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# Impact of Wheat Price Changes on Farmers' Willingness to Participate in Fallow

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**Abstract:** After operating for four years, the fallow project in the groundwater funnel area of the North China Plain has produced an initial water-saving effect. However, groundwater funnel remediation is a long-term process, and grain price changes over time may affect farmers' willingness to participate in fallow. Based on the estimation by the Cobb-Douglas production function, the relationship between farmers' satisfaction with fallow compensation and planting income is analyzed based on survey data collected from farming households in Hebei, a typical province located in the groundwater funnel area. Using this data, the impact of wheat price changes on farmers' willingness to participate in fallow is simulated. The results indicate wheat price changes affect farmers' expected planting income and consequently their willingness to fallow; 88% of farmers would be unwilling to participate in fallow with a 0.1 yuan per 500 g increase in the wheat price, whereas 71.4% of farmers would be willing to participate in fallow with a 0.2 yuan per 500 g decrease in the price. Finally, some policy implications are proposed, such as the recommendation that the fallow compensation should be adjusted according to the wheat price multiplied by the average wheat yield of the three years before fallow in the North China Plain.

**Key words:** wheat price change; fallow; ecological compensation; farmers

## 1 Introduction

Hebei Province is one of China's three major wheat-producing regions and among the most water-deficient provinces in China. In Hebei, agricultural water accounts for 70% of the total social water use, and winter wheat irrigation accounts for 70% of the agricultural water use. But since winter precipitation accounts for only 20% of the annual precipitation, groundwater has become the main source for winter wheat irrigation, leading to the over-exploitation of groundwater resources. Recently, groundwater over-exploitation has threatened the environment and future agricultural production capacity. The regional water environment is severely damaged, and the environmental carry capacity is close to being reached. Therefore, it is important to accelerate the transformation of the agricultural development modes.

In 2016, the Ministry of Agriculture (then), the Ministry of Environmental Protection (then), and 10 other ministries and commissions issued the "Exploration of the Pilot Program for the Implementation of the Rotation System" and launched a pilot project of 6.16 million mu (1 mu equals 667 $m^2$) of land for fallow and rotation in the country, including the groundwater funnel area, the heavy metal pollution area, and the ecologically degraded area. The Heilonggang River Basin in Hebei Province was selected as the main pilot area in the groundwater funnel area, in which seasonal fallow has been carried out for many years.

As of 2019, the pilot project of seasonal fallow in Hebei Province had been in the implementation mode for 4 years,

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and an initial water-saving effect had been obtained. According to a survey of 73 fallow points in 11 counties, irrigation frequency was reduced by 3.8 on average during the fallowing period, and the water savings were approximately 180 cubic meters per acre (Wang et al., 2013). The accumulated annual water savings for the 1.04 million mu of fallow land was 324 million $m^3$.

However, given the vast scale of the groundwater funnel in the North China Plain caused by a nearly 50-year history of mining, the amount of water saved by this effort in just a few years is not enough to restore the proper groundwater volume. To repair the groundwater funnel, the seasonal fallow project in the North China Plain needs to continue, with the same participation level, for at least 10 years. One key question is: For the implementation of medium- and long-term policies, can the current fallowing policy adapt to long-term agricultural development? In recent years, China's main grain prices have fluctuated greatly (Xu et al., 2012; Li et al., 2015; Arnade et al., 2017) due to the influences of international factors (e.g., the coronavirus disease, the weak US dollar, fund investment activities) and natural factors (e.g., changes in the global climate, natural disasters) (Lehmann et al., 2013; Bayramoğlu, 2014; Peng et al., 2016; Karimi et al., 2018; Alidoost et al., 2019; Kyriazi et al., 2019; Liu et al., 2019), and the domestic wheat market has experienced a rare decline in the past 10 years (Zhu and Si, 2015). With the adjustments of policies and markets, the prices of major crops are bound to be affected. According to economic theory, these price changes will lead to changes in farmers' agricultural production and livelihoods (Yamauchi and Dewina, 2012; Andrew, 2013; Gibson, 2013; Mao and Yang, 2015; Zinda and Kapoor, 2019). Thus, could the current fallow policy adapt to future changes in grain prices?

There has been a large amount of research on the impact of prices on the agricultural supply (Nerlove, 1979; Rosegrant et al., 1998; Kanwar, 2006; Imai et al., 2011; Zhang et al., 2019). For example, using data from India (1967–2000) for six major grains, Kanwar (2006) analyzed the impacts of the prices on their yields and concluded that prices have a significant impact on yield. The impact of price volatility on agricultural production in China has also been studied extensively (Ke, 1994; Jiang, 1998; Du and Coleman, 1997; Zhong and Hu, 2008; Wang and Huang, 2011). The main conclusion of these studies is that crop prices have an impact on production through the free market mechanism.

However, fallow has a different effect, as fallow requires farmers to stop planting specific crops for which they receive compensation from the government. Rational farmers will make the decision of whether to fallow or not by weighing the opportunity cost of fallow against the compensation.

Although many studies have explored the influences of individual, farming household, cognitive, and land features on farmers' willingness to fallow (Wu and Xie, 2017; Yu et al., 2017; Xie and Jin, 2019), there is little research on the impact of crop price changes on farmers' willingness to fallow.

The fallow pilot project in the groundwater funnel area of Hebei is a semi-mandatory planting mode change. The fallowing farmer needs to shift from the two-crop planting mode of one-season winter wheat and one-season summer maize to the one-crop planting mode of one-season natural fallowing and one-season rain nourishing. In return, the government issues a fallow compensation of 500 yuan $mu^{-1}$ which is essential to compensate for the loss of crop yield caused by fallowing. Two remaining questions regarding the farmers' participation in this system:

1) When the fallow compensation is fixed, will the farmer's fallowing behavior be affected by the crop price changes according to the current production technology?

2) As winter wheat is a type of grain crop, do the price changes have substantial impacts on farmers' fallowing decisions?

To address these questions, a farmer's agricultural production model is constructed to calculate the shadow price of agricultural labor based on household survey data from Jizhou City and Taocheng District of Hengshui City, two typical groundwater over-exploitation areas in Hebei Province. The opportunity cost of fallow (i.e., planting income) is then calculated through the cost-benefit function, and the relationship between the opportunity cost and the farmers' satisfaction with the fallow compensation is compared under the condition of a fixed fallow compensation. Second, the impact of wheat price changes on farmers' fallow opportunity cost is simulated, and the farmers' willingness to participate in fallow under different scenarios of wheat price changes is analyzed. Finally, we provide policy recommendations for the long-term implementation of fallow in the groundwater over-exploitation area in the North China Plain.

## 2 Data sources and methods

### 2.1 Study area

Jizhou City and Taocheng District of Hengshui City, Hebei Province, belong to the deep groundwater funnel area of the North China Plain, located between 115°10′E –116°34′E and 37°03′N –38°23′N.

There are 46 large-scale depressions of over 10000 mu in Hengshui, the largest of which is the "1000-ha depression (Qian-qing-wa)" in Jizhou City and Taocheng District with a total area of 75 $km^2$. This topographical condition provides convenient conditions for the groundwater funnel area. To restore the deep underground funnel, Hengshui City completed a project of planting mode adjustment (the seasonal fallow) of 400000 mu, which was increased to 490800 mu in 2015 according to the implementation plan for the comprehensive treatment of groundwater over-exploitation in Hebei Province. This project involves 11 counties (cities, districts), 71 townships, 669 villages, and 41177 farmers or business entities throughout the whole city. In 2016, a national fallow pilot project began.

### 2.2 Data sources

A stratified random sampling method and semi-structured interviews were used to investigate the farming households in the study area. The main contents of the survey included basic conditions of the farmland, farmer features, social and financial asset status, situation of household farming operations, and the farmers' perceptions of fallow. From July to August 2016, a team of 5 people (1 doctoral student and 4 master students) carried out the farming household survey in 33 villages. A total of 134 questionnaires were collected, including 126 valid questionnaires, and the effective rate of the questionnaire was 94%.

### 2.3 Methods

2.3.1 The mechanism through which wheat price influences the willingness to fallow

The compensation from the government is the main factor that affects farmers' willingness to participate in fallow. Farmers, as economically rational people, compare the opportunity cost of fallow with the compensation. When the two are far apart, the farmers' willingness to participate in fallow is affected. At present, the fallow compensation standard is fixed at 500 yuan mu$^{-1}$, so it is mainly the opportunity cost of fallow that affects the farmer's willingness to fallow. The net income of farmers before fallow is equal to output income minus input cost. A change in crop price will affect the output income under the premise of stable output and constant input cost.

Therefore, when the price of the crop changes, then the planting income will change, and the opportunity cost of fallow will change. Thus, the willingness of farmers to participate in fallow will be affected, as shown in Fig. 1. When the price of the crop rises, the willingness of farmers to participate in fallowing will decrease; when it falls, the willingness of farmers to fallow will increase.

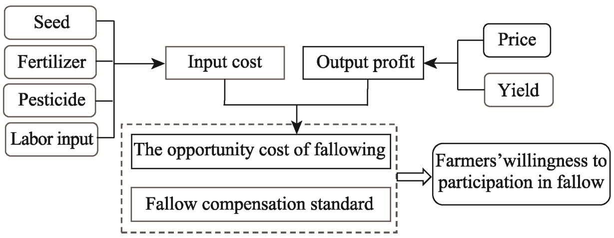


Fig. 1 The mechanism of wheat price change affecting fallow willingness

2.3.2 Production function

This study uses the Cobb-Douglas production function to simulate the agricultural production function of the non-fallowing farmer, which can be expressed as follows:

$$\ln G = \alpha + \beta \ln A + \lambda \ln L + \theta \ln C + \sum(\delta Z) + \varepsilon \quad (1)$$

In formula (1), $G$ represents the total agricultural income; $\alpha$ represents the constant term; $A$, $L$ and $C$ represent the land, labor, and capital inputs, respectively; $\beta$, $\lambda$, and $\theta$ represent the corresponding elastic coefficients, respectively; $Z$ represents exogenous variables, such as household features; $\delta$ represents the corresponding coefficient; and $\varepsilon$ represents the residual term.

$$G = P_{\text{wheat}} \times Q_{\text{wheat}} + P_{\text{corn}} \times Q_{\text{corn}} \quad (2)$$

In formula (2), $P_{\text{wheat}}$ represents the wheat price, $Q_{\text{wheat}}$ represents the yield of winter wheat; $P_{\text{corn}}$ represents the corn price; and $Q_{\text{corn}}$ represents the yield of corn.

2.3.3 Cost-benefit analysis

As economically rational people, farmers will participate in the fallow if the planting income after fallowing plus the compensation is greater than the planting income before fallowing. The above relationship can be expressed as follows:

$$I_{\text{aft}} + I_{\text{C}} > I_{\text{bef}} \quad (3)$$

In formula (3), $I_{\text{aft}}$ represents the net planting income after winter wheat fallowing, $I_{\text{C}}$ represents the compensation for fallowing, and $I_{\text{bef}}$ represents the net planting income before fallowing.

According to the situation of agricultural operations in the study area, the cost-benefit analysis for a plot can be expressed as follows:

$$I_{\text{net}} = Y \times p - I_{\text{seed}} - I_{\text{pesticide}} - I_{\text{fertilizer}} - I_{\text{machinery}} - I_{\text{irrigation}} - I_{\text{labor}} \quad (4)$$

where, $p$ represents the price of the agricultural products (yuan per 500 g); $Y$ represents the crop yield per unit area (500 g mu$^{-1}$); $I_{\text{seed}}$, $I_{\text{pesticide}}$, $I_{\text{fertilizer}}$, $I_{\text{machinery}}$, $I_{\text{irrigation}}$, and $I_{\text{labor}}$ represent the input costs of seed, pesticide, fertilizer, machinery, irrigation, and labor per unit area (yuan mu$^{-1}$), respectively. $I_{\text{labor}}$ is calculated by multiplying the shadow price of farming labor ($W_1$, yuan per workday) by the labor input (workday per mu) (Wang and Swallow, 2016). W is usually equal to the marginal income of labor input, that is, the change in total planting income from the unit labor input, which can be expressed as follows:

$$W_1 = \frac{\partial G}{\partial L} = \lambda \frac{G}{L} \quad (5)$$

In formula (5), $G$, $L$, and $\lambda$ have the same definitions as in formula (1).

## 3 Results and analysis

### 3.1 Farmers' features and their expectation of fallow compensation

From the farmer survey data, the basic conditions of the farmland mainly include the plot area, the situation of land contracted and transferred, and the irrigation status. The situation of a household farming operation mainly includes the input (seeds, fertilizers, pesticides, irrigation water, machinery, etc.) and the final output of the crop. Farmer features mainly include age, gender, education level, and occupation. Status of social and financial assets includes farming income, off-farm income, and household expenditure. Farmers' perceptions of fallow mainly include the farmer's willingness to fallow winter wheat, their satisfaction with the fallow compensation, and the expectation of fallow compensation. Table 1 describes several key features of the farmers and their expectations of fallow compensation.

As shown in Table 1, 80.1% of the farmers are male. Farmers aged 55 and above account for 56.1%, while those aged over 65 account for 17.3%, and the smallest proportion is farmers aged 35 or below, accounting for only 4.1% of the total sample. This age distribution indicates that the age of farmers in the study area tends to be older, and young labor is scarce. In terms of education level, more than 90% of the farmers have a junior middle school education or below, indicating that the sampled farmers in the study area are a low education-level group. About one-fourth (28.6%) of households have an off-farm income, and the remaining depend mainly on farming for their livelihoods. In terms of the expectation of fallow compensation, 50.8% of the total sample expects 500 yuan or lower, and 7.1% expects over 700 yuan. In general, the farmers' expectations of fallow compensation are within a rational range, and there is no phenomenon of unrealistic "skyrocketing prices".

### 3.2 The analysis of farmers' features and compensation satisfaction

When the expected compensation is higher than the actual compensation, farmers are not satisfied; and, conversely, when the expected compensation is equal to or lower than the actual compensation, farmers are satisfied with the actual compensation. In a free environment, compensation satisfaction is the most important factor affecting farmers' decision-making regarding fallow.

As shown in Table 2, male farmers are more satisfied with the current fallowing compensation than female farmers, as 55.45% of male farmers believe that the current compensation of fallow is satisfactory, while 72% of female

Table 1 Farmers' features and their expectations of fallow compensation

| Farmer feature | Levels | Percentage (%) |
|---|---|---|
| Gender | Male | 80.1 |
| | Female | 19.9 |
| Age | 35 years old or below | 4.1 |
| | 36–45 years old | 8.7 |
| | 46–55 years old | 31.1 |
| | 56–65 years old | 38.8 |
| | 66 years old or older | 17.3 |
| Education level | Uneducated | 8.2 |
| | Primary school | 33.2 |
| | Junior high school | 48.5 |
| | High school, Secondary school, Vocational college | 9.7 |
| | College or above | 0.1 |
| Does the family have an off-farm income? | Yes | 28.6 |
| | No | 71.4 |
| The expectation of fallow compensation | < 400 yuan mu$^{-1}$ | 24.2 |
| | 400–500 yuan mu$^{-1}$ | 26.6 |
| | 500–600 yuan mu$^{-1}$ | 23.4 |
| | 600–700 yuan mu$^{-1}$ | 18.7 |
| | > 700 yuan mu$^{-1}$ | 7.1 |

Table 2 The satisfaction of fallow compensation as related to different farmer features

| Farmer feature | Levels | Satisfied with the current compensation (%) | Unsatisfied with the current compensation (%) |
|---|---|---|---|
| Gender | Male | 55.45 | 44.55 |
| | Female | 28.00 | 72.00 |
| Age | 35 years old or below | 60.00 | 40.00 |
| | 36–45 years old | 63.64 | 36.36 |
| | 46–55 years old | 53.85 | 46.15 |
| | 56–65 years old | 30.61 | 69.39 |
| | 66 years old or older | 77.27 | 22.73 |
| Education level | Uneducated | 60.00 | 40.00 |
| | Primary school | 32.31 | 67.69 |
| | Junior high school | 57.38 | 42.62 |
| | High school, secondary school, vocational college | 58.33 | 41.67 |
| | College or above | 100.00 | 0.00 |
| Does the family have an off-farm income? | Yes | 63.89 | 36.11 |
| | No | 44.44 | 55.56 |

farmers believe that the current compensation standard does not meet their expectations. The sample data indicate that female managers are more likely to be unsatisfied with the current compensation standards for fallow farming.

The proportion of farmers aged 35 or below who are satisfied with the current compensation is 60%, which is larger than the unsatisfied group. The possible explanation is that farmers aged 35 or below are more likely to have higher off-farm income due to more off-farm employment opportunities. Therefore, the functions of farmland for farmers' overall employment, economic benefit, and social security tend to be reduced (Tian et al., 2010; Wang et al., 2016). Generally, as long as the opportunity cost of work off-farm is greater than the income from farming, the younger farmers will have more willingness to fallow, as the government will provide compensation for fallowing.

Among farmers aged 36–45 and 46–55, the proportions of farmers who are satisfied with the current compensation are larger than the unsatisfied proportions. Compared with the farmers aged 35 or below, the proportion of farmers who are satisfied with the current compensation decreases with an increase of age, as the opportunities to work off-farm are reduced, and the functions of farmland for farmers' overall employment, economic benefit, and social security gradually become more important.

In addition, only 30.61% of farmers aged 56–65 are satisfied with the current compensation. In other words, more than two-thirds of farmers aged 56–65 believe that the current compensation standard of 500 yuan per mu falls short of their expectations. In this age group, farmers attach the most importance to the functions of farmland for farmers' employment, economic benefit, and social security.

Among the farmers above 65 years old, the satisfaction with the current compensation is greatly improved. More than 77% of farmers in this group are satisfied with the current compensation. The most likely reason is that elderly farmers find it difficult to implement extensive management of farmland due to a lack of physical strength and energy. As a result, the yield of their farmland is not high, and the income of planting is proportional to yield. Since the current compensation of fallow is greater than or equal to the planting income of farmers above 65 years old, a high proportion of farmers in this age group report satisfaction with the current compensation of fallow.

Among the farmers with different educational levels, those who have only primary education are less satisfied with the current compensation than those with higher levels of education. Generally, it is believed that with more years of education, farmers are more likely to engage in off-farm jobs, which can be expected to improve their satisfaction with the current compensation. However, the present results may also support another point of view: that basic education is generally accepted by rural family members in China, which does not determine the occupation distribution (Feng et al., 2016). As seen from Table 2, 63.89% of the farmers in the sample report that the current compensation of fallow meets their expectations, while the proportion of farmers without off-farm income who are not satisfied with the current compensation is relatively high. Off-farm income generally refers to the income farmers earn through off-farm jobs. In recent years, the wages of ordinary workers in China have increased significantly faster than the prices of agricultural products and agricultural production materials (Li and Dai, 2014). As a result, the gap between planting income and the opportunity cost is increasing, and therefore farmers with off-farm income will be more satisfied with the current compensation than those without such income.

### 3.3 The relationship between the current compensation and expectation

The Cobb-Douglas production function for winter wheat and summer maize under the annual double-crop planting mode is estimated from the household survey data. The logarithm of *total planting income* is included as an explanatory variable, and explanatory variables such as *sown area*, *labor input*, and *capital input* are also log-transformed before analysis. The variables of *age* and *education level* are selected as covariates. The OLS regression was performed on the SPSS 17.0 platform, and the results are shown in Table 3.

Table 3 The estimation of the Cobb-Douglas production function

| Variables | *β* | *S.E.* | *Sig.* |
|---|---|---|---|
| ln (*sown area*) | 0.999 | 0.075 | 0.000*** |
| ln (*laborinput*) | 0.033 | 0.019 | 0.019* |
| ln (*capital input*) | 0.030 | 0.070 | 0.038* |
| Age | 0.015 | 0.557 | 0.579 |
| Educational level | –0.13 | –0.497 | 0.620 |
| Constant | 7.153 | 0.473 | 0.000 |
| $R^2$ | | 0.935 | |

Note: * means $P < 0.1$; *** means $P < 0.01$.

As shown in Table 3, the value of $R^2$ is 0.935, indicating that the models fit the data well and the model results are highly reliable. The elasticity coefficient ($\beta$) of *labor input* is 0.033, and when this coefficient is used in formula (5) to calculate the average shadow wage-price per household under the non-fallow planting mode in 2016, the result is 15.07 yuan. On this basis, the shadow wage price is entered into formula (4) to calculate the net income of planting winter wheat, and the relationship between the current compensation for fallowing and the net income of planting winter wheat is shown in Fig. 2.

As shown in Table 4, 32 households with the planting income of winter wheat less than 400 yuan per mu, account for 25.8% of the total households; 29 households with the planting income of winter wheat between 400–500 yuan per mu, account for 23.4% of the total households; 27 households with the planting income of winter wheat between 500 and 600 yuan per mu, account for 21.7% of the total households; 22 households with the planting income of winter wheat between 600–700 yuan per mu, account for 17.8% of the total households; and 14 households with the planting income of winter wheat more than 700 yuan per mu, account for 11.3% of the total households. Comparing the expected compensation of farmers and the planting income of winter wheat per mu shows that farmers' expectation of fallow is highly correlated with the planting income of winter wheat, indicating that farmers will expect compensation that is based on their planting income.

Figure 2 shows that for approximately half of the farmers' their planting income of winter wheat per mu is lower than the current compensation. We believe that these farmers will voluntarily participate in fallow. For the remaining 50.8% of the farmers, the planting income of winter wheat is higher than the current compensation, thus, they would have no willingness to participate in fallow (Yu et al., 2017).

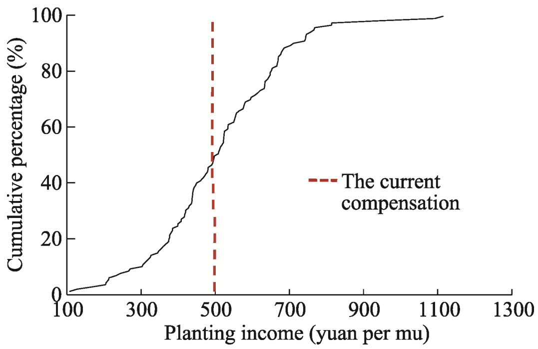


Fig. 2 Cumulative percentage of net income per mu

Table 4 Comparison of farmers' expected compensation and actual income per mu

| Classification | Farmers' expected compensation | Planting income | Gap |
|---|---|---|---|
| | Number of households | Number of households | |
| < 400 yuan | 30 | 32 | 2 |
| 400–500 yuan | 33 | 29 | –4 |
| 500–600 yuan | 29 | 27 | –2 |
| 600–700 yuan | 24 | 22 | –2 |
| > 700 yuan | 8 | 14 | 6 |
| Total | 124 | 124 | 0 |

### 3.4 Possible impacts of wheat price fluctuation on farmers' fallowing decisions

Under the current production environment and technology conditions, farmers cannot easily change their input factors, such as the amount of seed, fertilizer, and mechanical inputs.

However, China's grain prices have fluctuated significantly, especially the wheat price in recent years. As the prices change, farmers' net income also changes, but the current compensation of fallow is fixed at 500 yuan per mu. Once the wheat price increase exceeds a certain threshold, it is expected to affect the fallow adoption of winter wheat in the North China Plain. Based on the survey data, the impacts of winter wheat price fluctuations on farmers' net incomes and fallowing willingness are simulated. Survey data show that the average wheat price in Taocheng District and Jizhou City in Hengshui City was 1.11 yuan per 500 g in 2016. This study uses this base price to simulate the changes in the net income of farmers with a price fluctuation range of 0.1 yuan.

Table 5 shows the corresponding shadow wages and average net income per mu under different winter wheat prices. In 2016, the winter wheat price in the survey area was 1.11 yuan per 500 g, so the corresponding shadow wage was 15.07 yuan, and the corresponding average net income per mu was 507.30 yuan. In our simulation an increase in the winter wheat price by 0.1 yuan to 1.21 yuan per 500 g, increased the corresponding shadow wage to 15.82 yuan, and the corresponding average net income per mu increased by nearly 100 yuan. In general, as the winter wheat price increases, the corresponding shadow wage and average net income per mu also increase. Correspondingly, as the purchase price of winter wheat declines, the corresponding shadow wage and average income per mu also decrease. However, these results do not reflect the changes in farmers' willingness to participate in fallow based on the changes in wheat prices. Figure 3 shows the cumulative percentage of the net income per mu of the farmer under different wheat prices, and the compensation standard line of fallow is shown for comparison.

As shown in Fig. 3, when the price of winter wheat rises by 0.1 yuan, only 12% of farmers have a net income per mu less than 500 yuan; when the price rises by 0.2 yuan, only 6.5% of the farmers have a net income per mu less than 500 yuan; and when the price rises by 0.3 yuan, only 2.4% of the farmers have a net income per mu less than 500 yuan. With the decline of simulated winter wheat prices, the opposite trend appears. When the price of winter wheat decreases by 0.1 yuan, 51.6% of farmers have a net income per mu less than 500 yuan; when it decreases by 0.2 yuan, 71.4% of farmers have a net income per mu less than 500 yuan; and when it decreases by 0.3 yuan, 90.3% of farmers have a net income per mu less than 500 yuan. These findings demonstrate that under the current production technology conditions, the changes in winter wheat prices will greatly affect the average net income per mu of farmers, thus affecting their willingness to participate in fallow.

In the scenario of the wheat price rising by 0.1 yuan, 88% of the farmers have a net income per mu more than 500 yuan, so these farmers are likely to be reluctant to participate in fallow. To realize the goal of groundwater funnel restoration without changing the compensation standard, it would be necessary to force farmers to participate in the project, which could be expected to produce discontent among the farmers and increase the implementation cost of the government policies, leading to policy failure.

For farmers who have participated in fallow projects, especially those aged between 55 and 65 who have fewer opportunities for off-farm work, their farming income will increase once the price of wheat rises. Therefore, without supervision, they are likely to replant winter wheat.

In the opposite scenario, if the price of wheat falls by 0.2 yuan, 71.4% of farmers will have an average net income per mu of less than 500 yuan. Although farmers' participation in fallow is expected to be high under the fixed compensation standard, the government will bear a greater financial burden.

Table 5 The effect of wheat price changes on planting income per mu

| Winter wheat price (yuan per 500 g) | Price change (yuan per 500 g) | Shadow wage (yuan per day) | Average net income per mu (yuan) |
|---|---|---|---|
| 0.81 | –0.3 | 12.07 | 229.16 |
| 0.91 | –0.2 | 12.97 | 322.38 |
| 1.01 | –0.1 | 13.87 | 415.61 |
| 1.11 | 0 | 15.07 | 507.30 |
| 1.21 | 0.1 | 15.82 | 601.03 |
| 1.31 | 0.2 | 17.05 | 692.08 |
| 1.41 | 0.3 | 17.80 | 786.31 |

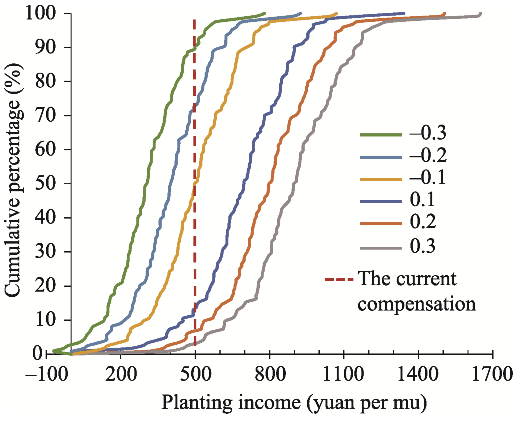


Fig. 3 Cumulative percentage of net income per mu under wheat price changes

## 4 Discussion

In recent years, many studies have examined the theme of fallow, including the calculation of fallow area, the measure of fallow compensation (Xie et al., 2018a), the willingness of farmers to participate in fallow and its influencing factors (Yu et al., 2017; Lu et al., 2019), the game relationship between fallow stakeholders (Xie et al., 2018b; 2019), and many other aspects. In contrast, few studies have focused on the impact of crop price changes on farmers' willingness to participate in fallow. The reasons are mainly related to two aspects. One is that China's grain prices are protected by policies. Therefore, some people believe that grain prices will not change appreciably, so there will be no significant impact on farmers' willingness to participate in fallow. However, according to this study, a price fluctuation of just a dime will greatly affect the opportunity cost of fallow farming households, and this will affect their willingness to fallow.

Secondly, a long period of sequential data is needed to analyze the impact of crop price changes on the farmers' willingness to participate in fallow according to the research logic of economics. However, since the current fallow pilot project has only been carried out for 4 years, the data from that project cannot meet this analysis requirements. Groundwater funnel remediation is a long-term process, so the farmers' satisfaction with fallow compensation directly affects the sustainability of the fallow project. This study attempts to start with the farmers' satisfaction with fallow compensation, construct the relationship between their satisfaction and planting income, and then analyze the impact of wheat price changes on planting income and consequently on their satisfaction with fallow compensation.

Furthermore, the data used in this study are derived exclusively from a household survey, and the survey reveals that farmers are not very clear about their land quality and soil types. Considering that the size of the study area is not very large, the impact of the minor variations in land quality on farming income is ignored in the calculation of the Cobb-Douglas production function.

## 5 Conclusions

Based on household survey data in Jizhou City and Taocheng District of Hengshui City in Hebei Province obtained in 2016, this paper describes several key features of the farmers and their expectations of fallow compensation in the study area. The analysis establishes the relationship between farmers' satisfaction with the current fallow compensation and planting income of winter wheat. The Cobb-Douglas production function is estimated using the input-output data of farmers, and the shadow wage-price of agricultural labor is calculated. On this basis, the impact of wheat price changes on farmers' willingness to participate in fallow is simulated. This analysis leads to several conclusions.

Female farmers are more likely to be dissatisfied with the current compensation for fallowing than male farmers. Among the farmers, those at 65 years old and above are the most satisfied with the current compensation. Furthermore, farming households with off-farm income are more satisfied with the current compensation than those without off-farm income. Although some features of farmers might influence their fallow participation, there is no correlation between any of the farmer features analyzed here and farmers' satisfaction with fallow compensation.

By comparing the expected compensation of farmers with the planting income of winter wheat, wheat price changes were found to affect farmers' expected planting income and, consequently, their willingness to participate in fallow.

By simulating price changes of wheat, when the wheat price rises by 0.1 yuan, 88% of farmers were found to have a net income per mu of more than 500 yuan, and these farmers are likely to be reluctant to participate in fallow. When the wheat price drops by 0.2 yuan, 71.4% of farmers have a net income per mu of less than 500 yuan, and although farmers' participation in fallow is high in this case, the government will bear a greater financial burden (Yu et al., 2017).

Therefore, the current unified fallow compensation standard (500 yuan $mu^{-1}$) cannot adapt to even relatively modest price changes of winter wheat, so it should be adjusted to the reflect the average wheat yield of three years before fallowing multiplied by the wheat price in that year. This step not only takes into account the difference in land income but also may reduce the impact of price fluctuations on farmers' decisions regarding fallow.

In addition, the government department should sign the fallow contract with farmers who participated in fallow, and the rights and obligations of both parties should be clarified so as to reduce the supervision costs and ensure the continuing sustainability of the fallow project.

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# 小麦价格变化对农户休耕参与意愿的影响研究

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摘　要：华北平原地下水漏斗区冬小麦休耕试点已实施四年有余，节水效果已初步显现，但地下水漏斗的修复是一个长期的过程，粮食价格变化很可能会影响农户的休耕参与意愿。本文基于 2016 年河北省衡水市冀州市和桃城区的农户调研数据，在分析案例区未参与休耕农户的基本特征、家庭收入情况以及休耕补偿金额满意度的基础上，利用农户的投入产出数据估计了案例区的 Cobb-Douglas 生产函数，并分析了农户休耕补偿金额满意度与冬小麦种植收入之间的关系。其次，模拟了小麦价格变化对农户休耕参与意愿的影响。结果显示：小麦价格变化会影响农户的预期种植收入，进而通过休耕补偿满意度影响他们的休耕参与意愿；当小麦价格每斤上涨 0.1 元时，有 88%的农户不愿继续参与休耕，而当小麦价格每斤下降 0.2 元时，有 71.4%的农户亩均净收益要小于当前休耕补偿标准，尽管在补偿标准不变的情况下农户休耕的参与度高，但会增加政府的财政负担。因此，本文提出应制定灵活的休耕补偿标准，如将现行的华北平原冬小麦休耕补偿标准调整为休耕前三年的平均小麦产量乘以补偿当年的小麦收购价。

**关键词**：小麦价格变化；休耕；生态补偿；农户