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Can the "multi-plan integration" pilot policy facilitate the low-carbon transformation of land use? Evidence from empirical studies in China

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The "multi-plan integration" pilot policy (MIPP) is a crucial measure for establishing a territorial spatial planning system and promoting the sustainable use of land. This study treats the implementation of MIPP as a quasi-natural experiment, using panel data from 283 Chinese cities between 2006 and 2019 to examine the impact of MIPP on the low-carbon transformation of land use (LCTLU). The results indicate that MIPP significantly promotes LCTLU, a conclusion supported by a series of robustness analyses. In cities where MIPP was implemented, the level of land low-carbon use increased by an average of 2.87%. MIPP primarily advances LCTLU by reducing land resource misallocation and leveraging economies of scale. Compared with southern regions, large cities, and non-resource-based cities, MIPP is more effective in promoting LCTLU in northern regions, small- to medium-sized cities, and resource-based cities. Moreover, MIPP more effectively promotes LCTLU in non-smart and non-innovative cities than in smart and innovative cities.

KEYWORDS

"multi-plan integration" pilot policy, low-carbon transformation of land use, land resource misallocation, economies of scale, a quasi-natural experiment

1 Introduction

With the intensifying challenges posed by global climate change, low-carbon development has emerged as a shared and vital objective for nations worldwide. Urban areas are responsible for over 70% of global carbon emissions, according to recent statistics (Shi et al., 2018; Wang and Zhu, 2024). As the primary sources of energy consumption and carbon emissions, urban land use patterns play a pivotal role in reducing emissions and combating climate change (Liu J. et al., 2022). The concept of Low-Carbon Transformation of Land Use (LCTLU) aims to optimize land use patterns, reduce resource wastage, lower carbon emissions, and improve land use efficiency, thereby facilitating low-carbon sustainable development (Xu et al., 2022). Consequently, advancing LCTLU has become a cornerstone in achieving global low-carbon sustainability objectives. As one of the world's largest carbon emitters, China recorded total emissions of 9,899.30 million tons in 2020, representing 30.70% of global emissions, according to the BP Statistical Review of World Energy 2021 (https://www.bp.com/statisticalreview, accessed on 20 May 2024). From 2005 to 2020, China's carbon emissions increased by 4,486 million tons. Concurrently, the built-up urban area expanded significantly, growing from 1.6221 million hectares in 2000 to 5.5155 million hectares in 2017 (Gao and Wang, 2020). Between 2000 and 2015, the annual growth rate of urban construction land outpaced the annual growth rate of the urban population by a factor of 1.65 (Wu et al., 2018). Additionally, carbon emissions from land use in China increased from 5.13×10^9 tons in 2001 to 17×10^9 tons in 2019. Optimizing land use structures, as outlined in the National Land Use Planning Outline (2005–2020), contributed 27.6% toward achieving the 2020 goal of reducing carbon emissions per unit of GDP by 40%–45% compared to 2005 levels (Wu et al., 2022a). Addressing how to promote LCTLU remains a pressing challenge for sustainable land use in China.

China's spatial planning system has historically been constrained by a fragmented administrative framework, characterized by widespread overlap, decentralization, and fragmentation in the development of various local plans (Su et al., 2022). These challenges have resulted in frequent conflicts and contradictions between planning objectives and measures, as well as a lack of cohesive coordination mechanisms during implementation. Consequently, these shortcomings have led to inefficient resource allocation, land waste, and ecological degradation, posing significant threats to the achievement of LCTLU. In response to these challenges, the Chinese government has steadily advanced efforts to integrate its planning system, evolving through phases of "two-plan integration," "three-plan integration," "four-plan integration," and eventually "multi-plan integration." The overarching goal of these initiatives has been to harmonize economic development with the protection of resources and the environment (Su et al., 2022). In August 2014, four ministries—the National Development and Reform Commission, the Ministry of Land and Resources, the Ministry of Environmental Protection, and the Ministry of Housing and Urban-Rural Development—jointly issued the notice *On Launching Pilot Work on "Multi-Plan Integration" in Cities and Counties*. This designated 28 cities and counties, including Huai'an, Jiaxing, Xiamen, Ezhou, Hezhou, and Yulin, as the first batch of pilot regions. These pilots adopted a top-down approach, aiming to integrate development-oriented and regulatory planning frameworks and achieve coordinated, unified planning processes. In October 2015, the 13th Meeting of the Central Leading Group for Deepening Overall Reform endorsed Hainan Province as the first provincial pilot for "multi-plan integration" reform, consolidating economic and social development planning, urban-rural planning, and land use planning. In April 2016, the 23rd Meeting of the Central Leading Group for Deepening Overall Reform approved the *Ningxia Hui Autonomous Region Spatial Planning (Multi-Plan Integration) Pilot Program*, expanding the initiative to Ningxia. Subsequently, in October 2016, the 28th Meeting of the Central Leading Group for Deepening Overall Reform approved the *Provincial Spatial Planning Pilot Program*. This effort was further extended in January 2017, when the General Offices of the CPC Central Committee and the State Council issued a directive adding Jilin, Zhejiang, Fujian, Jiangxi, Henan, Guangxi, and Guizhou provinces to the list of provincial pilot regions, thus broadening the scope of the initiative.

The pilot initiative launched in 2014 marked both an initial attempt by the state to enhance planning coordination and a nationally coordinated local experiment in public policy. This raises several key questions: Can the "multi-plan integration" pilot policy (MIPP) drive LCTLU? What are the mechanisms underlying its influence? Does spatial heterogeneity exist in its effects? Addressing these questions not only contributes to the theoretical framework of sustainable land use and urban planning but also provides China's empirical evidence and insights to guide other regions or countries in promoting global low-carbon sustainable land use through the lens of territorial spatial planning.

The objectives of this study are as follows: (1) To assess the impact of MIPP on LCTLU; (2) To examine the mechanisms through which MIPP influences LCTLU; (3) To evaluate the heterogeneous effects of MIPP on LCTLU in terms of geographic location, levels of low-carbon land use, and city-level pilot policies. The structure of this study is arranged as follows: Chapter 2 reviews the literature related to the effects of MIPP on LCTLU; Chapter 3 develops the theoretical framework for analyzing the impact of MIPP on LCTLU; Chapter 4 details the model specification, variable selection, and data sources; Chapter 5 presents the empirical results; Chapter 6 provides a discussion of the findings; and Chapter 7 concludes the study.

2 Literature review

Industrial agglomeration significantly enhances urban land use efficiency through mechanisms such as labor market externalities, technological spillovers, and capital externalities (Zhang R. et al., 2022). The marketization of land transfers not only markedly improves local urban land use efficiency but also imposes certain inhibitory effects on the land utilization rates of spatially adjacent regions (Jiang et al., 2021). The development of the digital economy drives green technological innovation by expanding the application and approval of green invention patents, effectively curbing carbon emissions from cultivated land use (Li et al., 2023). Additionally, it strengthens the green utilization efficiency of urban land by optimizing industrial structures, advancing green technological capabilities, and attracting digital talent (Wen and Li, 2024). Under the constraints of low-carbon development, irregular urban forms exert a negative impact on urban land use efficiency, whereas compact and concentrated urban forms contribute to its improvement (Wu et al., 2022b). Urbanization, in general, negatively affects the ecological efficiency of cultivated land use (Hou et al., 2019). Within this context, population-driven urbanization significantly enhances cultivated land use efficiency, whereas land-driven urbanization has adverse effects (Feng X. et al., 2023). Furthermore, a "U-shaped" relationship exists between industrial structure optimization and urban land use efficiency (Liu et al., 2021). From the perspective of public policy, the establishment of free trade zones has been shown to significantly enhance the green utilization efficiency of urban land (Feng Y. et al., 2023). While the low-carbon city pilot policy has achieved substantial success in reducing carbon emissions, it has also imposed certain adverse effects on urban land use efficiency (Liu X. et al., 2022).

Existing studies have investigated the influence of planning policies on economic development (Su et al., 2022). For instance, using panel data from Hubei Province, one study examined the impact of territorial spatial planning on economic growth in key development areas, taking the spatial planning of the Wuhan Urban

Circle as a case study. The results demonstrated that territorial spatial planning significantly promotes economic growth in key development areas but exerts differential effects on the economic growth rates of municipal districts and counties (cities) across various administrative levels within the region (Yu and Cai, 2016). Another study, based on policy experiments in economic zones, utilized the synthetic control method to evaluate the effects of economic zone policies on the Beibu Gulf Economic Zone and the Guanzhong-Tianshui Economic Zone. This analysis considered both the regional level and the constituent cities. The findings reveal that economic zone planning has a positive overall impact on regional economic growth, though the policy effects display a degree of variability over time (Li and Li, 2019). A separate study, drawing on statistical data from 82 counties (cities and districts) in Hubei Province, analyzed the effect of territorial spatial regulation intensity on local economic development. It found that in areas with high regulation intensity, local governments have relatively limited land resources at their disposal, reducing their competitiveness in regional economic competition. This results in lower economic development levels and widens the gap with areas of lower regulation intensity (Yu and Cai, 2018). Since the introduction of MIPP, some research has explored its potential to enhance the efficiency of urban construction land use (Fang, 2017) and to promote the intensive and economical use of land through qualitative analyses and case studies (Zhan, 2017). Conversely, other studies have suggested that MIPP may face challenges in achieving its coordination objectives within the short term (Gu, 2015; Yang and Yang, 2021). Furthermore, research has also evaluated the outcomes of MIPP from the perspectives of economic impacts and urban sprawl (Li and Yue, 2021; Su et al., 2022).

Utilizing panel data from 283 Chinese cities spanning 2006 to 2019, this study systematically investigates the key factors that drive LCTLU through the lens of MIPP. The potential contributions of this research are as follows: (1) By employing a multi-period difference-in-differences (DID) model, this study evaluates whether MIPP facilitates LCTLU, thereby broadening the scope of research on factors influencing LCTLU and contributing to the literature on the economic and environmental impacts of MIPP. (2) From the perspectives of land misallocation and economic agglomeration, the study explores the internal mechanisms by which MIPP fosters LCTLU, offering theoretical insights into the specific pathways through which MIPP exerts its effects. (3) This study further conducts a heterogeneity analysis across multiple dimensions, including urban geographic location, levels of land low-carbon use, and city-level pilot policies. It systematically synthesizes the implementation experiences of MIPP, providing a robust basis for comprehensive and objective evaluations of its impacts. Moreover, it offers targeted and actionable guidance for the effective promotion and replication of the policy.

3 Theoretical analysis

3.1 The direct effects of MIPP on LCTLU

The fragmentation and decentralization inherent in China's planning system have hindered the establishment of unified coordination mechanisms across government departments, leading to redundant construction and resource inefficiencies. For example, national economic and social development plans often emphasize economic growth, while urban-rural plans focus on urban expansion. The absence of effective integration among these planning objectives has exposed land resources to risks of overexploitation or inefficient use, undermining land-use intensification efforts and constraining progress toward low-carbon development goals. Conflicts and competition among diverse planning objectives further intensify tensions between resource utilization and ecological conservation. For instance, environmental protection plans may impose strict restrictions on development to safeguard ecosystems, whereas urban development plans prioritize economic growth and infrastructure expansion. This discord often results in the encroachment of ecological reserves and agricultural land. Such inconsistencies between planning goals compromise ecosystem integrity, heighten carbon emissions during land development, and hinder the realization of LCTLU objectives. Moreover, the lack of coordination among planning efforts has contributed to disorganized urban spatial management. Insufficient alignment between urban expansion and infrastructure development plans has led to redundant construction and inefficient spatial resource utilization in some cities. Unbalanced transportation network layouts and uneven distributions of public facilities further diminish the integration and connectivity of urban functions. These issues not only escalate energy consumption and carbon emissions but also increase infrastructure development and operational costs, making the pursuit of sustainable land use objectives more challenging. MIPP is designed to integrate multiple planning systems—including national economic and social development planning, urban-rural planning, land use planning, and ecological and environmental protection planning—into a unified spatial blueprint. Its primary goal is to address the challenges posed by independent operations, conflicting objectives, and inadequate coordination among existing planning systems. By doing so, MIPP seeks to improve the efficiency of land resource allocation, enhance government capabilities in spatial management, and promote the intensive, efficient, and sustainable utilization of spaces for production, living, and ecology (Fang, 2017).

3.2 The indirect effects of MIPP on LCTLU

MIPP integrates national economic and social development planning, urban-rural planning, land use planning, and environmental protection planning into a unified spatial blueprint, effectively reducing conflicts and redundancies among various plans. This high degree of integration enhances the efficiency and rationality of urban land resource allocation, mitigating waste and inefficient land use. First, MIPP employs scientifically grounded spatial planning to limit unnecessary land development, prioritizing the protection of ecologically sensitive areas and high-yield agricultural land. This approach prevents the misallocation of critical land resources to less optimal uses. Second, through strict land use controls and well-structured urban planning, MIPP curtails unregulated urban sprawl, reducing land resource mismanagement and waste. These measures collectively enhance overall land use efficiency, providing a robust foundation for realizing LCTLU.

In terms of infrastructure construction and management, MIPP promotes unified planning and centralized development, significantly reducing redundancy and resource inefficiencies. For example, in key areas such as urban public transportation, wastewater treatment, and energy supply, centralized planning and management decrease per-unit construction costs while improving resource utilization efficiency, demonstrating economies of scale. This not only lowers resource consumption but also advances LCTLU by fostering more sustainable urban development. Furthermore, MIPP fosters the rational spatial distribution of industries and the formation of industrial clusters. By enabling the sharing of infrastructure, knowledge, and technological resources, these clusters reduce production costs and energy consumption, amplifying economies of scale. Clustered production models also allow businesses to share supply chains and market resources, reducing energy use and carbon emissions in logistics and transportation. This industrial clustering effect not only optimizes the efficiency of land resource utilization but also drives the low-carbon transformation of land use, supporting the long-term achievement of LCTLU.

4 Research design

4.1 Model specification

This study utilizes a DID model to assess the effects of MIPP on LCTLU. Based on existing literature (Xu et al., 2022), the DID model is formulated as follows:

$$LCTLU_{it} = \alpha_0 + \alpha_1 MIPP_{it} + \alpha_2 Controls_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

According to Equation 1, $LCTLU_{it}$ represents the low-carbon transformation of land use. $MIPP_{it}$ is a dummy variable for the “multi-plan integration” pilot policy. $Controls_{it}$ represents a series of control variables affecting LCTLU. λ_i and μ_t represent individual fixed effects and time-fixed effects. ε_{it} is the random error term.

4.2 Variable definitions

4.2.1 Dependent variable

Based on the methodology outlined in the existing literature (Xu et al., 2022), this study employs a non-oriented, variable returns to scale super-efficiency EBM (Epsilon-Based Measure) model to measure the low-carbon utilization efficiency of urban land, which serves as the core indicator for assessing LCTLU. The indicator system for measuring urban land low-carbon utilization efficiency is designed as follows.

In terms of input indicators, land factor input is measured by the area of urban construction land (unit: square kilometers), labor factor input is represented by the total number of employed persons at the end of the year in the city (unit: ten thousand people), and capital factor input is measured by the capital stock estimated using the perpetual inventory method with a depreciation rate of 9.6% (unit: ten thousand yuan) (Fang et al., 2022). Additionally, the total urban energy consumption (unit: ten thousand tons of standard coal) is used as the representative variable for energy factor input, with energy consumption calculated in terms of equivalent standard coal (Zhang W. et al., 2022).

For desired output indicators, the added value of the secondary and tertiary industries in the city (unit: ten thousand yuan) is selected to reflect economic benefits, the green coverage rate of the built-up areas in the city (unit: percentage) is used to indicate the improvement of the ecological environment, and the average wages of urban employees (unit: yuan) are used to reflect the level of social welfare.

For undesired output indicators, this study calculates urban carbon emissions using the bottom-up accounting method recommended in the 2006 Guidelines for National Greenhouse Gas Inventories published by the Intergovernmental Panel on Climate Change (IPCC). The specific accounting scope includes carbon emissions from direct energy consumption, such as natural gas and liquefied petroleum gas, as well as carbon emissions caused by electricity and thermal energy consumption (Chen et al., 2023; Wang et al., 2024).

4.2.2 Core explanatory variable

In this study, a dummy variable indicating whether a city is designated as a “multi-plan integration” pilot city is employed as the policy grouping variable, denoted by Treat. Pilot cities are assigned Treat = 1, while non-pilot cities are assigned Treat = 0.

A time-group dummy variable, denoted as Post, is also constructed for pilot cities. For the years prior to the implementation of the pilot policy, Post = 0, and for the year of implementation and subsequent years, Post = 1. For non-pilot cities, the Post variable consistently takes a value of 0.

The interaction term, MIPP = Post × Treat, is used to identify the implementation effects of MIPP. The regression coefficient of the MIPP variable captures the effect of MIPP on LCTLU.

4.2.3 Control variables

To more accurately assess the impact of MIPP on LCTLU, this study selects the following key control variables, all of which are significant factors influencing LCTLU and have been thoroughly validated in existing literature.

Industrial structure upgrading (INDUST) is a critical factor affecting LCTLU (Wang et al., 2023), and in this study, INDUST is measured by the proportion of the added value of the tertiary industry in GDP. Environmental regulation (ER) is also a key factor influencing LCTLU (Zhang et al., 2021), and in this study, ER is measured by the sulfur dioxide removal rate. Financial development (FINA) and openness to the outside world (OPEN) are important factors affecting LCTLU (Fu et al., 2022). This study measures FINA by the proportion of year-end loan balances to GDP and OPEN by the proportion of total import and export volume to GDP.

Additionally, referring to existing literature (Ai et al., 2024), industrial agglomeration (AGG) is measured by location entropy based on the number of manufacturing employees. Government intervention (GOV) is measured by the proportion of fiscal expenditure (excluding education and science and technology expenditures) to total fiscal expenditure, and urbanization (URB) is measured by the proportion of the urban population to the total

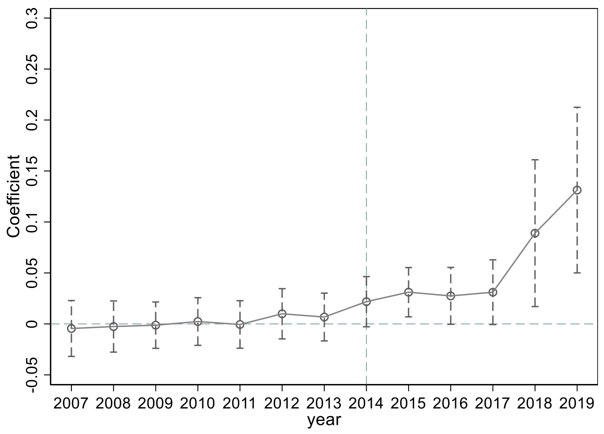

FIGURE 1
Parallel trend test results.

year-end population. AGG, GOV, and URB are all critical factors influencing LCTLU.

4.3 Sample selection and data sources

This study strictly adhered to the principles of data completeness and accuracy during the processes of sample selection and data preparation. Cities with substantial gaps in statistical data that failed to meet the study's requirements were excluded. For example, Sansha City in Hainan Province and Lhasa City in the Tibet Autonomous Region were omitted due to insufficient data availability. Moreover, two specific categories of cities were removed from the sample:

(1) Cities established relatively recently with incomplete statistical records, such as Danzhou City in Hainan Province.
(2) Cities affected by significant administrative boundary adjustments, which disrupted the continuity of statistical data, such as Chaohu City in Anhui Province.

After rigorous screening, the study retained 283 cities as the final research sample. To address missing data in specific variables for a small number of cities, linear interpolation and moving average methods were applied to supplement the data, thereby minimizing the influence of data incompleteness on empirical results.

The dataset used in this research was compiled from a variety of authoritative sources, including *China City Statistical Yearbook*, *China Urban Construction Statistical Yearbook*, *China Energy Statistical Yearbook*, *China Regional Economic Statistical Yearbook*, *China Industrial Statistical Yearbook*, the CNRDS database, and statistical yearbooks of selected prefecture-level cities. Data on "multi-plan integration" pilot cities were manually collected and organized from the official website of the People's Republic of China.

As a result, the study constructed a comprehensive panel dataset spanning 283 cities from 2006 to 2019, providing a robust and reliable foundation for subsequent empirical analysis.

5 Empirical analysis

5.1 Parallel trend test

The parallel trend test results, as illustrated in Figure 1, indicate that prior to 2014, the impact coefficients of MIPP on LCTLU were not statistically significant, confirming that the parallel trend assumption holds. Similarly, the impact coefficient in the year of MIPP implementation is not significant, which can be attributed to the inherent lag in policy effects. Policy initiatives often require a period for adjustment and adaptation, particularly in contexts involving multiple stakeholders, including local governments, enterprises, and the public. These stakeholders typically need time to align their plans and actions with the policy objectives. From 2015 onward, the impact coefficients of MIPP on LCTLU exhibit a fluctuating upward trend, peaking in 2019.

The gradual deepening and implementation of MIPP have increasingly demonstrated its effectiveness. As the policy has advanced, governments at various levels have developed a more comprehensive understanding of its objectives, leading to enhanced enforcement efforts. Notable progress has been achieved in harmonizing land use planning, urban-rural planning, and environmental protection planning, underscoring the policy's capacity to drive meaningful improvements in LCTLU.

5.2 Benchmark regression analysis

Table 1 reports the baseline regression results for the impact of MIPP on LCTLU. The results indicate that, irrespective of whether control variables are included or whether city and time fixed effects are accounted for, the coefficients of MIPP on LCTLU remain consistently and significantly positive. For instance, as shown in column (4), cities implementing MIPP experience an average 2.87% increase in low-carbon land utilization levels compared to cities without MIPP implementation. These findings suggest that MIPP plays a significant role in advancing LCTLU.

By integrating national economic and social development planning, urban-rural planning, land use planning, and environmental protection planning, MIPP resolves conflicts and inconsistencies among these plans, thereby enhancing the efficiency of land resource utilization. In contrast to traditional fragmented planning, which often results in redundant construction and resource waste, MIPP's comprehensive approach enables better coordination of diverse land uses, fostering intensive and efficient utilization. This approach reduces unnecessary land development and associated carbon emissions, contributing to the achievement of LCTLU objectives.

5.3 Robustness analysis

5.3.1 Placebo test

To eliminate the possibility that the positive effect of MIPP on LCTLU is confounded by other policies or random factors, this study conducts a placebo test based on established methodologies (Jinhua et al., 2019). The placebo test aims to verify the robustness of the policy effect by ruling out the influence of random disturbances

TABLE 1 Benchmark regression.

	(1)	(2)	(3)	(4)
MIPP	0.0981***	0.0372***	0.0302***	0.0287***
	(11.184)	(5.721)	(4.207)	(4.204)
INDUST		0.0019***		−0.0008
		(4.379)		(−1.428)
ER		0.1570***		0.0868***
		(13.291)		(6.795)
OPEN		0.0052		0.0094**
		(0.900)		(2.109)
AGG		−0.0850***		−0.0825***
		(−7.415)		(−7.477)
GOV		−0.4957***		−0.6065***
		(−7.799)		(−8.634)
URB		0.0024***		0.0009***
		(11.039)		(3.530)
FIAN		−0.0095*		−0.0212***
		(−1.676)		(−2.729)
_cons	0.6446***	0.8600***	0.6505***	1.1674***
	(218.361)	(16.980)	(395.686)	(18.300)
City-fixed effects	YES	YES	YES	YES
Year-fixed effects	NO	NO	YES	YES
N	3,962	3,962	3,962	3,962
r2	0.0242	0.7364	0.7398	0.7580
F	125.0737	160.8298	17.7019	30.2535

Note: t-values in parentheses, *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

and unobserved potential factors. By simulating pseudo-scenarios, this method effectively removes non-policy-related interferences from the model, providing robust support for the scientific validity and reliability of the study's conclusions.

Specifically, the study randomly constructs experimental and control groups based on the number of pilot cities and the timing of policy implementation, and sets pseudo-policy implementation periods. A pseudo-model is then developed using the interaction term between the pseudo-experimental group dummy variable and the pseudo-policy implementation time dummy variable. The baseline model is re-estimated 1,000 times, and the resulting MIPP impact coefficients on LCTLU are visualized as a kernel density distribution (see Figure 2). As illustrated in Figure 2, the mean of the random regression coefficients is close to zero, in stark contrast to the baseline regression coefficient of 2.87. This demonstrates that the baseline regression coefficient is not driven by random factors but reflects the genuine effect of the policy. In other words, the positive impact of MIPP on LCTLU is not significantly influenced by other policies or random disturbances. These robustness test results further confirm the reliability of the baseline regression, indicating that MIPP's significant role in enhancing LCTLU is both robust and credible. This finding provides compelling support for the scientific validity of the study's conclusions.

5.3.2 Other robustness tests

(1) Bacon Decomposition. Traditional DID models generally assume uniform treatment effects across individuals and over time, implying that policy impacts are consistent for all treated units at all time points. However, in real-world policy implementation, this homogeneity assumption is often unrealistic, as treatment effects may vary significantly based on treatment timing, individual characteristics, and different phases of policy implementation. Such heterogeneity can introduce bias into DID model estimates, thereby undermining their interpretability and scientific rigor. To address this issue, the Bacon decomposition method was introduced, which breaks down DID estimates into multiple weighted components to identify the sources of policy effects across different treatment groups and time periods. Drawing on existing research on decomposition methods for DID estimation (Baker et al., 2022), this study

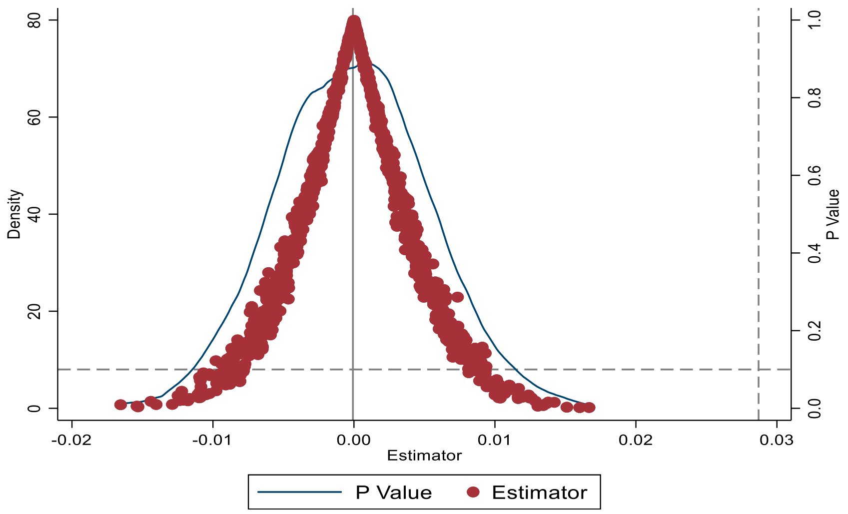

FIGURE 2
Placebo test.

TABLE 2 Bacon decomposition.

DD comparison	Weight	Avg DD Est
Earlier T vs. Later C	0.012	−0.000
Later T vs. Earlier C	0.006	−0.064
T vs. Never treated	0.983	0.031

analyzes potential biases in multi-period DID estimates under a two-way fixed effects framework. The Bacon decomposition results are displayed in Table 2. The findings reveal that the weight of the inappropriate treatment group accounts for only 1.7%, whereas the appropriate treatment group carries a weight of 98.3%. Since the weight of the inappropriate treatment group is minimal, the study's core conclusions can be regarded as highly robust.

(2) Two-stage DID Estimation. The two-stage DID estimation method represents an enhancement of the traditional two-way fixed effects model, addressing potential biases inherent in the latter. This study utilizes the Two-stage DID approach to perform a robustness analysis. The regression results presented in column (1) of Table 3 confirm that MIPP continues to have a significant positive impact on LCTLU.

(3) Alternative Measurement of the Dependent Variable. We employ the SBM model to measure LCTLU and subsequently re-estimate the baseline model. The regression results, presented in column (2) of Table 3, indicate that MIPP significantly enhances LCTLU.

(4) Excluding Other Pilot Policies. To exclude potential interference from other pilot policies affecting LCTLU, this study incorporates variables representing the Civilized City Pilot Policy (postwen), Smart City Pilot Policy (postzh), Low-Carbon City Pilot Policy (postdt), and Innovative City Pilot Policy (postcx) into the baseline regression model to validate the independent effect of MIPP. The regression results, shown in column (3) of Table 3, reveal that even after controlling for postwen, postzh, postdt, and postcx, the coefficient of MIPP remains significantly positive. These findings indicate that, even when accounting for the influence of other pilot policies, MIPP continues to have a significant positive effect on LCTLU.

(5) Propensity Score Matching (PSM) DID. To address potential systematic differences between the treatment and control groups that could bias the model results, this study adopts the PSM method. By constructing a more balanced control group within the observational dataset, the PSM approach enhances the robustness and reliability of the estimation results. In this study, the 1:1 nearest neighbor matching method is used to pair treatment and control group samples on a yearly basis, ensuring that each treatment group sample is matched with the most similar control group sample. The results of the PSM-DID analysis, shown in column (4) of Table 3, indicate that MIPP continues to have a significant positive effect on LCTLU.

(6) Excluding Special Samples. Column (5) of Table 3 reports the regression results after excluding special samples. The findings indicate that even after removing municipalities and sub-provincial cities, MIPP continues to have a significant positive effect on LCTLU.

5.4 Transmission mechanism test

To investigate the mechanisms by which MIPP facilitates LCTLU, this study draws on established literature on the specification of panel mediation effect models (Xu et al., 2022) and develops a panel mediation effect model tailored to the context of this research. The specific construction of the model is as follows:

$$M_{it} = \alpha_0 + \beta_1 MIPP_{it} + \beta_2 Controls_{it} + \lambda_i + \mu_t + \varepsilon_{it} \tag{2}$$

TABLE 3 The robustness of the empirical analysis results.

	(1)	(2)	(3)	(4)	(5)
	Two-stage DID	Alternative Measurement of the Dependent variable	Exclusion of other pilot policies	PSM-DID	Exclusion of special samples
MIPP	0.0319**	0.0187***	0.0275***	0.0277***	0.0346***
	(0.0129)	(2.868)	(4.049)	(4.070)	(4.979)
postwen			0.0427***		
			(6.973)		
postdt			0.0333***		
			(5.314)		
postcx			0.0656***		
			(8.349)		
postzh			0.0038		
			(0.679)		
Controls	YES	YES	YES	YES	YES
_cons	—	1.1634***	1.0117***	1.1288***	0.9867***
	—	(17.335)	(16.901)	(17.500)	(16.204)
N	3,962	3,962	3,962	3,949	3,696
r2	—	0.7388	0.7698	0.7597	0.7644
F	—	25.0500	36.6084	29.9569	27.7987

Note: t-values in parentheses, *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. We control for city fixed effects and year fixed effects.

TABLE 4 Conduction mechanism test results.

	(1)	(2)	(3)	(4)
MIPP	−0.0208***	0.0326***	0.0769***	0.0157**
	(−2.666)	(4.473)	(7.435)	(2.307)
Land resource misallocation		−0.0388***		
		(−3.100)		
Economies of scale				0.1688***
				(15.602)
Controls	YES	YES	YES	YES
_cons	−0.1927*	1.1172***	7.3632***	−0.0757
	(−1.833)	(17.537)	(86.362)	(−0.779)
N	3,380	3,380	3,962	3,962
r2	0.5319	0.7662	0.9914	0.7731
F	5.0549	28.4129	164.5104	61.8964

Note: t-values in parentheses, *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. We control for city fixed effects and year fixed effects.

$$LCTLU_{it} = \delta_0 + \delta_1 MIPP_{it} + \delta_2 M_{it} + \delta_3 Controls_{it} + \lambda_i + \mu_t + \varepsilon_{it} \tag{3}$$

In Equations 2, 3, M is the conduction mechanism variable, β_1 measures the effect of MIPP on M, and δ_2 measures the effect of M on LCTLU. If MIPP influences LCTLU through M, then β_1 and δ_2 should be significant. In this context, M represents land resource misallocation and economies of scale. Building on previous studies (Duan and Li, 2020; Xie et al., 2023), land resource misallocation is measured as the ratio of land transferred through agreements to the

TABLE 5 Heterogeneity of urban geographic location.

	(1)	(2)	(3)	(4)	(5)	(6)
	Southern region	Northern region	Large cities	Medium and small cities	Resource-based cities	Non-resource-based cities
MIPP	0.0086	0.0398**	0.0026	0.0578***	0.0554***	0.0105
	(1.170)	(2.230)	(0.285)	(5.730)	(4.639)	(1.279)
Controls	YES	YES	YES	YES	YES	YES
_cons	0.9721***	0.9778***	1.1891***	0.8613***	0.9145***	1.2199***
	(13.883)	(7.210)	(14.939)	(9.963)	(9.206)	(15.890)
N	2,618	1,344	1960	2002	1,596	2,366
r2	0.7915	0.7374	0.7866	0.7451	0.7108	0.7990
F	25.3682	15.3609	22.0648	20.2851	16.1856	27.2875

Note: t-values in parentheses, *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. We control for city fixed effects and year fixed effects.

total land transfer area. Following established literature (Wang et al., 2022; Xu et al., 2022), economies of scale are quantified using GDP output per unit of administrative area.

Table 4 presents the results of the mechanism analysis for MIPP's impact on LCTLU. From columns (1) and (2) of Table 4, it can be concluded that MIPP significantly reduces urban land resource misallocation, and land resource misallocation negatively affects LCTLU. This indicates that MIPP promotes LCTLU by mitigating land resource misallocation. From columns (3) and (4) of Table 4, it is evident that MIPP generates economies of scale, which positively contribute to LCTLU. This demonstrates that MIPP promotes LCTLU by fostering economies of scale.

The underlying reason is that MIPP facilitates the rational allocation of land use, ensuring that land resources are better aligned with actual demand. This helps to prevent disorderly competition and inefficient allocation of land resources, laying a foundation for achieving LCTLU. Furthermore, MIPP encourages the concentrated development of land resources, leading to the formation of economic zones or industrial clusters with scale effects. This reduces resource consumption and carbon emissions per unit of land development, contributing to the realization of LCTLU.

5.5 Heterogeneity analysis

5.5.1 Heterogeneity based on urban geographic location

Table 5 presents the results of the heterogeneity analysis by urban geographic location. Columns (1) and (2) demonstrate that MIPP is more effective in advancing LCTLU in northern regions compared to southern regions. This can be attributed to the more acute land resource and environmental challenges in northern regions, such as water scarcity and desertification, which intensify ecological fragility and resource scarcity. MIPP facilitates intensive land resource management in northern regions, mitigating the resource waste and environmental degradation associated with unregulated expansion, thereby providing stronger support for LCTLU.

TABLE 6 Heterogeneity on the degree of LCTLU.

	(1)	(2)	(3)	(4)	(5)
	15%	35%	55%	75%	95%
MIPP	0.0295***	0.0337***	0.0379***	0.0426***	0.0498***
	(2.961)	(4.663)	(5.614)	(4.575)	(3.134)
Controls	YES	YES	YES	YES	YES
N	3,962	3,962	3,962	3,962	3,962

Note: Z-values in parentheses. Others are the same as Table 3.

Columns (3) and (4) show that MIPP has a greater effect on promoting LCTLU in small- to medium-sized cities than in large cities. This is due to the relatively underdeveloped and underutilized land resources in small- to medium-sized cities, offering substantial opportunities for optimization. The systematic planning provided by MIPP offers scientific guidance, enabling these cities to prioritize low-carbon and sustainable development from the outset of their growth trajectories.

Columns (5) and (6) indicate that MIPP more effectively promotes LCTLU in resource-based cities compared to non-resource-based cities. Resource-based cities typically allocate land resources to activities such as energy development, industrial production, and urban expansion, which often result in land use conflicts and inefficiencies. By integrating diverse planning frameworks, MIPP establishes a holistic approach to land use, enhancing the overall efficiency and sustainability of land resource utilization in resource-based cities.

5.5.2 Low-carbon level of land use

Table 6 reports the heterogeneity analysis results based on the degree of land low-carbon use. Columns (1) through (5) indicate that at the 15th, 35th, 55th, 75th, and 95th percentiles of land low-carbon use, the effects of MIPP on promoting LCTLU are 0.0295, 0.0337, 0.0379, 0.0426, and 0.0498, respectively, demonstrating a steadily increasing trend.

TABLE 7 Heterogeneity on urban pilot policies.

	(3)	(4)	(5)	(6)
	Smart cities	Non-smart cities	Innovative cities	Non-innovative cities
MIPP	0.0140	0.0323***	0.0190	0.0384***
	(1.346)	(3.596)	(1.602)	(4.960)
Controls	YES	YES	YES	YES
_cons	1.0541***	1.1290***	1.1384***	0.9428***
	(6.642)	(15.637)	(6.009)	(15.126)
N	661	3,301	476	3,485
r2	0.8406	0.7777	0.8981	0.7755
F	11.3652	22.4820	4.7223	24.7710

Note: t-values in parentheses, *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. We control for city fixed effects and year fixed effects.

This can be attributed to the fact that cities with higher levels of land low-carbon use tend to have well-established low-carbon policy frameworks and extensive practical experience. The introduction and implementation of MIPP further reinforce and amplify the impacts of these pre-existing low-carbon policies. For instance, such cities may already enforce strict land use regulations, green building standards, and energy-saving and emission reduction measures. MIPP enhances the coherence and coordination of policy execution, accelerating the implementation and effectiveness of low-carbon initiatives.

5.5.3 Heterogeneity in urban pilot policies

Table 7 reports the results of the heterogeneity analysis based on urban pilot policies. Columns (1) and (2) demonstrate that, relative to smart cities, MIPP has a greater impact on promoting LCTLU in non-smart cities. This can be attributed to the fact that non-smart cities generally lack robust information infrastructure and advanced technological capabilities, relying instead on traditional and extensive land use practices. The implementation of MIPP significantly improves land use efficiency in these cities, facilitating a transition toward low-carbon and intensive land utilization.

Columns (3) and (4) reveal that MIPP is more effective in enhancing LCTLU in non-innovative cities compared to innovative cities. Non-innovative cities often lack advanced technological resources and intelligent systems, operating with conventional and inefficient land use patterns that frequently result in substantial underutilization. MIPP introduces systematic land use planning frameworks in these cities, markedly promoting intensive and rational land use practices.

6 Discussion

6.1 Result interpretation

Urban areas, as the primary engines of economic and social development, exert significant influence on carbon emissions and the ecological environment through their land use practices. With the rapid pace of urbanization, Chinese cities are confronting pressing challenges, including land resource scarcity, environmental degradation, and ecological destruction. Advancing LCTLU has therefore become a pivotal strategy for achieving sustainable urban development. One of the key barriers to LCTLU in China has been the overlapping, fragmented, and decentralized nature of local planning processes. In response, the Chinese government introduced the MIPP in 2014 and has progressively implemented it since. The primary objective of MIPP is to integrate the territorial spatial planning framework, thereby expediting the transition toward sustainable urban land use.

In contrast to prior studies that primarily examine the economic impacts of singular policies such as metropolitan area planning, urban-rural planning, or regulatory spatial planning (Yu and Cai, 2018; Li and Li, 2019), this study focuses on the effect of MIPP on LCTLU, yielding positive and conclusive findings. The results demonstrate that MIPP implementation significantly improves the low-carbon utilization of urban land. This conclusion remains robust across a series of rigorous robustness tests, indicating that MIPP's impact is both substantial and widely applicable. Diverging from the conclusions of certain studies (Gu, 2015; Yang and Yang, 2021), this research provides further evidence of MIPP's positive contributions to urban sustainable development.

MIPP plays a pivotal role in advancing LCTLU, primarily through two key mechanisms: First, MIPP optimizes urban land resource allocation, effectively mitigating issues of land resource misallocation. The traditional fragmented and overlapping planning systems have often resulted in inefficient land use, an increase in idle land, and suboptimal land utilization. By integrating national economic and social development planning, urban-rural planning, land use planning, and ecological and environmental protection planning, MIPP establishes a unified spatial planning framework. This integration minimizes conflicts between functional zones, optimizes land use allocation, and significantly enhances the intensive use of land resources, aligning with insights from related studies (Zhan, 2017). Second, MIPP fosters economies of scale by promoting industrial concentration and functional zoning. In land use, MIPP facilitates the concentrated development of high-efficiency industries and the construction of specialized functional zones, reducing resource wastage and improving land use efficiency. For example, through the development of industrial parks and the concentrated utilization of industrial land, MIPP curtails fragmented development and redundant construction. This, in turn, lowers transportation and energy consumption, effectively driving the realization of LCTLU.

This study reveals that the effects of MIPP implementation vary significantly across regions and city types, reflecting the complexity and diversity of policy outcomes in differing contexts. First, northern regions, grappling with severe environmental challenges such as water scarcity and desertification, are characterized by fragile ecosystems and limited resources. The implementation of MIPP has driven local governments to prioritize intensive land resource management and ecological conservation, thereby effectively advancing LCTLU in these areas. Second, small- to medium-sized cities have shown remarkable progress under MIPP. These cities typically exhibit lower land use efficiency, presenting considerable opportunities for optimization. MIPP provides systematic planning guidance, enabling these cities to embed low-carbon and sustainable development principles into their core objectives from the outset. This helps to circumvent the drawbacks of traditional extensive development approaches. Resource-based cities also face unique challenges due to their economic dependence on natural resource extraction and utilization. These cities often encounter land use conflicts and inefficiencies. MIPP integrates territorial spatial planning, industrial alignment, and ecological protection into a cohesive framework, reducing resource waste and environmental damage while steering resource-based cities toward low-carbon and sustainable land use practices. Furthermore, the heterogeneous effects of MIPP across city types underscore the policy's multifaceted nature and adaptability. The findings indicate that non-smart and non-innovative cities, often constrained by insufficient infrastructure and technological capacity, experience more pronounced improvements through MIPP implementation, highlighting the policy's potential to bridge developmental gaps across diverse urban contexts.

This study provides a series of insights with significant implications for other countries, particularly developing nations. The findings reveal that MIPP markedly improves the intensification and efficiency of land use by addressing land resource misallocation and fostering economies of scale. The policy's implementation not only enhances the capacity for urban low-carbon development but also offers a systematic approach to land resource management. In the global context, many countries—especially those in the developing world—are grappling with the twin challenges of rapid urbanization and escalating resource and environmental pressures. By integrating planning frameworks and optimizing resource utilization, MIPP exemplifies a replicable model for success. Countries seeking to advance territorial spatial planning and low-carbon development policies can draw valuable lessons from MIPP's experience. Building comprehensive planning systems, harmonizing cross-sectoral policy objectives, and ensuring efficient resource allocation are key strategies that can be informed by MIPP's approach. Additionally, the heterogeneous impacts of MIPP across varying city types and regions underscore its flexibility and adaptability. When implementing similar policies, nations should carefully consider their unique resource endowments, levels of economic development, and sociocultural contexts to craft policies that address local needs. Notably, for non-smart and non-innovative cities with limited access to advanced technologies and financial resources, MIPP's success highlights that low-carbon land use transformation is achievable through policy and institutional innovation, even in the absence of high-tech or capital-intensive support.

6.2 Policy recommendations

MIPP has been shown to significantly enhance LCTLU, underscoring the need to continue advancing and expanding the "multi-plan integration" reform pilots. Concurrently, dynamic monitoring platforms should be established at national, provincial, and municipal levels to enable real-time tracking and evaluation of MIPP's implementation progress, land use efficiency, carbon emission dynamics, and other key indicators. Best practices from high-performing pilot areas should be systematically summarized and disseminated to other regions. For pilot areas that do not meet policy expectations, an early warning mechanism should be implemented. Regular performance evaluation results should be published, accompanied by targeted recommendations for improvement in underperforming areas. Such areas should be granted a rectification period during which policy adjustments and resource support can facilitate improvement. If the expected objectives are still not achieved within this period, the pilot area may enter an exit procedure.

To enhance MIPP's effectiveness in mitigating land resource misallocation and fostering economies of scale, this study offers the following integrated policy recommendations: First, optimize the territorial spatial planning system by consolidating urban-rural planning, land use planning, and ecological and environmental protection planning into a cohesive spatial blueprint. This integration will minimize land use fragmentation and conflicts at their source. Establish a dynamic land use adjustment mechanism tailored to regional demands to address inefficient and idle land through targeted interventions. Additionally, delineate functional zones scientifically, based on ecological carrying capacity and resource endowments, and implement land use conflict resolution mechanisms. This approach will optimize the spatial configuration of ecological zones, industrial zones, and urban construction zones, ensuring the rational allocation of land resources. Second, to promote economies of scale, prioritize the development of industrial clusters. Establish efficient, low-carbon industrial parks to consolidate scattered industrial land, thereby achieving scale effects. Centralize the planning and deployment of green infrastructure, including urban green spaces, ecological corridors, and wetland parks, to build interconnected regional ecological networks. Furthermore, encourage the co-construction and sharing of public service facilities to reduce land wastage stemming from dispersed development and redundant infrastructure.

Furthermore, a multi-level collaboration and knowledge-sharing platform should be established to enable the exchange of experiences and resources across different regions and city types, fostering the nationwide promotion and deeper implementation of MIPP. For northern regions, small- to medium-sized cities, and resource-based cities, the implementation of MIPP should be intensified. Efforts should be tailored to local contexts to optimize land use, promote ecological restoration, and facilitate industrial restructuring, thereby tapping into the potential for low-carbon land use transformation.

6.3 Limitations and future research

This study offers critical empirical evidence on the impact of MIPP on LCTLU; however, several limitations warrant further exploration and refinement. First, the temporal scope of this study's dataset, spanning 2006–2019, may not fully capture the long-term effects of MIPP. Multi-period DID models are typically designed to evaluate policy impacts within relatively short timeframes, potentially underestimating the long-term effects of policies like MIPP, which require extended periods to influence low-carbon land use transformation. Future research should include datasets with longer time horizons to more comprehensively evaluate the policy's enduring impacts. Second, the analysis is confined to data from Chinese cities. While the findings are representative within this context, their generalizability and external validity remain to be tested. Cities in other countries and regions may face distinct challenges and opportunities when implementing similar policies due to differences in resource endowments, levels of economic development, and sociocultural factors. Future studies should explore the applicability of this policy framework in diverse international settings to validate its effectiveness and provide broader practical insights for promoting low-carbon land use and sustainable development on a global scale.

7 Conclusion

MIPP serves as a critical mechanism for establishing a territorial spatial planning system and promoting sustainable land use. Utilizing MIPP as a quasi-natural experiment, this study analyzes its impact on LCTLU using panel data from 283 Chinese cities from 2006 to 2019. The study's key findings are as follows:

1. MIPP significantly enhances LCTLU, a conclusion supported by a series of robustness analyses. Cities implementing MIPP experienced an average 2.87% improvement in low-carbon land use levels.
2. MIPP advances LCTLU primarily through mitigating land resource misallocation and fostering economies of scale.
3. MIPP demonstrates greater efficacy in promoting LCTLU in northern regions, small- to medium-sized cities, and resource-based cities compared to southern regions, large cities, and non-resource-based cities. Similarly, MIPP is more effective in non-smart and non-innovative cities than in smart and innovative cities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JQ: Conceptualization, Investigation, Software, Supervision, Project administration, Data curation, Formal Analysis, Funding acquisition, Methodology, Resources, Validation, Visualization, Writing–original draft, Writing–review and editing. XZ: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–review and editing. NX: Conceptualization, Investigation, Project administration, Software, Supervision, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. The authors declare that ChatGPT-4 was used for translation and language refinement in the preparation of this manuscript.

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