting from groundwater overdraft, the MLR and MWR jointly issued the '*National Prevention and Control Plan for Land Subsidence (2011-2020)*' in 2012. In 2014 the No. 1 Document of the Central Committee stated that China would launch a pilot project of the Comprehensive Control of Groundwater Overdraft (CCGO). In the same year it was decided that this would take place in Hebei Province, which then promulgated the '*Comprehensive Control Plan of Groundwater Overdraft in Hebei Province (2014-2030)*'. Since 2017 the CCGO has been extended to three other provinces and in the future the number of provinces will be increased to 13. Among many measures taken by the CCGO the implementation of the SLFP has captured the highest attention of policy makers and scholars since it is expected to directly reduce groundwater consumption through the fallowing of land that would otherwise be used to grow winter wheat.

Theoretical foundation for the Seasonal Land Fallowing Policy

Argument for real water saving

Governments spend billions of dollars every year subsidising advanced irrigation technologies, such as sprinklers or drip systems, to improve irrigation efficiency. However, this strategy often achieves engineering-type, rather than real water savings. The main role of most irrigation technology is to reduce leakage losses but with a relatively low reduction in water consumption. Yet, although the efficiency is low, and only a small part of the irrigation water is consumed by crops, the 'lost' water (that is not consumed by crops) is likely to be reused in agriculture or through channel return-flow, field drainage and groundwater recharge.

[2] In 2018 the Ministry of Environmental Protection was replaced by the Ministry of Ecological Environment, and the Ministry of Land Resources was replaced by the Ministry of Natural Resources.

Many studies have pointed out that improving irrigation efficiency often fails to reduce water consumption (Ward and Pulido-Velazquez, 2008; Contor and Taylor, 2013; Grafton et al., 2018; Zhang et al., 2020). In locations such as Spain, Morocco and the Murray-Darling Basin, Australia, saving water at the farm scale does not tend to contribute to reduced water consumption at the watershed or basin scale (Grafton et al., 2018). Even if irrigation efficiencies were to save water, this could induce a shift towards the cultivation of more water-intensive crops (such as the proliferation of greenhouses with multiple vegetable crops in the North China Plain in recent years) or an increase in the total irrigation area of a river basin, although the latter is not observed in the North China Plain as there is no further cropping land to be developed. In fact, total agricultural water consumption is mainly determined by cropping patterns and the planting area of crops in a given region (Sun et al., 2015). Policies designed to adjust crop patterns, especially shifting the cropping pattern from wheat-maize double crops to a single crop of maize would be more likely to reduce water consumption and groundwater overdraft in the NCP (Shen et al., 2013). The SLFP in Hebei encourages farmers not to grow winter wheat, with a growing season from October to May, by providing them with compensation to the tune of 7500 CNY/ha/year (€960/ha/year), to be paid in cash, in line with the principle that farmers' incomes should not be negatively affected (HDARA, 2019).

Payments for ecosystem services

Groundwater is often considered a typical example of common pool resources (CPR) (Wade, 1987; Ostrom, 1990; Ostrom et al., 1994), since it is free and available to all – commonly referred to as 'non-excludability'. However, groundwater is a limited resource, and 'rivalries' over abstraction put it at risk of depletion. Each user maximises their own welfare but fails to take into account the full social cost of abstraction (Müller et al., 2017). The depletion of CPR, as with groundwater overdraft, is a market failure, and private governance is often inadequate, meaning government intervention is needed.

Over the last few decades market-based instruments (MBIs, or incentive-based policies) have been promoted as economically efficient solutions to intractable environmental externalities, including groundwater overdraft (Lockie, 2013). Incentive-based policies (often in the form of financial compensation) address externalities by altering the economic incentives private actors face, while allowing those actors to decide whether and how much to change their behaviour (Jack et al., 2008). As an incentive-based policy, 'payments for ecosystem services' (PES) has emerged around the world to realign the private and social benefits resulting from decisions related to the environment. The PES approach is based on a theoretically straightforward proposition: pay individuals or communities to undertake actions that increase levels of desired ecosystem services (Jack et al., 2008). Similar to Grain to Green (Wu et al., 2019; Yost et al., 2020), as a PES programme, SLFP provides farmers with an economic incentive to reduce agricultural water application, thereby alleviating groundwater overdraft (Zuo et al., 2020).

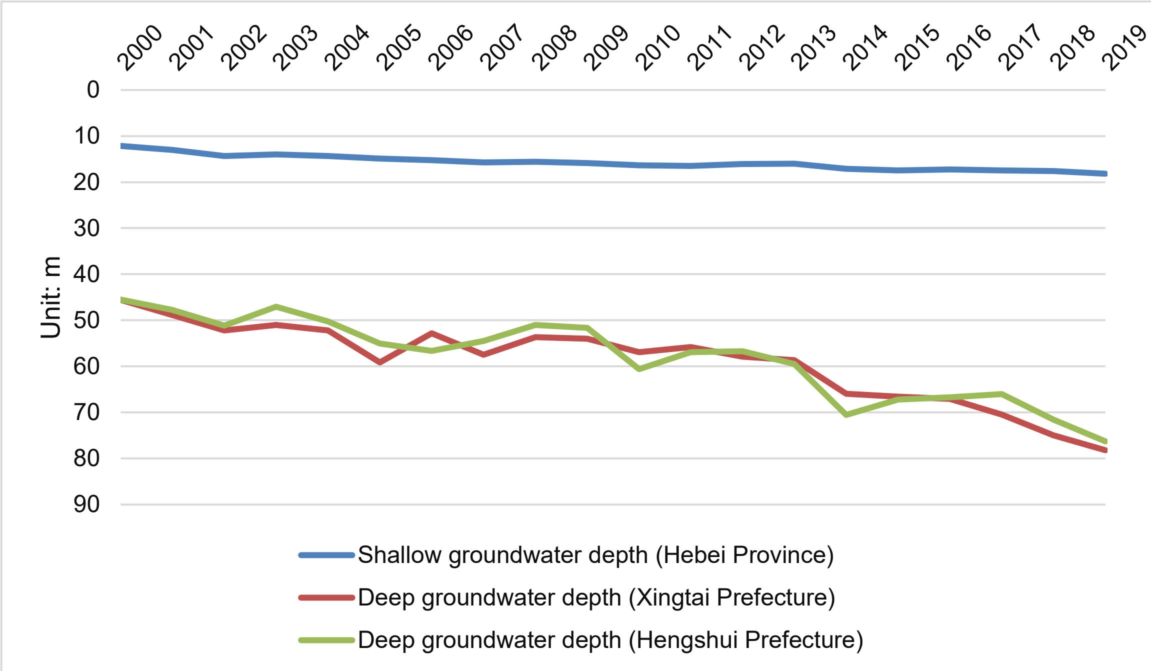
RESEARCH SITE AND DATA

Research Site

Hebei Province is the pilot region of the CCGO and the focus of the SLFP's implementation so far. Due to rising water demand and a limited supply of surface water, the use of groundwater has accelerated since 1970, the annual volume of extraction reaching 9.6 billion m^3 in Hebei in 2019, representing a three-fold increase in the past 50 years. Currently 53% of water supply in Hebei comes from groundwater (HBWR, 2019), much higher than the national average of 16% (MWR, 2019). More importantly, agricultural production on almost 70% of cultivated land requires irrigation; and 80% of irrigated land depends on groundwater irrigation in this region (HBWR, 2019).

Unfortunately, the dependence on groundwater has resulted in serious overdraft, about 70% of which is due to the development of agricultural production. According to local government reports, 92% of the plain area in Hebei Province is within overdraft regions (HPPG, 2015). Annual groundwater overdraft has so far reached 6 billion m^3 and in more than 60% of Hebei Province abstraction exceeds recharge. Indeed, Hebei Province, which accounts for more than one third of the total groundwater overdraft in China, has seen declining trends in both shallow and deep groundwater depth in the last 20 years (Figure 1).

Figure 1. Groundwater depth in plain region.



Source: Hebei Water Resources Bulletin (2001-2019).

Hebei is an important grain-producing region, particularly for its contribution to wheat output. As one of 13 major grain-producing provinces in China, 80% of its sown area was allocated to grain crops in 2019 (NSBC, 2019). Wheat is the second major grain crop after maize in Hebei, and almost all is winter wheat, contributing to 75% of wheat yield in the NCP and 11% in China. In Hebei the major cropping pattern is two season crops, winter wheat plus summer maize, while one season cropping pattern (only summer maize or cotton) also exists in some regions. Based on scientific estimates, the average evapotranspiration (ET) of winter wheat is 497 mm, higher than maize (340 mm) but lower than cotton (629 mm) (Holst et al., 2014). Obviously, two successive crops consume more water than a single crop. Therefore, in order to reduce groundwater use, the SLFP aims to change cropping patterns from two seasons to one. In addition, since winter wheat grows in the dry season (from early October to late June) while summer maize grows in the wet season (from late June to early October),[3] the irrigation requirements of winter wheat (2475 m^3/ha) are far higher than summer maize (750 m^3/ha) (MWR, 2020a; MWR, 2020b). Hence, winter wheat was selected as the target crop in the implementation of the SLFP. Cotton also grows in the wet season and its irrigation requirements [1780 m^3/ha] are also lower than those of winter wheat.

[3] In Hebei Province more than 70% of the total precipitation falls in July and August.

Data

In order to gain an overall understanding of the implementation of the SLFP, we conducted face-to-face interviews with local government officials overseeing the project. In Hebei, the Bureau of Agriculture and Rural Affairs (BARA) and the Bureau of Water Resources (BWR) are the two major local government agencies responsible for the implementation. We also selected a number of representative counties, and townships within the counties, to gather further relevant information. Our interviews with officials and experts revealed information regarding the background of the SLFP, the selection principles for pilot sites and the overall implementation status over time, as well as the challenges and experiences in the project's administration. Relevant secondary data and information were provided by certain interviewees during the interviews, e.g. implementation areas at county level, water use of major sectors and cropping patterns at provincial and prefecture levels, water level at the monitoring sites, and climate data.

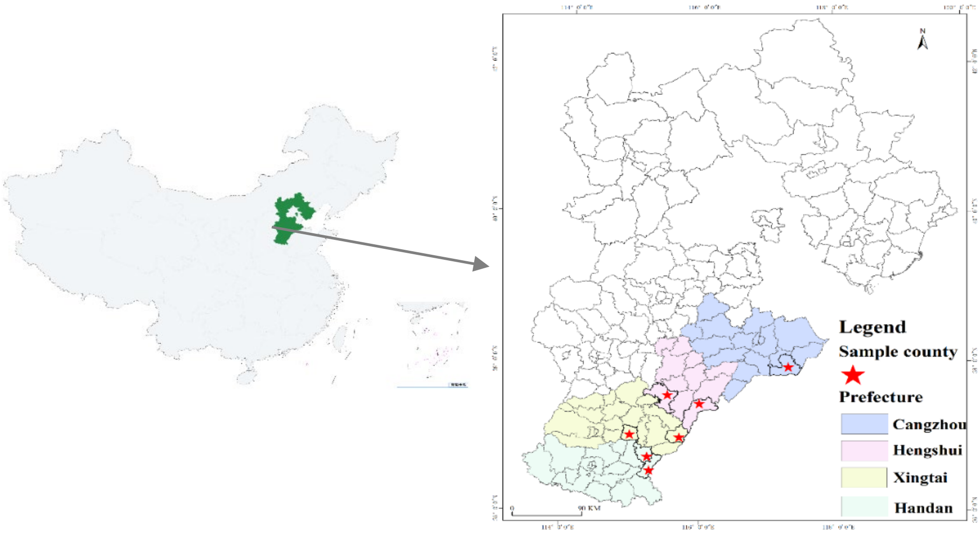
A large-scale field survey was undertaken in Hebei in 2019 to complement the information gathered from the interviews. According to the secondary data obtained from the interviews, four prefectures (Cangzhou, Handan, Hengshui and Xingtai) had participated in the SLFP from its first year (2014) and accounted for nearly 90% of the implementation area. These four prefectures also have the most serious groundwater overdraft in Hebei and were therefore selected as the survey sites. Within these, seven counties (Yanshan, Pingxiang, Qinghe, Gucheng, Jizhou, Qiuxian and Guantao) were chosen as survey counties given the following two major conditions among 55 counties that implemented the SLFP: (i) participants of the SLFP were mainly small-scale farmers[4] and (ii) they continued to participate in the SLFP each year after the first year of participation. Of the seven counties one is in Cangzhou, two are in Hengshui, two are in Xingtai and two are in Handan (Figure 2). The stratified random sampling method was adopted to ensure the geographical coverage of the sample and the proper proportion of participants and non-participants, improving the representativeness of the sample. Within each county two townships were randomly selected.

After selecting the townships we applied the stratified random sampling method and matching approach to select the SLFP and non-SLFP villages. First we classified villages into two groups within each township: participants and non-participants of the SLFP. Within each group we randomly selected one village. Second, we applied the matching approach to ensure similar physical characteristics between SLFP and non-SLFP villages within the same township. The characteristics include scale of contiguous area, cropping pattern, irrigation condition and distance from the village committee to highway or county government. If we found these to be significantly different, we would conduct the second round of random selection of non-SLFP villages, but this was only necessary in a few cases. Finally, 20 farm households were randomly selected in both SLFP and non-SLFP villages. The final sample included 560 households in 28 villages of 14 townships in 7 counties and 4 prefectures. Of the 28 villages surveyed, 14 participated in the SLFP and 14 did not. Of the 560 households surveyed, 249 participated in the SLFP and 311 did not.

Farmers participated in the SLFP on a voluntary basis, but the local government made the final selection of participants. The selection process can be summarised as follows: initially, based on the central government fund for farmer subsidies, and internal discussions among relevant agencies, the provincial government selected the pilot prefectures and allocated funds to each (related to the total SLFP area). The same process was then used by each pilot prefecture to select the pilot counties. The pilot counties in turn asked all township leaders to collect information on which villages would like to apply, and all village leaders were required to communicate with individual farmers. Finally, based on the information collected from the villages and in accordance with the government's stipulations regarding participation, farmers were selected to participate by county government.

[4] The participants in the SLFP may also be family farms, farmer cooperatives, major agricultural businesses or other new types of agribusiness, but this article focuses on the participation of small-scale farmers.

Figure 2. Locations of Hebei Province in China and the sample counties in four prefectures.



There were questionnaires at both the village and household levels and the interviewees were village leaders and household representatives respectively. Both questionnaires covered a wide range of issues, but this study focused on specific information from the village-level survey: (i) cultivated land, population and other basic data; (ii) SLFP participation information; (iii) crop patterns and the irrigation of each crop; and from the household-level survey: (i) basic features of the household; (ii) features of the cultivated land (iii) willingness to participate in the SLFP; (iv) labour allocation information; and (v) crop pattern and irrigation behaviour of households before and after participating in the SLFP. Most of the data at the household level referred to the period 2014 to 2019, in addition to irrigation data from 2017 to 2019 while the majority of the village-level data were from 2017 to 2019.

Descriptive data analysis was used for both primary and secondary data, including comparisons between SLFP participants and non-participants as well as between the pre- and post-SLFP periods. Where sample size allowed, two-sample mean tests were undertaken.

IMPLEMENTATION STATUS OF THE SLFP

Table 1 suggests that the period from 2014 to 2019 witnessed a rapid increase in regions enrolled in the SLFP across Hebei. At the beginning of the pilot programme there were 34 counties within four prefectures (Cangzhou, Handan, Hengshui and Xingtai), which by 2019 had increased to 47 in six prefectures (Cangzhou, Handan, Hengshui, Xingtai, Baoding and Langfang). The SLFP counties were mainly located in the southern Hebei plain region with the most serious groundwater overdraft. Meanwhile, there was also an obvious upward trend in the gross area enrolled in the SLFP, from 50,700 ha in 2014 to 133,300 ha in 2019. After 2017 the SLFP budget remained at 1 billion CNY (€12.8 million).

Although the SLFP was implemented in six prefectures (Hengshui, Cangzhou, Xingtai, Handan, Baoding and Langfang), it was concentrated in four of these due to their severe groundwater depletion. The Groundwater Overdraft Area (GOA) in Hengshui, Cangzhou, Xingtai and Handan covers 46,092 km^2 and accounts for 69% of the total GOA in Hebei Province. In Cangzhou and Hengshui respectively more than 93% and 85% of the land is located in the GOA (HPPG, 2014a). Consequently, the SLFP was first implemented in these four prefectures in 2014, and it was not until 2016 that the other two prefectures were included in the pilot. In 2019 the share of SLFP counties in Hengshui, Cangzhou, Xingtai and Handan was more than 80%, and the share of SLFP areas in these four prefectures was 90% of total SLFP areas in Hebei.

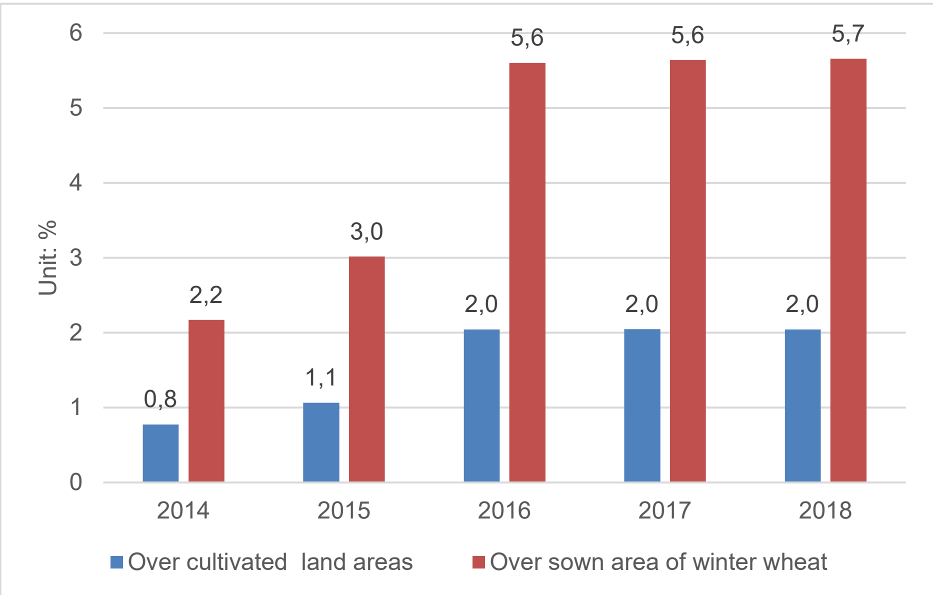
Table 1. Expansion of SLFP in Hebei Province.

Year	SLFP counties	SLFP areas(ha)	SLFP investment(10^9 CNY)
2014	34	50,700	0.38
2015	41	69,300	0.52
2016	57	133,300	1
2017	51	133,300	1
2018	45	133,300	1
2019	47	133,300	1

Source: Pilot Scheme for Comprehensive Control of Groundwater Overdraft in Hebei Province (2014, 2015, 2016, 2017); Hebei Province Groundwater Overdraft Comprehensive Management Agricultural Project Implementation Plan (2018, 2019).

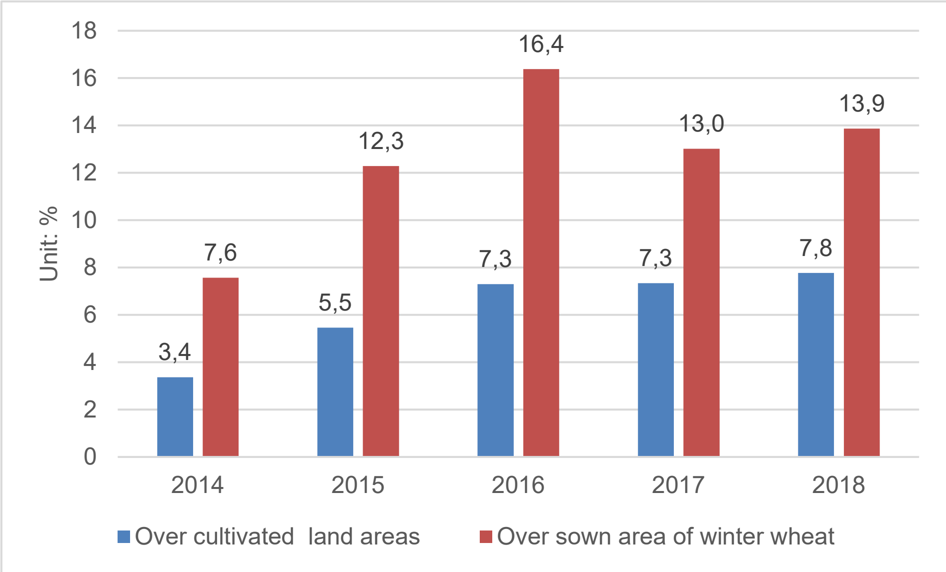
Despite the expansion of the SLFP regions, its pilot areas occupied small parts of the total area in Hebei. The ratio of gross SLFP areas across the whole province was small, only accounting for 2.0% of cultivated land area and 5.7% of the total sown area of winter wheat in 2018, and over the past five years these two percentages increased 1.2% and 3.5% respectively (Figure 3). The percentages of pilot areas in sample counties are of course higher than those at the provincial level. In 2018 on average 7.8% of cultivated land and 13.8% of sown area of winter wheat implemented the SLFP (Figure 4). There are obvious variations in the implementation area over samples counties. For example, in 2018 the SLFP areas accounted for nearly 10% of cultivated land and 25% of sown areas of winter wheat in Qiuxian County but less than 4% and 8% in Jizhou County. These differences imply potentially different impacts of groundwater use.

Figure 3. Ratio of SLFP area over cultivated land area and sown area of winter wheat in Hebei Province.



Source: Hebei Rural Statistical Yearbook (2015-2019).

Figure 4. Ratio of SLFP area in cultivated land area/sown area of winter wheat in sample counties in Hebei Province.



Source: Hengshui Statistical Yearbook (2015-2019), Xingtai Statistical Yearbook (2015-2019), Cangzhou Statistical Yearbook (2015-2019), Handan Statistical Yearbook (2015-2019).

There were five types of agricultural business entity enrolled in the SLFP: farmer cooperatives, family farms, large grain growers, agricultural companies and small-scale farmers. The share of SLFP area among different types of participants varied. More than half of the SLFP area in Cangzhou and Xingtai between 2014 and 2017 were from smallholder farmers. Meanwhile, the SLFP areas of large-scale agribusiness, especially farmer cooperatives, was relatively high in Hengshui. In Handan the share of SLFP area among different agricultural business entities was generally equal.

EFFECTS OF SEASONAL LAND-FALLOWING POLICY (SLFP)

Relatively high targeting efficiency

According to the policy guidelines (HPPG, 2014b), pilot sites participating in the SLFP should satisfy four conditions: they should be located in a groundwater overdraft zone; irrigation should mainly depend on groundwater; they should grow winter wheat; and plots considered for fallowing should cover a contiguous area of at least 3.33 ha (50 mu, 1 mu=1/15 ha).

The survey results show that most pilot sites participating in the project met these requirements. First, all sample villages are located in groundwater overdraft zones in accordance with the definition given by Hebei Province (HPPG, 2014a). Among 14 villages, six are not only located in *General Overdraft Zones of Shallow Groundwater* but in *Serious Overdraft Zones of Shallow Confined Groundwater.* Eight villages belong to the *Serious Overdraft Zones of Deep Confined Groundwater*. Due to serious groundwater overdraft, in addition to deepening shallow tubewells farmers must dig deep tubewells to meet their irrigation needs. Based on our survey, in the SLFP villages 24% of all tubewells are deep, with an average depth of 256 metres, pumping from the deep aquifer, while the depth of shallow tubewells tapping the shallow aquifer is 75 metres.[5]

Second, groundwater is the major water source for agricultural irrigation in the pilot sites. The survey results show that in the three years from 2017 to 2019, 96% of cultivated land in the SLFP villages used groundwater for irrigation, either solely depending on groundwater (76%) or treating groundwater as an important conjunctive water source. That is, only 4% of cultivated land in the sample villages relies completely on surface water for irrigation. None of the SLFP villages depended on surface water alone for their irrigation supply and all villages had groundwater irrigation supply.

Third, most plots in the project had planted winter wheat prior to their participation. Winter wheat is widely grown in Hebei Province, and the survey results show that before the SLFP the share of winter wheat sown in participant villages reached up to 71.7%. This also means that nearly a third of pilot plots had not already planted winter wheat, which suggests that the majority of project sites met this requirement.

Finally, most cultivated land participating in the project is contiguous. In order to reduce monitoring costs and better realise the potential in reducing groundwater use, local government officials stipulate that the SLFP be implemented in contiguous land plots covering an area of at least 3.33 ha. Our survey results reveal that most of the cultivated land (93%) of the participating villages is concentrated, making it easy to find contiguous plots covering more than 50 mu.

Reduction of groundwater irrigation

The purpose of the SLFP is to reduce groundwater irrigation and resolve the issues of groundwater overdraft. Farmers' use of groundwater irrigation is also influenced by physical and socioeconomic factors, whose role needs to be controlled for in order to separate the impact of the SLFP. To this end we established an econometric model at the household level that is described in the Appendix. The main results were as follows.

Firstly, with all other factors constant, if households participated in the SLFP, they reduced groundwater irrigation by 473 m^3 (1% significance level, Table 4 column [1]). This equates to the SLFP reducing the participant's groundwater irrigation by 24.3% (Table 4 column [2]). If the groundwater saving by area is more interesting, our econometric results suggested that, keeping all other factors constant, for every additional hectare of arable land in the SLFP, groundwater irrigation decreased by 1152 m^3 (1% significance level, Table 4 column [3]). The Hebei Provincial Government claims that the SLFP can reduce annual agricultural groundwater use by 2100-2400 m^3/ha. However, since farmers only participated in the SLFP with part of their arable land, the reduction in groundwater use per hectare was on average 51.2% of that value.

The reduction in agricultural water use by SLFP households was mainly driven by altered cropping patterns and decreased irrigated area for winter wheat. After joining the programme farmers' multiple-cropping pattern (winter wheat and summer maize) transformed into monocropping (maize or cotton only) (Table 2, Figures 5 and 6). Because most participants did not grow any other summer crops during the project period, the crop-sown area and cropping index decreased significantly. The crop-sown area decreased by 22%, from 1.11 ha in 2014 to 0.87 ha in 2019, mainly due to the reduction in the sown area of winter wheat, which was on average 0.25 ha per participant – around 60% of the implementation area

[5] The sample counties are located on the Heilonggang Plain Aquifer, which belongs to the central part of the North China Plain. There is no regionally continuous groundwater aquifer bounded by an impermeable layer but rather multilayer aquifers. In general, the groundwater aquifers in this area are divided into four (I-IV) groups (group I belonging to the shallow aquifer and the other three belonging to the deep aquifer). In these sample areas it is possible to draw water from both deep and shallow aquifers. The maximum depth of deep groundwater can reach 400 metres in the sample counties.

of SLFP per participant (0.42 ha). The decline in crop-sown area was almost the same as the decline in irrigated sown area. The adjustment of cropping pattern is mainly manifested in the decline in the sown area of winter wheat, and winter wheat is heavily dependent on irrigation as its growing season does not overlap with the rainy season.

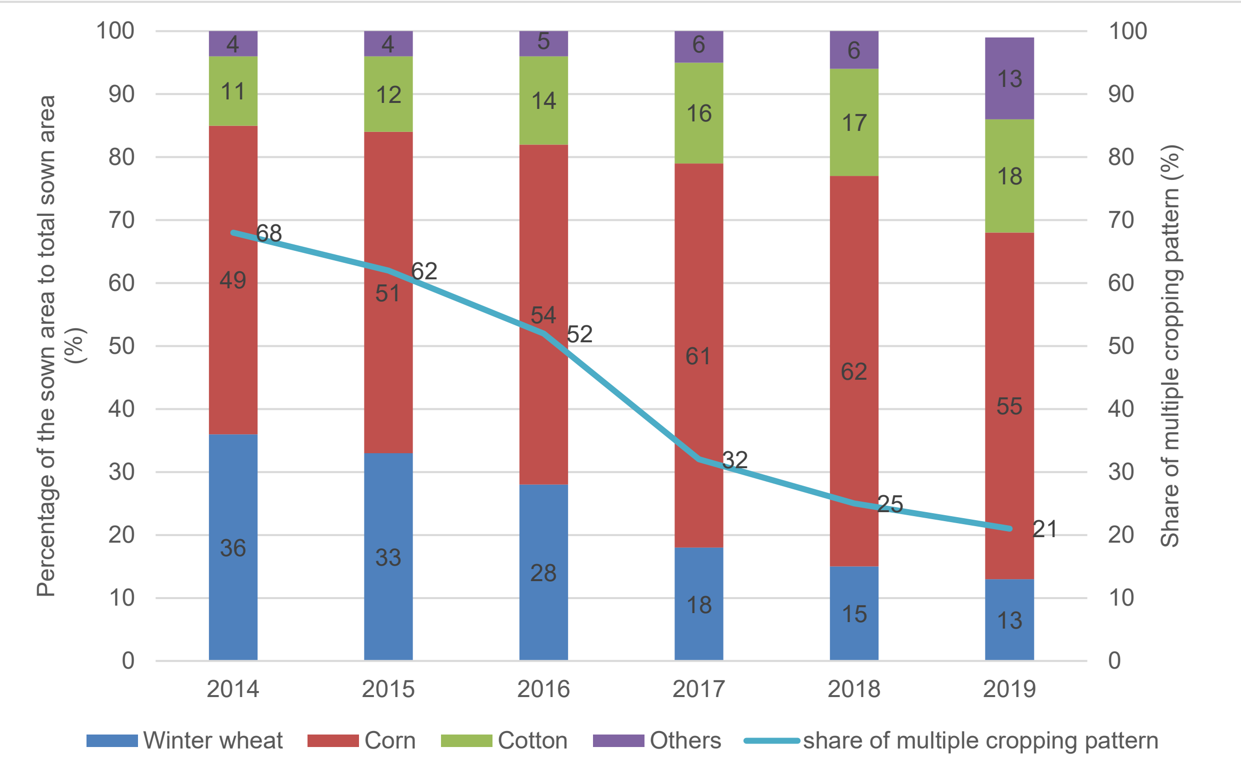
Table 2. Sown area of main crops per household (Unit: ha).

	Participants			Non-participants		
	2014	2019	Change	2014	2019	Change
Total	1.11	0.87	-0.24	1.15	1.15	-0.01
Wheat	0.44	0.19	-0.25	0.51	0.50	-0.01
Maize	0.53	0.43	-0.11	0.52	0.53	0.01
Spring Maize	0.04	0.08	0.04	0.01	0.01	0.00
Summer Maize	0.49	0.35	-0.15	0.51	0.52	0.01
Cotton	0.11	0.19	0.09	0.10	0.08	-0.02
Other	0.03	0.06	0.03	0.03	0.04	0.01

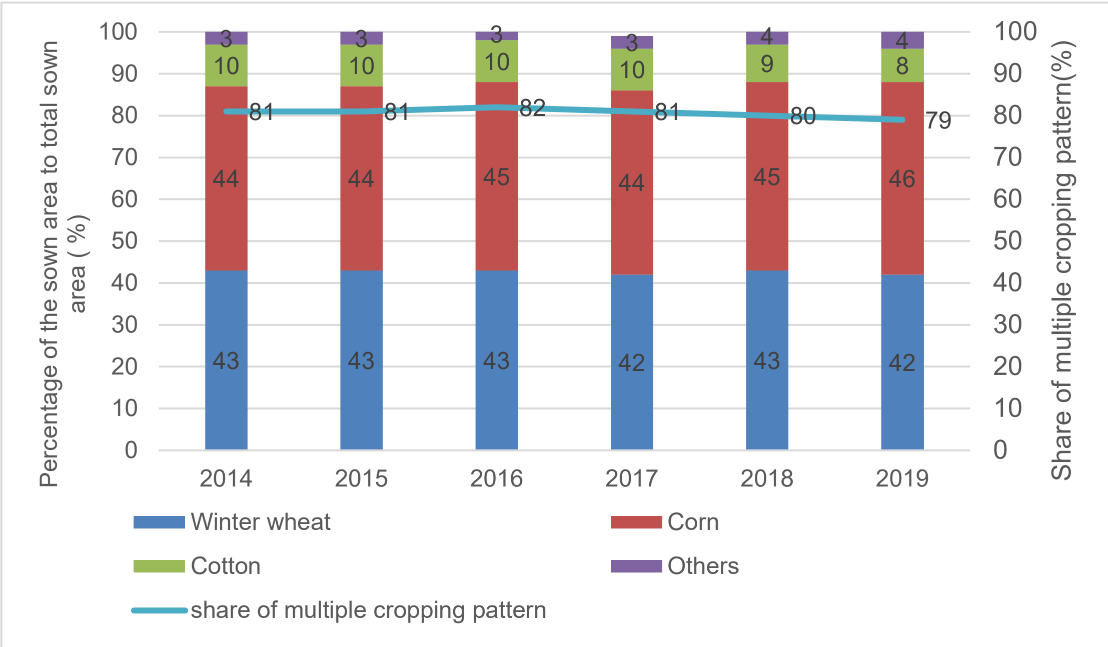
Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University.

Figure 5. Percentage of the sown area of main crops relative to total sown area.

(a) Participant



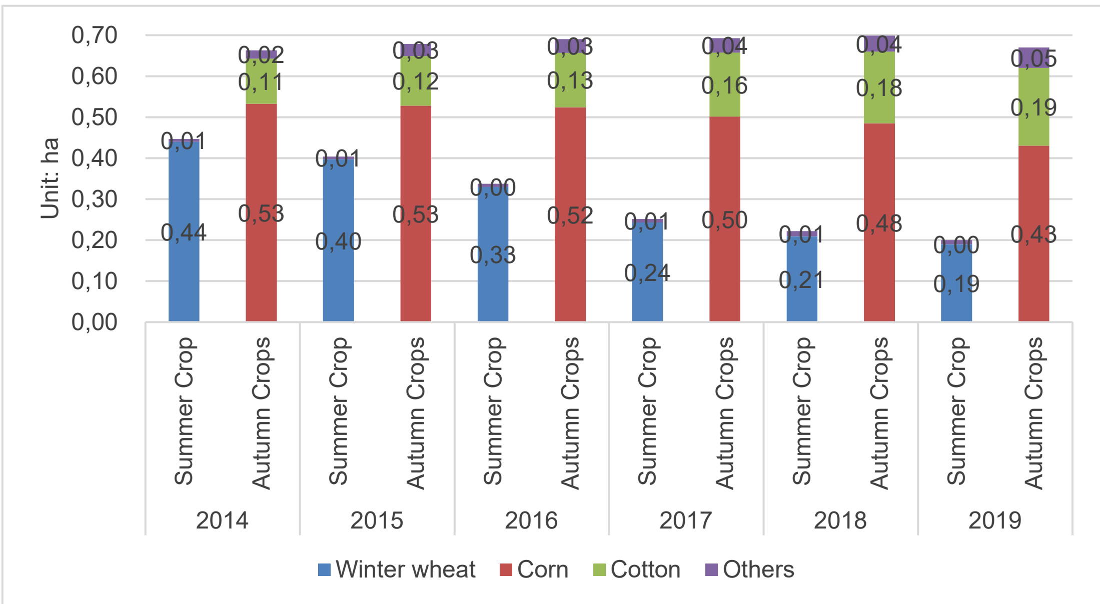
(b) Non-participant



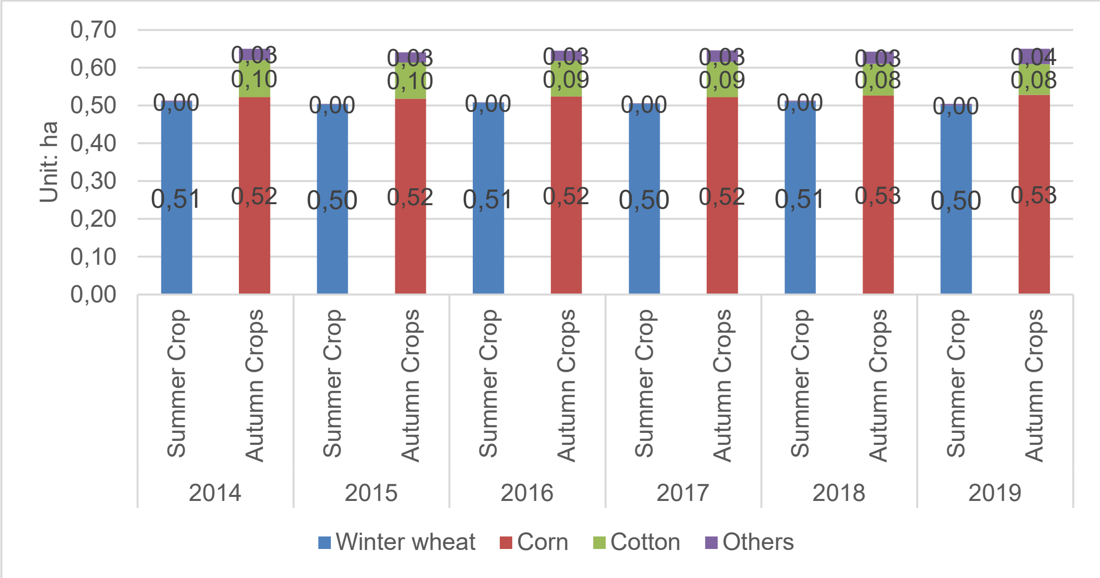
Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University.

Figure 6. Sown area of summer and autumn crops per household.

(a) Participant



(b) Non-participant



Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University.

The above analysis shows that the SLFP can significantly reduce groundwater irrigation by adjusting the cropping pattern. However, it is difficult to draw a conclusion as to the programme's effect on the groundwater level as this is also affected by other factors, such as the scale of the project's implementation, hydrogeological conditions and precipitation. Indeed, it may not be impossible to ascertain the effect on the groundwater level in the short term, meaning further study will be required in the future.

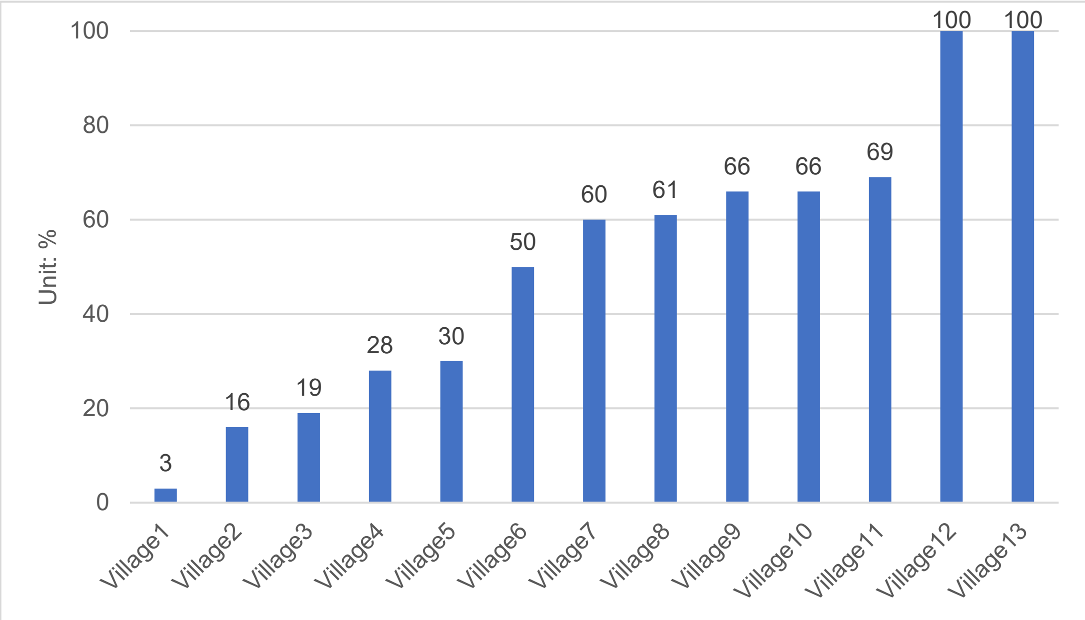
CHALLENGES FACING THE IMPLEMENTATION OF THE SLFP

Not all land included in the SLFP either at village or household level

The survey results reveal that only part of the participants' land was covered by the SLFP. Nonetheless, the figure was more than half at both village and household levels. On average, 51% of the total area in participant villages was included in the SLFP in 2019 (Figure 7). Among 13 participant villages, eight enrolled more than half of their cultivated land in the project, while only four enrolled less than 30% (3% to 30%). Similar participation patterns were apparent in other years since 2014. For those households who participated in the SLFP in 2019, more than half of their cultivated land (67%) was enrolled. Among all participant households, 65% enrolled more than half of their land. Correspondingly, 35% of the households enrolled less than half of their cultivated land.

While the proportion of land included in the SLFP villages is not low, it failed to reach the target of all the land. There are two major potential advantages with enrolling all land: first, it reduces the project's transaction costs since all farmers in one site have similar production behaviour. In addition, since the total implementation area for the SLFP is limited, if all land and households in a village participate, it is easier to monitor and administer. Second, the goal of controlling groundwater abstraction is more likely to be achieved, particularly in the long term. Based on interviews with policymakers in Hebei Province who are in charge of the SLFP, they prefer to implement the project with those villages/households that can enrol all their cultivated land. The survey results indicate that among 13 villages, only two enrolled all their land. As to the total participants, 39% enrolled all their land. This means the policymakers' aim of enrolling all land from a village or household was not achieved.

Figure 7. Share of land participating in each village.



Note: Each bar represents one village in 2019 (13 participant villages) as an example. The situation is similar in other years.
Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University.

The level of participation is unstable

The level of participation across the regions fluctuates from year to year, which possibly influences the long-term effect of the project. When the SLFP was first introduced in 2014 there were 34 pilot counties involved. As more counties participated, the number grew to 57 in 2016. At the same time the cultivated land area in the SLFP increased from 50,700 ha in 2014 to 133,300 ha in 2016 and has remained stable. However, the number of participating counties had declined to 47 by 2019. This implies that after 2016 the SLFP's pilot regions changed over time, with some regions ceasing participation while others joining. In other words, some land will return to planting winter wheat at the end of its participation in the SLFP.

Due to the fluctuating number of participating counties, the number of farmers involved is unstable. Among our 249 participating households some participants left and some joined almost every year.[6] Based on our survey, from 2014 to 2019, 21 households abandoned the SLFP, accounting for 8.4% of the total sample. Instability of participation may affect the effective implementation of the SLFP in the long term and its sustainability needs to be carefully addressed.

Some participating farmers were ineligible

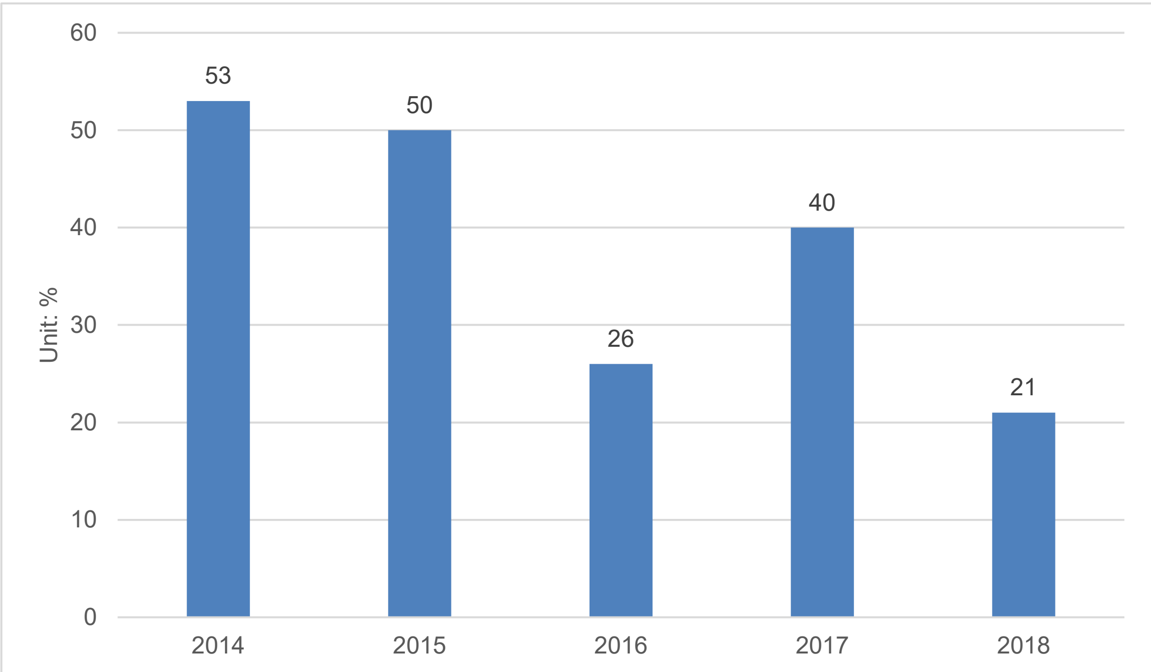
Our survey reveals that fallowing land is economical for some farmers irrespective of the subsidy. One reason is the higher income from off-farm work to which they could allocate the labour otherwise used to plant winter wheat. Based on our survey, the off-farm income of households spontaneously fallowing land is higher than that of other participants who did not spontaneously fallow land. Second, they grow

[6] We investigated farmers' participation in the SLFP from 2014 to 2019.

only one higher-value crop, such as cotton, instead of the wheat-maize rotation.[7] Based on our survey, 44% of participant households who fallowed their land spontaneously replaced winter wheat with cotton prior to the SLFP, and, without taking into consideration the cost of family labour input, the net income of cotton is 62% higher.

The SLFP farmers would have had all their former winter wheat growing-land subject to the programme, as required for eligibility. However, this was not found to be the case: some farmers had fallowed their land spontaneously, before participating in the project. From 2014 to 2019, on average over a third of the farmers did not meet this requirement. The percentage of farmers who had fallowed their participating land spontaneously was higher at the early stages of the programme's implementation. For example, in 2014, 53% of farmers fallowed their eligible land prior to their participation. By 2015 it was 50% (Figure 8), and the percentage of ineligible farmers declined substantially, reaching 21% in 2018. This implies that the implementation of the SLFP has been strengthened over time.

Figure 8. Share of households who had fallowed participating land spontaneously before participating in the SLFP.

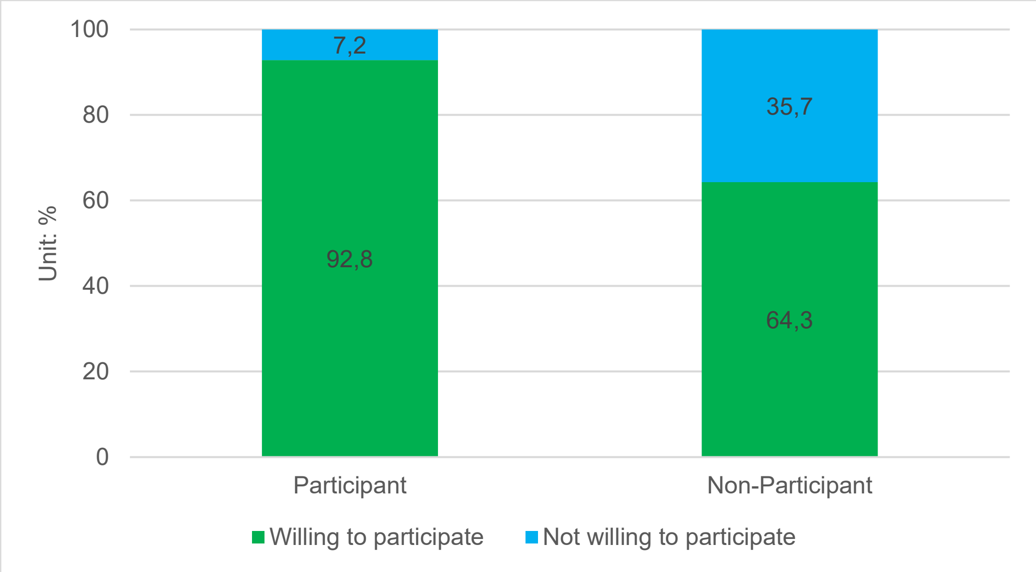


Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University

Those farmers who were not eligible for the SLFP, having fallowed their land anyway, prior to participation, would have crowded out other farmers who would have actually fallowed land – and thus saved water – because of their participation. In other words, such a phenomenon would be a counterproductive effect of the subsidy, which is shown by the survey results. For example, we found that non-participant farmers had a high willingness to participate in the SLFP but had no opportunity. On average 64.3% of non-participant farmers were willing to participate in the SLFP with the current level of compensation (7500 CNY/ha/yr, or 960 €/ha/yr) (Figure 9).

[7] In the NCP cotton is usually sown in March and April and harvested from July to August. Winter wheat is usually sown in October and November and harvested in June. Summer maize is usually sown in June and harvested in September and October. Thus planting winter wheat means farmers cannot grow cotton.

Figure 9. Willingness to participate in the SLFP for both participants and non-participants (in %).



Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University

Small proportion of participating farmers shifting their labour to off-farm work

In the survey, enumerators asked each respondent whether the SLFP affected their labour allocation and if so, what the participating household did with the time that was freed up. As shown in Table 3, 89% of participating households believed that the SLFP had no effect on their labour allocation. This means most households did not change their labour allocation among several major agricultural and non-agricultural activities even if they had more free labour due to fallowing their winter wheat land. Based on our survey, we found that they have increased their leisure time and spent more time resting at home.

Table 3. Farmers using their time differently due to participation in the programme.

Influence	Share of farmers (%)
No Change	89.0
Change	11.0
Off-farm time (+)	10.1
Agricultural time (+)	0.9

Note： + means increase ; – means decrease

Source: the SLFP survey in 2019 organized by China Center for Agricultural Policy (CCAP), Peking University

Although most farmers did not adjust their labour allocation due to their participation in the SLFP, 11% did. As expected, to increase income farmers are more likely to find off-farm employment opportunities if they have more free labour time. Our results also reveal that for those participant farmers who changed their labour allocation, most (10.1%) increased off-farm time, while a few (0.9%) shifted their extra labour to other agricultural activities. This shows it is not easy (or not necessary) to reallocate extra labour to other agricultural activities.

Unexpectedly, compared with non-participants, the SLFP did not significantly increase the off-farm employment of participating households. Theoretically, since the participants had more free labour to allocate to off-farm work compared to non-participants the family members should have a greater opportunity to benefit from off-farm work. However, our survey found the contrary. For example, from 2014 to 2019, for participants, the percentage of individuals with off-farm work increased by 0.8%, while it increased by 2.2% for non-participants, and this difference is statistically significant. One possible reason is that due to the subsidies from the SLFP farmers have less incentive to find off-farm jobs. Another possible reason is that it is difficult to find short-term off-farm work. However, it should be noted that the impact of the SLFP on off-farm work is limited. What is worrying is that if the subsides were to be reduced or even discontinued, the participating farmers with no off-farm opportunities would return to planting winter wheat. In other words, the availability of off-farm work will influence the SLFP's long-term sustainability. This is a challenge faced by other, similar projects, such as China's Grain-for-Green programme (Kelly and Huo, 2013; Uchida et al., 2009).

Subsidies did not reflect variability in opportunity cost of land fallowing

The subsidy for the SLFP was fixed at 7500 CNY/ha/yr (€960/ha/year), irrespective of local circumstances, meaning it may have been lower than farmers' expectations in some areas and higher in others. Based on our field survey, the opportunity cost of planting winter wheat varies with the yield and the price of wheat. Yield in turn is affected by many factors, such as soil quality and the availability of irrigation water. The survey shows that, on average, not considering the cost of family labour input, the net revenue of winter wheat per ha was 8145 CNY/ha/yr (€1043/ha/year) – slightly higher than the SLFP's subsidy. We found that 40% of households had a net revenue for wheat of below 7500 CNY/ha/yr. Thus, 40% would earn more money with the project but 60% would be financially worse off without changing to a more economical crop than summer maize, albeit by a small margin. Therefore, compensation within the SLFP should be adjusted according to the local conditions for agricultural production in order to achieve fairness and effective incentives for farmers. In addition, the specificities of the farmers' situations should be taken into consideration, such as crop care or skills, and the operability of policy.

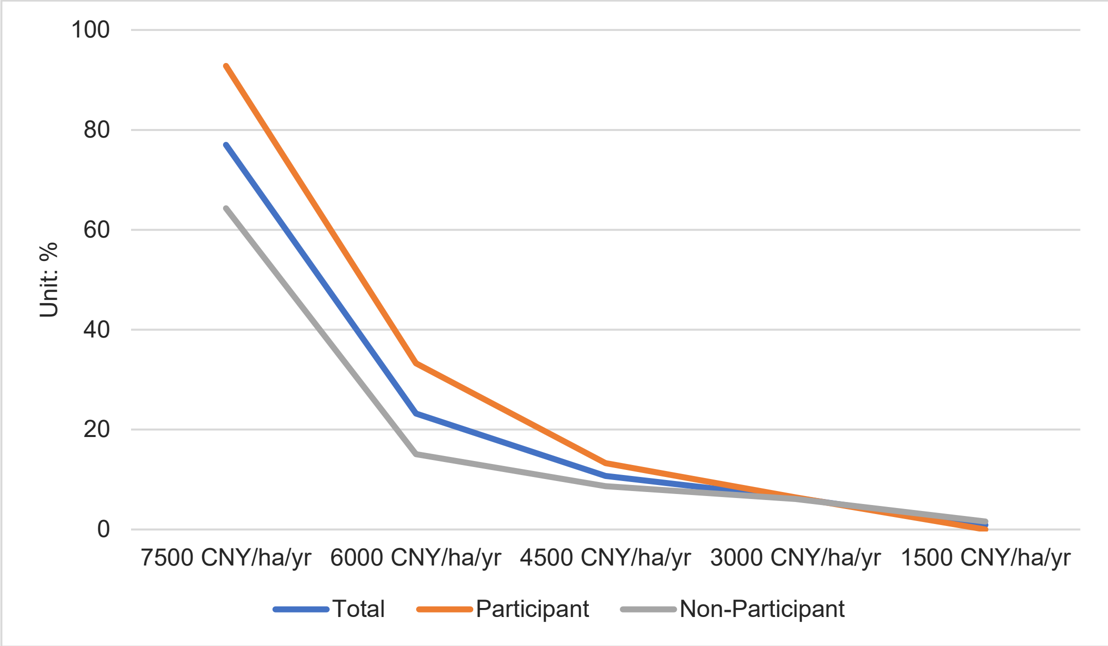
Research has been conducted into the appropriate compensation standard within the SLFP, and results have differed according to the method applied (opportunity cost or Contingent Valuation Method). For example, Zuo et al. (2020) suggest the mean willingness to accept (WTA) compensation is 10,125 CNY/ha/yr (€1296/ha/year), with a 95% CI range from 9315 to 10,995 CNY/ha/yr (€1192-€1407/ha/year). 7770 CNY/ha/yr (€995/ha/year) was suggested by Xie et al. (2017), while Wang et al. (2016) suggested a level of 5250 CNY/ha/yr (€672/ha/year) at the initial stage of a fallowing project aimed at groundwater recovery and restoration and 4200 CNY/ha/yr (€538/ha/year) thereafter. The difference among the studies is likely to be due to differences in crop yields by region. For example, Zuo et al. (2020) studied six provinces in Northern China while Wang et al. (2016) focused solely on Cangzhou prefecture in Hebei province. Nevertheless, this demonstrates that there is a high degree of heterogeneity in farmers' opportunity cost in participating in land fallowing projects, which must be taken into account when calculating the level of compensation, although it is very hard to consider the whole range of factors that account for differences in productivity.

Policy sustainability is doubtful

Many farmers commented that if the programme ended, they would grow winter wheat again. Indeed, the survey shows that 57.1% of households would revert to winter wheat after leaving the SLFP. However, it is encouraging to see that almost 43% of farmers planned to continue fallowing.

As expected, the lower the subsidy the less willing households are to participate in the SLFP (Figure 10). The share of farmers willing to participate in the SLFP declined from 77% to less than 1% when the subsidy decreased from 7500 CNY/ha/yr (€960/ha/yr) to 1500 CNY/ha/yr (€192/ha/yr). The issue is even more pronounced among participant farmers, 92.8% of whom were willing to continue with the programme with the current subsidy, while only 33.3% for a slightly lower subsidy of 6000 CNY/ha/yr and none was willing to participate if it was reduced to 1500 CNY/ha/yr (Figure 10).

Figure 10. Share of farmers willing to participate in the SLFP at different subsidy levels.



Source: the SLFP survey in 2019

Following the SLFP farmers no longer have an incentive to fallow land, partly because their income is very low and fallowing land under the SLFP has an impact – albeit small – on their income. When the subsidy is taken away they will plant winter wheat again to compensate for the loss. In most cases the time allocation was not affected by the fallowing of land. Only 10% of farmers said that the time they engaged in off-farm work increased due to their participation in the SLFP. This indicates that for most farmers fallowing land has little impact on their life.

Fallowing land was underused

The Chinese government encourages the growing of green manure crops, such as oilseed rape and alfalfa, on retired land in winter and spring. However, only a fraction of the arable land involved in the SLFP has been planted with such crops. Most fallowed land has remained uncultivated, which may affect its fertility and productivity. In the North China Plain the wind erodes the soil surface, especially in winter and spring when there is no plant cover and the winds are strong. Of a total of 2374 plots subsidised under the SLFP in our sample, 93.8% carried no crops in winter and 3.58% fallowed their land for the entire year. Only 2.6% of the plots carried some crops in winter, mainly oilseed rape.

Planting green manure crops helps to maintain and improve soil fertility while reducing water use, but farmers rarely plant them. There are a number of reasons. First of all, local government (at county or town level) demands the fallowing of land in winter without sufficient publicity or scientific guidance regarding the planting of green manure crops. Second, these crops generate costs for seeds, labour and other items. It takes a long time for green manure crops to be converted into fertiliser in the soil, so in the short term the improvement in soil fertility is limited or even not apparent at all. In addition, due to the late sowing time, seedlings may die from frost. Many farmers lack experience in planting such crops. In conclusion, the willingness of farmers to plant green manure crops is very low, leaving the fallowed land underused and the SLFP's potential unfulfilled.

CONCLUSION AND POLICY SUGGESTIONS

The NCP is facing a severe groundwater overdraft crisis. Hebei Province has carried out CCGO in recent years, within which the Seasonal Land Fallowing Policy is an important ecological compensation mechanism. The survey results indicate that most pilot sites participating in the project satisfied all requirements according to the policy guidelines, showing relative high targeting efficiency. The findings suggest that the SLFP can reduce farmers' agricultural water use by about 1403 m^3/ha/year, which is mainly driven by the change in cropping patterns with a decreased irrigated area for winter wheat. However, the SLFP also faces a number of issues and challenges affecting its effectiveness and sustainability, based on which this paper puts forward the following policy suggestions for improving the SLFP in the future.

First, the government should make efforts to achieve full participation of all households within the village and all the households' land. When all other conditions are met, enrolment priority could be given to the villages where this is possible. A price signal may also be used to incentivise full participation at the village and household levels. For example, premium compensation may be paid to such participants. Another strategy to facilitate full participation is to set up career/employment information and skill training centres in full-participation villages so that extra farm labour can find alternative use more efficiently. Although most farmers are willing to engage in off-farm work, many are poorly educated with limited skills. Thus, services offered at these centres, especially regarding local employment, are critical for farmers to gain off-farm employment and become less dependent on year-round agricultural production. One promising approach is to develop a local processing industry that features local agricultural produce and employs local off-farm labour. Streamlining the approval process may also contribute to full participation and attrition reduction. At present, it is necessary to apply and be approved for the SLFP each year. An enrolment term of multiple years such as three or five may be considered, improving the stability and long-term participation of farmers.

Second, information campaigns in the community are important and often effective in raising awareness of and participation in conservation practices. Civil servants and village leaders play an important role in implementing the SLFP. Their comprehensive understanding of the policy is crucial and should be enhanced. For example, they may better communicate the purpose of the policy to villagers. Interactive approaches, such as social media, programme pamphlets and local radio and TV, can be used to raise the profile of the policy. Another aim of programme campaigns is to make the eligibility criteria transparent and clear to the wider community so that farmers have a better idea of whether they are eligible. At the administrative level, in order to avoid the enrolling of previously fallowed land into the programme agricultural subsidies granted in the years prior to the SLFP can be checked to verify eligibility. Awareness campaigns should cover not only pre-participation, but also provide post-participation land care and maintenance guidance, such as information on growing green manure crops on fallowed land. This would lessen confusion about the utilisation of fallowed land and increase confidence in participation.

Finally, flexible compensation standards may be used to better reflect the varying opportunity costs of land fallowing among heterogeneous farmers. For example, subsidies may be adjusted according to historical winter wheat yields in different areas and could also be tied to the current winter wheat price. Another approach to elicit farmers' land fallowing opportunity cost is through open tenders, where willing farmers submit the figure they would accept and the government selects the least costly submissions given the limited budget.

Overall, the SLFP can be an effective policy instrument to control groundwater overdraft. Given that the Chinese government intends to implement it in more areas with serious groundwater overdraft problems in the coming years, it is critical to improve its design based on actual experience and feedback so that its objectives are achieved effectively and efficiently. The initial benefits from reductions in groundwater extraction, including environmental improvements and sustainable socioeconomic development, would outweigh the cost of the SLFP by a considerable margin. With the implementation of the SLFP and related measures recommended above, farmer behaviour is expected to change collectively on a long-term basis. For example, cropping patterns could change permanently without losses to farm household income thanks to high-income crops being grown, more off-farm employment and rural-to-urban migration. Compared to China's '*Grain for Green*' programme introduced in 1999 to retire farmland permanently for flood prevention and soil conservation purposes, the SLFP offers a seasonal and more flexible approach that may also assist the process of rural transformation in water-scarce regions. Its successful implementation will provide insights into environment management and socioeconomic development in similar resource-dependent rural areas around the world. The central government is planning to extend the CCGO to 13 provinces of Northern China and the SLFP will be an important policy option within this package. However, the scale of its implementation depends not only on the central government's financial capacity, but also on how trade-offs with food security are solved. This is a crucial issue that needs to be addressed by further scientific studies in the future.

ACKNOWLEDGEMENTS

This work was supported by National Natural Science Foundation of China (NSFC) (71874007, 41861124006, 71903047), Hebei Education Department (BJ2020075) and National Social Science Fund of China (18ZDA074).

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APPENDIX: ECONOMETRIC MODEL

The purpose of the SLFP is to reduce groundwater irrigation and resolve the issues of groundwater overdraft. Farmers' approaches to groundwater irrigation are also influenced by physical and socioeconomic factors, whose salience needs to be controlled for in order to separate the impact of the SLFP on groundwater irrigation. Therefore, the following econometric model at the household level was established:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 X_{it} + \delta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

The subscript *i* indicates the households and *t* indicates the year (2017, 2018 and 2019). The dependent variable Y_{it} represents the volume of groundwater irrigation by household *i* for all crops in the year *t*. Three steps are used to calculate the dependent variable at the household level. Step 1: calculate the volume of groundwater in each irrigation round for each crop, which is derived by multiplying the volume of groundwater pumped per hour by pumping time. Step 2: add up the volume of groundwater irrigation of all irrigation rounds for each crop. Step 3: add up the volume of groundwater irrigation of all crops.

The key independent variables we are interested in are T_{it}, representing the SLFP policy, which is measured by two alternatives: (1) a dummy variable that measures whether a household participates in the SLFP (1 = yes; 0 =no) and (2) a continuous variable that measures the area of arable land of the household that participated in the SLFP. We also incorporated a set of control variables X_{it} in the model, consisting of socioeconomic and physical factors that are expected to influence households' volume of groundwater irrigation but are not a result of the SLFP, such as cropping pattern. These include: (i) household-level variables: household size (number of family members, persons), share of non-working age members (%), age of household representative (year), farm size (ha), degree of fragmentation of arable land (ha/plot), value of durable goods in log form, (ii) village-level variables: distance from the village committee to the county government (km); and (iii) county-level variables: annual Palmer Drought Severity Index (PDSI),[8] the best known indicator that attempts to encapsulate drought severity on a regional basis (Alley, 1984). ε_{it} is the random error term. Finally, β_1 is the coefficient of interest.

[8] The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardised index that generally spans -10 (dry) to +10 (wet).

We used the two-way fixed effects (δ_i for household and γ_t for year) model to estimate Equation One.[9] In addition, the cluster robust standard error at the village level is used considering the existence of correlations among households within one village. The estimation results are presented in Table 4.

Table 4. The regression results of the impact of the SLFP on groundwater irrigation.

	Groundwater irrigation (m^3) (except for column (2) in log form)		
	(1)	(2)	(3)
Whether to participate in SLFP (1=yes; 0=no)	-473***	-.279***	
	(85.24)	(0.09)	
Implementation area of SLFP (ha)			-1152***
			(395.17)
Household size (persons)	228	.009	236*
	(141.98)	(0.08)	(136.32)
Share of non-working age members (%)	-2.03	-.006	-1.92
	(2.22)	(0.01)	(2.25)
Age of household representative (year)	72.6	.134**	71.4
	(45.73)	(0.06)	(47.07)
Farm size (ha)	14660***	.33	14828***
	(4351.59)	(2.04)	(4364.27)
Degree of fragmentation of arable land (ha/plot)	4291	-18.1***	3720
	(4486.12)	(2.57)	(4740.74)
Value of durable goods in log form	7.87	-.0926	1.68
	(66.98)	(0.07)	(67.04)
Distance from the village committee to the county government (km)	-13.6***	-.029***	-13.5***
	(2.94)	(0.07)	(3.01)
PDSI	1.57	.102**	.429
	(35.84)	(0.04)	(37.81)
Household FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	1678	1678	1678
Within R^2	0.05	0.04	0.05

Note: Absolute value of standard errors clustered by village reported in parentheses; *, **, *** denote levels of statistical significance at 10%, 5%, and 1%, respectively.

[9] First, F test of the fixed effects model and the Hausman test show that the fixed effects model is preferred to the pooled regression and random effects models. Second, we use Least Square Dummy Variables (LSDV) and fixed effects estimator to estimate the model and find that the direction and significance of the estimated coefficients are stable, and there is little difference in the value of the coefficient of interest, so it is robust.