Ecological Compensation for Desert Electric Irrigation Projects Based on Opportunity Cost of Ecosystem Service Value: A Case Study of the Jingdian High-lift Electric Pumping Irrigation Project (Postprint)

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Date: 2019-09-10T00:00:00+00:00

Abstract

Taking the Jingdian high-lift pumping irrigation project as an example, this study calculated the ecological service value of the irrigation area to ecological migrants from the Qilian Mountains using factor equivalence, determined the ecological service value of the irrigation area in mitigating sandstorms in downwind regions using the cosine distance formula, and computed the corresponding opportunity costs, thereby examining the ecological compensation issues associated with desert electric pumping irrigation projects. The results indicate that: (1) The ecological service value of ecological migrants from the Jingdian irrigation area for vegetation restoration in the Qilian Mountains is 4.01×10^9 yuan, while the ecological service value of the irrigation area oasis in reducing sandstorms downwind of the irrigation area is 7.09×10^7 yuan. The opportunity cost of ecological migrants from the Qilian Mountains and the opportunity cost of windbreak and sand fixation downwind of the irrigation area are 2.05×10^8 yuan and 3.63×10^6 yuan, respectively. (2) The beneficiaries of vegetation restoration in the Qilian Mountains by ecological migrants from the Jingdian irrigation area include the counties and municipalities in the Shiyang River basin and Jingtai County in the Yellow River basin at the eastern terminus of the Qilian Mountains, with the state also being a beneficiary; the compensation recipients are Gansu Province and the Gansu Jingtaichuan Electric Power Irrigation Management Bureau. (3) The prevention and control of desertification and sandstorms and the protection of national ecological public welfare forests are priorities in China' s ecological environment construction; ecological compensation is conducive to stimulating and promoting the development of identical or analogous ecological public welfare undertakings, thereby vigorously advancing national ecological environment construction.

Full Text

Ecological Compensation of a Desert Water-Lifting Irrigation Project Based on Opportunity Cost of Ecosystem Service Value: A Case Study of the Jingtaichuan Water-Lifting Irrigation Project

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Abstract: This paper examines the ecological compensation mechanism for a desert water-lifting irrigation project. The ecosystem service value of vegetation increased through ecological migration from the Qilian Mountains to the Jingdian Irrigated Area was calculated using the factor equivalence method, while the ecosystem service value derived from sandstorm reduction in the leeward area was estimated using the cosine distance formula. The opportunity cost was also calculated. The results demonstrate that: (1) Ecological compensation should be based on the opportunity cost of external ecosystem service values. The ecosystem service value of the Jingdian Irrigated Area from Qilian Mountains ecological migration to vegetation regeneration is 4.01×10 yuan RMB, and the ecosystem service value from sandstorm reduction in the leeward area is 7.09×10 yuan. The opportunity cost of ecological migration is 2.05×10 yuan, and the opportunity cost of sandstorm control in the leeward area is 3.63×10 yuan; (2) The primary beneficiaries of vegetation regeneration through ecological migration from the Qilian Mountains to the irrigated areas are the counties within the Shiyang River Basin and Jingtai County in the eastern Qilian Mountains of the Yellow River Basin, with the state also being a beneficiary. The compensation subjects are Gansu Province and the Administration of Jingtaichuan Water-Lifting Irrigation Project; (3) Desertification prevention and control, sandstorm mitigation, and national ecological forest protection are priorities of China' s ecological environmental construction. Ecological compensation is conducive to driving and promoting the development of similar public welfare undertakings and vigorously advancing national ecological environmental construction.

Keywords: desert water-lifting irrigation project; ecosystem service value; ecological migration; windbreak; sand fixation; ecological compensation; Jingtai County; Gansu

1 Introduction

Water resources are fundamental natural resources and strategic economic resources essential for ecological and environmental protection as well as economic and social development. The implementation of ecological compensation mechanisms for water resources has become a critical issue in China. Ecological com-

pensation for water resources should be based on the value of water ecosystem services, which represents the cornerstone of such compensation mechanisms. The Jingtaichuan Water-Lifting Irrigation Project is a large-scale water diversion initiative that pumps water from the Yellow River to irrigate farmland in arid desert regions. By 2013, the project had irrigated 5.70×10 hm^2 of land, with a water conveyance capacity of 450 million m^3 and an annual water supply of 230 million m^3. The ecological compensation for this project should be calculated based on the opportunity cost of ecosystem service value, which reflects the value of foregone alternative uses of water resources.

Current research on ecological compensation for water resources primarily focuses on water source areas and river basins, with limited studies on desert water-lifting irrigation projects. Existing research methods include factor equivalence, contingent valuation, and opportunity cost approaches. However, few studies have applied the opportunity cost method to calculate ecological compensation for desert water-lifting irrigation projects. This paper addresses this gap by employing the opportunity cost method to calculate ecological compensation for the Jingtaichuan Water-Lifting Irrigation Project, providing a scientific basis for establishing such compensation mechanisms.

2 Methods

2.1 Data Sources

The study area encompasses the Jingtaichuan Water-Lifting Irrigation Project region and its surrounding areas. Basic data were obtained from the Jingtaichuan Water-Lifting Irrigation Project Administration and Gansu Provincial statistical yearbooks. The reference year for calculations is 2016. The ecosystem service value of vegetation increased through ecological migration from the Qilian Mountains to the Jingdian Irrigated Area was calculated using the factor equivalence method, while the ecosystem service value from sandstorm reduction in the leeward area was estimated using the cosine distance formula. The opportunity cost was calculated based on the investment costs of the project.

2.2 Calculation Methods

The ecosystem service value of vegetation regeneration through ecological migration was calculated using the factor equivalence method, which converts different vegetation types into equivalent standard units based on their ecological service functions. The ecosystem service value from sandstorm reduction was estimated using the cosine distance formula, which calculates the reduction in sandstorm intensity based on distance from the windbreak. The opportunity cost was calculated as the investment cost of the project, including construction, operation, and maintenance expenses.

The formula for calculating the ecosystem service value of vegetation regeneration is:

$$V_j = a_j \times 1.077 \times \cos(\alpha)$$

where V_j represents the ecosystem service value of vegetation type j, a_j represents the area of vegetation type j (in km²), and α represents the correction factor.

The total ecosystem service value is the sum of the values from vegetation regeneration and sandstorm reduction.

3 Results

3.1 Ecosystem Service Value Calculation

The total ecosystem service value of the Jingdian Irrigated Area from ecological migration is 3.63×10 yuan. Specifically, the ecosystem service value from vegetation regeneration is 2.01×10 yuan, the value from sandstorm reduction in the leeward area is 1.07×10 yuan, and the value from other ecological services is 5.44×10 yuan (Table 2).

The ecosystem service value from vegetation regeneration through ecological migration from the Qilian Mountains is 4.01×10 yuan, which is significantly higher than the value calculated using other methods. This demonstrates that ecological migration is an effective approach to vegetation restoration and ecosystem service enhancement.

3.2 Opportunity Cost Calculation

The opportunity cost of ecological migration is 2.05×10 yuan, while the opportunity cost of sandstorm control in the leeward area is 3.63×10 yuan. The total opportunity cost of the project is 2.08×10 yuan. The opportunity cost accounts for approximately 0.12% of the total investment, indicating that ecological compensation based on opportunity cost is economically feasible.

The investment in the Jingtaichuan Water-Lifting Irrigation Project has increased over the years. From 1969 to 2016, the total investment reached 6.61×10 yuan in the initial phase, 4.44×10 yuan in the second phase, and 4.44×10 yuan in the third phase. The annual dedicated investment has shown an increasing trend, reaching 2.09×10 yuan in recent years.

3.3 Beneficiaries and Compensation Subjects

The primary beneficiaries of vegetation regeneration through ecological migration are the counties in the Shiyang River Basin and Jingtai County in the eastern Qilian Mountains of the Yellow River Basin. The state is also a beneficiary through improved national ecological security. The compensation subjects are Gansu Province and the Administration of Jingtaichuan Water-Lifting Irrigation Project, who are responsible for implementing the ecological compensation mechanism.

The prevention and control of desertification and sandstorms, along with the protection of national ecological forests, represent key priorities in China' s ecological environmental construction. Establishing an ecological compensation mechanism for the Jingtaichuan Water-Lifting Irrigation Project will provide valuable experience for similar projects nationwide and promote the development of ecological civilization.

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Note: Figure translations are in progress. See original paper for figures.