Quality or quantity of urban greenery: Which matters more to mental health? Evidence from housing prices in the Pearl River Delta

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Highlights

- The quality and quantity effects of urban greenery on mental health were compared
- Housing price and ownership were considered
- A serial moderated multiple mediating model was used with first-hand survey data collected in the Pearl River Delta (PRD)
- Quality of green spaces boosts mental health through neighborhood ties and place attachment, while quantity affects via place attachment.
- Green space quality benefits renters' mental health more than homeowners', especially when considering housing prices.

Abstract

Recent urbanization in China has highlighted the critical role of urban green space (UGS) interventions in alleviating mental health issues associated with urban environments. While existing literature broadly supports the positive effects of green spaces on psychological well-being, less attention has been given to the relative impact of UGS quality versus quantity, particularly when considering housing prices and homeownership. This study investigates the relationship between urban greenery and mental health through the mediating roles of neighborhood ties and place attachment. A random sample of 1,309 participants from 30 communities in the Pearl River Delta, China, was analyzed using structural equation modeling to explore multiple mediating and moderating effects. The findings reveal that: (1) neighborhood ties and place attachment predominantly mediate the relationship between UGS quality and mental health; (2) UGS quality has a greater influence on mental health than quantity, particularly among renters; (3) in wealthier neighborhoods, neighborhood ties attenuate the mental health benefits provided by UGS quantity, with renters experiencing more significant mental health improvements from high-quality UGS than homeowners. This study enhances our understanding of how urban greenery affects mental health, emphasizing the importance of UGS quality over quantity. Furthermore, it underscores the need to incorporate high-quality green spaces into the built environment of tenure-mixed neighborhoods to mitigate health disparities linked to housing economic status.

Keywords: mental health, urban greenery, neighborhood ties, place attachment, housing prices, home ownership

1. Introduction

As rapid urbanization continues worldwide, projections from the United Nations (UN) indicate that 55% of the world's population resides in urban areas, a proportion expected to rise to 68% by 2050 (United Nations, 2019). During this period, about one in eight people worldwide suffered from mental disorders,

as recorded in 2022 by the World Health Organization (WHO); this had doubled compared with the 2001 report (World Health Organization, 2001, 2022). And 81% of those with mental disorders live in Low- and Middle-income Countries (LMICs) (The Lancet, 2022). The increasing exposure to mental disorder risk factors arising from the urban environment has become a growing concern, owing to the challenges it may pose to social and economic stability. In the WHO's Sustainable Development Goals (SDGs), mental health refers to individual illness as well as overall well-being outcomes in physical, mental, and societal terms – often overlooked by city planners and urban governance agencies. In a narrow sense, mental health problems were typically conceptualized as short-term psychological disorders such as emotions and moods (e.g., anger, anxiety, and stress), whereas mental well-being involves long-term individual experiences (Conceição et al., 2023). In 2020, UN-Habitat published a sourcebook integrating health into urban and territorial planning, with urban green space (UGS) highlighted as a crucial factor related to mental health. Research on urban nature exposure and mental well-being is not a new area of interest, as evidenced by numerous studies that have confirmed significant correlations (Gascon et al., 2015; van den Berg et al., 2015; van den Bosch & Sang, 2017; Reyes-Riveros et al., 2021; Jimenez et al., 2021). Subsequently, recent studies have suggested that attributes related to the quality of UGS can also provide mental benefits, both directly and indirectly. The quality of UGS, such as accessibility to better quality parks (R. Zhang et al., 2022), high qualitative amenities (Wu et al., 2023), esthetic urban furniture (Aram et al., 2019), increased biodiversity (Wood et al., 2018), and functionality (Gómez et al., 2018), are likely to contribute to its attractiveness, encouraging more frequent and prolonged visits. As public spaces for informal social activities, the casual and friendly nature of UGS fosters neighbor contact and relationship preservation, thereby enhancing place attachment, particularly for residents of lower socio-economic status (Gómez et al., 2018; Maas et al., 2006a; Ybarra et al., 2008). Thus, UGS may provide social and mental health benefits for residents (Van Den Berg et al., 2016, 2017; M. M. van den Berg et al., 2019).

Nevertheless, the process of urban sprawl and population growth has posed a challenge to mental well-being inequality, given the increasing demand for high-quality public green space, particularly in dense urban areas of Global South (GS) countries (Gruebner et al., 2012; Shuvo et al., 2020; Yang et al., 2020; Cobbinah et al., 2021). During the rapid urban economic growth process, housing affordability in urban cores generally tends to be much lower than in surrounding suburbs (Goebel, 2007; Yu et al., 2020). The closer to the urban core, the lower and more fragmented the green space density, making UGS more valuable (Amponsah et al., 2022; W. Zhang et al., 2025). In the context of a commercialized and capitalized pattern of urban land tenure in China, expanding UGSs to improve residential environments might unintentionally lead to increased housing prices and living costs (Li et al., 2021a; Lin & Yi, 2011). Gaps in housing affordability shape socioeconomic disparities of different groups in accessing green spaces of higher quality, further exacerbating environmental justice concerns regarding health inequalities (Breitung, 2012; W. Y. Chen & Hu, 2015). For instance, in Sub-Saharan Africa—the fastest urbanizing area worldwide—a large population segment lives in informal peripheral settlements or slums, driven by the limited formal and affordable urban housing supply (Cobbinah et al., 2021; Berdejo-Espinola et al., 2024). These settlements or slums are often bordered by degraded and poorly maintained informal green space where risks like natural disasters and the spread of disease may arise. Such conditions may be detrimental to mental health(Gruebner et al., 2012; Shuvo et al., 2020; Cobbinah et al., 2021). In contrast to the widespread benefits of green spaces observed in the Global North (GN), a small number of studies from GS countries have implied that residents living in informal settlements or slums in the suburbs with higher green space coverage may experience lower levels of mental health well-being (Gruebner et al., 2011, 2012; Venter et al., 2022). Moreover, rising housing and living costs restrict the possibility of vulnerable groups to access green spaces that support individual health and unintentionally displace economically disadvantaged people, replacing them with wealthier residents. This reinforces social segregation and health inequalities (Schnake-Mahl et al., 2020). Such displacement might disrupt the residents' neighborhood ties and attachment to their neighborhoods,

negatively impacting mental health, especially of those without housing tenure (Baker et al., 2015; Wu F., 2015; Morris, 2018). Given the context of rising housing prices and the increasing risk of mental health inequalities, urban planners and policymakers in GS countries must be cautious when establishing and implementing greening policies to promote health and well-being. Specifically, does improving UGSs lead to invisible mental health inequities, and how can these be mitigated?

While evidence broadly supports the mental benefits of sensing, or exposing to green spaces in GN cities, the urban environment in GS cities differs from that of the North. This might limit the generalizability of such evidence to appropriate urban public health and governance policy in the South. In rapidly urbanizing cities of the GS, it is crucial to understand how urban greenery, socioeconomic factors, and environmental factors affect mental health and well-being outcomes. However, empirical research on green space and health outcomes has been conducted in only approximately 10% of the LMICs listed by the UN – far less than in the GN (Shuvo et al., 2020). The evidence of well-being from UGS in the GS, primarily in China, has been steadily increasing recently. *The White Paper on the Mental Health of China's Urban Residents in 2018* shows that over 70% of people living in urban areas have mental sub-health[1], which implies that China has suffered an increasing mental health crisis with rapid urbanization. The current study aims to contribute to the theoretical understanding of mental health-related theory and guidance on reducing inequitable mental well-being outcomes in green space planning and policy practices in China and other GS countries. First, this study contributes to the theoretical understanding of the relationship between UGS and mental health. To date, there is limited evidence available regarding the impact of the quality and quantity of UGS on mental health. Although a few studies have acknowledged the relationship between these two factors and mental health, they have not yet compared how differences in UGS quality and quantity impact mental health from a social perspective. Specifically, this study addresses this gap, focusing on neighborhood ties and place attachment through structural equation modeling (SEM). Furthermore, it examined whether there are differences in these pathways between green space quality and quantity. This contributes evidence on how socio-environmental factors mediate the association between UGS and mental health. Second, little research has specifically examined how housing affordability might influence the relationship between green space and mental health. It remains unclear how improvements to green space could mitigate the effects of housing prices and homeownership on mental health inequality, particularly in densely populated metropolitan regions of the GS. To address this, the study conducted a survey among 30 communities in the Pearl River Delta (PRD) of China – one of the most densely urbanized regions in China (C. Wei et al., 2017). This research investigated how housing prices moderate the pathways through which the quality and quantity of UGS influence mental health using a serial moderated multiple mediation model. Considering home ownership, the study further assessed whether there are different mechanisms between homeowners and renters. Overall, the findings provide valuable insights for urban designers, planners, and public housing policymakers in addressing mental health disparities during the long-term process of dense urbanization. This research also informs the implementation of balanced green space enhancement measures that consider environmental, economic, and equity aspects in UGS planning.

2. Literature review and theoretical framework

2.1. UGS and mental health

A growing body of environmental, psychological, and sociological literature has highlighted the potential impact of urban built environments on resident health. This research interest stems partly from the multiple environmental exposures that influence mental health and well-being in epidemiological and neurological contexts. Evidence has shown that the structure and function of the brain regions essential for processing emotions, social cognition, and stress in the life course of residents are influenced by the urban environment (Hagerhall et al., 2008). As van den Bosch and Meyer-Lindenberg

[1] The data comes from: https://news.cnr.cn/native/gd/20180502/t20180502_524218716.shtml.

(2019) noted, exposure to the physical environment directly affects specific brain structures, resulting in cell damage or functional changes in the central nervous system. For instance, depression—a prevalent mental health disorder—is significantly correlated with these brain structure and function modifications, and associated with detrimental urban environmental exposures, including airborne pollution, pollen, noise, and urbanization-induced stress (Moore et al., 2018; Bower et al., 2019).

UGSs are components of a "man-made environment" with natural elements, primarily used for leisure activities. Additionally, UGS provides essential ecosystem services, including parks, gardens, forests, and greenways (Swanwick et al., 2003; J. R. Wolch et al., 2014a). Evidence indicates that green spaces can significantly mitigate the negative effects of the built environment by their structural characteristics, coverage degree, and vegetation composition, thus promoting health (Niu et al., 2022; Chen et al., 2025). According to the "biophilia hypothesis," mental fatigue, stress, negative emotions, depressive mood, and anxiety can be reduced by interacting with natural spaces (Ulrich et al., 1991). For example, in Palo Alto, California, a study randomly invited residents to have a 50-minute walk in either a natural or urban environment. Natural experiences resulted in affective benefits, such as the preservation of positive affect and a reduction in anxiety, rumination, and negative affect, as compared with urban experiences (Bratman et al., 2015).

Research on the relationship between UGSs and mental health has primarily focused on the presence or quantity of green spaces rather than quality. For example, most studies have used indicators such as the normalized difference vegetation index, per capita green space area, and green exposure to relate the structure, biodiversity, and naturalness of UGSs to mental health (Reyes-Riveros et al., 2021; Chen Y. et al., 2022). However, the limited research on the quality of urban greenery suggests a potential association with mental health. Recent findings provide several measurement frameworks for evaluating the quality of green spaces, such as maintenance and cleanliness, activity, environmental quality, amenities, and safety (Akpinar, 2016a; Wei Z. et al., 2021; Zhang L. et al., 2021; Wang R. et al., 2022). Evidence shows that the quality of urban greenery benefits from reducing social inequalities that may cause health disparities (Wang Q. & Lan, 2019), providing psychological health in women postpartum (Nguyen et al., 2021), increasing the frequency of physical activity (Akpinar, 2016b), or providing other restorative effects (Hartig et al., 1991). Nevertheless, the mechanism between the quality of urban greenery and mental health was mixed. For instance, the quality of street greenery, rather than green space quality, was associated with mental health because of differences in accessibility (Dillen et al., 2012). Conflicting findings exist regarding mental health benefits when comparing the objective and perceived quality of urban greenery (Jacinta Francis et al., 2012; Kruize et al., 2020). Moreover, few studies have examined how the quality of green space affects mental health, and evidence comparing the psychological effects of quality versus quantity is lacking. Given such findings, we compared the quality and quantity of urban greenery, proposing the following hypothesis:

Hypothesis 1: The quality of green spaces impacts mental health more than quantity, with both direct and indirect effects.

2.2. Mediating mechanisms underlying the relation between urban greenery and mental health

2.2.1 Neighborhood ties

Neighborhood ties is often defined as the social embeddedness of individuals in a neighborhood (Campbell & Lee, 1992; Ross & Jang, 2000). It was considered the fundamental form in which social ties can be captured geographically (Luo, Xiaoshuang Iris, 2022). Previous research has shown that the physical environment of a neighborhood is widely associated with social health benefits among neighborhoods (Huang & Lin, 2023). (Hill & Maimon, 2013)'s mental health theory, based on neighborhood context, describes how perceptions of individual experience within a neighborhood might influence psychological dispositions, in turn influencing mental health. UGS in the neighborhood provides social support by encouraging regular visits that provide more frequent opportunities to meet new friends or neighbors. Although residents may not make contact with strangers in urban public places, they frequently establish relationships with their neighbors through informal interactions, such as brief greetings or casual conversation in gardens, parks, greenways, and other areas with grass or shrubbery in proximity to their residences (Dines et al., 2006; Dinnie et al., 2013; Dennis & James, 2016). Gardens

in neighborhoods, for example, have been shown to minimize social isolation and expand social networks (Milligan et al., 2004; Gagliardi et al., 2020). Additionally, difficult-to-access neighborhoods' green spaces (Otsuka et al., 2024) lack of services and amenities (Kawachi & Berkman, 2000), and poor safety and cleanliness (Bertram & Rehdanz, 2015) have been found to increase barriers to everyday informal interactions that help to create or maintain relations among neighbors (Peters et al., 2010).

The mechanisms linking UGS, social ties, and the mental health of individuals appear evident. Cohen & Wills (1985) emphasizes the importance of perceptive social support in buffering the effects of chronic or acute mental illness (e.g., stress) (Cohen & Wills, 1985). Numerous empirical studies have demonstrated that green spaces benefit the mental health of residents by improving social capital, cohesion, interaction, or ties in neighborhoods (House et al., 1988; Liu et al., 2019; Cohen & McKay, 2020; Wei Z. et al., 2021). The availability of open green spaces in the neighborhoods, the accessibility of parks through various transportation options, and the intention to use UGSs can positively influence the social fabric in neighborhoods, with mental benefits (Wolch J. et al., 2011a; Jennings & Bamkole, 2019).

2.2.2 Place attachment

Place attachment is defined as the emotional bond between an individual and a specific place and is characterized by a strong desire to remain connected to one's living area (Hidalgo & Hernández, 2001; Hummon, 1992). The relevant literature generally treats place attachment as a dependent variable influenced by physical and social environments. Physical environmental features, such as neighborhood park accessibility and walkability, green area size, and urban forest services, can strongly predict place attachment (Y. Zhang et al., 2015; Romolini et al., 2019). Additionally, Lewicka (2010) posited that close relationships with neighbors can predict attachment to neighborhoods, city districts, and cities. Terms related to neighborhood ties, including the number of friends and relatives (Kasarda & Janowitz, 1974), social bonding (Lai et al., 2020), social capital (Long & Perkins, 2007), civic engagement and social trust (R. Wu, Huang, et al., 2019; R. Wu, Li, et al., 2019), and neighborhood contact (Zhu et al., 2012), are commonly identified as the positive predictors of place attachment. Individuals who have stronger social connections within their neighborhood are more likely to develop a deeper attachment to their local area and the larger neighborhoods (Hipp & Perrin, 2006; Luo, Xiaoshuang Iris, 2022). However, place attachment can also be explained as an important mediating factor between the natural environment and mental restoration (Y. Zhang et al., 2015). For instance, exposure to emotional preference and meaningful UGS provides stronger health outcomes (Wilkie & Clements, 2018). Residents who attach more to the green space with better accessibility and availability tend to report better mental health (Y. Zhang et al., 2015; Kim & Miller, 2019). Given the association between place attachment and recreational activities in green spaces, residents can alleviate daily stressors by engaging with green spaces within their neighborhood (Scannell & Gifford, 2017; Li et al., 2023).

I. Kawachi (2001) established a framework about social factors and mental health, adapted from Lakey & Cohen (2000), which considers the psychological effect of affective states. A growing body of empirical work has also highlighted the potential interrelation between social ties in neighborhoods, emotional bonds to place, and UGS. The relationships between place attachment and mental benefits are partly mediated by neighborhood-based social interaction within trees and fresh air (Fried, 1982; P. E. W. van den Berg et al., 2022; McGrath et al., 2024). With more accessible and usable green spaces, an initially superficial, simple interaction may turn into a meaningful emotional connection to places, thus improving mental health (Gao et al., 2024; Zhang L. et al., 2021). UGS perception impacts individuals more on social aspects than on their physical characteristics (Huang & Lin, 2023). This indicates that neighborhood ties and place attachment have a significant and positive impact on the links between UGS and mental health. Based on this, we proposed the following hypothesis:

Hypothesis 2: Neighborhood ties and place attachment positively mediate the effects of urban greenery on mental health.

2.3. Moderators of the relationship between urban greenery and mental health

2.3.1 Housing prices

Green space improvements, such as new parks and gardens, enhance health by promoting physical activity, developing social support, and reducing stress, exposure to air pollution, and other environmental toxins during the urbanization process (Hartig et al., 2014). However, recent research has revealed that green space improvements aimed at promoting resident health and well-being in vulnerable neighborhoods in dense urban areas may accidentally trigger housing price surges (Luo et al., 2022; C. Wu et al., 2022; Y. Chen et al., 2023; J. Zhang, 2023), which could elevate the risk of residents' housing disadvantages (e.g., unaffordable housing, displacement) (Singh et al., 2019). For instance, the luxury effect of UGS has been implied to correlate with increasing maintenance and housing prices (H.-L. Zhang et al., 2022). This implies that health justice related to well-being is impinged by environmental injustice, such as reducing the options for lower social class individuals to remaining or accessing quality housing with better ecological facilities (Gibson, 2018; Na'Taki Osborne Jelks et al., 2021; Marmot & Wilkinson, 2005; Nyelele & Kroll, 2020; Kiani et al., 2023). This leads to geographically concentrated poverty perpetuation, disrupted social connections, discrimination in green spaces, a weakened sense of belonging, increased exposure to chronic stress, displaced original residents, or less attached newcomers, which together cause inequalities in mental health (J. R. Wolch et al., 2014b; H. V. S. Cole et al., 2017; Cole H. V. et al., 2019; Anguelovski et al., 2019). The rising housing prices potentially increase the consultations for mental disorders, such as depressive symptoms (Z. Feng et al., 2024). Therefore, we propose the following hypothesis:

Hypothesis 3: Housing prices act as a moderating factor in the mediated path between urban greenery and mental health.

2.3.2 Home ownership

Although most studies have found that housing prices influence mental health, such research findings are limited without accounting for home ownership. The impact of housing prices on mental health differs across different housing tenure groups. Several studies show that homeowners have better mental health than renters, influenced by emotional perception and social networks (Bentley et al., 2016; H.-Q. Wang & Liang, 2022; Thompson et al., 2024; Kosīte et al., 2025). Among economically vulnerable groups, such as renters and younger individuals, there is a distinctive correlation between unaffordable living spaces and lower mental health scores (Arundel et al., 2024). Moreover, the demand for neighborhood and urban parks has been found to differ between homeowners and renters owing to varying needs concerning neighborhood quality; this potentially reduces opportunities for cross-class interactions or stable neighborhood ties (Zeng et al., 2019; Xiao et al., 2020; Zhang L. et al., 2021).

Although there is significant evidence that housing prices play a direct role in shaping mental health and well-being, the moderating role of housing prices in urban environments has received insufficient attention. Moreover, few studies have investigated the effects of greenery on mental health from the perspectives of social interactions and place attachment when accounting for groups of renters. Consequently, we hypothesized that urban greenery is related to residential mental health through neighborhood ties and place attachment and that this relationship may vary according to the impact of housing prices and the disparity of home ownership. The hypothesis was as follows:

Hypothesis 4: The impact of urban greenery on mental health differs by home ownership, with renters benefiting more from the quality of green spaces.

The hypothesis framework used in this study is depicted in Fig. 1.

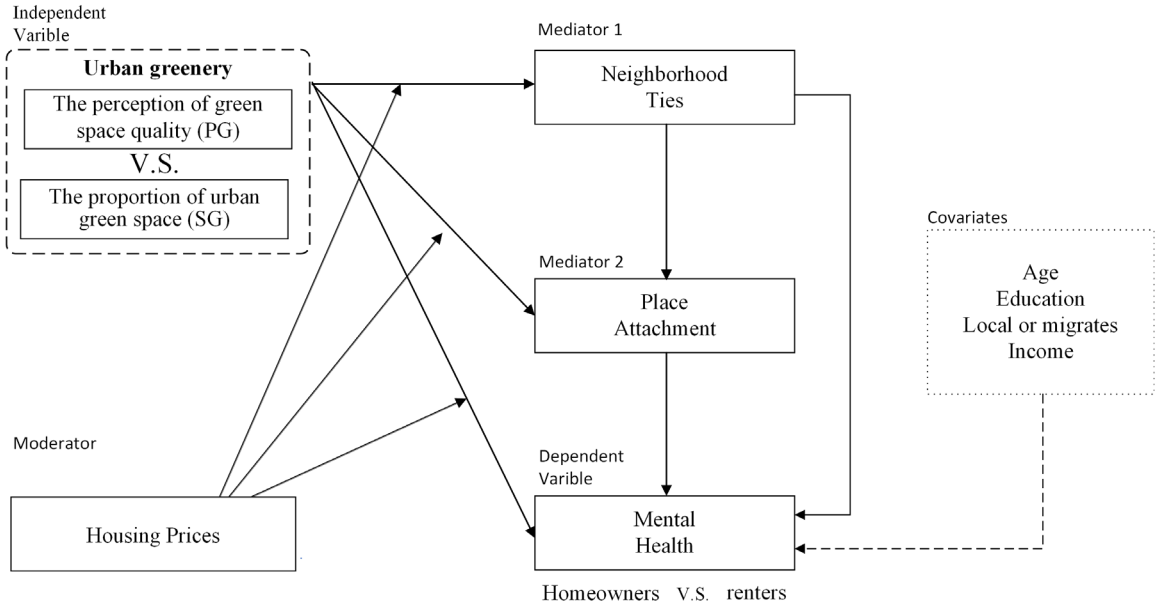

Fig. 1. The hypothesis framework

3. Materials and methods

3.1. Research area

The study area was the Pearl River Delta (PRD) in Guangdong Province, which known as China's 'South Gate' (Fig. 2). Covering 55,368.7 square kilometers, it is the largest plain area in Guangdong Province and the most populated, comprising 53.35% of its population and 79.67% of its economic activity. The PRD has developed into a prominent urban conglomeration with the second-highest GDP in China. This metropolitan region includes two cities, Guangzhou and Shenzhen, which are among the top five cities in China for GDP[11]. The socioeconomic landscape, influenced by the water system and traffic corridors, has led to the PRD being divided into three metropolitan areas: Guangzhou Metropolitan Area (GMA), Shenzhen Metropolitan Area (SMA), and Pearl River West Metropolitan Area (PRWMA). Each location has unique developmental advantages and positions, resulting in two cities with GDP exceeding three trillion yuan (approximately equal to $400 billion) and two cities with GDP over one trillion yuan (approximately equal to $100 billion), fostering close communication and a high level of economic development[2]. The PRD region has experienced a relatively rapid population growth rate over the past decade, with a significant number of individuals relocating to the core area (S. Wang et al., 2020). This provides a suitable environment for research on the mental health of its residents.

[1] The data comes from the National Bureau of Statistics of China.
[2] The data comes from the People's Government of Guangdong Province.
[3]The study was approved by the School of Architecture and Urban Planning, Guangdong University of Technology (Approval date: December, 2021)

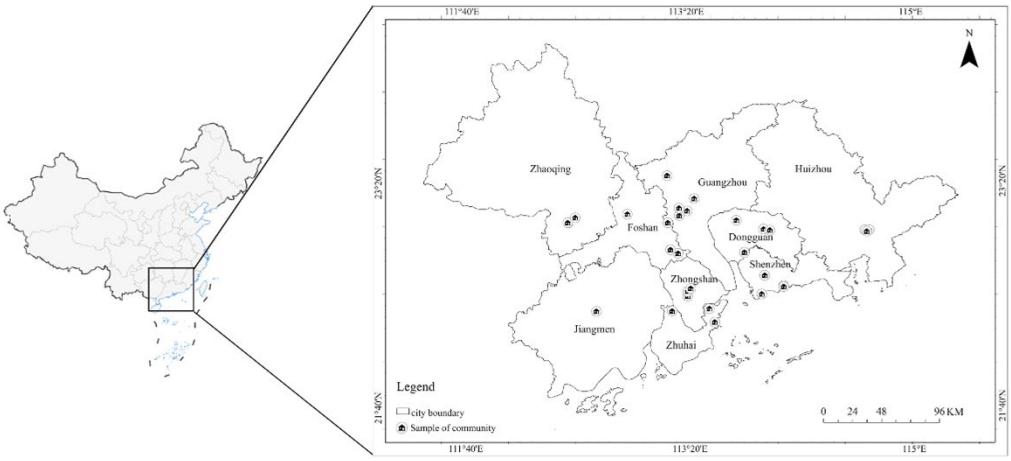

Fig. 2. The research area with the location of the sample neighborhoods
(Notes: The map is created based on the standard map with figure number GS (2019)1822)

3.2. Survey instrument

This study[3] involved a field survey among nine cities in the PRD region from January to March 2022. A stratified probability proportional to size method was employed to determine the proportion of questionnaires distributed in each metropolitan area. We first randomly select 30 neighborhoods based on the proportion of neighborhoods in the Guangzhou Metropolitan Area, the Shenzhen Metropolitan Area, and the Pearl River West Metropolitan Area, comprising 12, 11, and 7 neighborhoods, respectively. These neighborhoods had not implemented restrictions on access to public green spaces to prevent the spread of the COVID-19 epidemic before the survey was concluded. Secondly, we employed systematic sampling to randomly select 50 households based on street numbers, thereby meeting the sample size requirement for statistical analysis. Finally, we selected one family member from the selected household as a respondent using the Kish selection method (Kish, 1949). A total of 1,500 questionnaires were distributed, and 1,455 were returned, resulting in a response rate of 97%. After excluding invalid responses—defined as incomplete—the individual inconsistency and failure in bogus items were removed, and the final dataset comprised data from 1,039 respondents.

The sociodemographic traits and socioeconomic characteristics of the 1,039 participants are presented in Supplementary Table 1. Most participants were adults (94%), of whom 47% had a bachelor's degree (the majority), and 30% of their monthly income fell within the 2000–5000-yuan range (approximately $275–690). These participants are representative of the PRD, as the characteristics are highly similar to the official statistical distributions of the Seventh National Population Census.

3.3. Measures

3.3.1. Dependent variable: Mental health

Mental health was assessed using the Centre for Epidemiological Studies Depression Questionnaire (CES-D), published by the American Psychological Association and originating from Radloff (1977). The CES-D scale is a short self-report scale designed to measure depressive symptomatology (Radloff, 1977). It is an accurate and reliable indicator of measuring the general mental health conditions in urban studies (J. Chen & Chen, 2015; Koohsari et al., 2023; R. Wang et al., 2018, 2019). This questionnaire has been employed in several national large-scale tracking surveys in China, such as the China Family Panel Studies and the China Labor-force Dynamics Survey (Y. Wang et al., 2022; Nie et al., 2025). It includes 20 statements, each with five response options, rated 1–5. The CES-D summary score was used as a continuous variable, with lower values suggesting a lower prevalence of mental health issues. The Cronbach's α value for the CES-D was 0.974. Nearly half of the respondents in this survey reported moderate to below-average mental health scores.

3.3.2. Independent variable: Urban greenery

The quantity of urban greenery was calculated as the proportion of UGS within the official administrative boundary of sample neighborhoods (Data available from: https://cloudcenter.tianditu.gov.cn). The greenspace area coverage was derived from the Dynamic World real-time database launched by Google in 2021. This database is supported by Google Earth Engine and artificial intelligence platform technology and is based on 10-m resolution Sentinel-2 imagery produced using deep learning with high real-time accuracy. A higher value indicates a larger green space within the buffer of sample neighborhoods.

The perception of green space quality (PG) has been used in several studies as a quality indicator of green spaces (Delgado-Serrano et al., 2024; Liu et al., 2019; Putra et al., 2021; Ruijsbroek et al., 2017). Additionally, we employed a question to measure the general subjective quality of UGS for respondents in the sample neighborhood: "How satisfied are you with the green spaces commonly used within your neighborhood? Completely dissatisfied= 1, dissatisfied= 2, neutral= 3, satisfied= 4, very satisfied = 5'. This was regarded as a continuous variable.

3.3.3. Mediators: Neighborhood ties & place attachment

We employed a direct measurement questionnaire adapted from previous studies (Ross & Jang, 2000b; Liu et al., 2017; E. S. Kim & Kawachi, 2017; Xiao et al., 2020b). After factor analysis extraction, the following question with five items and related responses was used to measure neighborhood ties: "How did you feel during the past week, including today? (1) If there is a quarrel in the neighborhood, you are willing to deal with it and come together with neighbors. (2) It's a united neighborhood. (3) You and the neighbors are willing to help each other. (4) You can trust the other neighbors to assist with family matters in emergency situations (such as picking up a package, caring for pets or children, and providing help during medical emergencies). (5) You and other residents who know each other in the neighborhood generally get along well." Respondents were asked to choose the degree of each of the above statements, with always (every day) = 1, most of the time (5–6 days) = 2, occasionally (3–4 days) = 3, a few times (1–2 days) = 4, almost never (less than 1 day) = 5." Higher scores represent a higher level of mental health of residents. Approximately 65 % of the respondents in this survey reported below-average scores for neighborhood ties, indicating a deficit in social engagement within their neighborhoods.

Place attachment at the neighborhood level was measured using eight items adapted from previous studies (Lewicka, 2005; Jorgensen & Stedman, 2006; Lewicka, 2010; Wu et al., 2019; Wu et al., 2019b; Wu et al., 2019a). The place attachment instrument consists of the following items: "(1) I feel like I belong to where I live. (2) I'm so much attached to where I live. (3) I love my neighborhood. (4) I'm concerned about what the newspapers and TV are saying about our neighborhood. (5) Being part of a neighborhood is important to me. (6) I would like to live in this neighborhood for a long time. (7) I can't bear to move out of this neighborhood. (8) My neighbors mean a lot to me." Respondents were asked to rate the degree to which they agreed or disagreed with each of the above statements using a five-point Likert scale, where 1 represented "Completely disagree" and 5 indicated "Completely agree." Higher scores mean a higher level of place attachment to the neighborhood. 76% of participants reported high scores for place attachment. To assess the reliability of internal consistency, as well as the convergent and discriminant validity of the constructs in questionnaires, we conducted a reliability analysis and convergent validity analysis using SPSS 27.0. As presented in Supplementary Table 1, the scales of neighborhood ties, place attachment, and mental health have acceptable internal consistency, reliability, and convergent validity.

3.3.4. Moderators: Housing prices & home ownership

Housing prices were calculated as the average of the housing prices of all compounds within the neighborhood. The data were collected from the Anjuke website (https://www.anjuke.com/), which provides information on established and new development compounds in 2021, and were matched with spatial location information using the API provided by AutoNavi Map. Home ownership was derived from the following question in the questionnaire: "Do you own the real estate ownership certificate for

the house in which you currently live?"

3.3.5. Socio-economic factors

As shown in Supplementary Table 2**,** there is considerable variation depending on factors such as home ownership, age, household registration (*Hukou* in Mandarin), location, and monthly income. Immigrants (9%) were more likely to rent than native inhabitants (55%). Renters (15%) had a lower monthly income, while those with a higher income (50%) tended to own a home. Therefore, we analyzed the discrepant characteristics mentioned above concerning homeowners and renters in a sample of 1,039 individuals, using an independent-sample t-test. Homeowners and renters exhibit distinct characteristics, as determined by two independent sample t-tests (Supplementary Figure 1).

3.4. Methods

3.4.1. LISA analysis

To investigate the spatial dependency between the quantity of UGS and housing prices, we employed a bivariate spatial correlation analysis using Geoda. In this study, global bivariate Moran's I was employed to investigate whether spatial correlations existed between the quantity of UGS and housing prices across the entire PRD region, while local bivariate Moran's I identified spatial correlations within different neighborhood units (Anselin et al., 2009).

3.4.2. Mediated-moderated analysis

SEM is suitable for estimating mediating and moderating effects, which cannot be effectively captured by standard regression models (Barbara M. Byrne, 2013). In this study, we employed a serial moderated multiple mediation model as presented by Hayes (2015). The models were implemented in Mplus 8.3, to examine the hypothesized path (Fig. 1). The interval indirect effect in this study was analyzed using the bias-corrected confidence intervals bootstrap test because of its broader applicability and greater power to test data that are not normally distributed (Shrout & Bolger, 2002). Because the normal distribution of the total indirect effect is rare in finite samples (Preacher & Hayes, 2008a). Shrout & Bolger (2002) suggested that bootstrapping methods can be extended to address this problem. The bootstrap method involves repeated sampling with replacement to ensure that each sample has an equal chance of being selected. The bootstrap test is superior to the Sobel test because of its higher efficacy and lower error rate (MacKinnon et al., 2004; Fritz & MacKinnon, 2007). This method determines significance by testing whether the confidence interval (CI) contains zero and whether the coefficient product passes the bootstrap test to establish the presence of mediation effects (Hayes, 2015). Therefore, this study did not report whether the mediating effect was complete; however, it accounted for the mediating effect percentage to discuss the magnitude of the impact of the mediating factor on the relationship between the dependent and independent variables. In the bootstrap test, the model in this study was sampled 5,000 times, reporting the 95% CI.

4. Results

4.1 Spatial pattern between housing prices and UGS

As shown in Fig. 3, the map reflects the spatial disparity of green space cover and housing prices in the PRD region. An inverted U-shaped trend is observed in green space coverage from the inner to the outer urban core areas, with an overall increasing trend toward the outer regions of the PRD. Higher housing prices are primarily concentrated in the cores of prime cities, such as Guangzhou, Shenzhen, and Zhuhai, within metropolitan areas. This spatial distribution pattern is consistent with the cluster results of spatial correlation shown in Fig. 4. The Global Bivariate Moran's I highlights a significant negative correlation between housing prices and green space (Moran's $I = -0.371$, $p < 0.001$). In Fig. 4, the "L–H" clusters were mainly concentrated in and around the urban core areas of Guangzhou and

Foshan in GMA and Shenzhen in SMA, while the “H–H” clusters were decentralized near the outside in these areas. The "L–L" cluster was partially concentrated in and around the urban core areas of sub-prime cities such as Zhaoqing, Huizhou, Jiangmen, and Zhongshan. Meanwhile, the “H–L” cluster was distributed throughout the western and eastern outer areas of PRD. These patterns suggest that higher housing prices are more frequently associated with a lower provision of UGS in proximity to dense metropolitan areas. Conversely, in inner regions outside the urban core, low UGS coverage is accompanied by lower prices on the urban fringe.

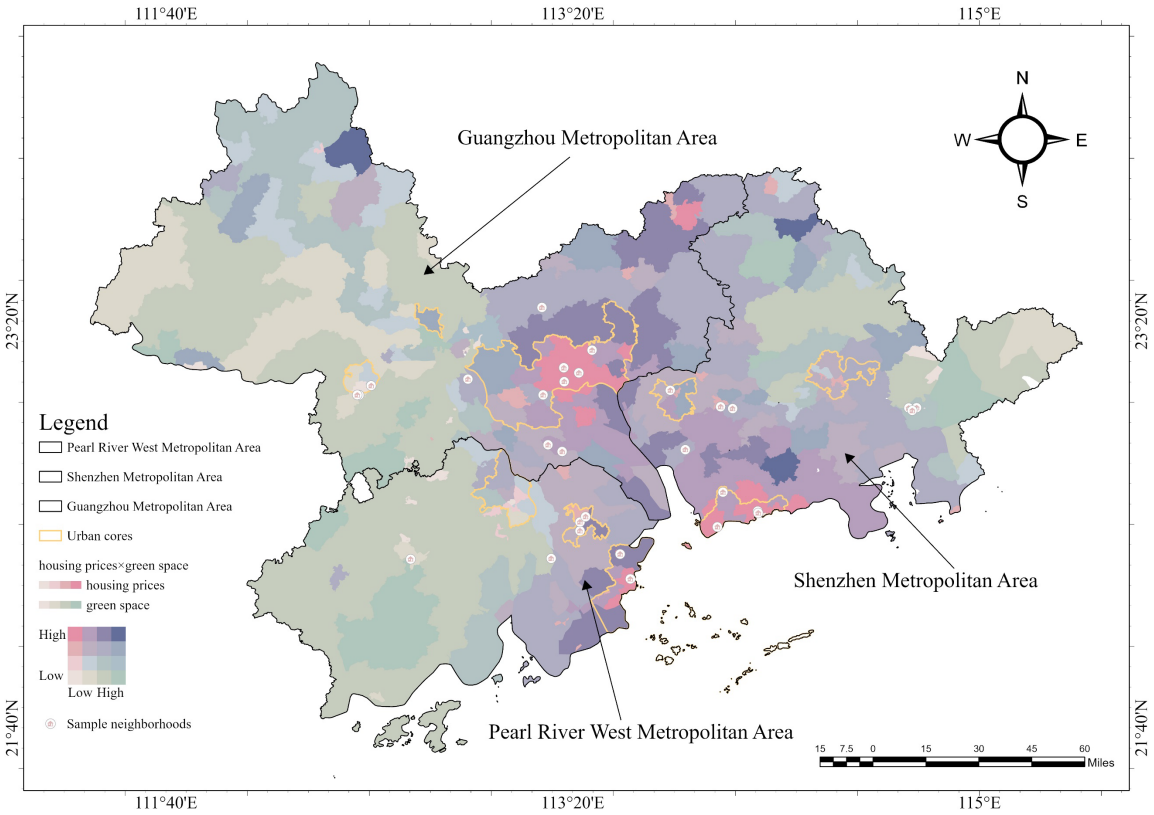

Fig. 3. Spatial distribution of green space coverage and housing prices in PRD

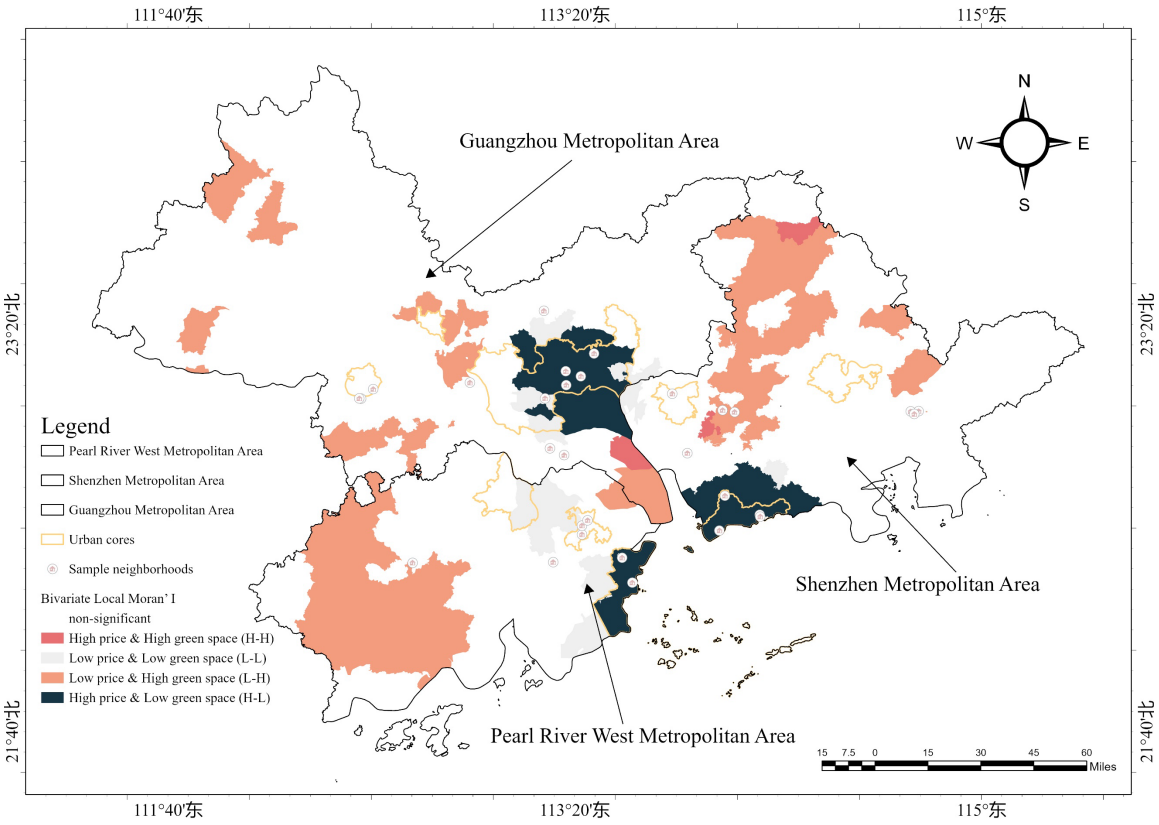

Fig. 4. Spatial correlation of housing prices and green space coverage

4.2. Hypotheses analysis

4.2.1. Association between urban greenery and mental health

After examining the modification indices, it can be inferred that all the analysis models in this research fit the data well, as indicated by the goodness-of-fit metrics presented in Supplementary Table 3. The models had an excellent goodness of fit. Supplementary Figure 2 shows the significant correlations. The perception of green space quality (PG) was significantly and positively related to neighborhood ties, place attachment, and mental health. The proportion of UGS was positively related to place attachment and mental health. Mental health was also significantly associated with age, hukou status (local resident or immigrant), and monthly income. Model 1 and Model 3 in Table 1 show the direct relationship between the quality and quantity of urban greenery and mental health. As control variables, we included age, education, hukou, and income (Table 1). In Models 1 and 3, age was positively associated with mental health (Coeff. = 0.135, $P < 0.001$; Coeff. = 0.139, $P < 0.001$), while migrants tended to exhibit better mental health compared to homeowners (Coeff. = -0.058, $P < 0.1$). The results show that the quality and quantity of urban greenery have significant direct effects on mental health, after controlling for these variables. The standardized path coefficient of the PG to mental health was 0.144 ($P<0.001$), and the SG was 0.118 ($P<0.001$). There was a positive direct relationship between PG and neighborhood ties (Coeff. = 0.396, $P < 0.001$) and place attachment (Coeff. = 0.152, $P < 0.001$). However, the SG was directly related positively to place attachment (Coeff. = 0.068, $P < 0.001$) and mental health (Coeff. = 0.118, $P < 0.001$). Furthermore, there were significant positive direct effects between mental health, place attachment, and neighborhood ties (Fig. 5). Consequently, urban greenery quality had a greater

influence on mental health than its quantity.

4.2.2. The mediation effect of neighborhood ties and place attachment

To examine the mediation effects, we investigated significant interrelationships using maximum likelihood with 5,000 bootstrap samples at 95% bias-corrected confidence intervals (Taylor et al., 2008). Following the suggestion of Preacher and Hayes (2008), we examined the significance of the indirect effects by calculated confidence intervals (CIs) for both lower and upper bounds. Mediated effects were observed between urban greenery and mental health (Table 2). The total model results explained 41.77% of the PG mediation on mental health. Specifically, the bootstrap test results confirmed a positive and significant mediating impact of neighborhood ties on PG and mental health (Coeff. = 0.073, P < 0.001). Simultaneously, the positive mediating effects of place attachment and its combined impact on neighborhood ties were also significant at the 95% CI. With the mediating role of place attachment, the positive effect of PG on mental health increased by 0.016. The direct significant associations between neighborhood ties and place attachment contributed to the conjoined effects. The presence of co-effects increased mental health by 0.017 points in the association between PG and mental health. In addition, there was an approximately 88.55% probability that SG could directly improve mental health. However, there was only a 6% indirect effect, indicating that SG could improve mental health by enhancing place attachment, with a 95% CI. Therefore, hypothesis 1 and 2 were supported.

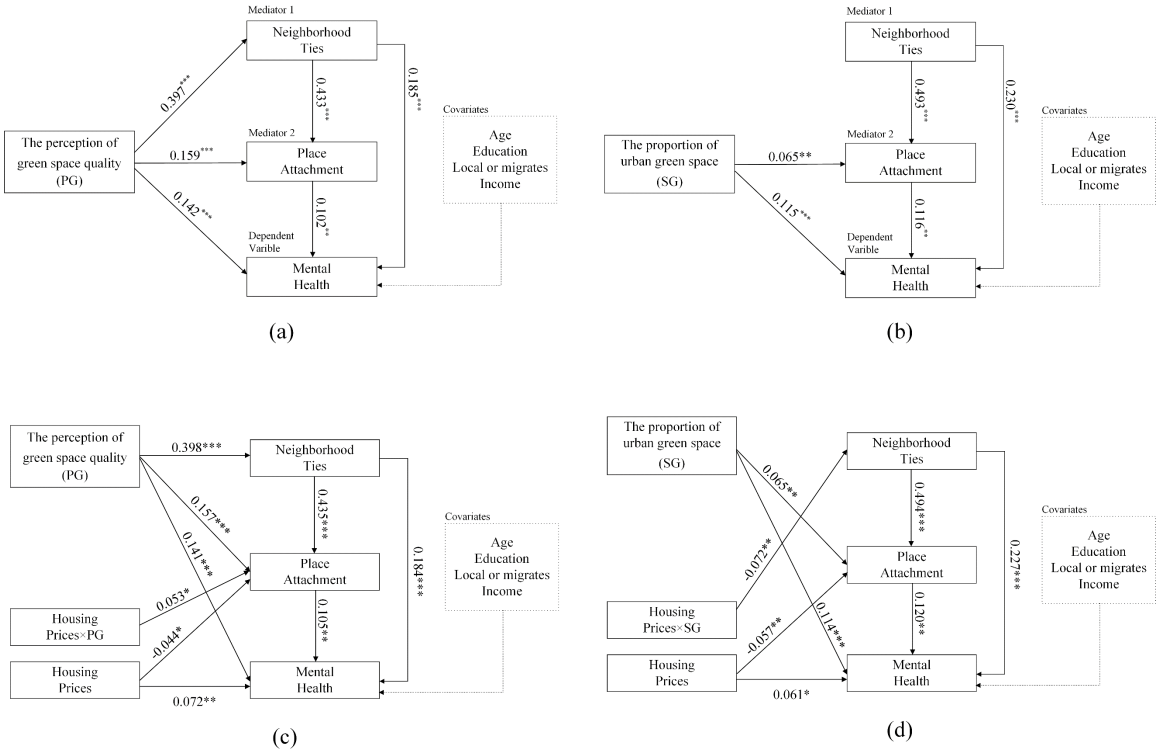

Fig. 5. Results of the serial multiple model

Notes: *p < 0.10, **p < 0.05, ***p <0.01; (a) and (b) results with mediators; (c) and (d) results with mediators and moderator.

4.2.3. The moderating effect of housing prices

Supplementary Figure 2 shows the significant correlations between housing prices and other variables. Higher housing prices were positively correlated with larger green spaces in the neighborhoods and higher levels of mental well-being. To examine the moderating effect of housing prices on urban greenery and mental health, we first considered a potential moderating effect that did

not include the mediating factors (Fig. 5). After taking housing prices into account, Models 5 and 7 (in Table 3 and Table 4) have shown that higher housing prices were negatively related to place attachment (Coeff. =-0.044, P=0.070<0.10; Coeff. = -0.087, P=0.031<0.10) while the interaction term of PG and housing price was positively correlated with place attachment (Coeff. =0.053, P=0.057<0.10). Additionally, the interaction term between SG and housing price was associated with a 0.072-point reduction in neighborhood ties, while housing prices had a nonsignificant relation to neighborhood ties. Although housing price was positively associated with a rise of mental health, with coefficients of 0.072 (P=0.017<0.05) in Model 5 and 0.061(P=0.061<0.10) in Model 7, the interaction terms of urban greenery and housing prices were not significantly related with mental health; thus, housing prices did not moderate the direct correlation between urban greenery and mental health. We then constructed a moderated mediation model (Table 5) and examined whether there was a potential moderator-mediating effect between urban greenery and mental health using the bootstrap method. After controlling for covariates, housing prices only negatively moderated the mediation of neighborhood ties between SG and mental health at the 0.05% level (Coeff. = -0.007, P=0.048 < 0.05) and within the 95% CI (-0.01, -0.001). Thus, hypothesis 3 was supported.

4.2.4. Mental health: Homeowners vs. renters

Supplementary Figure 1 illustrates significant differences in housing prices, monthly income, neighborhood ties, place attachment, and mental health between homeowners and renters. The medians for these variables were lower for renters than for homeowners, excluding housing prices. Most renters had lower incomes but lived in neighborhoods with higher prices than homeowners. Thus, different potential mechanisms need to be considered for improving mental health among homeowners and renters, especially in the context of fluctuating housing prices. Models 2 and 4 in Table 1 and Fig. 6 present compelling evidence that the difference between renters and homeowners can be explained mainly in terms of the association between PG and mental health, regardless of the moderating effect of housing prices. A comparison between Models 2 and 4 (Table 2) shows that the total indirect effect between PG and mental health in renters (56.36%) was larger than that in homeowners (35.60%), particularly regarding the significant positive mediating effect of neighborhood ties (Renters: Coeff. =0.104 > house buyer: Coeff. =0.053). Specifically, the serial mediating effects of neighborhood ties and place attachment were significantly positive on the links between PG and the renter's mental health at the 95% CI (Coeff. = 0.020). However, SG has a non-significant impact on mental health through neither neighborhood ties nor place attachment at the 95% CI.

The moderated-mediation results between the groups, considering housing prices, are presented in Fig. 7. As shown in Models 6 and 8 (Table 3 and Table 4), the interaction term of PG and housing price positively moderate the direct effect of PG on place attachment (Coeff. =0.109, P=0.009<0.01) and mental health (Coeff. =0.067, P=0.047<0.05) in renters but weaken the positive effect of PG on neighborhood ties in homeowners (Coeff. =-0.114, P=0.009<0.01). Specifically, as shown in Table 5, housing prices only negatively moderate the relationship between PG and mental health (Coeff. = -0.011, P=0.110), weakening the PG benefits on neighborhood ties in the homeowner group at the 95% CI (-0.032, -0.002). Despite housing prices being significantly positively related to renter mental health (Coeff. =0.094, P=0.028<0.05), the housing price has a non-significant moderating effect on the mediated path between PG and renter mental health. The moderated effect of housing price on the mediated path between SG and mental health was also non-significant. Overall, hypothesis 4 was supported.

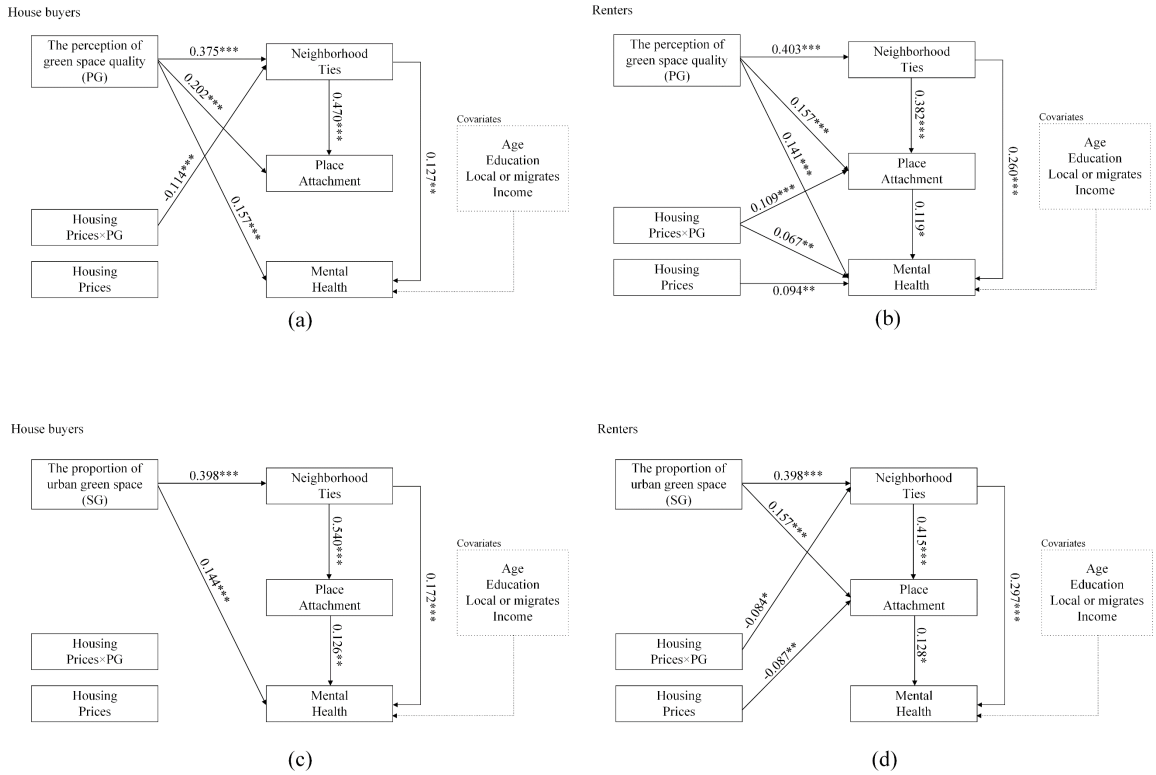

Fig. 6. Results of the serial multiple mediation model (homeowners vs. renters)
Notes: *p < 0.10, **p < 0.05, ***p <0.01.

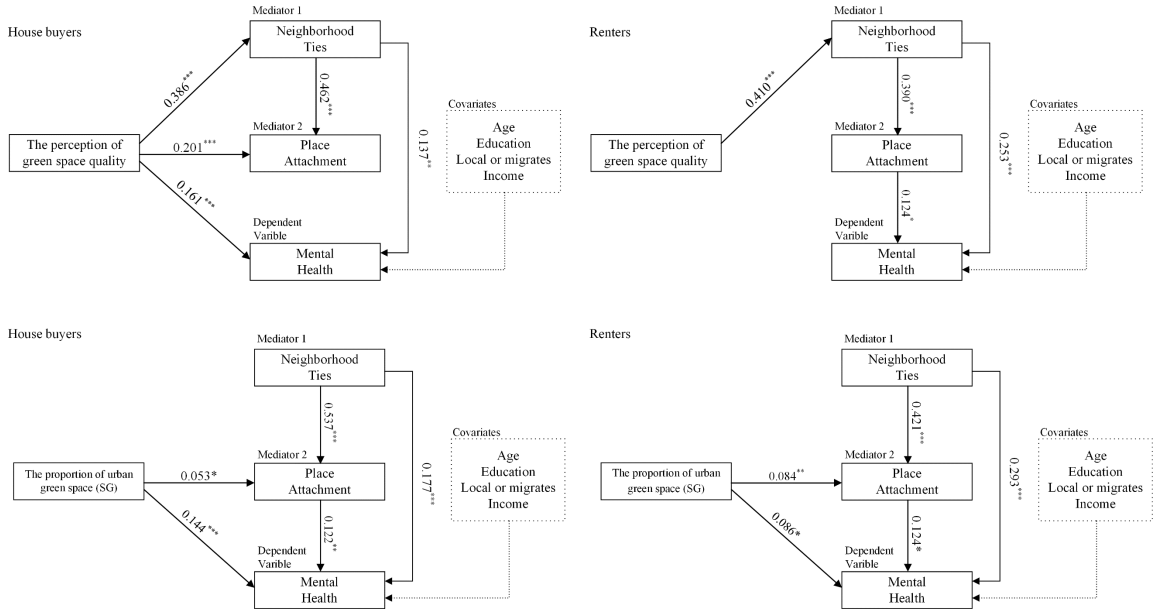

Fig. 7. Results of the serial multiple mediation model with a moderator (homeowners vs. renters)
Notes: *p < 0.10, **p < 0.05, ***p <0.01.

Table 1 Standardized direct effects of urban greenery on mental health

Model 1-2	Total Sample	House buyer	Renter
	direct effect		
	Estimate (Est./S.E.)		
the perception of green space quality (PG)	0.142(3.78)***	0.161(3.47)***	0.103(1.63)
neighborhood ties (NT)	0.185(3.66)***	0.137(2.41)*	0.253(2.83)**
place attachment (PA)	0.102(2.13)*	0.096(1.55)	0.124(1.77)
Control Variables			
age	0.135(3.52)***	0.206(4.61)***	-0.006(-0.08)
education	-0.001(-0.03)	0.043(1.01)	-0.029(-0.40)
hukou	-0.052(-1.55)	-0.131(-2.81)**	0.063(1.68)
income	0.039(1.15)	-0.016(-0.38)	0.136(2.65)**
Model 3-4	direct effect		
	Estimate		
the proportion of urban green space (SG)	0.115(4.34)***	0.144(4.25)***	0.086(1.88)
neighborhood ties	0.230(5.05)***	0.177(3.18)***	0.293(3.91)***
place attachment	0.116(2.43)*	0.122(1.96)*	0.124(1.80)
Control Variables			
age	0.139(3.47)***	0.223(4.81)***	-0.013(-0.17)
education	-0.004(-0.10)	0.055(1.27)	-0.048(-0.66)
hukou	-0.058(-1.71)*	-0.144(-3.08)**	0.059(1.55)
income	0.050(1.45)	-0.001(-0.03)	0.137(2.65)**

Notes: Est./S.E. in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2 Standardized indirect and total effects of urban greenery on mental health

model 1-2	total sample		house buyer		renter	
	Estimate	95%CI	Estimate	95%CI	Estimate	95%CI
path1(NT)	0.073(3.65)***	[0.036,0.116]	0.053(2.29)*	[0.010,0.087]	0.104(3.20)***	[0.051,0.180]
path2(PA)	0.016(1.94)*	[0.002,0.035]	0.019(1.39)	[-0.003,0.044]	0.010(1.01)	[-0.002,0.040]
path3(NT-PA)	0.017(1.91)*	[0.002,0.038]	0.017(1.48)	[-0.003,0.037]	0.020(1.40)	[0.001,0.059]
total indirect	0.107(5.29)***	[0.069,0.150]	0.089(3.36)***	[0.035,0.126]	0.133(4.50)***	[0.144,0.354]
total effect	0.249(7.44)***	[0.183,0.315]	0.250(5.92)***	[0.140,0.296]	0.236(4.27)***	[0.091,0.214]
model 3-4	total sample		house buyer		renter	
	estimate	95%CI	estimate	95%CI	95%CI	95%CI
path1(NT)	0.006(0.88)	[-0.007,0.021]	0.008(1.21)	[-0.003,0.023]	0.000(-0.02)	[-0.035,0.036]
path2(PA)	0.008(1.68)	[0.001,0.019]	0.006(1.19)	[0.000,0.023]	0.010(1.19)	[0.000,0.035]
path3(NT-PA)	0.002(0.79)	[-0.001,0.007]	0.003(1.04)	[-0.001,0.011]	0.000(-0.02)	[-0.009,0.008]
total indirect effect	0.015(1.62)*	[-0.003,0.035]	0.017(1.75)	[0.000,0.038]	0.010(0.46)	[-0.032,0.054]
total effect	0.131(4.88)***	[0.075,0.179]	0.161(4.82)***	[0.092,0.223]	0.096(2.08)*	[0.000,0.182]

Notes: Est./S.E. in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3 The results of the serial multiple mediation model with a moderator on the quality of green space

Model 5-6	Total Sample			house buyer			Renter		
	neighborhood ties	place attachment	mental health	neighborhood ties	place attachment	mental health	neighborhood ties	place attachment	mental health
	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)	Estimate(Est./S.E.)
PG	0.398(9.92)***	0.157(4.24)***	0.141(3.75)***	0.375(7.60)***	0.202(5.22)***	0.157(3.40)***	0.403(6.25)***	0.063(0.87)	0.091(1.42)
neighborhood ties		0.435(10.12)***	0.184(3.62)***		0.470(10.86)***	0.127(2.20)*		0.382(4.44)***	0.260(2.98)**
place attachment			0.105(2.19)*			0.100(1.62)			0.119(1.72)
housing prices	-0.005(-0.16)	-0.044(-1.81)*	0.072(2.39)*	0.045(1.13)	-0.031(-1.04)	0.055(1.36)	-0.045(-1.07)	-0.055(-1.46)	0.094(2.20)*
PG×HP	-0.034(-0.83)	0.053(1.90)*	-0.006(-0.21)	-0.114(-2.62)**	0.043(1.35)	-0.047(-1.31)	0.043(0.79)	0.109(2.60)**	0.067(1.99)*
Control Variables									
age			0.125(3.25)***			0.196(4.33)***			-0.028(-0.38)
education			-0.017(-0.45)			0.032(0.74)			-0.051(-0.69)
hukou			-0.070(-2.10)*			-0.143(-3.09)**			0.046(1.21)
income			0.025(0.71)			-0.023(-0.54)			0.122(2.25)*

Notes: Est./S.E. in parentheses; *p < 0.10, **p < 0.05, ***p <0.01.

Table 4 The results of the serial multiple mediation model with a moderator on the quantity of green space

Model 7-8	Total Sample			house buyer			Renter		
	neighborhood ties	place attachment	mental health	neighborhood ties	place attachment	mental health	neighborhood ties	place attachment	mental health
	Estimate								
SG	0.051(1.56)	0.065(2.20)*	0.114(4.07)***	0.049(1.49)	0.046(1.38)	0.144(4.25)***	0.057(0.70)	0.112(2.08)*	0.066(1.11)
neighborhood ties		0.494(12.41)***	0.227(4.98)***		0.540(13.47)***	0.172(3.08)**		0.415(5.33)***	0.297(3.93)***
place attachment			0.120(2.51)*			0.126(2.02)*			0.128(1.85)
housing prices	0.006(0.17)	-0.087(-2.16)*	0.061(1.84)	0.048(1.12)	-0.033(-1.03)	0.041(0.99)	-0.043(-0.84)	-0.087(-2.16)*	0.078(1.62)
SG×HP	-0.072(-2.20)*	-0.008(-0.22)	-0.027(-0.95)	-0.047(-1.35)	0.046(1.64)	-0.028(-0.82)	-0.084(-1.68)*	-0.008(-0.22)	-0.003(-0.07)
Control Variables									
age			0.128(3.17)**			0.212(4.43)***			-0.026(-0.34)
education			-0.019(-0.49)			0.040(0.90)			-0.063(-0.84)
hukou			-0.074(-2.19)*			-0.153(-3.31)***			0.039(0.97)
income			0.039(1.10)			-0.009(-0.21)			0.119(2.20)*

Notes: Est./S.E. in parentheses; *p < 0.10, **p < 0.05, ***p <0.01.

Table 5 The bootstraps examination results of the moderated-mediating effect

	Total Sample		house buyer		Renter	
	Estimate	95%CI	Estimate	95%CI	Estimate	95%CI
Model 5-6						
PG						
path1(NT)	-0.004(-0.81)	[-0.016,0.006]	-0.011(-1.60)	[-0.032,-0.002]	0.007(0.54)	[-0.012,0.040]
path2(PA)	0.004(1.32)	[0.000,0.012]	0.003(0.98)	[-0.001,0.015]	0.008(1.17)	[0.000,0.026]
path3(NT-PA)	-0.001(-0.68)	[-0.005,0.001]	-0.004(-1.29)	[-0.014,0.000]	0.001(0.44)	[-0.002,0.010]
Model 7-8						
SG						

path1(NT)	-0.007(-1.98)**	[-0.015,-0.001]	-0.004(-1.20)	[-0.012,0.001]	-0.009(-1.06)	[-0.029,0.005]
path2(PA)	0.001(0.80)	[-0.001,0.005]	0.003(1.16)	[0.000,0.011]	0.000(-0.13)	[-0.007,0.005]
path3(NT-PA)	-0.002(-1.57)	[-0.005,0.000]	-0.002(-1.05)	[-0.006,0.000]	-0.002(-0.80)	[-0.009,0.001]

Notes: Est./S.E. in parentheses; *p < 0.10, **p < 0.05, ***p <0.01.

5. Discussion

Improving the mental health of urban inhabitants has emerged as a significant concern for government departments, urban planners, and the urban demographic research field. Although the importance of UGS quality in promoting health equity is frequently emphasized in research on green spaces and human health, evidence regarding the relationship between the quality of UGS and mental health remains inconsistent. Jacinta Francis et al. (2012) suggest that residents living in neighborhoods with higher-quality UGS are more likely to experience better mental health. In addition, the findings reveal that the objective measure of POS quality was stronger correlated with mental health than the subjective measure. Sugiyama et al. (2008) found that PG was more strongly correlated with mental health than walkability. Dillen et al.(2012)argued that the quality of green spaces is unrelated to mental health due to the low frequency of usage in these areas. Ruijsbroek et al. (2017) found comparable evidence at the neighborhood level. Although the social environment does not mediate the relationship between green spaces and mental health, these findings contrast with those of Sugiyama et al. (2008), who highlighted the significant mediating role of local social interaction in the relationship between green spaces and mental health. These results have been found in GN countries, with limited evidence available in GS countries. Hence, we conducted a comparative analysis between UGS quality and quantity to help understand the intrinsic mechanism between UGS and mental health.

5.1 How does urban greenery quality matter more to mental health than its quantity?

Our study suggests that urban greenery quality had a greater impact than its quantity in the PRD, with neighborhood ties and place attachment playing an important role in mediating the association between UGS quality and mental health. As previously documented, these results indicate that higher-quality UGS provides residents with more comfortable and well-designed public spaces (e.g., street view greenery quality and facility maintenance) that promote usage and increase opportunities for neighbor socialization. This strengthens emotional bonds within the neighborhood, consequently providing mental health benefits (Kawachi & Berkman, 2000; Cramm et al., 2013; Veitch et al., 2018; Kajosaari et al., 2024). Substantial and varied evidence indicates that the positive effects of social relationships and green space on place attachment are strongly influenced by the physical and social environments in the neighborhood (Wu et al., 2019; Lewicka, 2010; van den Berg et al., 2022; Wu et al., 2019a). Furthermore, our research clearly shows that UGS quality is not only positively associated with place attachment directly but also contributes to better mental health. These results corroborate the previous findings on psychological restoration through place attachment facilitated by green spaces. Place attachment can be enhanced by satisfaction with green areas in a neighborhood, as the quality of green spaces—such as their esthetic, recreational, economic, spiritual, and therapeutic values—improves (Brown & Raymond, 2007). In turn, place attachment can create particular psychological benefits. Residents who more frequently experience psychological restoration from natural environments tend to have stronger place attachment, particularly those who visit their favorite outdoor green spaces, as they are more likely to exhibit a greater capacity for psychological restoration (Ma et al., 2024; Subiza-Perez et al., 2021). Furthermore, the contrasting mediation effects in this study suggest that the solely mediated effect of neighborhood ties was also found to be stronger than the combined effect with place attachment. In other words, the positive effects derived from the neighborhood social environment are more pronounced than those from place attachment when discussing the mental health benefits provided by green spaces (I. Kawachi, 2001; Cohen & McKay, 2020). It should be noted that our finding was unexpected and suggests that the quantity of UGS is only positively related to mental health, with insignificant indirect effects on mental health linked to social ties. A possible explanation for this direct relationship is that natural environmental exposure related to the quantity of green space

directly triggers a neuroendocrine response, which may influence affective cognition and mental health (I. Kawachi, 2001).

5.2 How do housing prices and ownership factor into the association between urban greenery quality or quantity and mental health?

Combining housing prices and ownership provides a more comprehensive understanding of group heterogeneity in the impact of socio-economic factors on experiences of UGS, particularly in densely urbanized regions where higher housing costs and the shortage of green space provision are prevalent. Recent research shows that green space planning may unintentionally be accompanied by rising housing prices, which could undermine the potential mental health benefits for socio-economically vulnerable groups (Cole H. V. et al., 2019). For example, wealthier individuals are more willing to pay for green space services (Zhu et al., 2008; Xiao et al., 2017). Studies conducted in the largest cities in China have also shown that accessibility to green spaces is limited, and there are fewer and/or smaller urban parks in disadvantaged neighborhoods compared to formal communities (Feng S. et al., 2019; Guo et al., 2019; Yuzhen et al., 2021). However, our study demonstrates a positive correlation between housing prices and mental health, consistent with another study based on a panel dataset collected in China (H.-Q. Wang & Liang, 2022). Further analysis in this study shows that housing prices do not moderate the direct link between UGS and mental health but rather positively affect neighborhood ties and place attachment. Increasing UGS areas in wealthier neighborhoods may be negatively relevant to the impediment in neighborhood ties formation, yielding impairment of mental health benefits. As a consequence of higher housing costs (e.g., mortgages, rent, maintenance fees), which increase individual financial pressure and lead to "time poverty," residents may prioritize work and income-related time commitments, with socializing in green spaces regarded as less important. Our findings also show that rising housing prices is significantly related to the green space area rather than its quality, as current green space planning—in China and other GS countries—focuses primarily on expanding the range of green space (L. Wu & Kim, 2021). This also aligns with earlier research showing that an increase in green space areas often attracts property developers, triggering urban renewal in the surrounding regions. This, in turn, tends to increase housing prices (Bottero et al., 2022; D'Acci, 2019; Li et al., 2021; Zhu et al., 2025).

Evidence is lacking on the disparity between green space and mental health across various home ownership groups GS countries. Our study contributes to filling this gap by identifying the different mechanisms involved in the relationship between green space quality and homeowner or renter mental health. The empirical results indicate that the quality of green spaces is more important than their quantity in relation to mental health, particularly in terms of housing prices. The mental well-being of homebuyers residing in expensive neighborhoods was not linked to green space expansion; rather, it was hindered by the diminished positive impact of UGS quality on neighborhood ties. In other words, improving the quality of UGS is positively associated with enhanced social interaction in neighborhoods that are more likely to be located on the fringe of urban cores with lower housing prices. The spillover effect of green space quality improvements on property prices in the urban cores may drive wealthier newcomers to move to these areas, while socio-economically disadvantaged residents might be pushed to relocate, potentially leading to the disruption of existing neighborhood ties (Wolch et al., 2014a; Li et al., 2023; Zhu et al., 2025). Interestingly, our study also found that for renters in neighborhoods, the direct positive links between mental health benefits and green space quality are amplified by housing prices. Even though some studies suggest that rising housing prices negatively affect the health of renters (Rohe et al., 2002; H.-Q. Wang & Liang, 2022), we found that renters benefit more from a higher quality of UGS over quantity, especially those who live in a neighborhood with higher housing prices.

Similarly, studies in GS countries have also found that disadvantaged groups may experience greater health benefits from green space (Berdejo-Espinola et al., 2024; Rigolon et al., 2021). Moreover, although there is no evidence to suggest that improvements in green space quality in these neighborhoods promote the renters' mental health via either place attachment or neighborhood ties, such improvements do positively relate to place attachment among renters. In conclusion, the empirical results of this study underline that improving the quality, rather than quantity, of neighborhood green spaces remains important for advancing resident mental health equality, which accords with recent findings that improving green space quality can reduce the impact of socioeconomic inequality on mental health (Maas et al., 2006b; Wang R. et al., 2022).

5.3 Implications for community planning policy and design

The contradiction between the insufficient supply of high-quality green spaces and residents' increasing demand for mental health in high-density urban areas—closely related to the well-being of residents and social stability—requires greater attention from urban planners and policymakers. The PRD in China has green space spatial distribution characteristics and housing prices comparable to those of other GS countries. Specifically, with increasing distance from the urban center, housing prices decrease and green space area increases. However, the previous general green space planning policies in China that focused on increasing the area per resident capita might diminish the practical effects of greening health benefits by leading to latent inequality in socio-economic and mental well-being. Therefore, this study provides other GS countries a new perspective on implementing urban greening policies. The related socio-economic consequences should be acknowledged to avoid an excessive focus on metrics.

Our study emphasizes that neighborhood-based planning should prioritize improving the quality of existing green spaces in megacities or metropolitan areas during the densification process of urbanization, particularly by enhancing UGS capacity to attract residents and foster neighborhood interactions. Disadvantaged neighborhoods or slums in the built-up areas with higher housing prices in the urban cores typically lack high-quality formal green spaces, whereas neighborhoods at city fringes may have a higher proportion of green space, albeit less accessible and usable (McConnachie & Shackleton, 2010; Shuvo et al., 2020; Cobbinah et al., 2021; Mayen Huerta, 2022). However, the budget for maintenance and green infrastructure construction might not be the priority in GS countries (Berdejo-Espinola et al., 2024). Thus, it is essential to implement a phasing plan to improve green space quality, taking into account the specific needs of different regions. Priority should be given to disadvantaged neighborhoods (e.g., urban villages, public rental housing, and affordable housing neighborhoods) with a high concentration of renters within the urban core, and to the aged and deteriorated neighborhoods with a high concentration of earlier homeowners, or the peripheral urban slums. Furthermore, it is essential to integrate both objective and subjective indicators into an evaluation system for green space quality in these neighborhoods, which should guide the implementation outcomes of health-oriented neighborhood micro-renewal planning. Emphasis must also be placed on assessing the promotion of green space active use by residents. It is also still required to mitigate the risk of inequalities in the provision of UGS in disadvantaged neighborhoods, particularly those without access to UGS within highly urbanized areas (Xiao et al., 2017; Li et al., 2025). Small and high-quality public green spaces can be created in these neighborhoods by transforming underutilized areas—such as transitional spaces, empty lots, or poorly maintained green spaces—into green infrastructure, including pocket parks or linear green trails alongside urban rivers. A small, high-quality public green space should be prioritized in green space development planning for its lower construction and

maintenance costs and reduced complexity, especially in urban cores (Gruebner et al., 2012; Peschardt et al., 2012). Public small-sized green space also mitigates the negative impacts of rising housing prices and provides mental health benefits (Wei Z. et al., 2021; Yu et al., 2024).

Moreover, the intermediation of neighborhood ties and place attachment was found to be robust relative to UGS and mental health. This suggests that health-oriented UGS design and green infrastructure planning should not focus solely on "going green" but must also meet the diverse needs of neighborhood residents, such as dog walking, children's play areas, socializing with neighbors, resting, and engaging in physical activities (Wolch J. et al., 2011b; Gómez et al., 2018; Guo et al., 2019; van den Berg et al., 2019). Thus, additional attention should be paid to the design of urban furniture in the planning of green infrastructure to better accommodate the needs of vulnerable groups, such as the elderly, migrant children, and individuals with disabilities, as well as pets and their owners. Once residents benefit from nearby green spaces, they are likely to develop a stronger preference for them and visit more frequently, creating a virtuous cycle for mental health.

5.4 Limitations and future studies

This study emphasizes that when implementing UGS planning policies, the complex underlying mechanisms should be considered to promote public health equity. However, the following limitations of this study should be noted. First, this study conducted a survey using a small sample in each neighborhood, which might have introduced self-selection bias. Moreover, the ability to establish causality between changes in green space quality and quantity and their impact on residents' mental health is limited owing to the use of cross-sectional data in SEM models. Additionally, this study has not considered the impact of home mortgages on homeowners, the respondents' gender, and their physical health status. Despite these limitations, the relationship between quality, quantity, and mental health remains an important topic. Future research should focus on developing an indicator system for objectively measuring green space quality and exploring the neurophysiological impacts that occur as green spaces influence residents' psychological processes to avoid same-source bias. Although this study has examined the differential effect of housing prices on various home ownership groups in the PRD region of China, additional empirical studies utilizing longitudinal large sample sizes that incorporate both objective characteristics and perceived quality of UGS in different metropolitan areas of GS countries would help explore the generalized mechanisms linking UGS and mental health in the context of rapid urbanization.

6. Conclusion

We emphasized the necessity of enhancing the quality of UGS to strengthen neighborhood ties and place attachment, which support mental health, by incorporating housing prices and home ownership. The quality of green spaces had a greater association with mental health than quantity, with or without the consideration of housing prices. In contrast to our previous assumption, housing prices have a positive impact on mental health. In wealthier neighborhoods, the benefits of greenery quality on mental health were greater. Housing prices had differing moderating effects on renters and homeowners.

These findings can contribute to the research field of health equity and inspire the optimization of urban planning, the transformation of green infrastructure, and the development of green space planning policies in neighborhood micro-renewal, with the goal of achieving a healthy city. Neighborhoods may be the appropriate level for implementing targeted improvements in green space quality within urban planning and design. In addition to the physiological and epidemiological benefits of green spaces, sociological factors and affective reactions cannot be ignored. Hence, it is important to transform negative space or underutilized areas into high-quality green spaces in tenure-mixed neighborhoods. Furthermore, in creating green spaces, consideration should be given to providing public spaces that promote interaction among residents using attractive facilities, which would encourage residents to stay and communicate, rather than simply increasing the size of green spaces in land-use planning.

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Authorship contribution statement

Qingyin Li: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Rong Wu: Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis. Pengyu Zhu: Writing – original draft, Supervision.

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