Assessing the Ecological Function Value of Fruit Tree Industry Production in Arid Regions Under the New Pattern of Harmonious Coexistence Between Humans and Nature: A Case Study of Southern Xinjiang (Postprint)

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Abstract

Quantitatively assessing the ecological function value of fruit and forestry production in arid regions can enable people, especially fruit and forestry growers, to more fully recognize the role and effectiveness of such production in improving local ecological environments, thereby prompting them to consider not only economic factors but also ecological factors more heavily in their production decisions, and achieving synergistic enhancement of environmental protection, fruit and forestry economic development, and growers' income increases. Taking the arid region of southern Xinjiang as an example, this study employs the shadow engineering method, afforestation cost method, opportunity cost method, and cost substitution method to calculate the various ecological function values provided by fruit and forestry production. The results show that: (1) The total ecological function value in southern Xinjiang increased from 41.22$×108 45.11×108 yuan in 2003 to 110.86×108 121.05×108 yuan in 2018, reaching its highest level of 141.02×$10 yuan in 2010; in terms of specific ecological function values, carbon sequestration and oxygen release > biodiversity conservation > soil conservation > water conservation > environmental purification; the ranking of total ecological function value from fruit and forestry production across prefectures remained fixed (except in 2003), namely Kashgar Prefecture > Aksu Prefecture > Bayingolin Mongol Autonomous Prefecture > Hotan Prefecture > Kizilsu Kirghiz Autonomous Prefecture; Kizilsu Kirghiz Autonomous Prefecture exhibited a development trend similar to that of Kashgar Prefecture, with large fluctuations and closest alignment to the overall development trend; Hotan Prefecture demonstrated stable growth with an 11.10% increase rate. (2) Due to the instability of planting scale, the total ecological function value level of fruit and forestry production in southern Xinjiang developed fluctuatingly, showing a declining trend after reaching its highest level in 2010. (3) For regions characterized by both drought and sandstorms, fruit and forestry planting demonstrates strong sustainability and more profound significance in environmental purification and water conservation. It is recommended that the government vigorously publicize the ecological benefits of fruit and forestry planting and formulate supportive policies for ecological fruit and forestry production to provide partial subsidies to growers; simultaneously, considering spatial proximity effects, all prefectures should uniformly and rationally plan the layout of fruit and forestry production.

Full Text

Abstract

Quantitative evaluation of the ecological function value of fruit plantation in arid areas can help people, especially fruit growers, to fully recognize the role and effectiveness of fruit plantation in improving the local ecological environment. This awareness encourages decision-making that considers not only economic factors but also ecological factors, thereby achieving synergistic benefits among environmental protection, fruit-based economic development, and farmer income growth. Taking the arid region of southern Xinjiang as an example, this study employs the shadow project method, afforestation cost method, opportunity cost method, and cost substitution method to measure various ecological functions provided by fruit plantation production. The results indicate: (1) The total ecological function value in southern Xinjiang increased from 41.22$\times 10^8$ yuan in 2003 to 110.86$\times 10^8$ yuan in 2018, reaching a peak of 141.02$\times 10^8$ yuan in 2010 (excluding certain y
yuan. (2) Regarding specific ecological function values, the ranking from highest to lowest is: carbon fixation and oxygen release, biodiversity protection, soil conservation, water conservation, and environmental purification. (3) The ranking of total ecological function value across prefectures remains fixed (except for 2003), from highest to lowest: Kashgar Prefecture, Aksu Prefecture, Bayingol Mongolian Autonomous Prefecture, Hotan Prefecture, and Kizilsu Kirgiz Autonomous Prefecture. Kizilsu Kirgiz Autonomous Prefecture shows similar development trends to Kashgar Prefecture, with large fluctuations that closely match the overall trend. Hotan Prefecture demonstrated stable growth at 11.10%. (4) Due to unstable planting scale, the total ecological function value of fruit plantation in southern Xinjiang fluctuated and declined after reaching its peak in 2010. (5) For regions characterized by aridity and sandstorms, fruit plantation's role in environmental purification and water conservation is particularly sustained and profound. The government should vigorously publicize the ecological benefits of fruit plantation and formulate supportive policies for ecological fruit production, including partial subsidies for growers. Meanwhile, considering spatial proximity effects, all prefectures should coordinate and rationally plan the layout of fruit plantation production.

Keywords: fruit industry; ecological function value; arid area; southern Xin-

jiang

Introduction

At the 2021 Leaders Summit on Climate, General Secretary Xi Jinping stated that "protecting the ecological environment equals protecting productivity, and improving the ecological environment equals developing productivity." He called for abandoning development models that damage or destroy the ecological environment, rejecting short-sighted practices that sacrifice the environment for temporary economic gains, and exploring synergistic approaches that protect the environment while developing the economy, creating employment, and eliminating poverty. The essence is that the ecological environment forms the foundation of sustainable economic development; short-term economic interests must not be pursued at the expense of environmental damage. Following the implementation of the rural revitalization strategy, fruit plantation scale has expanded nationwide. As an important component of agriculture, fruit plantation, like crop farming, possesses economic, social, and ecological functions. The production process not only provides products and employment but also purifies air, conserves water, and protects biodiversity. However, since the ecological services provided by fruit plantation belong to the category of public goods, their value cannot be fully measured by market prices. Consequently, growers and relevant departments tend to focus excessively on the economic value created by fruit plantation while neglecting its hidden ecological value, resulting in incomplete representation of its ecological function value. In this paper, the ecological function value of fruit plantation refers specifically to the regulation and support service values of fruit plantation ecosystems, excluding the economic value of material products (fruits, trees, etc.) and the social value of recreational, entertainment, and cultural services.

Most academic research has monetarily measured the service value of agricultural ecosystems, but the focus has primarily been on grasslands, forests, and cultivated land, with limited attention to fruit plantation—particularly scarce research on ecologically fragile arid areas. Existing studies mainly employ three methods to evaluate grassland service function value: the equivalent factor method, function value method, and model calculation method, examining specific values such as product economic value, water conservation, gas regulation, organic matter production, soil and water conservation, biodiversity protection, and eco-tourism value. Some scholars have constructed evaluation systems for forest economic, ecological, and social functions based on the "three functions" theory, using internationally mature methods like travel cost method, classification valuation method, and alternative cost method to assess specific regional forest economic function value, ecological function value (water conservation, soil and water conservation, carbon fixation and oxygen release, and air purification), and social function value (employment and income generation, landscape aesthetics). For cultivated land, research has focused on ecosystem service value measurement, ecological function value evaluation, driving factors of farmer protection behavior, and incentive policy protection. Very few studies have evaluated the ecosystem service value of economic forests in semi-humid and humid regions, and research on arid areas is particularly rare. Against the backdrop of ecological civilization transformation in the new era of rural revitalization, quantitatively assessing the ecological function value of fruit plantation in ecologically fragile arid areas holds important practical and theoretical significance for comprehensively re-understanding and redefining the status of fruit plantation and its role in climate regulation and ecological environmental protection.

Based on this context, this study takes the representative arid area of southern Xinjiang as the research object and employs methods such as the shadow project method to evaluate the ecological function value of fruit plantation production. The objectives are to help the public, especially fruit growers, understand the ecological utility of fruit plantation in the local environment, encourage them to consider ecological factors alongside economic factors in production decisions, and provide references for the government to formulate supportive policies for ecological fruit production to compensate growers—particularly when market failures occur, thereby ensuring reasonable planting scale and enabling fruit plantation to protect the ecological environment at normal or even higher levels. This is significant for achieving synergistic effects among fruit industry prosperity, stable income growth for growers, and continuous improvement of the regional ecological environment in arid areas, while also enriching research on the multi-functional value, especially ecological function value, of fruit plantation in arid regions.

1 Study Area Overview

The Tianshan Mountains divide Xinjiang into northern and southern parts. Southern Xinjiang features a typical warm temperate extreme arid desert climate, with scarce rainfall (annual precipitation 20–100 mm) and high evaporation (annual evaporation exceeding 2000 mm). The annual average temperature is 10–13°C, with annual sunshine duration of 2500–3500 hours—the longest in China. The region experiences frequent sandstorms, with over 20 days of annual sandstorm weather, more than 30 days of blowing sand, and over 100 days of floating dust, featuring intense and severe sandstorm activity. Southern Xinjiang includes Bayingol Mongolian Autonomous Prefecture (Bayingol), Kizilsu Kirgiz Autonomous Prefecture (Kizilsu), Kashgar Prefecture, Hotan Prefecture, and Aksu Prefecture (Figure 1). Xinjiang is a major fruit-producing region in China, with southern Xinjiang accounting for over 85% of the province's fruit plantation area, serving as an important characteristic fruit base. Kashgar Prefecture, located between 71°65 –79°87 E and 35°47 –40°27 N, is nationally renowned as the "Pomegranate Hometown" (Yecheng County). Aksu Prefecture, situated between 78°05 –84°12 E and 39°50 –42°68 N, is famous for its apples and walnuts, particularly the "Rock Candy Heart" apples from Aksu City. Bayingol Mongolian Autonomous Prefecture, located between 35°63 –43°60 N and 82°63 –93°75 E, has its capital Korla City as the origin of the famous "Korla Fragrant Pear" brand.

The period from 2003 to 2010 witnessed rapid expansion of fruit plantation scale in southern Xinjiang, increasing at an average annual rate of 12.97% to reach a historical peak of 64.95$ $\times 10^4 hectaresin2010, afterwhichitdeclinedslowly.From2010to2018, walnutplantingar$ hectares. Southern Xinjiang's fruit industry is a key industry supported by national science and technology. The State Forestry Administration implemented the "Southern Xinjiang Fruit Industry Development Science and Technology Support Action Plan" in 2010, which accelerated the development level of the fruit industry. Currently, fruit growers in southern Xinjiang account for 35%–50% of rural households, with fruit product sales becoming an important pathway for increasing grower income and rural economic development.

2.1 Statistical Scope

According to the definition of fruit industry in the "Encyclopedia of Chinese Agriculture: Fruit Volume"—"the cultivation industry that develops and utilizes perennial woody or herbaceous fruit trees to provide dry and fresh fruits for large-scale commercial production, as a component of agricultural production"—this paper defines fruit plantation as perennial woody fruit trees in orchard cultivation, belonging to the planting subsystem of the agricultural production system. The statistical scope includes fruits and dried fruits, excluding melons and watermelons; statistical data excludes the Xinjiang Production and Construction Corps.

2.2 Data Sources

Fruit plantation statistics and meteorological data were obtained from the "Xinjiang Statistical Yearbook," "Aksu Statistical Yearbook," "Bayingol Statistical Yearbook," "Kashgar Statistical Yearbook," "Hotan Statistical Yearbook," and "Kizilsu Statistical Yearbook." Other data primarily reference national industry standards.

2.3 Research Methods

One academic perspective holds that agricultural ecological function value includes five functional values: water conservation, soil conservation, carbon fixation and oxygen release, environmental purification, and biodiversity protection. Another perspective expands this scope to include recreational, entertainment, and cultural service values. Given that the UN Millennium Ecosystem Assessment defines cultural functions such as leisure, recreation, and entertainment of agriculture and forests as cultural functions, and the agricultural "three functions" theory categorizes these cultural functions under social functions, this paper defines the ecological function value of fruit plantation as including five functional values: soil conservation, water conservation, carbon fixation and oxygen release, environmental purification, and biodiversity protection. In the following formulas, U represents the value of each ecological function generated by fruit plantation (yuan), and A represents fruit plantation area (hectares).

2.3.1 Water Conservation

The water conservation function of fruit plantation mainly includes water quantity regulation, water quality purification, and surface runoff regulation. Due to southern Xinjiang's climate characteristics of low rainfall and high evaporation, combined with flat orchard ground, this study ignores surface runoff, focusing on water quantity regulation and water quality purification.

$$U_{\text{water conservation}} = U_{\text{water quantity regulation}} + U_{\text{water quality purification}} = 10 \times C_{\text{reservoir}} \times A \times (P-E) + K \times A \times (P-E)$$

where: P is annual precipitation (mm); E is annual evaporation (mm), typically 30%–80% of P for national forests. Given southern Xinjiang's special climate, E takes the maximum value; Creservoir is the investment cost per unit reservoir capacity (yuan · m^{-3}), adjusted according to the reporting period price index; K is water purification cost, substituted by the 2015 average water price for large and medium-sized Chinese urban residents (3.5 yuan · t^{-1}).

2.3.2 Soil Conservation

The soil conservation function of fruit plantation mainly manifests in reducing soil erosion and maintaining soil fertility. Reduced soil erosion is represented by the difference between potential and actual soil erosion amounts, calculated using the Universal Soil Loss Equation. Soil fertility maintenance value is measured based on the content of nitrogen, phosphorus, potassium, and organic matter in orchard soil.

$$U_{\text{soil conservation}} = A \times C_{\text{soil}} \times 24\% \times (M_{\text{non-forest}} - M_{\text{forest}})/\rho + A \times \sum_{i=1}^{n} (C_i \times R_i \times P_i)$$

where: Csoil is unit earthwork excavation cost (yuan · m^{-3}); Mnon-forest is average annual soil erosion modulus for non-forested land (280–630 t · hm^{-2} · yr^{-1}); Mforest is average annual soil erosion modulus for forested land (28.20 t · hm^{-2} · yr^{-1}); is forest soil bulk density (1.49 t · m^{-3}); n is the number of nutrient elements (4, including nitrogen, phosphorus, potassium, and organic matter); Ci is the content of each nutrient element in soil (N = 0.00395%, P = 0.00186%, K = 0.01404%, Corganic = 0.95900%); Ri is the conversion ratio of nutrients to urea, superphosphate, potassium chloride, and organic matter (1:0.43:0.79:1); Pi is fertilizer and organic matter price (urea: 1800 yuan · t^{-1}, superphosphate: 700 yuan · t^{-1}, potassium chloride: 2200 yuan · t^{-1}, organic matter: 320 yuan · t^{-1}).

2.3.3 Carbon Fixation and Oxygen Release

The carbon fixation and oxygen release function of fruit plantation is prominently manifested through photosynthesis and respiration of fruit trees, understory vegetation, and soil, achieving carbon sequestration and releasing oxygen to regulate the relative balance of CO_2 and O_2 in the biosphere. Its value quantifies the role of fruit plantation in this function.

$$U_{\text{carbon fixation and oxygen release}} = U_{\text{carbon fixation}} + U_{\text{oxygen release}} = C_{\text{carbon}} \times A \times B_{\text{annual}} \times R_{\text{carbon}} + A \times B_{\text{annual}} \times C_{\text{o}}$$

where: Rcarbon is carbon content in CO_2 (27.27%); Bannual is annual net productivity of fruit trees (7.76 $\text{t} \cdot \text{hm}^{-2} \cdot \text{yr}^{-1}$); Fsoil is annual carbon sequestration per unit area of orchard soil (0.2 $\text{t} \cdot \text{hm}^{-2} \cdot \text{yr}^{-1}$); Ccarbon is carbon fixation price (1200 $\text{yuan} \cdot \text{t}^{-1}$), converted to RMB according to the reporting period exchange rate; Coxygen is oxygen release price, substituted by industrial oxygen production cost (1000 $\text{yuan} \cdot \text{t}^{-1}$).

2.3.4 Environmental Purification

The environmental purification function of fruit plantation mainly includes providing negative ions, absorbing pollutants, and intercepting dust. This study quantifies the role of fruit production in absorbing sulfur dioxide, fluoride, and intercepting dust.

$$U_{\text{environmental purification}} = U_{\text{SO2}} + U_{\text{fluoride}} + U_{\text{dust interception}} = Q_{\text{SO2}} \times K_{\text{SO2}} + Q_{\text{fluoride}} \times K_{\text{fluoride}} + Q_{\text{dust interception}}$$

where: Q is pollutant absorption capacity per unit fruit plantation area ($Q\text{SO}_2$ = 152.13 $\text{kg} \cdot \text{hm}^{-2} \cdot \text{yr}^{-1}$, Qfluoride = 3.58 $\text{kg} \cdot \text{hm}^{-2} \cdot \text{yr}^{-1}$, Qdust interception = 21.655 $\text{kg} \cdot \text{hm}^{-2} \cdot \text{yr}^{-1}$); K is pollutant treatment cost ($K\text{SO}_2$ = 1200 $\text{yuan} \cdot \text{t}^{-1}$, Kfluoride = 690 $\text{yuan} \cdot \text{t}^{-1}$, Kdust interception = 150 $\text{yuan} \cdot \text{t}^{-1}$), adjusted according to the reporting period price index.

2.3.5 Biodiversity Protection

The biodiversity function of fruit plantation refers to providing habitats for species survival and reproduction. This study quantifies its role in increasing biodiversity and controlling biomass.

$$U_{\text{biodiversity protection}} = U_{\text{increasing biodiversity}} + U_{\text{controlling biomass}} = C_{\text{damage}} + C_{\text{support}} + C_{\text{prevention}}$$

where: Cdamage is biodiversity value loss caused by fruit tree logging (4000 $\text{yuan} \cdot \text{hm}^{-2}$); Csupport is public willingness to pay for biodiversity maintenance

(453 yuan · household^{-1} · yr^{-1}); Cprevention is average annual protection and treatment cost of orchard land (5.65 yuan · hm^{-2} · yr^{-1}), adjusted according to the reporting period price index.

3 Results and Analysis

Based on the above methods, this study calculated the ecological function value of fruit plantation in southern Xinjiang from 2003 to 2018, analyzing the results from three perspectives: individual ecological function scale, prefecture scale, and comprehensive scale.

3.1 Individual Ecological Function Scale

From the perspective of total ecological function value level (taking the maximum potential modulus), the ecological function value of fruit plantation in southern Xinjiang from 2003 to 2018 showed an overall trend of first rising then declining. Specifically:

2003–2010: Growth stage. Ecological function value increased from 45.11\$$\times 10^8$*yuanto*141.02$\times$\$10^8 yuan, reaching the highest level in history. The annual growth rate decreased from 27.04% to 6.42%, with other years ranging from 21.47% to 25.56%.

2010–2018: Fluctuating development with overall decline. During this period, the ecological function value level decreased from 130.98\$$\times 10^8$*yuanto*121.05$\times$\$10^8 yuan, with negative growth rates in 2011, 2014, 2015, and 2017.

When taking the minimum potential modulus, the ranking of individual ecological function values (Table 1) shows that except for 2003 when water conservation value was slightly less than soil conservation value, the ranking of all other years' ecological function values remained fixed: carbon fixation and oxygen release > biodiversity protection > soil conservation > water conservation > environmental purification. When taking the maximum potential modulus, the ranking of individual ecological function values also remained fixed and unchanged.

3.2 Prefecture Scale

The ecological function value of fruit plantation in various prefectures of southern Xinjiang (Table 2) shows that when taking the maximum potential modulus, except for 2003 when Kashgar and Aksu had basically equal ecological function values, the ranking of all other years remained fixed: Kashgar Prefecture > Aksu Prefecture > Bayingol Mongolian Autonomous Prefecture > Hotan Prefecture > Kizilsu Kirgiz Autonomous Prefecture. Among them, Kashgar Prefecture and Kizilsu Kirgiz Autonomous Prefecture show the most similar development trends, with large fluctuation amplitudes that closely match the overall development trend. Hotan Prefecture demonstrated stable growth at 11.10%. Bayingol showed development trends similar to Hotan Prefecture, reaching its maximum value of

23.40$ $\times 10^8$ yuan in 2010, with an increase of 162.06 $\times 10^8$ yuan to 43.41 $\times 10^8$ yuan from 2003 to 2010, with an averaged
yuan.

From the perspective of the proportion of ecological function value of fruit plantation in each prefecture of southern Xinjiang (taking the maximum potential modulus), compared with 2003, the proportions in Bayingol, Aksu, Kizilsu Kirgiz Autonomous Prefecture, and Hotan all decreased in 2018, while only Kashgar Prefecture's proportion increased by nearly 9.00 percentage points. Although the ranking of individual function values remained almost unchanged, the proportions of each function value showed small changes. Water conservation value increased from 4.08$ $\times 10^8$ yuan to 13.04 $\times 10^8$ yuan, an increase of 219.61 $\times 10^8$ yuan to 65.63 $\times 10^8$ yuan, an increase of 163.51 $\times 10^8$ yu
yuan, an increase of 236.59%, with its proportion decreasing from 0.91% to 1.13%.

3.3 Comprehensive Scale

From the perspective of total ecological function value, Bayingol and Hotan Prefectures show relatively similar development trends (Figure 2). Kizilsu Kirgiz Autonomous Prefecture and Kashgar Prefecture show relatively consistent development trends with similar fluctuation amplitudes, representing the two prefectures with the largest fluctuation amplitudes in southern Xinjiang (Figure 3). Compared with Kizilsu Kirgiz Autonomous Prefecture and Kashgar Prefecture, Aksu Prefecture's development trend is relatively simpler, mainly experiencing a rise-and-fall stage.

Overall (Figure 2), except for water conservation function, the rankings of other function values across prefectures remained the same and fixed annually: Kashgar Prefecture > Aksu Prefecture > Bayingol Mongolian Autonomous Prefecture > Hotan Prefecture > Kizilsu Kirgiz Autonomous Prefecture. Regarding water conservation function value, Kizilsu Kirgiz Autonomous Prefecture shows relatively stable development trends, followed by Hotan Prefecture. Before 2010, Kizilsu Kirgiz Autonomous Prefecture, Hotan Prefecture, and Bayingol had basically equal development levels, after which Bayingol's development level became much higher than the other two prefectures and showed large fluctuations. Hotan Prefecture began to be significantly higher than Kizilsu Kirgiz Autonomous Prefecture from 2005 and increased steadily. Kashgar Prefecture showed large fluctuation amplitude, increasing from 2.54$ $\times 10^8$ yuan to 10.64 $\times 10^8$ yuan, 5.68 $\times 10^8$ yuan higher than Aksu Prefecture. Aksu Prefecture's developmentle
yuan.

4 Discussion

This study revised and estimated the ecological function value per unit area of fruit plantation production, finding it slightly higher than that of forestry and cultivated land. The total ecological function value of fruit plantation production far exceeds the direct economic value brought by fruit products. However, since the statistical values do not include difficult-to-monetize values such as windbreak and sand fixation for natural disaster protection, the estimated results remain lower than actual values.

Fruit plantation production plays an important role in climate regulation and environmental protection, with even more prominent effects in arid areas. Comparing the levels of various ecological function values from 2003 to 2018, environmental purification and water conservation showed the largest growth rates and were the only functions whose proportions increased. Precipitation is an important factor affecting water conservation function value levels, while conversely, reduced local fruit plantation scale may affect precipitation in the local and neighboring prefectures in the following year. Therefore, regional governments should actively publicize the ecological benefits generated by fruit plantation, especially its sustained role and profound significance in water conservation in arid areas.

5 Conclusion

This study takes the arid region of southern Xinjiang as an example, using the shadow project method to measure the ecological function value generated by fruit plantation production from 2003 to 2018 and analyzes its dynamic development trends, reaching the following conclusions:

1) The ranking of individual ecological function value levels over the years remains fixed: carbon fixation and oxygen release > biodiversity protection > soil conservation > water conservation > environmental purification. Compared with 2003, only the proportions of water conservation and environmental purification functions increased.

2) The ranking of ecological function value levels across prefectures (except for 2003) is: Kashgar Prefecture > Aksu Prefecture > Bayingol Mongolian Autonomous Prefecture > Hotan Prefecture > Kizilsu Kirgiz Autonomous Prefecture. Among them, Kashgar Prefecture and Kizilsu Kirgiz Autonomous Prefecture show the most similar total ecological function value development trends; Kizilsu Kirgiz Autonomous Prefecture and Kashgar Prefecture show similar development trends; Aksu Prefecture mainly experienced a rise-and-fall stage; Bayingol and Hotan Prefectures show relatively similar development trends. The development trend of ecological function value levels in each prefecture is related not only to local fruit plantation scale but also to spatial geographic location, being influenced to some extent by the ecological benefits generated by neighboring prefectures' fruit plantations. Therefore, all prefecture governments should coordinate and rationally plan the layout of fruit plantation production with the goal of stabilizing fruit industry development to continuously improve the ecological environment of southern Xinjiang.

3) The ecological function value of fruit plantation in southern Xinjiang increased from 45.11\$$\times 10^8 yuanin2003toamaximumlevelof141.02\times 10^8 yuanin2010, afterwhichitfluctuate$

> $unstablefruitplantationscale, withthefruitmarketpriceindexreaching124.6in2010, ahistoricalhigh; the$
> hectares in 2014. Rapid scale expansion led to sharp production increases, while limited market sales channels caused fruit market prices to decline after 2015, resulting in increased production without increased income and prompting reductions in plantation area that affected regional ecological improvement.

Fruit plantation generates enormous ecological function value, with sustained effects on water conservation and environmental purification. The fluctuating development of ecological function value levels is influenced not only by unstable plantation scale but also by neighboring prefectures' plantations. With the goal of stabilizing fruit industry development to continuously improve the regional ecological environment, it is recommended that prefecture governments coordinate and rationally plan fruit plantation layouts, actively publicize ecological benefits through multiple channels, and formulate supportive policies for ecological fruit production to partially subsidize growers—especially during market failures—to stabilize plantation scale and ensure sustained ecological protection, promoting synergistic benefits among fruit industry prosperity, environmental protection, and grower income growth.

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