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Exploring the Factors Shaping Urban Greenspace Interactions: A Case Study of Nagpur, India

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Abstract: This study aims to investigate how urban residents interact with Urban Green Spaces (UGSs) in Nagpur, India, specifically focusing on the patterns of visitation and engagement. Data were collected via a face-to-face questionnaire survey using the Survey 123 app. The analysis included interaction (types of UGSs, visitation frequency, and UGS availability); engagement (activities); demographics (age, gender, and work status); and nature connection (self-reported) aspects. Using data from 2002 participants, the study employs statistical analyses using R software (4.3.2) to explore the correlations between these variables. The results revealed key factors influencing UGS usage, highlighting the interplay between environmental and social aspects. Neighborhood UGSs, proximity, and accessibility were found to be pivotal in promoting frequent visitation, while physical activity emerged as the most common activity among daily visitors. Older adults visited UGSs less frequently, suggesting potential barriers, while employed individuals visited more often. A strong association between nature connection and UGS interaction was highlighted, emphasizing the psychological and emotional aspects of UGS usage. For example, individuals who felt more connected to nature reported using UGSs for physical activities, mental relaxation, and socializing. These findings underscore the need for integrating UGSs within broader urban social-ecological systems, which means recognizing these spaces as vital components contributing to overall health and resilience and catering to the population's diverse needs, ensuring that these spaces are accessible and enjoyable for all community members, including those from different cultural, age, and socioeconomic backgrounds. Additionally, fostering nature connectedness through education and exposure to natural environments is recommended to enhance UGS usage, supporting broader urban planning strategies to create sustainable and healthy urban environments.

Keywords: Urban Green Space; urban sustainability; nature connection and urbanization

Citation: Lahoti, S.A.; Dhyani, S.; Saito, O. Exploring the Factors Shaping Urban Greenspace Interactions: A Case Study of Nagpur, India. *Land* **2024**, *13*, 1576. https://doi.org/10.3390/land13101576

Academic Editor: Thomas Panagopoulos

Received: 20 August 2024
Revised: 24 September 2024
Accepted: 26 September 2024
Published: 27 September 2024

1. Introduction

"Cities are here to stay, and the future of humanity is undoubtedly urban" [1]. Projections suggest that, by 2050, over 68% of the global population will live in urban areas [2]. As cities continue to grow, they must evolve to minimize negative impacts on global sustainability [3,4] while promoting the well-being of dwellers. This expansion presents numerous challenges and opportunities, particularly in balancing urban development with the preservation of natural environments [5,6]. Similar challenges have been documented in cities around the world. For instance, European cities like London and Paris are integrating green infrastructure into urban planning to mitigate urban heat islands and promote social cohesion [7]. In North America, cities such as New York and Toronto have implemented green corridors and parks as part of broader urban sustainability plans to address both environmental and public health challenges [8]. In rapidly developing regions like Latin America, cities such as São Paulo face similar issues of inequitable access to green spaces, where marginalized communities have less access to UGSs [9]. The interplay between urban growth and urban nature is crucial for urban sustainability and the well-being of urban residents [5,10].

Urban Green Spaces (UGSs), an integral part of green infrastructure (GI) [11], play a key role in addressing these challenges. Urbanization is intertwined with several global challenges, especially in low-income countries, where urban populations are projected to grow nearly two and a half times by 2070 [1]. In Southeast Asian cities such as Jakarta, unplanned urban sprawl has left little room for accessible green spaces, affecting both the environment and public health [12]. Strategic urban and territorial planning, led by urban planners and policymakers, becomes essential to accommodate this growth sustainably [2].

GI, which includes assets such as parks, green corridors, and wetlands, enhances the flexibility and multi-functionality of urban spaces. In cities like Copenhagen and Singapore, green infrastructure has been integrated into urban planning frameworks to improve resilience to climate change and pandemics, supporting both environmental sustainability and public health [13]. Their role in integrating green infrastructure into urban planning enhances the flexibility and multi-functionality of urban spaces, making them more resilient to future pandemics and climate change impacts [10,14]. Creating networks of green areas and corridors within cities can improve accessibility, promote social cohesion, and support public health by providing opportunities for physical activity and mental relaxation [15,16]. Urban nature is increasingly considered pivotal for sustainable urban planning and development [17,18], highlighting the importance of incorporating natural elements into urban spaces to address the multifaceted challenges of urbanization effectively.

In particular, UGSs, as a subset of GI, like parks and gardens, urban forests, woodlands, and green allotments, are essential in mitigating urbanization's adverse effects [6,10,19–21]. Research in Melbourne, Australia, highlights the role of UGSs in reducing chronic disease risks through the promotion of physical activity [22]. In South Korea, UGSs have been found to significantly improve air quality and mental health among urban residents [23]. They enhance air quality, mitigate urban heat islands, manage stormwater runoff [24–26], and support biodiversity by providing habitats for various species [27]. Additionally, UGSs enhance urban life by offering areas for recreation, relaxation, and social interaction, promoting physical activity and reducing chronic disease risks [28]. Access to UGSs improves mental health, offering refuge from urban stress and enhancing emotional well-being [23,29,30]. During the COVID-19 pandemic, UGSs were crucial for safe outdoor activities and social distancing [31,32]. The presence, accessibility, and quality of UGSs significantly impact their usage [19,33,34]. Thus, city planners should ensure UGSs are within practical distances from residential areas to encourage public engagement and foster a connection with nature. Nature connection has long been recognized for its role in promoting psychological well-being and environmental stewardship [35,36]. Nature connection refers to an individual's relationship and sense of belonging to the natural environment [37,38]. Engagement with UGSs through walking, exercising, and socializing can foster a stronger connection to nature, enhancing overall well-being. The relationship between engagement with nature and both physical and mental well-being has been well established in the literature for many years. Recent literature emphasizes that an individual's motivation to use greenspaces is frequently influenced by their connection to nature rather than physical aspects relating to ease of access and available UGSs [30,39]. Therefore, a more culturally aware approach to studying UGS visitation is recommended [40].

However, rapid urbanization presents significant challenges in maintaining and effectively utilizing UGSs. Contemporary urban development models, such as ecocities and compact cities, necessitate a reevaluation of UGS design and integration within urban frameworks to maximize their benefits [41,42]. Beyond promoting physical and mental well-being, UGSs also play a significant role in climate change adaptation, providing natural cooling, reducing urban heat islands, and managing stormwater runoff [25,43]. Moreover, understanding the factors influencing individuals' willingness to visit and engage with UGSs is crucial for developing effective urban green planning and management strategies [44], particularly in rapidly urbanizing regions of the Global South. Previous studies have shown that access to UGSs alone is not sufficient; the quality, safety, and inclusivity of these spaces are equally important [9,45]. This research addresses these gaps by examining the access and quantity of UGSs and exploring the nature connection and various aspects of UGS usage. By focusing on a rapidly urbanizing Indian city, this study provides novel insights into optimizing UGSs to enhance urban sustainability and the well-being of residents.

While existing studies have documented the availability and distribution of UGSs in various urban contexts, limited research exists on how these factors influence residents' interaction and engagement with these spaces, especially in rapidly urbanizing cities in the Global South. This study aims to fill these research gaps by examining the patterns of interaction and engagement with UGSs in Nagpur, India, and understanding how the availability and types of UGSs and demographic factors influence these patterns. The specific research questions addressed in this study are (1) How do visitation frequencies differ across the types of UGSs, and how does the availability of UGSs influence interaction with these spaces? (2) How do individuals engage with UGSs regarding preferred activities, and how does engagement vary with visitation frequency? (3) How do visitation frequency and demographics (gender, age, and work status) influence the likelihood of engagement? (4) How does engagement with UGSs relate to individuals' connection with nature? The findings will contribute to developing policies and strategies for enhancing the accessibility and usability of UGSs, thereby promoting environmental sustainability and improving the well-being of urban residents.

2. Materials and Methods

2.1. Study Area

The study area is Nagpur, a city located in Central India (Figure 1). Nagpur, a tier II city, spans approximately 218 square kilometers and has a population of 2.4 million. The city is divided into ten administrative zones managed by the Nagpur Municipal Corporation (NMC). Known for its greenery, Nagpur has seen significant reductions in its natural green spaces, reflecting urban landscape changes [46,47]. The city's green and blue infrastructure includes lakes, river basins, urban forests, green spaces connected to institutions, parks and gardens, playgrounds, and plantations along roadways. However, disparities exist in the distribution and availability of public UGSs [34,48]. The city-wide per capita public UGS is 3.65 square meters, below the WHO standards, with significant variation among the ten zones [34]. There are also notable differences in UGS proximity and service area coverage within these zones. For this study, Nagpur was categorized into three groups based on UGS availability using predictive modeling, as derived from previous studies [34] and validated by more recent research [39], as no official data exist at this level of detail, as shown in Figure 2.

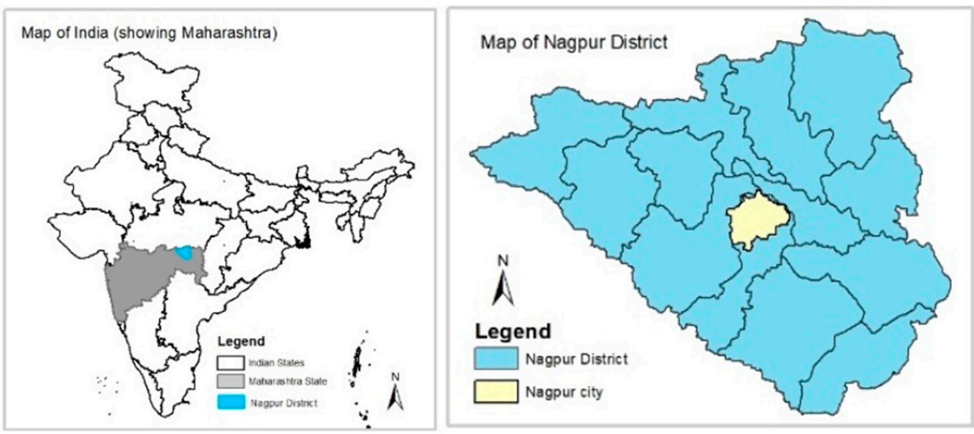


Figure 1. Geographic location of the study area, Nagpur City, Maharashtra, India.

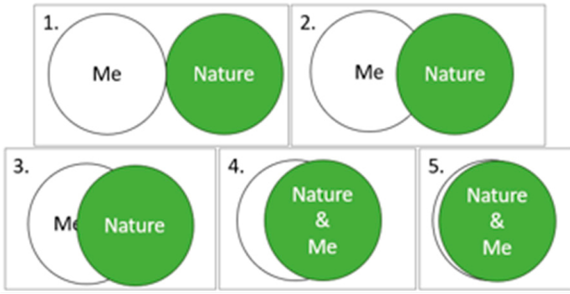
2.2. Data Collection

The study's data were gathered through face-to-face surveys using the Survey123 field app (version 3.19.114), which facilitated capturing respondents' residential locations within Nagpur's ten administrative zones. This allowed us to identify the administrative zone where each respondent resides, and the UGS availability for each zone was derived from previous studies [34,39]. The digital questionnaire collected information on UGS visitation frequency, preferred activities, and self-reported connection to nature (CN). The survey focused on four main areas: (1) interaction with UGSs, including visitation frequency and reasons for non-visitation; (2) relationship with urban nature; (3) involvement in pro-environmental activities; and (4) demographic details. This research is part of a broader project to understand various aspects of UGS usage and interactions in rapidly urbanizing cities. The study explores the relationship between UGS interaction and engagement with nature connection. The detailed questionnaire is available in Supplementary Materials. The survey was conducted in January 2024 by sixteen trained research assistants using an electronic form to enhance efficiency. The Survey123 field app allowed the setting of local languages and taking geotags. The spatial data of existing administrative boundaries and public UGSs were integrated with Google Maps and derived from previous fieldwork [34]. Respondents used the Google Maps interface to pinpoint their household locations, which were then mapped to the corresponding administrative zones. The target population for the survey was individuals aged 18 and above. Verbal consent was obtained from the participants before initiating the survey, as no personal information was collected; thus, written consent was not required. Ethical approval was not sought since the questionnaire was anonymous, and the author's institution does not have an ethical board. However, internal approval was obtained from the project team members.

2.3. Measures and Data Variables

The measure, explanatory variables, and their categories were carefully selected to comprehensively capture individuals' interaction with UGSs, as shown in Table 1. Three explanatory variables were selected to understand the interactions: types of preferred UGSs, UGS availability, and visitation frequency. UGS types were classified into three categories: Neighborhood UGSs (parks and gardens and playgrounds), community UGSs (larger recreational parks and gardens), and city UGSs (city-scale lakes and forests), as identified in the city development plan and thematic maps [49]. Most neighborhood parks and gardens share a similar design but vary in size and maintenance levels and are typically accessible within 500–750 m [34,39]. The questionnaire featured seven categories for visitation frequency: at least once a year, 2–3 times a year, once a month, once a fortnight, once a week, 2–3 times a week, and every day. However, the analysis focused on frequent visitors (every day, 2–3 times a week, and once a week), excluding less frequent visitors as outliers. For availability aspects, administrative zones were categorized into high, moderate, and low levels based on per capita UGS availability within each administrative zone, following Lahoti et al. 2019 [34], as in Figure 2. To capture how individuals engage with UGSs, their preferred activities were recorded, which were then categorized under three heads: physical activity, sitting/relaxing, and socializing. In terms of socio-demographics, various aspects were captured, but in this study, we mainly focus on age, gender, and work status. To understand individuals' "nature connection", self-reported measures employed a visual representation adapted from Schultz's "Inclusion with Nature in Self" scale. Participants were asked to select from the five options that depict their relationship with nature using two circles: one representing nature and the other representing themselves.

Table 1. Measure and variables used to understand the interaction of individuals with UGSs.

Measures	Explanatory Variables	Categories
Interaction	Types of UGSs	City, Community, Neighborhood
	UGSs availability	High, Moderate, Low
	Visitation frequency	Every day, 2–3 times per week, and once a week
Engagement	Activities in UGSs	Physical activity, Sitting/relaxing, Socializing
Demographics	Age	18–29, 30–39, 40–49, 50–59, Over 60
	Gender	Male, Female
	Work status	Retired, Studying, Unemployed, Working
Nature connection	Self-reported connectedness to nature (Self_CN)	1—Separate, 2—Somehow connected, 3—Connected, 4—Close connection, 5—Human, and nature are inseparable 

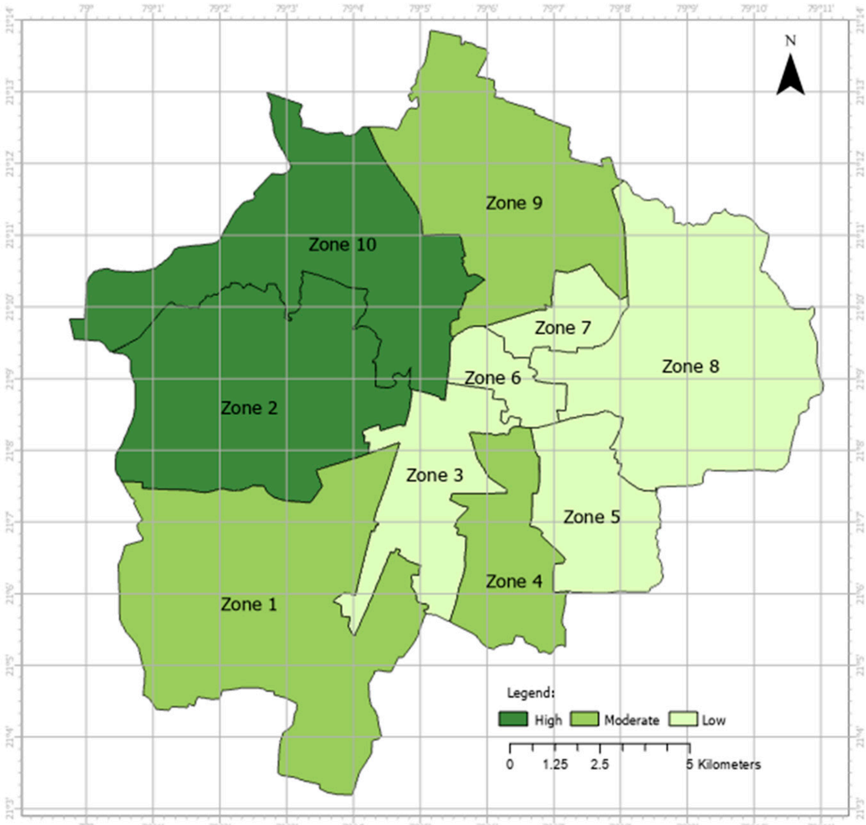


Figure 2. Ten administrative zones of Nagpur City showcasing available UGSs among the zones based on per capita UGS availability in the zones (zones with high UGS availability include Zone 2, Zone 10, and peri-urban areas, offering more than 6.5 m^2 per capita; moderate availability is found in Zones 1, 9, and 3, with 1.5–6.5 m^2 per capita; low availability is observed in Zones 4, 5, 6, 7, and 8, providing less than 1.5 m^2 per capita) [34,39].

2.4. Statistical Data Analysis

The analyses were conducted using R software (4.3.2), while spatial data analyses were performed using ArcGIS Pro 2.8. Data on interactions with UGSs were analyzed from a sample of 2193 participants, which included the variables shown in Table 1. Initially, datasets were checked for missing values and outliers and prepared for statistical analysis. The "frequency of visit" as a means of interaction was analyzed across different types of UGSs to address the first objective. Following this, the study focused on frequent interaction, filtering for participants who visited UGSs "every day, 2–3 times per week, or once a week", resulting in a total of 2002 participants when accounting for outliers. To study how the availability of UGS influenced these visitation patterns, a Generalized Linear Mixed Model (GLMM) was employed to account for both fixed and random effects. The fixed effect was the overall intercept representing the baseline log odds of using UGS. Random effects were included to capture the variability in UGS usage across different levels of UGS availability. The GLMM was fit using the glmer function from the lme4 package in R, with a binomial family and logit link function.

To analyze preferred activities within UGSs (under engagement), the filtered dataset accounting for outliers was used for descriptive statistics, including mean, median, standard deviation, and interquartile range. Based on these statistics, activities with substantial data (physical activity, sitting/relaxing, and socializing) were selected for further analysis. ANOVA tests were then conducted to determine significant differences in these substantial activities across visitation frequencies, and the same were visualized using bar plots with error bars to illustrate the mean frequency and variability of activities. Post hoc Tukey's HSD tests were performed to pinpoint specific group differences. Following this, we employed Generalized Linear Models (GLMs) to analyze engagement behaviors association with demographics and visiting frequency. The models included visitation frequency (every day, 2–3 times a week, or once a week); gender (male or female); age (coded as numeric based on age groups); and work status (retired, studying, unemployed, or working) as fixed effects. Furthermore, additional GLMs were conducted to explore the relationship between engagement with UGSs and individuals' connection with nature. These models included the "self-reported connectedness to nature" and the previously mentioned demographic factors to assess their impact on visitation frequency. We conducted a chi-square test of independence to explore the relationship between individuals' connection to nature and their engagement in specific activities within UGSs. The analysis focused on participants who visited UGSs frequently (every day or 2–3 times per week). The association between self-reported connection to nature and engagement in three primary activities: physical activity, sitting/relaxing, and socializing was analyzed using contingency tables.

3. Results

3.1. Interaction Patterns and the Impact of UGS Availability on Visitation Frequency

The frequency distribution reveals distinct patterns in visitation rates across different types of UGSs (Figure 3a). Higher visitation frequencies are observed in the "Neighborhood" UGSs, indicating a greater preference for and more frequent visits to these areas. Conversely, lower frequencies are recorded in the "city" category, suggesting fewer interactions. Among the frequent visitors, 68% visited UGS every day, 22% visited 2–3 times per week, and 10% visited once a week. The heatmap analysis of UGS visitation frequency and availability revealed that daily visitors predominantly have "low" availability of UGS, indicating a potential need to enhance UGSs (Figure 3b). In contrast, those visiting 2–3 times per week show a more balanced distribution across availability levels. UGS availability has less of an impact on occasional visitors (those who visit once a week). These findings suggest that targeted improvements in UGS availability could promote more frequent use, especially for daily users.

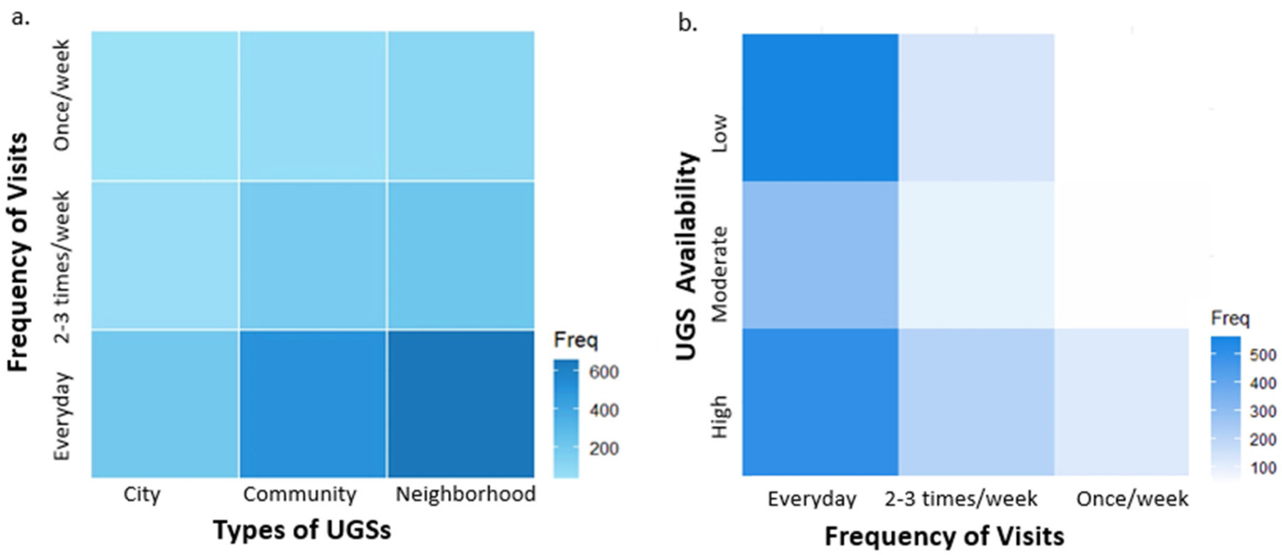


Figure 3. (**a**) Frequency of visits across UGS types. (**b**) Heatmap of UGS visitation frequency and availability.

The GLMM analysis revealed a significant influence of UGS availability on the frequency of usage. The intercept estimate was 1.2901 ($p < 0.0001$), indicating a strong baseline inclination towards UGS usage (Figure 4a). The random effects associated with different availability categories (variance = 0.02474, Std. Dev. = 0.1573) suggested variability in UGS usage due to availability differences (Figure 4b). Model fit statistics included an AIC of 2102.2, BIC of 2113.4, and log-likelihood of −1049.1, with 2002 observations. The two plots were created to visualize the fixed and random effects of UGS availability on usage frequency (as shown in Figure 4a,b). The fixed effects plot displays the intercept estimate and 95% confidence interval. The high estimate value and narrow confidence interval indicate a significant baseline effect on UGS usage frequency. The QQ plot (Figure 4c) validates the normality assumption of the random effects, showing that the points falling approximately along the reference line indicate that the random effects are normally distributed, with slight deviations.

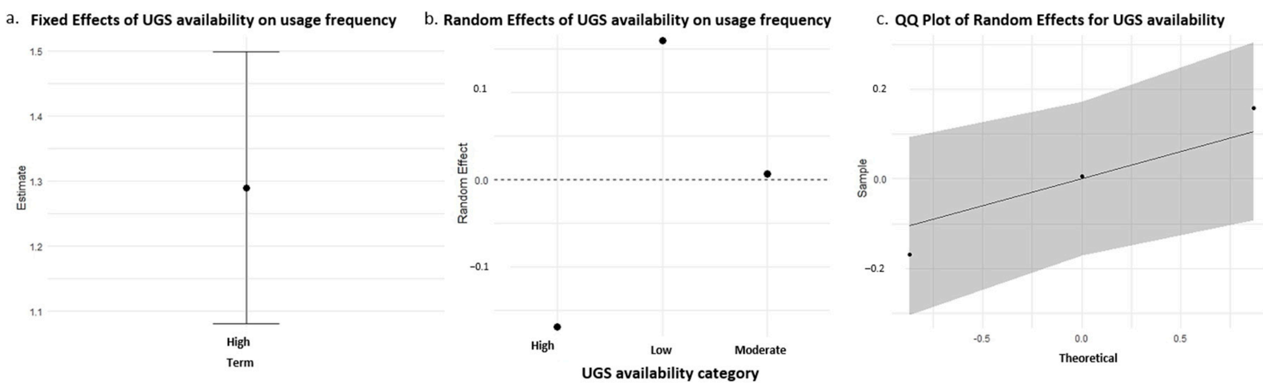


Figure 4. (**a**) Fixed effects plot of UGS availability on usage frequency, (**b**) random effects plot of UGS availability on usage frequency, and (**c**) QQ plot of random effects for UGS availability (In the random effects plot, each point represents the random effect for a category, and the dashed line at zero helps identify categories with higher or lower usage frequency variations).

3.2. Engagement in Terms of Activities among Frequent Visitors

The descriptive analysis, based on the categorized survey responses, revealed that the most common activities among UGS visitors were physical activity, sitting/relaxing, and socializing. Physical activity had the highest mean frequency among everyday visitors

(0.716), indicating significant engagement. Sitting/relaxing was most frequent among those visiting 2–3 times a week (mean frequency = 0.644), highlighting relaxation as a primary reason for visiting UGSs. Socializing had a mean frequency of 0.291 among everyday visitors, suggesting social interactions were notable but less frequent.

The ANOVA results showed significant differences in the frequency of activities: physical activity ($F(2.1999) = 55.04$, $p < 0.0001$), sitting/relaxing ($F(2.1999) = 5.228$, $p = 0.0054$), and socializing ($F(2.1999) = 2.849$, $p = 0.0582$, borderline significance); see Table 2. The Tukey HSD post hoc tests further revealed significant pairwise differences. For exercise, significant differences were found between all visitation frequency pairs. The mean exercise frequency was significantly lower for once a week visitors than every day and 2–3 times a week visitors ($p < 0.0001$). Significant differences were observed for sitting between every day and once a week visitors ($p = 0.0086$) and between 2–3 times a week and once a week visitors ($p = 0.0054$). For socializing, a significant difference was found between every day and once a week visitors ($p = 0.0452$).

Table 2. Summary statistics and ANOVA results for primary activities by visitation frequency with post hoc Tukey HSD tests (significance levels are indicated as follows: *** $p < 0.001$, ** $p < 0.01$.

Activity	UGSs_Freq	Mean	SD.	F Value	Pr (>F)	Comparison	Diff.	*p*-Value
Physical exercise	everyday	0.716	0.451	55.04	$<2 \times 10^{-16}$ ***	2–3 times/week—everyday	−0.1128	2.88×10^{-5}
	2–3 times/week	0.603	0.490			Once/week -everyday	−0.3555	0
	Once/week	0.360	0.481			Once/week—2–3 times/week	−0.2427	0
Sitting/relaxing	everyday	0.624	0.485	5.228	0.0054 **	2–3 times/week—everyday	0.0199	0.7347
	2–3 times/week	0.644	0.479			Once/week—everyday	−0.1089	0.0086
	Once/week	0.515	0.501			Once/week—2–3 times/week	−0.1288	0.0054
Socializing	everyday	0.291	0.454	2.849	0.0582	2–3 times/week—everyday	−0.0125	0.8675
	2–3 times/week	0.279	0.449			Once/week—everyday	−0.0811	0.0452
	Once/week	0.210	0.408			Once/week—2–3 times/week	−0.0685	0.1733

The bar plot with error bars in Figure 5 visually compares the mean frequencies and their variability by visitation frequency. It shows that physical activity and sitting/relaxing are common across all visitation frequencies, while socializing decreases slightly for visitors who visit once a week. The error bars indicate substantial variability within each group, highlighting the differences in engagement levels across the visitation frequencies, suggesting diverse usage patterns and motivations for visiting UGSs.

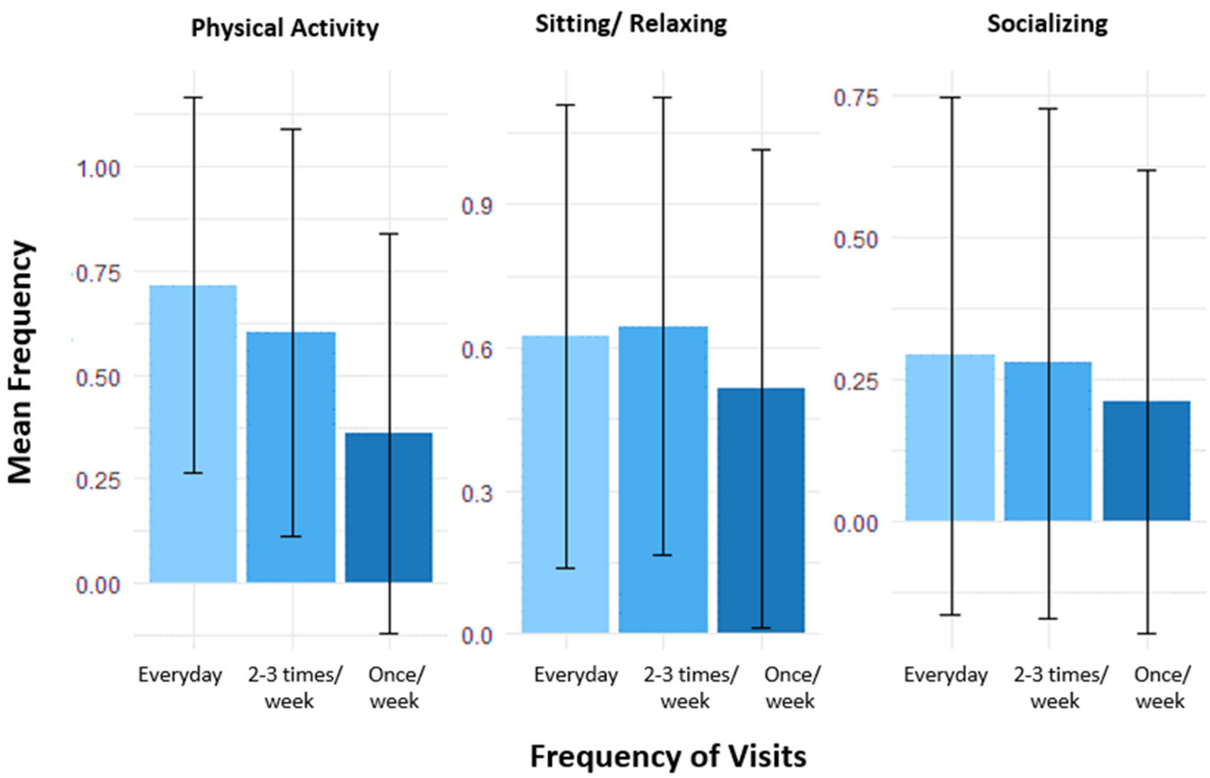


Figure 5. The distribution of activities by visitation frequency illustrates each activity's median, interquartile range, and outliers, highlighting the variability in activity engagement among the different visitor groups.

3.3. Impact of Demographic Characteristics on the Engagement of Frequent Visitors

The GLM results revealed significant effects in visitation frequency and age on the likelihood of engaging in "physical activity" and "sitting/relaxing" activities. At the same time, gender significantly affected "sitting/relaxing" and "socializing" (Figure 6). Specifically, visitors who frequented UGSs 2–3 times/week had significantly lower odds of engaging in "physical activity" (Estimate = −0.385, p = 0.0011) and "sitting/relaxing" (Estimate = 0.162, p = 0.1681) compared to everyday visitors. Those visiting once/week had even lower odds for "physical activity" (Estimate = −1.372, $p < 2 \times 10^{-16}$). Age was positively associated with "physical activity" (Estimate = 0.183, p = 0.0003) and showed a borderline significant association with "sitting/relaxing" (Estimate = 0.093, p = 0.0572). Males had significantly lower odds of "sitting/relaxing" (Estimate = −0.331, p = 0.004) and "socializing" (Estimate = −0.331, p = 0.004) compared to females. Work status did not show significant effects across all activities, except for a borderline significance for unemployed individuals engaging in "physical activity" (Estimate = −0.380, p = 0.0522). The findings underscore the importance of daily visits to UGSs for promoting "physical activity", especially among older adults. The lack of significant effects of work status on engagement highlights the potential benefits of UGSs regardless of employment status. These insights can guide urban planners and policymakers in designing inclusive and effective UGSs that cater to diverse demographic groups and promote healthy and social lifestyles.

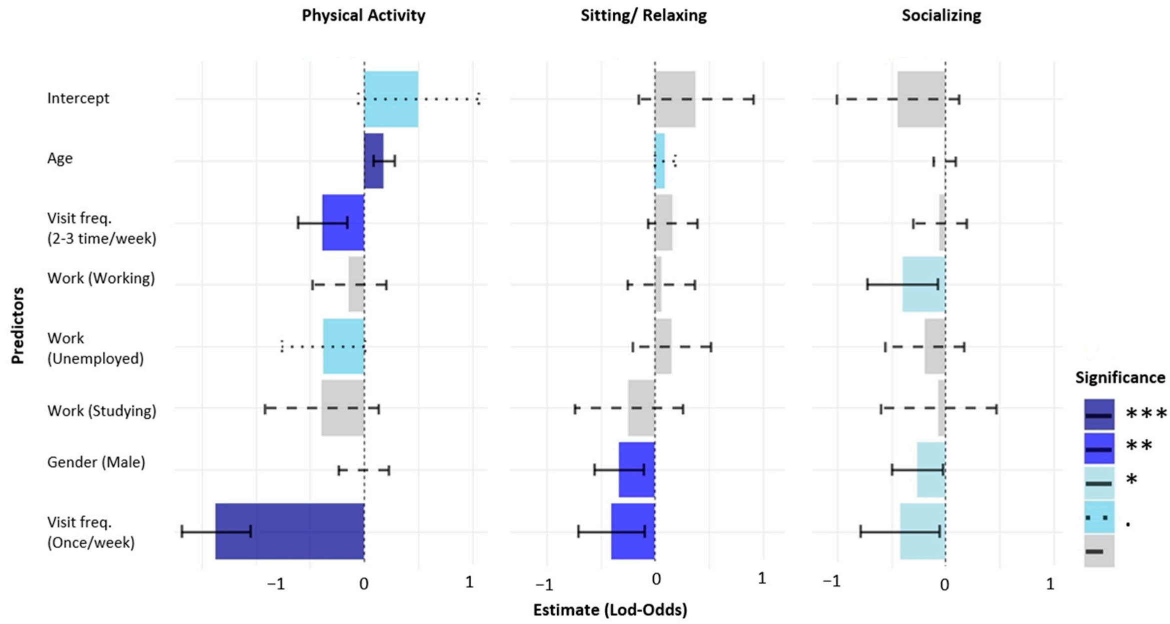


Figure 6. Effect of predictors on engagements in UGSs across three activities: exercise, sitting/relaxing, and socializing (predictors include age; visitation frequency (every day, 2–3 times/week, or once a week); work status (working, studying, or unemployed); and gender. The estimates represent the log-odds of engagement in each activity, with significance levels indicated by color: dark blue (*** $p < 0.001$), medium blue (** $p < 0.01$), light blue (* $p < 0.05$), and light gray ($p < 0.1$). Error bars show the 95% confidence intervals for each estimate).

3.4. Correlation of "Connection with Nature" on Other Variables

The GLM analysis revealed several significant predictors of frequent UGS visitors, as illustrated in Figure 7. Participants with a self-reported "strong connection" to nature were significantly more likely to visit UGSs frequently (Estimate = 0.636, $p < 0.001$). Those who felt "somehow connected" to nature (Estimate = 0.307, $p = 0.040$) or "separate" from nature (Estimate = 0.874, $p < 0.001$) also exhibited higher odds of frequent UGS visitation. Regarding demographics, age was negatively associated with UGS visitation frequency (Estimate = -0.229, $p < 0.001$), indicating that older participants were less likely to visit UGSs regularly. Gender did not significantly influence visitation frequency, though males had slightly lower odds than females (Estimate = -0.194, $p = 0.103$). Regarding work status, those who were working had significantly higher odds of frequent UGS visits (Estimate = 0.379, $p = 0.036$). These findings underscore the importance of a personal connection to nature in promoting UGS visitation. The negative association with age suggests that interventions may be necessary to encourage older adults to visit UGSs more frequently. The significant impact of employment status highlights the potential influence of lifestyle and routine on UGS engagement.

Furthermore, the chi-square tests revealed significant associations between the "connection with nature" and engagement in all three primary activities. For physical activities, the chi-square statistic was 205.36 (df = 4, $p < 2.2 \times 10^{-16}$); for sitting/relaxing, it was 34.771 (df = 4, $p = 5.177 \times 10^{-7}$); and for socializing, it was 27.162 (df = 4, $p = 1.844 \times 10^{-5}$). The bar plots illustrate these associations (Figure 8), showing that individuals with a stronger connection to nature are likelier to visit for physical activity and socializing. In contrast, sitting/relaxing activities are more evenly distributed across all levels of connection. Individuals with a "strong connection" to nature (human and nature are inseparable) are significantly more likely to engage in physical activity than those with weaker connections. Sitting/relaxing activities are relatively consistent across different levels of connection to nature, though those with a "close connection" or who feel "somewhat connected" show higher engagement. Socializing is notably higher among those with a "strong connection" to nature, highlighting the role of a strong "connection with nature" in promoting social interactions within UGSs. These findings emphasize the importance of fostering a strong connection to nature to enhance physical activity and social engagement in UGSs.

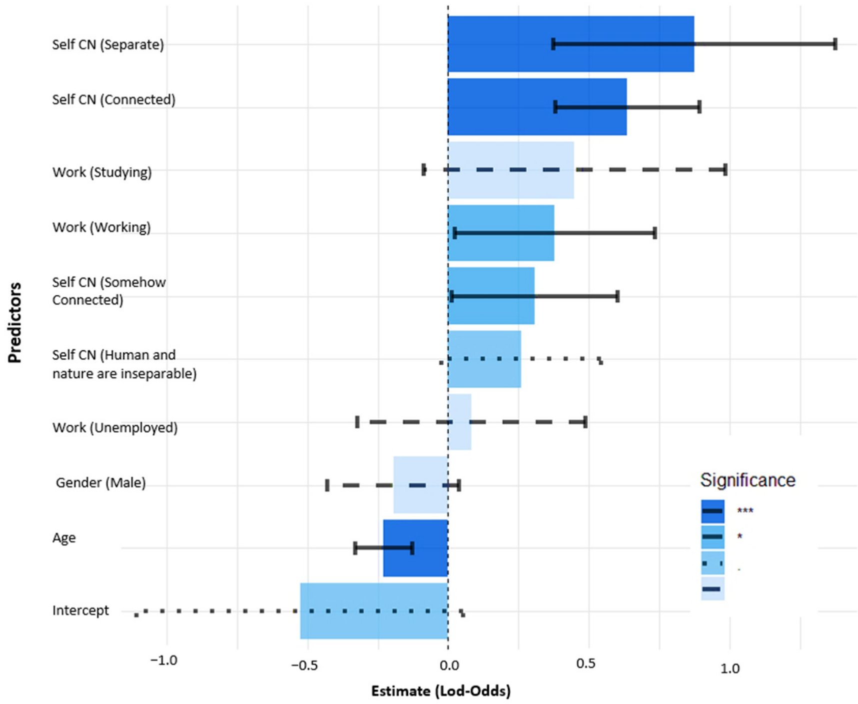


Figure 7. Likelihood of frequent visitor engagement in UGSs against the predictors of self-reported connection to nature (Self CN), work status, gender, and age. (The estimates represent the log odds of engagement, with significance levels indicated by color: dark blue (*** $p < 0.001$), medium blue (** $p < 0.01$), light blue (* $p < 0.05$), and light gray ($p < 0.1$). Error bars show the 95% confidence intervals for each estimate).

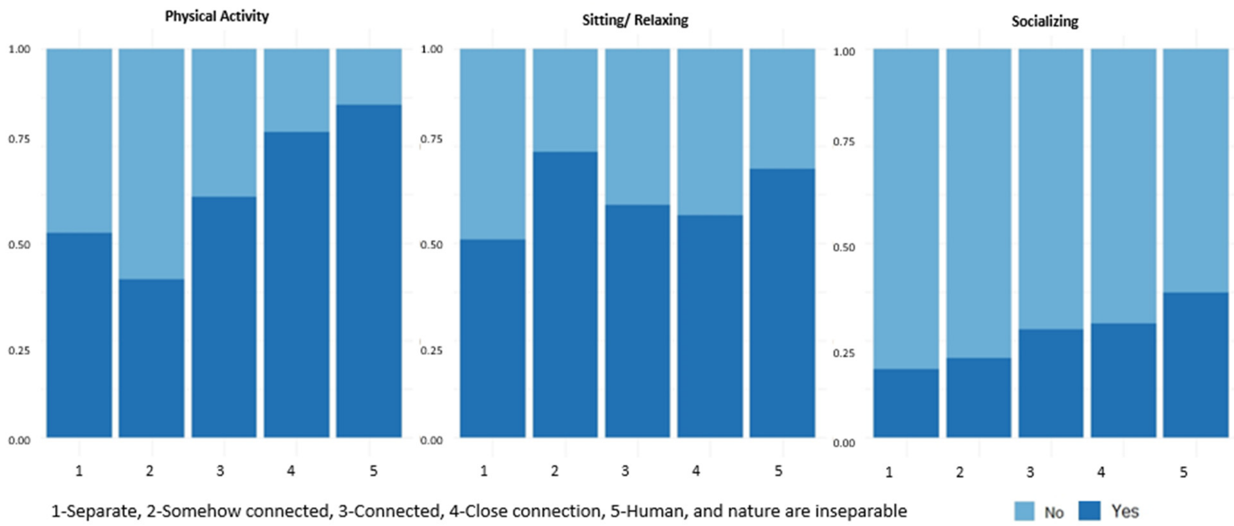


Figure 8. The proportions of participants engaging in three primary activities—physical activity, sitting/relaxing, and socializing—across five levels of self-reported connection to nature. (The levels of connection to nature are 1—separate, 2—somehow connected, 3—connected, 4—close connection, and 5—human and nature are inseparable. Dark blue bars represent participants who engage in the activities ("Yes"), while light blue bars represent those who do not ("No")).

4. Discussion

The findings provide critical insights into how urban residents interact with UGSs. We identified key variables across different measures and documented how interaction, engagement, demographic characteristics, and self-reported connection with nature in Nagpur collectively influence the usage of UGSs. This underscores the complex interplay between environmental and social factors in shaping interactions with UGSs. Neighborhood UGSs emerged as pivotal in promoting frequent visitation, highlighting the significance of proximity and accessibility. This is in line with other studies mentioning visitation rates are higher when UGSs are closer to residents, allowing them to walk to their preferred locations [33,50,51]. Further, the heatmap showing higher everyday visitation in low UGS areas indicates an unmet demand for UGSs (Figure 3b), necessitating targeted interventions to increase their availability, as echoed in previous research in Nagpur [48]. This may indicate an unmet demand for UGSs and suggests that residents might be making extra efforts to access these spaces, underscoring the need for a more equitable distribution of UGSs. This also highlights the need for a more detailed understanding of socio-demographics, as it concerns not just equitable distribution but also the fact that sometimes certain groups with the least access to local parks are the ones who frequent them most often [52]. Furthermore, the GLMM analysis revealed a significant influence of UGS availability on visitation frequency (Figure 4), with the intercept estimate indicating a strong baseline inclination toward UGS usage. The variability in UGS usage due to availability differences suggests that improving the distribution and accessibility of UGSs can significantly impact their utilization. This finding aligns with recent studies emphasizing that the equitable distribution of green spaces enhances their use and the associated health benefits [9,45,51–53]. Thus, enhancing UGS accessibility can lead to more frequent use, promoting physical and mental health, social cohesion, and environmental sustainability.

Additionally, the study identified significant engagement in physical activity, sitting/relaxing, and socializing, with physical activity being the most prevalent among daily visitors. This supports existing research indicating that green spaces are pivotal in encouraging physical activity and reducing chronic disease risks [54,55]. Such spaces can significantly enhance urban residents' well-being by promoting physical and social activities [25]. Furthermore, the study found that older adults visited UGSs less frequently, suggesting potential barriers to their engagement. While these barriers may include design or planning issues, other factors, such as mobility limitations or illness, could also play a role. This aligns with previous research advocating for age-friendly green spaces to encourage older adults' participation in physical and social activities [50,51]. Conversely, a study in Sweden found that more frequent users were older and more likely to be female [50]. Additionally, our research found that males had significantly lower odds of "sitting/relaxing" and "socializing" than females. These gender differences, alongside findings from previous research [9,45], indicate the necessity for tailored programming to ensure equitable usage among males and females. The significant effects of age and gender on UGS engagement underline the necessity for demographic-sensitive urban planning.

The significant differences in physical activity and sitting/relaxing frequencies across visitation patterns emphasize UGSs' critical role in promoting physical activity and relaxation among frequent visitors. The borderline significance in socializing activities suggests a trend towards more frequent social engagement among everyday visitors, warranting further investigation. As in other studies, infrequent users mainly associate greenspace with social benefits, indicating that frequent users benefit more from multifunctional UGS [50]. Additionally, our study found that work status significantly influences visitation, with employed individuals more likely to visit UGSs frequently. This highlights the role of routine and lifestyle in green space engagement, suggesting accommodating diverse work schedules by ensuring UGSs are accessible during different times of the day and strategically located near residential areas and workplaces to promote higher UGS usage. Similar findings were reported by van Heel et al. [52], who noted that flexible work hours and proximity to green spaces positively impacted the frequency of UGS visits among urban residents. Enhancing UGS availability and accessibility could increase the frequency of visits and the associated benefits, particularly for exercise and relaxation activities [31,32].

The study highlights a strong association between nature connection and UGS interaction, emphasizing the psychological and emotional aspects of UGS usage. Participants with a stronger connection to nature were more likely to engage with UGSs. This aligns with other studies showing that individuals with a strong nature connection tend to use green spaces more frequently [39,44,50]. Lin et al. (2014) suggested that connectedness to nature significantly influences green space visitation rates, often more than availability. Globally, fostering a deep connection to nature enhances UGS usage, promoting mental and physical health. For instance, a European study found that individuals with a strong connection to nature were more likely to use green spaces for physical activities, improving overall health [44]. Similarly, Lumber et al. (2017) found that nature-connected individuals in urban areas engaged more in community gardening and outdoor activities, enhancing social interactions and environmental stewardship [53].

The results of this study underscore the importance of strategic urban planning and targeted interventions in the development and management of Urban Green Spaces (UGSs), particularly in rapidly urbanizing areas. Urban planners should prioritize the creation of accessible, high-quality green spaces, focusing on underserved areas and integrating UGSs into urban development projects. Given the challenges of enhancing UGS availability, especially in rapidly urbanizing cities like Nagpur, planners could explore innovative solutions such as repurposing underutilized land or incorporating green spaces into an existing infrastructure. These efforts can promote more frequent use of UGSs, improving physical and mental health, social cohesion, and environmental sustainability [54]. This aligns with several SDGs, including good health and well-being (SDG 3), sustainable cities and communities (SDG 11), and climate action (SDG 13). Moreover, this study supports the call for more inclusive UGS planning frameworks that consider different user groups' diverse preferences and perspectives [52]. This requires a systems approach to UGS planning, viewing these spaces as integral parts of a broader urban social-ecological system and coordinating efforts across sectors [52,55]. Urban planners should incorporate the views and needs of diverse populations, ensuring that UGS designs are inclusive and reflect the varied experiences desired by different groups [50,51,54]. Integrating UGSs into urban frameworks through green infrastructure and nature-based solutions can strengthen urban resilience against climate change and public health challenges [14,43]. Educational and community-based initiatives that foster a strong connection to nature are vital for encouraging frequent and meaningful engagement with UGSs [35,39]. Such strategies can help cities create vibrant, sustainable, and healthy environments, benefiting all residents and contributing to global efforts to achieve sustainability and resilience in urban development [44,53].

While this study provides valuable insights, it has limitations. The reliance on self-reported data may introduce biases related to social desirability or recall accuracy. Additionally, the cross-sectional design limits the ability to infer causal relationships. Future research should explore qualitative aspects of UGS experiences to capture how individuals interact with these spaces, employing in-depth interviews or participatory methods for rich, contextual data. Expanding the scope to include diverse urban contexts across different countries would help validate the findings and offer a broader understanding of global UGS dynamics. Moreover, investigating specific barriers older adults face in accessing UGSs and developing targeted interventions can enhance their engagement. Examining the impact of different employment types and work schedules on UGS usage can provide deeper insights into accommodating diverse lifestyles through urban planning.

5. Conclusions

This study offers valuable insights into the factors influencing UGS usage in Nagpur, India, particularly in the context of a rapidly developing city. The findings highlight the importance of equitable access to UGSs, the role of proximity in promoting frequent engagement, and the influence of demographic characteristics such as age and gender on UGS usage. Neighborhood UGSs play a pivotal role in supporting physical activity, but the study also identifies unmet demand in areas with lower UGS availability, underscoring the need for more equitable green space distribution. Additionally, the study emphasizes the significant impact of nature connection on UGS engagement. Fostering a deeper connection with nature through targeted educational and community-based initiatives can lead to more frequent and meaningful interaction with UGSs, contributing to urban residents' physical and mental well-being.

Urban planners should focus on developing more inclusive and accessible UGSs, particularly in underserved areas, while considering the diverse needs of different demographic groups. Addressing these challenges through thoughtful urban planning can enhance the sustainability, health, and social cohesion of rapidly urbanizing cities like Nagpur. Future research should delve deeper into the specific barriers faced by older adults and other underserved populations in accessing UGSs and explore the influence of work schedules and employment types on UGS usage. By addressing these aspects, cities can better design UGSs that promote equitable access and foster vibrant, healthy urban communities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13101576/s1.

Author Contributions: Conceptualization, S.A.L.; Methodology, S.A.L.; Formal analysis, S.A.L.; Writing—original draft, S.A.L.; Supervision, S.D. and O.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Institute for Global Environmental Strategies (IGES) grant number (230719) SMO(RP)/SRF(VUE).

Data Availability Statement: The data presented in this study are available on request from the corresponding author. As the research is ongoing, we cannot share the data publicly.

Acknowledgments: We thank the research assistants, Pranav Gorle and Nutan Ghate, for their fieldwork leadership. We also thank Mousumi Bhowal and Parma Majumdar for allowing their students to participate in the fieldwork for data collection.

Conflicts of Interest: The authors declare no conflicts of interest.

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