A Way to Determine the Rationality of Well Irrigation Scheme in Land Consolidation

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Abstract Through the analysis of investment and benefit in agricultural production, we explore the relationship between the cost of motor-pumped well irrigation and pump head, and provide a simple but effective way to determine whether the well irrigation scheme is economically rational.
Key words Land consolidation, Well irrigation scheme, Rationality

Well irrigation is a form of water conservancy project widely used in the land consolidation. Motor-pumped well irrigation is not only conducive to the rational allocation and utilization of water resources in the project area, but also beneficial to the adjustment of the industrial structure of agriculture and increase in farmers' income[1]. To determine whether the well irrigation scheme is rational, we should not only consider the technical feasibility, but also consider the economic rationality[2]. If the farmers' costs of adopting well irrigation are too high, it will make motor-pumped well lay idle, thereby restricting efficiency of the entire project. Therefore, for the project decision makers, finding a way to determine whether the well irrigation scheme is economically reasonable and feasible in the project is very necessary[3].

1 Method introduction

For farmers, the overall objective in the economy is that in a given agricultural production cycle, the actual total benefit earned is not less than the expected total benefit, namely:

$$\sum_{i=1}^{n} c_i - \sum_{j=1}^{m} y_j \geqslant P \quad (1)$$

where means type *i* benefit (yuan) within a given agricultural production cycle; means type *j* investment (yuan) within a given agricultural production cycle; *P* means the total expected net proceeds (yuan) within a given agricultural production cycle.

In economy, the actual total benefit obtained by the farmers is largely the benefit from selling the grain, which can be derived by summing up the products of yield of a variety of grain crops and respective corresponding prices; the total investment in production includes irrigation costs, costs of the purchase of seed and fertilizer, costs of mechanical cultivation and other aspects[4]. In the analysis of well irrigation project benefit, we take the benefits of grain yield and the costs of seed, fertilizer, and mechanical cultivation, as known quantity; the costs of adopting motor-pumped well irrigation as unknown quantity.

At this time, the formula (1) can be transformed into the following form:

$$X \leqslant C - Y - p \quad (2)$$

where *X* is the total cost of well irrigation (yuan) within a given agricultural production cycle; *C* is the total benefit from planting various kinds of grain crops (yuan) within a given agricultural production cycle; *Y* is the total investment in the purchase of seed, fertilizer and mechanical cultivation apart from the well irrigation costs (yuan) within a given agricultural production cycle.

The two parameters, *C* and *Y*, can be determined by referring to the average benefit and investment of local food production, respectively.

2 Estimation of well irrigation costs

In motor-pumped well irrigation, pump power machine mainly includes two types: electric motor and diesel[5]. The state or government invests in the land consolidation project[6], and in the majority of projects, the pump power machine adopts electric motor. The major fees paid by farmers in using motor-pumped well irrigation, are electric power charge.

Now we take the case of the electric motor, to estimate the cost of well irrigation.

The total well irrigation costs within a given agricultural production cycle can be expressed as:

$$X = \sum_{i=1}^{n} n_i \times a_i \times x_i \quad (3)$$

where n_i is the irrigation frequency of type *i* crop within a given agricultural production cycle; a_i is the area of farmland which needs to be irrigated at a time for type *i* crop (mu); x_i is the costs of well irrigation per mu at a time for type *i* crop (yuan).

$$x_i = l_i \times C_{electricity} \quad (4)$$

where *l* is electricity consumption for well irrigation per mu at a time for type *i* crop, which can be estimated by the product of pump power and pump working hours (kilowatt); $C_{electricity}$ adopts the electricity prices of well irrigation (yuan/kilowatt).

2.1 Calculation of motor power The calculation formula of matching motor power of pump is as follows:

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$$P_{electricity} = P_{pump} \times a = Q \times H \times 9.81 \times \upsilon \div 3600 \div \eta \times a \quad (5)$$

where P_{pump} is pump power (kilowatt); a is spare coefficient of electric motor power; Q is pump flow rate (m^3/h); H is pump head (m); υ is the proportion of water; η is pump efficiency.

2.2 Calculation of pump working hours Electricity consumption time per mu for well irrigation at a time for type i crop can be determined by the following formula:

$$t_i = \frac{m_i}{Q} \quad (6)$$

where m_i is the irrigation quota of type i crop (m^3/mu); Q is pump flow rate (m^3/h).

2.3 Costs of well irrigation From formula (3) to formula (6), the function of the cost of motor-pumped well irrigation is as follows:

$$X = \frac{9.81 \times H \times C_{electricity} \times a}{3600 \times \eta} \quad (7)$$

Therefore, when the power machine is electric motor, the costs of well irrigation are directly proportional to head of motor-pumped well, as shown in Fig. 1.

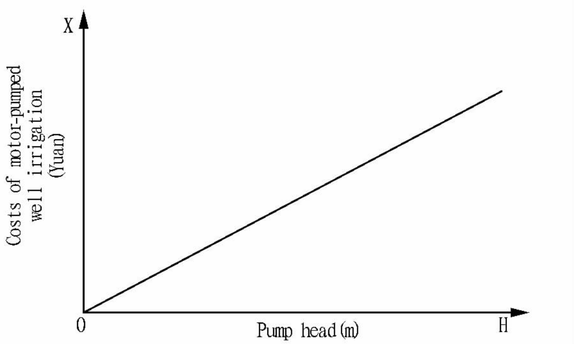

Fig. 1 Relationship between costs of motor-pumped well irrigation and pump head

3 Rationality analysis of well irrigation scheme

Substituting formula (7) into formula (2), we can derive that:

$$H \leqslant \frac{3600 \times \eta \times (C - Y\text{-}p)}{9.81 \times C_{electricity} \times a \times (\sum_{i=1}^{n} n_i \times a_i \times m_i} \quad (8)$$

Thus, we can know that only when the pump head satisfies the formula (8), can the farmers accept the cost of adopting motor-pumped well irrigation, can the well irrigation scheme be reasonable and feasible.

4 Application Example

4.1 The basic information One land consolidation project area plans to adopt the motor-pumped well irrigation scheme. Through the preliminary estimate, the head of pump should be at least 150m; pump efficiency takes 60%; the spare coefficient of electric motor power takes 1.3. It tries to determine whether the irrigation costs in this scheme can be accepted by the local farmers.

Through survey, the planting structure of crops in the project area is winter wheat and summer corn; the price of electricity for irrigation is 0.56 yuan/kilowatt. The crop production in the typical years can be seen in Table 1.

4.2 Scheme analysis In the project area, two types of crop, wheat and corn, are planted. Formula (8) can be transformed into the following form:

$$H \leqslant \frac{3600 \times \eta \times (C_{wheat} + C_{corn} - Y_{wheat} - Y\,corn - P_{wheat} - P_{corn}}{9.81 \times C_{electricity} \times a \times (n_{wheat} \times a_{wheat} \times m_{wheat} + n_{corn} \times a_{corn} \times m_{corn}} \quad (9)$$

Substituting the relevant data in Table 1 into formula (9), we can derive that the pump head $H \leqslant 116$ m.

Table 1 The crop production in the typical years

Crop name	Planting area//mu	Irrigation frequency	Irrigation quota m³//mu	Crop yield kg//mu	Crop prices yuan//kg	Production costs yuan//mu	Expected return yuan//mu
Wheat	5	4	40	350	2.0	400	300
Corn	5	3	35	410	2.2	450	350

Note: Production costs in the table are the sum of the costs of seed, fertilizer, pesticide, machinery operating, *etc.*

Therefore, if the pump head is greater than or equal to 150 m, the irrigation cost will be too high for the farmers, so that the farmers can not achieve their expected benefit. Thus, the utilization rate of motor-pumped well will be very low, failing to achieve the goal of implementation of the project.

5 Conclusion

The above method is applicable to the project area in adopting motor-pumped well irrigation, irrigation by lifting water to a higher level with a water pump, and other schemes. The key is to determine whether the pump head can meet the requirements of economic rationality. In addition, we should also determine the feasibility of the scheme, based on the level of economic development, irrigation water sources and other factors in different project areas.

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