Postprint: Impacts of Shenzhen Basic Ecological Control Line Designation on Ecosystem Services Value

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Abstract

Based on land use change survey data for Shenzhen in 2002, 2005, and 2010, this study analyzes the characteristics of land use area changes in Shenzhen before and after the designation of the basic ecological control line, assesses ecosystem service values using a method based on per-unit-area value equivalent factors, and employs the difference-in-differences method to investigate the impact of the basic ecological control line policy on ecosystem service values. The results indicate that: from 2002 to 2010, land use in Shenzhen generally exhibited decreasing areas of cultivated land, orchard land, grassland, and water bodies, increasing construction land area, and a trend of initial decrease followed by increase in forest land area; the total ecosystem service value in this region decreased overall, but the rate of decrease in total value slowed after the designation of the basic ecological control line; among various land use types, forest land and water bodies constitute the primary sources of ecosystem service value in Shenzhen, and among individual ecosystem services, water source conservation generates the greatest value; the spatial extent of low ecosystem service values continuously expanded, encroaching upon high-value areas, with the most significant value reductions observed particularly in the western coastal areas, northern Bao' an, Guangming New District, northern Longhua, and southern Longgang districts; within the basic ecological control line, ecosystem service values are predominantly medium to relatively high with insignificant changes, while outside the line they are primarily low to relatively low and exhibit a continuously decreasing trend; difference-in-differences results demonstrate that the basic ecological control line policy exerts a promoting effect on the enhancement of ecosystem service values, with an improvement magnitude of approximately 1.6%.

Full Text

Preamble

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Effects of Basic Ecological Control Line Policy on Ecosystem Services Value in Shenzhen

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Abstract

Based on land use data from three periods (2002, 2005, and 2010) in Shenzhen, this study evaluates ecosystem services value (ESV) using the value equivalent factor method per unit area and investigates the effects of the basic ecological control line policy on ESV using the difference-in-differences approach. The results indicate that from 2002 to 2010, cultivated land, orchard, grassland, and water bodies decreased in area, while construction land increased. Forest land first decreased then increased, but the rate of decrease slowed after implementation of the basic ecological control line policy. Forest land and water bodies were the two main sources of ESV, with water supply generating the highest value among all services. Areas with low ESV expanded and eroded high-ESV areas. The most significant value decreases occurred in the western coastal region, northern Bao'an and Longhua districts, Guangming District, and southern Longgang District. ESV grades within control line zones were mainly medium and relatively high, while ESV outside the control line were primarily low and relatively low, showing a decreasing trend. Difference-in-differences results demonstrate that the basic ecological control line policy has a positive effect on ESV, increasing it by approximately 1.6%.

Keywords: ecological control line; land use change; ecosystem services value; difference-in-differences method; Shenzhen City

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Introduction

Ecosystem services represent the various benefits that humans obtain from ecosystems, and their valuation serves as an important foundation for environmental economic accounting and ecological compensation decision-making. In 1997, Costanza et al. published a seminal article in *Nature* on global ecosystem services valuation, sparking widespread research interest in ecosystem services. Since then, ecosystem services have rapidly become a research hotspot and frontier in geography and environmental science. Numerous studies have explored ecosystem services valuation methods, though a unified assessment system has yet to be established. Among these, Xie Gaodi et al.' s research on developing a per-unit-area ecosystem services value equivalent factor table for China' s terrestrial ecosystems has been widely adopted by scholars due to its intuitive usability and minimal data requirements.

Land use change contains substantial information about human activities and significantly impacts ecosystem services by altering ecosystem types, spatial patterns, and ecological processes. With land use/cover change (LUCC) becoming a focal point of global change research, its effects on ecosystem services have received increasing attention. The basic ecological control line, an ecological policy enacted by Shenzhen in 2005, added mandatory constraints to urban construction and development, substantially altering land use patterns and consequently affecting ecosystem services.

The difference-in-differences method, first introduced by Meyer in *Natural and Quasi-Experiments in Economics*, has been widely applied in public policy analysis and program evaluation due to its operational simplicity and clear logic. Its primary advantage lies in directly eliminating the influence of common factors before and after policy implementation, isolating the policy' s true effect. The method has been extensively used in economics and environmental science, such as in studies examining relationships between highway tolls and air pollution. To investigate the control line' s impact on Shenzhen' s ecosystem services value, this study employs land use data from 2002, 2005, and 2010, along with control line data, to analyze land use changes before and after policy implementation, estimate ecosystem services value, and explore the relationship between ecological policy and ecosystem services value. The findings aim to provide decision-making support for rational land resource allocation, ecological environmental protection, and policy adjustment and optimization in Shenzhen.

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1. Study Area Overview

Shenzhen is located on the eastern shore of the Pearl River Delta in southern coastal China (113°46 -114°37 E, 22°27 -22°52 N). Since China' s reform and opening-up, the city has transformed from an agricultural border town into a highly urbanized metropolis, experiencing dramatic landscape pattern changes. Continuous urban expansion has fragmented and encroached upon ecological

land, leading to ecological degradation. The *Shenzhen Basic Ecological Control Line Management Regulations*, enacted in 2005, became China' s first policy to incorporate ecological protection into law. The policy designated primary water source protection zones, scenic areas, nature reserves, forest land, highlands exceeding 50 m within the special economic zone and 25 m outside it, and concentrated basic farmland protection zones into the control line, ultimately covering approximately half of the city' s total area. Construction activities within the control line are strictly restricted, and existing legal buildings cannot be arbitrarily renovated or expanded.

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2. Data

This study is based on Shenzhen' s land use change survey data from 2002, 2005, and 2010. Using the Ministry of Land and Resources' land use classification system as a reference, we reclassified land use into seven categories and merged them according to research needs into: cultivated land, orchard, forest land, grassland, water bodies, construction land, and other land. Control line data were obtained from the Shenzhen Urban Planning Commission. Additional data included grain production-related socioeconomic information from Shenzhen' s 2002 and 2005 statistical yearbooks, which were used to adjust area calculations.

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3. Research Methods

3.1 Land Use Dynamics

Land use dynamics describes the quantitative changes and rates of various land use types in a region over a specific period. The calculation formula is as follows:

$$K = (Ub - Ua) / (Ua \times T)$$

Where K represents the dynamic degree of a particular land use type during the study period; Ua and Ub represent the area of a specific land use type at the beginning and end of the study period, respectively; and T represents the study period length. When T is measured in years, K represents the annual change rate of that land use type.

3.2 Ecosystem Services Value Estimation

This study calculates Shenzhen' s ecosystem services value using the value coefficient method proposed by Xie Gaodi et al., with partial adjustments to the ecosystem services value equivalent factor table based on Shenzhen' s actual conditions. The correspondences are: cultivated land to farmland, orchard taking the average of forest and grassland, forest land to forest, water bodies to water, other land to bare land, and construction land assigned a value of 0. Using the average grain yield and market price from Shenzhen' s 2002 and 2005

statistical yearbooks (5,915 kg/hm² and 2.28 ¥/kg), we determined the average grain production market value and calculated that one ecosystem services value equivalent factor equals 1/7 of this value, or 13,486.2 ¥/hm². This yields the per-unit-area ecosystem services value coefficients for different land use types in Shenzhen.

The total ecosystem services value (ESV) is calculated as:

$ESV = \Sigma(Ak \times VCk)$

Where Ak is the area of land use type k, and VCk is the ecosystem services value coefficient.

Shenzhen Per-Unit-Area Ecosystem Services Value Coefficients by Land Use Type

3.3 Difference-in-Differences Method

To analyze whether control line designation affects ecosystem services value, we compare value changes before and after designation. However, direct comparison cannot yield accurate conclusions because differences may result from numerous other factors such as natural environmental changes and socioeconomic influences, not just the policy itself. This study employs the difference-in-differences (DID) approach to construct treatment (within control line) and control (outside control line) groups.

The study area is divided into 500 m × 500 m grids. Based on each grid' s land use type areas and per-unit-area ecosystem services value coefficients, we calculate each grid' s ESV. All grids are classified into treatment and control groups before and after control line designation. Grids within the control line serve as the treatment group, while those outside serve as the control group. The year 2005 represents pre-designation, and 2010 represents post-designation. Two dummy variables measure group classification: du (treatment group = 1) and dt (post-designation = 1).

The regression equation is specified as:

f_it = + dt_it + du_it + (du_it × dt_it) + _it

Where f and represent ecosystem services value and disturbance term, respectively; i and t denote grid number and time period; and measures the control line' s effect on ecosystem services value (the policy effect).

To control for construction land area proportion, we add variable x_it (ratio of construction land area to grid area), yielding:

f_it = + dt_it + du_it + (du_it × dt_it) + x_it + _it

We focus on parameter , which indicates whether control line designation improves regional ecosystem services value. A positive suggests the policy enhances ESV, while a non-significant coefficient indicates no effect.

4. Results

4.1 Land Use Change Analysis

Overall, land use type changes from 2002 to 2010 show: cultivated land, grassland, and water bodies decreasing; construction land increasing; forest land and other land first decreasing then increasing. Specifically, construction land accounts for the largest and continuously increasing proportion. Water bodies show a decreasing trend. The post-designation decrease rates for all land types are smaller than pre-designation rates. Pre-designation, construction land was the only type with positive annual change rate, with its pre-designation increase rate far exceeding the post-designation rate, indicating construction expansion encountered significant resistance. Forest land, as primary ecological land, shows an obvious trend reversal from decrease to increase, demonstrating clear protection and restoration effects from the ecological policy.

Annual Land Use Change in Shenzhen
Annual Land Use Change Within/Outside Control Line

4.2 Ecosystem Services Value Estimation

Shenzhen' s total ecosystem services value continuously decreased from 2002 to 2010, dropping from 37.641 billion ¥ to 31.481 billion ¥ (an 11.38% decrease). By land use type, the values of cultivated land, orchard, grassland, and water bodies continuously decreased, while forest land and other land showed initial decreases followed by increases. Post-designation, ecosystem services value rebounded, but increases in forest land and other land could not compensate for losses in other types, so total value continued to decline, though at a slower rate.

Forest land and water bodies constitute the main components of total ecosystem services value, with their combined share exceeding 70%. Orchard value accounts for 14-16%, while grassland and other land contribute the smallest proportions. Although land use types show distinct differences in their contribution to total ESV, their proportional changes from 2002 to 2010 were not significant.

Both within and outside the control line, ecosystem services values continuously decreased, but values within the line remained substantially higher than those outside, with the gap widening over time. For specific land types, cultivated land, water bodies, and other land show lower values within the control line than outside, while orchard and forest land show higher values within the line, especially forest land.

Shenzhen Ecosystem Services Value (2002-2010)
ESV of Different Ecosystem Services in Shenzhen (2002-2010)

The four major service categories (provisioning, regulating, supporting, and cultural) all decreased, but the rate of decrease slowed after control line designation. The service value structure remained unchanged, though gaps between services narrowed. Ranked by value: water conservation > waste treatment > biodiversity protection > soil formation and protection > climate regulation > gas regulation > raw materials > food production > entertainment culture.

Spatially, Shenzhen' s ecosystem services value shows an overall declining trend. Pre-designation, low-value areas continuously expanded, eroding high-value areas, with the most significant decreases in the western coastal region, northern Longhua, and southern Longgang. Post-designation, the situation improved slightly. Within the control line, ESV grades are primarily medium and relatively high, with high values scattered and overall values relatively high. Outside the control line, ESV grades are mainly low and relatively low, showing a decreasing trend.

[Figure 1: see original paper] ESV in Shenzhen (2002-2010)
[Figure 2: see original paper] ESV Within Control Line
[Figure 3: see original paper] ESV Outside Control Line

4.3 Policy Effect Analysis

Using the difference-in-differences method, we construct a regression model between ecosystem services value and control line policy. The model includes 8,976 samples (500 m × 500 m grids), with each grid' s ESV as the dependent variable and construction land proportion as an independent variable.

The regression results show the final model: ESV = 0.016(du × dt) - 0.769x. The model passes F-test ($p < 0.01$) with $R^2 = 0.617$, indicating high explanatory power. The construction land proportion coefficient is negative (-0.769, $p < 0.01$), confirming its negative effect on ESV. The key coefficient (du × dt) is 0.016 ($p < 0.01$), indicating the control line policy positively affects ecosystem services value, increasing it by approximately 1.6%.

Difference-in-Differences Results

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5. Conclusions and Discussion

5.1 Conclusions

Based on land use change survey data from 2002, 2005, and 2010 in Shenzhen, this study analyzes land use changes before and after control line policy implementation, evaluates ecosystem services value using the per-unit-area value equivalent factor method, and quantitatively examines the policy's impact using difference-in-differences.

1. From 2002 to 2010, Shenzhen' s land use changes were characterized by decreasing cultivated land, grassland, and water bodies, increasing con-

struction land, and forest land that first decreased then increased. Forest land and water bodies contributed the most to ecosystem services value, with their combined value exceeding 70% of the total. Pre-designation, urbanization-driven construction land expansion encroached on ecological land, reducing total ESV. Post-designation, ecological land received policy protection and its value decline rate slowed significantly, though not enough to fully offset construction expansion losses, so total value continued decreasing.

2. Spatially, Shenzhen' s ecosystem services value showed an overall declining trend. Pre-designation, low-value areas expanded continuously, eroding high-value areas, particularly in the western coastal region, northern Longhua, and southern Longgang. Post-designation, the situation improved modestly. Within the control line, ESV grades were medium to relatively high with stable overall values; outside the line, grades were low to relatively low with a decreasing trend. The difference-in-differences analysis confirms the control line policy' s positive effect, increasing ecosystem services value by about 1.6%.

5.2 Applicability of Difference-in-Differences Method

The difference-in-differences method is a widely used policy evaluation tool in economics and public management, though rarely applied in ecological policy effect research. Since policies are difficult to quantify, qualitative descriptions often cannot exclude influences from non-policy factors. The DID method offers operational simplicity and effectively addresses challenges in policy quantification and isolation, making it increasingly popular. Shenzhen' s control line policy is a mandatory spatial ecological policy that all urban development must follow. Studying its impact on ecosystem services value falls within policy effect research, and our results confirm the method' s applicability for ecological policy evaluation.

5.3 Limitations and Future Directions

Since land use classification does not perfectly correspond to natural ecosystem types, the per-unit-area service values represent approximations. Different calculation methods may yield substantially different total ESV estimates for Shenzhen. Although we adjusted the value equivalent factor table based on Shenzhen' s actual conditions, the water conservation service value equivalent factor for water bodies appears 偏高 (high), potentially causing overestimation of water-related values. However, this study focuses on spatiotemporal ESV changes, which can eliminate impacts from different unit value assignments and objectively reflect value changes, ensuring reliable conclusions.

Our DID analysis considers only a single time period. Future research should examine longer time series to more accurately measure temporal effects of urban ecological spatial policies, assisting policymakers in timely adjustments and

providing theoretical and practical foundations for sustainable eco-city development.

References

[1] MEA (Millennium Ecosystem Assessment). *Ecosystems and Human Well-Being*. Washington DC: Island Press, 2005.
[2] [Reference details on improved ecosystem services valuation methods]
[3] Costanza R, D' Arge R, de Groot R. The value of the world' s ecosystem services and natural capital. *Ecological Economics*, 1998, 25(1): 3-15.
[4] [Reference on ecosystem services trade-offs and integration methods]
[5] Zhang B, Li WH, Xie GD. Ecosystem services research in China: Progress and perspective. *Ecological Economics*, 2010, 69(7): 1389-1395.
[6] Yu ZY, Bi H. The key problems and future direction of ecosystem services research. *Energy Procedia*, 2011, 5: 64-68.
[7] Yu ZY, Bi H. Status Quo of Research on Ecosystem Services Value in China and suggestions to future research. *Energy Procedia*, 2011, 5: 1044-1048.
[8] Jian S. Research advances and trends in ecosystem services and evaluation in China. *Procedia Environmental Sciences*, 2011, 10: 1791-1796.
[9] Xie GD, et al. Valuation of ecological assets in the Qinghai-Tibet Plateau. *Journal of Natural Resources*, 2003, 18(2): 189-196.
[10] [Reference on land use change impacts on ecosystem services]
[11] [Reference on land use change and ecosystem processes]
[12-16] [Additional references on LUCC and ecosystem services]
[17] Meyer BD. Natural and quasi-experiments in economics. *Journal of Business & Economic Statistics*, 1995, 13(2): 151-161.
[18-20] [References on DID method applications]
[21] Fu SH, Gu YZ. Highway toll and air pollution: Evidence from Chinese cities. *Journal of Environmental Economics and Management*, 2017, 83: [page numbers].
[22] [Reference on Shenzhen' s ecological degradation trends]
[23] Shenzhen Municipal Government. *Shenzhen Basic Ecological Control Line Management Regulations*. (2005-11-01) [2016-02-14]. http://www.szpl.gov.cn/main/csgh/zxgh/stkzx/index.htr
[24-26] [Methodological references]
[27] Limburg KE, O' Neill RV, Costanza R, Farber S. Complex systems and valuation. *Ecological Economics*, 2002, 41(3): 409-420.

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