



Impact of Physical Density on Nature and Use of Open Spaces: A Pilot Study of Two Residential Areas from Jaipur, India

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Abstract Numerous buildings are raised every day as a result of increasing urbanization and the need for creating larger number of accommodations for people in the cities. These buildings transform the cities into concrete jungles, without taking into consideration either the identity of the residential neighbourhoods, or the necessary open and green spaces required for a livable and sustainable environment. Hence, there arises a need to overcome the negative effects within those precarious settings and find a solution for improving the quality of life in residential areas, by assessing the impact of different physical density in residential areas on the nature and use of open spaces (NUOS). In the present study, the case study approach is used to conduct a pilot study and compare two residential localities of Jaipur, India, with different physical densities and assess the NUOS, outlining both qualities and deficiencies of their planning. A conceptual framework showing possible correlations between density variables and indicators of NUOS is developed and based on primary and secondary data, a correlation coefficient analysis is undertaken that shows significant relationships between the density variables and indicators of NUOS. It suggests that more people engage in different activities and greater social interaction happens in higher density neighbourhoods. The study also emphasizes on the fact of less ground coverage and more open spaces as a way towards the design of sustainable communities. The

distribution of physical and social infrastructure as given by the spatial density variables improves peoples' willingness to come to these spaces for various activities and social interaction. Thus, it indicates an enhanced use of the open spaces as shown by the positive correlation. The multiple regression analysis is used to ascertain the percentage variation in NUOS with change in physical density variables. The findings are statistically tested and aggregate quality profiles of the open spaces are generated for both the areas. The quality profiles serve as tools to identify commonalities and differences in the indicators of NUOS and help in suggesting measures for improving the conditions. The proposed methodology can be adapted and used for various other existing and upcoming residential areas to assess and improve NUOS and promote sustainable development in our cities.

Keywords Physical density · Nature and use of open spaces (NUOS) · Residential areas · Aggregate quality profile of open spaces

Introduction

The urbanization process is not equal for all regions across the globe. Africa and Asia are urbanizing faster than other regions, being expected to become 56% and 64% urban by 2050. Furthermore, by 2050 it is expected that more than 68% of the world population will be urbanized, even though the rural population that has slowly grown for the past 60 years, will “reach its peak” in a few years. However, this will be only for a short period of time, followed by a drastic decrease in the following years [1, 2]. The premise people follow before moving to urban areas is the promise of a better life that the city has to offer. Generally, cities are considered focal points for economic growth, innovation and

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employment. People move to the cities to experience better life conditions with access to education, health care, sanitation, electricity and water, all the above marking a brief definition of what urban areas mean today.

In time, the uncontrolled mass urbanization has led to insurmountable flaws that before only occurred in the rural areas: inadequate drainage systems, lack of sanitary conditions, poor environmental quality and deficiency in electricity. Moreover, it is even more alarming as the urban poor is increasing at a higher rate than the overall rate of urban population growth. Almost 30% of urban population lives in slums and 64% of these people belong to Asia. This is the result of an unfortunate government management system and the absence of pre-defined limitations on the existing settlements in which they develop [1–3].

The primary pillars of sustainable development within the urbanization process are economic development, social development and environmental protection. Even though these are sine qua non conditions to livability in a modern city, people seem to overlook them, especially when it comes to environmental involvement. The tendency of modern society is to procure colossal amount of built land for new inhabitants completely ignoring the necessity of a healthy and green environment for abating pollution and unsustainable growth. Greenery influences the urban climate, decreases global warming and environmental damages. Naturalness also mitigates “the urban heat island effect”, by creating an ecological balance within the city. Environmental contaminations such as air, noise and water pollution produced by industrial areas are easily absorbed by green and open spaces [4].

As it is stated in the review on the quality of green open spaces by Malek et al. [5], “both buildings and open spaces benefit from each other through the quality of each space”. Moreover, parks and open spaces not only have benefits upon the social, economic and aesthetical aspects, but also on the mental and physical health of the residents. Regarding the environmental issues, with respect to the habitat or neighbourhood scale, the ones that stand up are the lack of proximity to recreational and health facilities for the children and the elderly, such as parks or squares and also the low quality of the settings because of air and noise pollution [6]. Hence, there is a need to understand how the development in residential areas effects the environment and the livability standards of their inhabitants. The first step to do this is to understand in terms of density the residential patterns most prevalent in cities. The subsequent challenge is to find the effects of the residential patterns or density upon the nature and use of open spaces. This is important to chalk out a clear way of comprehending and resolving the most importunate problems in today’s cities and extend the conceptual framework and methodology for adoption and use in other rapidly urbanizing cities across the globe.

Nature of Open Spaces and Urbanization in India

For better accentuating the importance of green and open spaces in the living organisms of the city, it is important to categorize their valuable effects both at the micro and macroscale. For example, at the city scale green spaces can have a significant long-term impact upon the quality of life. Surveys conducted show that the minimal criteria for livability throughout the cities differ from region to region, but there are certain standards that are pertinent for citizens well-being. The URDPFI Guidelines 2014 [7] in India recommend 1.2–1.4 hectares/1000 population or 12–14 sqm/capita for community open spaces while it is seen that the open spaces have been constantly decreasing in metropolitan cities because of rapid urbanization and increase in built-up areas. Mumbai has just 1.1 sqm of open space—gardens, parks, recreation grounds (RG) and playgrounds (PG)—per person [8]. In comparison London has 31.68 sqm per person while New York has 26.4 sqm per person. Chicago’s 17.6 sqm per person also puts India’s financial capital to shame. The poor green ratio in Mumbai translates into a terrible quality of life and poor environment. It also strikes a blow to Mumbai’s reputation as a global hub [9, 10]. Similarly, Jaipur has about 0.2 hectares/1000 population or 2 sqm of open space per person which is much less than the prescribed standards. According to the proposed Master Development Plan 2025, it is proposed to enhance the per capita open space to 8.80 sqm. For a population projected to grow to 6.5 million by the year 2025, even at the minimum scale, Jaipur will require to establish 58.50 sqkm of urban green space. From another perspective, overall, the people and planners will have to strive for regenerating at least one medium sized mature tree as desirable number per person in Jaipur, Rajasthan [11]. Several other studies have also tried to understand the greenery status of our cities and suggested measures for strengthening the network of urban green spaces through linkages between various components. Financial innovations can be the key to generate resources to manage the open spaces sustainably [12, 13]. Public ground area consisting of streets (carriageways and footpaths) and parks available to each resident of the area is also instrumental in establishing how good or bad the locality is. The study by Dutta et al. [14] shows that building byelaws/regulations with respect to FAR, plot coverage, setbacks, etc. varies across Indian cities. FAR ranges from 1.2 to 3.25 with plot coverage varying between 35 and 70%. Any attempt at increasing FAR is generally not supported with adequate infrastructure thus leading to severe problems and degraded urban environment.

From ancient times until today, India has undergone major political, social and economic changes, which have left their imprints on the development of this country, whether they have been caused by external or internal factors [15, 16].

Urbanization as a process spread throughout India more in the Post-Independence period. Two of the major causes of this urban growth were the influx of refugees or immigrants and people moving from rural areas to urban areas or from small towns to metropolis due to the standardization of development in urban settlements [17]. In the years that followed the Independence, there were cities planned and built pursuant to western principles, such as Chandigarh and Islamabad. All these cities had one thing in common—the consideration they gave for improving the quality of life, such as: infrastructure (in Chandigarh, there were networks of roads geometrically disposed, most of them being tree-lined), cleanliness, high living standards, but most importantly of them all, greenery. One of the highest living standards of such Indian cities till date is the environmental care, because in this lies the power of improving one's life, not only physically, but also mentally.

However, over the years, the rise of interest in urban life caused extensive population growth that led to uncontrollable growth of the popular cities and decay of the inconspicuous ones. India is amongst the countries with the highest percentage of urban population, with a rate of 31.1%, and is ranked second in the world after China, both together consisting 30% of the world's urban population [1, 2, 17]. India is also home to two of the world's largest cities with an agglomeration of 25 million people in Delhi and 23 million people in Mumbai and it is expected by 2031 that 70 cities in the country will reach a million population due to the economic growth brought in by IT (information technology) and other flourishing high-tech industries [18, 19]. Thus, it is imperative to understand the challenges cities are facing so as to improve the quality of life in the residential neighbourhoods that constitute the basic module of a city.

Problems and Challenges of Urbanization in India

Surveys show that along with the increase in urban population and number of towns since 1951, the large towns and metropolitan cities have developed at a much higher rate than small towns, leaving the latter at a considerable distance behind. Nowadays, the population living in large cities or metropolitan cities (cities with population above 1,000,000) represent more than two-thirds of the entire urban population of India. Metropolises are functioning as focal points for modern activities, attracting workers, and contributing more than 55% of the total GNP of this country [20].

The corona virus or COVID-19 pandemic has brought to light the severe deficiencies in the urban management systems globally. It points to the urgent need to enable inclusive, just and ecologically conscious cities with enhanced access to urban oases/public green spaces that communities can count on during times of crisis [21]. Environmental degradation is affecting people physically, psychologically

and socially. Several studies in recent years are showing that Indians are losing on an average 5.2 years of their lives at current pollution levels in our cities [22, 23]. There is a large variety of issues that need to be resolved for a better quality of life, but most significant ones are:

- i. Increasing disparities between the city core and the peripheral areas

The economic differences between parts of the same town are to be found in most of the metropolises, where extreme poverty and unemployment (usually characteristics of the peripheral areas) can lead to a higher crime rate and social tension. Likewise, the lack of access to social and health care services regardless of the area can increase the vulnerability of people to diseases and development challenges [24].

- ii. Degradation and disappearance of open spaces both at the city and neighbourhood level

Deficiency in green open spaces results in escalation of pollution levels. Air is polluted and people get intoxicated over time, facing precarious physical and mental health. On a larger scale, it helps exacerbating global warming.

- iii. Lack of environmental infrastructure

Authorities cannot keep up with the ever-growing cities and so there are difficulties with providing the minimum required environmental infrastructure, such as water supply, waste disposal, sewerage and pollution control services. The consequences of these actions are spread of epidemics, degradation of ecosystems and neighbourhoods.

- iv. Disposal of garbage and untreated sewage creating insanitary conditions

Untreated sewage and inefficiency in garbage disposal can bring back illnesses eradicated before. In many Indian metropolises, local authorities fail in maintaining the well-being of the neighbourhoods due to the overcrowded settlements.

- v. Increasing traffic volumes leading to air pollution and noise pollution.

Noise pollution can cause permanent reduction of hearing sensitivity, while air pollution can cause respiratory problems. Constant exposure to noise and dust can cause a decrease in time spent outside, automatically making people anxious and unwilling of sustaining any human interaction or being socially active.

The need to promote the qualities and the benefits that open and green spaces have upon inhabitants' lives, it is essential to undertake this study in order to understand how the number of people and dwelling units (density) impact the type, distribution and quality of open spaces, and the activities undertaken by the inhabitants as well as their way of life.

The study is also essential to arrive at sustainable solutions for environmentally conducive development of residential areas for future sustainable cities. The study objectives are:

1. To identify physical density variables that define the residential patterns
2. To identify the indicators of nature and use of open spaces (NUOS)
3. To understand the relationship between the residential patterns (given by physical density variables in this case) and indicators of NUOS
4. To assess the impact of physical density on NUOS
5. To suggest design strategies for (development of) environmentally conducive residential areas in the city

Based on the literature review and similar studies by Del-sante [25], Garau and Pavan [26], the pilot study is limited to the formal organized sector by selecting two neighbourhoods namely Urban Woods, Vatika Infotech City (medium density) and Rangoli Gardens, Vaishali Nagar (high density) from Jaipur city, Rajasthan, India. The city of Jaipur is selected as it is a capital city and has the potential to turn into a much larger centre in the near future. Ease of accessibility to the two neighbourhoods (within 15–30 min) as authors were based in Jaipur at the time of the study has been an important decisive factor in selection of the city. The study and consequent analysis enumerate the physical and social benefits assured by an adequate natural environment within the residential areas. The socio-economic factors are presently kept out of the scope of study.

Study Methodology

Information required for the pilot study is mainly collected from primary and secondary data. Primary data consist of visual survey and photographic documentation made during visits to the neighbourhoods, narratives and oral histories collected from the inhabitants and questions answered by interviewed people. The survey is formed of questions regarding neighbourhood satisfaction, activity intensity, neighbourhood surroundings and aesthetics, traffic hazard, facilities and commodities analysis, cleanliness and the willingness of people to stay or leave the neighbourhood. The questionnaire survey is administered to approximately 100 households (320 individuals) from different age groups after suitably ascertaining the sample size statistically. Both open and close-ended questions are asked thus eliciting peoples' impressions and observations on how they perceive the relationship between built area and naturalness in their locality. Secondary data entail information collected from published sources such as URDPFI 2014 [7], earlier research, personal records and mass media material. Additionally, the

statements are also supported by unpublished sources such as maps, plans and drawings of both the residential areas.

Information collected is used for an exhaustive comparative analysis between the two case study areas. The comparison aims to identify the relationship between residential patterns given by physical density parameters as per Cheng's [27] study and indicators of NUOS. A correlation analysis establishes the type (positive/negative) and strength of association (strong/weak) between the density variables and indicators of NUOS. The multiple regression analysis helps to ascertain the R^2 value that explains the impact of physical density on NUOS. The model is statistically tested using the one-way ANOVA. Finally, aggregate quality profile of NUOS is evolved for both the case study areas, revealing the conclusions for an optimal way of living. All the observations and conclusions are based on a restricted area analysis, to encourage further development and applicability to similar residential areas in other cities. It is envisioned that future studies can consider neighbourhoods with varied densities to take into consideration the heterogeneous structure of the cities.

Conceptual Framework

The conceptual framework is formulated on the basis of density variables and indicators of NUOS to understand the connection between them. This process is necessary to outline the existing situation, identify the problems and their causes, and identify means by which one can accede the solution and finally give answers for the problems encountered [28].

According to Cheng [27], Physical Density is usually measured by population (number of people per unit area) or dwelling units commonly referred to as residential density (the number of dwelling units per area) given by people density. Additionally, floor area ratio (FAR), plot coverage (given by plot covered by buildings) give building density while distribution of open spaces, distribution of roads and sidewalks, distribution of street lights and distribution of social infrastructure give spatial density.

Taking this further, nature and use of open spaces (NUOS) is defined by types of open spaces (such as parks, playgrounds, streets, squares or dead ends), condition of the open spaces (whether they are maintained, unmaintained or encroached), naturalness (measured in terms of tree coverage, green, paved or metaled surfaces), level of cleanliness (domestic waste disposal, sewerage and drainage), activity intensity (number of people per unit area), activity diversity (number of different types of activities as a ratio of the population) and walkability (the condition of sidewalks, street lights, open space and proximity to daily needs) [14].

As indicated in Table 1, different density variables influence one or more indicator(s) of nature and use of open spaces (NUOS). Here, variables determine the spatial

Table 1 Relationship between physical density variables and indicators of NUOS. *Source:* Authors’ elaboration based on literature review

Physical density variables		Indicators of nature and use of open spaces (NUOS)						
		Type	Condition	Naturalness	Level of cleanliness	Activity intensity	Activity diversity	Walkability
People density	Population density	✓✓	✓		✓✓	✓✓	✓✓	✓
	Residential density	✓✓	✓		✓✓	✓✓	✓✓	✓
Building density	FAR					✓✓	✓✓	
	Plot coverage	✓✓		✓				
Spatial density	Dist./Amount of open spaces			✓✓		✓✓	✓✓	✓✓
	Dist. of roads and sidewalks			✓		✓✓	✓	✓
								✓✓
	Dist. of Street lights					✓	✓	✓✓
	Dist. of social infrastructure		✓✓		✓	✓✓	✓✓	✓

Assumed strong correlation—✓✓

Assumed weak correlation—✓

Empty cells—no apparent correlation

organization while indicators help in ascertaining the livability of neighbourhoods.

Larger population and residential densities are generators of different types of open spaces as all the needs of different age groups of residents must be fulfilled within a completely functioning zone [29]. At the same time, more inhabitants can also mean that open spaces might be more or less taken care of. Depending on the willingness of residents to pay for facilities or take care of the open spaces by themselves, the level of cleanliness in a highly occupied area might be higher or lower. Activity intensity as well as activity diversity is affected by the occupancy level of the neighbourhood and the age group of the inhabitants [25]. Walkability may differ from district to district but it is mostly determined by the age group of the people within the residential area. Youngsters may walk more than the elderly, or they may even have sports orientated activities such as jogging or cycling on the streets and sidewalks.

Higher floor area ratio generally as per the observed scenarios in Indian cities implies more dwelling units and higher population/residential density. The direct consequence of this is the increase in diversity and intensity of activities [30]. Plot coverage marks the spatial distribution of green and open spaces, a higher plot coverage generally implying lesser/smaller/fragmented open spaces [31, 32]. The various spatial density variables and their probable relation with the indicators can be explained as:

i. Distribution/Amount of Open Spaces

According to URDPFI 2014 Guidelines [7] by MoUD, open and green spaces must be calculated with respect to the normative of 12 sqm/person, which provides the minimum necessary space for every inhabitant. A greater amount of open space leads to more

intense and diverse activities as a result of more social interaction [33]. Moreover, green and open spaces can constitute shortcuts and alternatives to roads, thus encouraging walkability.

ii. Distribution of Roads and Sidewalks

Parks and playgrounds need to be in close proximity to the buildings and have sufficient space for residents, which shall promote more activities regardless of the different age groups. Shaded open spaces which are in the proximity of buildings create a comfortable microclimate for both outdoors and indoors. Distribution of roads and sidewalks also encourage more diversity in activities, such as walking, jogging or cycling, providing the possibility of a healthy lifestyle for the respective residents [34].

iii. Distribution of Street lights

Street lighting can determine one’s perception of safety of the neighbourhood they live in or pass by. Studies have shown that a well-lighted space encourages people to spend time outside regardless of the time. Better lighted spaces and sidewalks are used and encourage people to walk more [35].

iv. Distribution of Social Infrastructure

Well-managed and distributed social infrastructure determines an increase in the number of people frequenting the area. A consequence of this is the attraction of even more people as they feel safer around populated buildings [36, 37].

Brief Overview of Jaipur City

Jaipur, also known as the “Pink City”, is the capital of Rajasthan State, located in the north-western part of the Indian subcontinent. It is one of the most historically

important cities of India, having a tumultuous evolution where every event has left its mark on the architectural development of the city, resulting into the contrasting metropolis of today.

The city of Jaipur was founded by Sawai Jai Singh, in 1727 AD, transferring the capital of the state from Amber 11 km to the east. The Raja's decision came as a consequence of two possible factors: first was the geographical factors that influenced the shifting of the capital to a flatter land and proximity to resources, as the old fort of Amber was situated upon a hill, making it harder for the town to expand; the second possible reason could have been the wish to establish a city as a strong political statement at par with Mughal cities [38].

In the nineteenth century the city went through modernization brought by the new technology, such as railways, gas lights on the streets, improved drainage system and piped water supply. In the last decade, Jaipur has seen a colossal growth becoming one of the most desired urban centres in India, expanding its boundaries through real estate development.

Studies have shown there is a preference for the southern part of the city, which has expanded more due to several factors. The main advantage is represented by the ring road that not only enables the connection between the business zones, the commercial and the residential areas, but also facilitates the way to the exterior. Furthermore, the development of the railway station and airport have gained popularity in this part of the city. Secondly, most of the business headquarters take an interest in developing in this specific area alongside commercial centres, hotels and hospitals [39].

Selection of Case Study Areas

Two residential areas are chosen from the rapidly developing areas in the south and south-western parts of the city of Jaipur.

The first locality is Urban Woods, located along Jaipur-Ajmer Expressway in the southern part of the city. Urban Woods is a low-rise medium density (LRMD) neighbourhood as shown in Fig. 1 with a density of approximately 235 persons per hectare, calculated with an average household of 3.8 as per census 2011 of Jaipur city. It is a planned neighbourhood with tree-lined streets, row housing (G+3) and two parks for the residents' recreation and sport activities. It is also equipped with a club house with different facilities and convenience shopping for the residents.

The second locality is Rangoli Gardens, located towards the south-western part of Jaipur. Rangoli Gardens is a high-rise and high density neighbourhood (HRHD) as shown in Fig. 2, with a density of approximately 1662 persons per hectare. The location is easily accessible within the city, due to proximity to main circulation axes. Furthermore, the



Fig. 1 Urban Woods, Jaipur. *Source:* Authors, 2019



Fig. 2 Rangoli Gardens, Jaipur. *Source:* Authors, 2019

gated community is equipped with an elaborate commercial centre and sports centre within easy reach of the residents.

Data Organisation

The study emphasizes on the primary data collected from both the case studies. Observations are mainly focused on the nature and use of open spaces, representing a fundamental phase in understanding how the development of residential areas have affected the natural environment and the livability standards of their inhabitants.

Urban Woods, Jaipur

Urban Woods has a total area of 17.33 acres with a residential density of 24 DUs/acre or 62 DUs/hectare. Figure. 3 shows the map and salient features of the neighbourhood. The built-up area constitutes 34% of the total area and the detailed land use distribution is as indicated in Fig. 4.



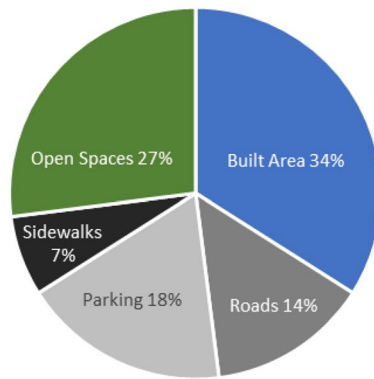
Fig. 3 Map of urban woods, Jaipur. Source: Authors, 2019

Rangoli Gardens, Jaipur

Rangoli Gardens has a residential density of 174 DUs/acre

or 435 DUs/hectare. Figure. 5 shows the map and salient features of the neighbourhood. The built-up area constitutes

Fig. 4 Land use distribution, urban woods, Jaipur. *Source:* Authors, 2019



COLOUR	LANDUSE	AREA (acres)	%
Yellow	Residential	5.6	32.3
Blue	Commercial	0.12	0.7
Red	Public Building	0.17	1
Grey	Roads	2.42	14
Light Grey	Parking Lots	3.04	17.56
Dark Grey	Sidewalks	1.26	7.31
Green	Open Spaces	4.72	27.13
	Total	17.33	100

25% of the total area and the detailed land use distribution is as indicated in Fig. 6.

Data Analyses

After organization of the primary data, the values of the density variables of both residential areas are compared with the recommended values as given in different standards/guidelines as shown in Table 2.

Table 2 shows that in most cases Urban Woods has better overall values compared to Rangoli Gardens. Most of the indicators used for the survey and present in the following table are measured on a five-point Likert Scale where 5 is the highest score that refers to most favourable/acceptable quality and 1 refers to the least favourable/acceptable quality.

After analysing the survey's outcome in Table 3, it is clear that unlike Table 2, Rangoli Gardens scores more than Urban Woods, as it is better perceived by the people living there. For a conclusive outcome, the results are further explained to bring out the relationship between the different density variables namely People Density, Building Density, Spatial Density and Indicators of Nature and Use of Open Spaces (NUOS) as follows:

i. People Density and NUOS

Larger population / residential densities can be generators of different types of open spaces as per the needs of different age groups of residents. Hence, people density directly influences the *types of open spaces* as shown by the case of Rangoli Gardens in Fig. 7a. A large number of residents also implies that the open spaces are better taken care of. The graph shows that Urban Woods, which has a lower occupancy rate, tends to maintain the public open spaces less, while Rangoli Gardens, which has a higher occupancy rate, has better maintained open spaces as shown in Fig. 7b.

While type, condition of open spaces, activity intensity and activity diversity show a positive correlation with people density, cleanliness and walkability show

negative relationship with people density. If there are more residents the level of cleanliness in the area is generally less, as in the case of Rangoli Gardens (Fig. 8a). The graph in Fig. 8b shows that higher the people density, the lower is the score of walkability. This is a consequence of the high-rise development and the fact that people feel too overwhelmed by the buildings to walk among the blocks or to communicate/interact with their neighbours. The higher traffic also impedes the willingness to walk.

ii. Building Density and NUOS

Higher plot coverage of 34% in Urban Woods implies lesser open spaces, as shown in the comparative graph between Urban Woods and Rangoli Gardens (Fig. 9a). However, as Fig. 9b indicates that higher values of FAR generally imply more DUs and higher people density show increased activity intensity and diversity as substantiated by the case of Rangoli Gardens with FAR 2.04 as compared to Urban Woods having a FAR of 1.31. This is also in-line with the findings above in Fig. 8b showing a similar relationship between people density and activity intensity and diversity.

iii. Spatial Density and NUOS

Open spaces can constitute shortcuts or alternatives to daily roads and thus increase walkability. The graph in Fig. 10a shows that there is a direct influence of the naturalness upon walkability, spaces that have a higher score in naturalness, directly impact the walkability. On the other hand, the graph in Fig. 10b shows that the amount of open spaces does not really influence the intensity and diversity of activities. Rangoli Gardens has a high score in activities, even though it has a low amount of greenery in terms of sqm/capita

The distribution of social infrastructure like convenience shopping, community centre, club, etc. also promote more activities and social interaction in the various types of open spaces adjoining these facilities as shown in Fig. 11a. Similarly, higher percentage



Fig. 5 Map of Rangoli Gardens, Jaipur. Source: Authors, 2019

of sidewalks influence walkability in Urban Woods as shown in Fig. 11b. Thus, it can be concluded that spatial density has a definite impact on NUOS in neighbourhoods.

Correlation Analysis Between Density Variables and Indicators of NUOS

To further establish the type and strength of association

Fig. 6 Land use distribution, Rangoli Gardens, Vaishali Nagar, Jaipur. *Source:* Authors, 2019

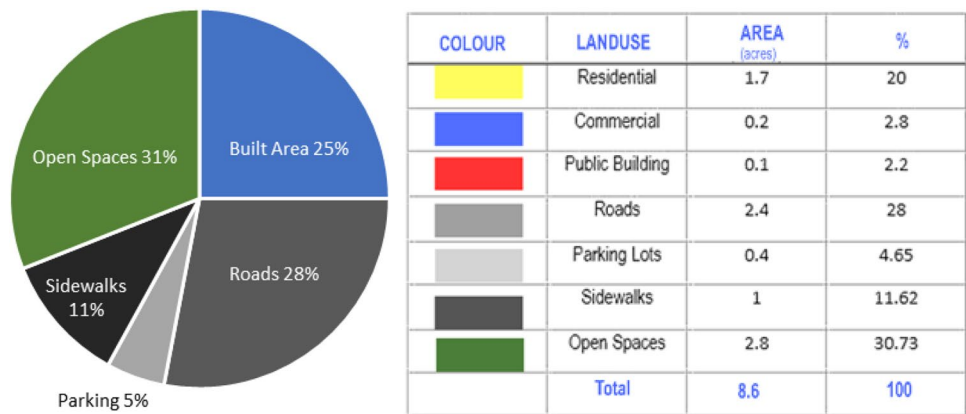


Table 2 Value of density variables w.r.t standards/guidelines. *Source:* Literature review, URDPFI 2014 and report on Indian urban infrastructure and services, HPEC Committee, March 2011

No	Density variables	Standards/guidelines	Urban woods	Rangoli gardens
1	Population density (pph)	111–787	235	1662
2	Residential density (DUs/ha)	25–175	62	435
3	FAR/FSI/plot coverage	0.50 (should not exceed 1.75)	1.31	2.04
4	Plot coverage (%)	25–35%	34%	25%
5	Distribution of open spaces (sqm/capita)	12–14	11.66	2.19
6	Distribution of roads (m/capita)	0.91	1	0.33
7	Distribution of sidewalks (%)	–	7.31	11.62
8	Distribution of street lights (c/c distance)	30–31 m	15	20
9	Distribution of social infrastructure (sqm/1000persons)			
	Convenience shopping	220	86	152
	Local shopping including service centre	300	61	116
	Community centre with service centre	500	146	68

between the physical density variables and indicators of NUOS, the correlation coefficient analysis using SPSS 22 is carried out on the data. The Pearson correlation coefficient analyses show that significant relationships exist between the density variables and indicators of NUOS (refer Table 4 below).

The correlation matrix indicates that there is a strong positive correlation between people density and activity intensity. The similar results are also observed for values of activity diversity thus suggesting that more people engage in different activities and greater social interaction happens in high density neighbourhoods. The correlation of FAR with indicators of NUOS also suggests a similar trend, i.e. higher the FAR, more is the intensity and diversity of activities.

With an increase in people density, the level of cleanliness and walkability deteriorates as shown by the negative correlation. Traffic congestion on internal roads due to high per capita vehicle ownership and on-street parking also impact the willingness of people to walk due to increased crowding in the locality.

The high plot coverage also creates an overwhelming feeling and deters people from walking and interacting at the street level. This is corroborated by the strong negative correlation. Higher plot coverage also leads to considerable decrease in naturalness as shown by the negative correlation.

The spatial density variables indicate that as the distribution of open spaces and sidewalks increases, the public ground area per capita increases. With the increase in the distribution of open spaces and better level of services (street lights and other social infrastructure), the spatial quality and willingness to walk improves as shown by the positive correlation. The increase in open spaces also reduces congestion as more people walk within the neighbourhood using the sidewalks, pedestrian pathways and shortcuts. This is particularly noticed in the present case studies and shown by the strong positive correlation between distribution of sidewalks and walkability. The distribution of infrastructure like community facilities, street furniture, waste collection bins, street lights, etc. also improve the condition of the open spaces. This then enhances peoples' willingness to come to

Table 3 Outcome of opinion survey

No	Indicators of nature and use of open spaces (NUOS)	Urban Woods	Rangoli gardens
1	Type of open space (Parks, Playground, Sports Field, Squares, Sidewalks, Roads, and Parking Lots)	Score: 2/5 (not many types of open spaces, two parks, side-walks and roads) Score: 4/5 (generally the streets, sidewalks and parks are well-maintained, but due to the low level of occupancy, the vacant yards are less maintained)	Score: 5/5 (large variety of open spaces such as playgrounds, sports fields, and parks) Score: 5/5 (due to the high rate of occupancy, all the open spaces are well-maintained)
2	Condition of open space (Maintained, Unmaintained, and Encroached)	Score: 5/5 (high amount of greenery throughout the area)	Score: 2/5 (the area is dominated by the presence of buildings and the greenery is not sufficient to compensate)
3	Naturalness	Score: 5/5 (the streets are cleaned everyday)	Score: 4/5 (the streets are cleaned very often)
4	Level of cleanliness	Score: 3/5 (most every day activities are children orientated and they take place in the parks and playgrounds)	Score: 5/5 (the parks, sports fields and playgrounds are always used by residents of all age groups)
5	Activity intensity	Score: 2/5 (fairs, meetings, festivals are being held in the open space and the clubhouse, but only occasionally)	Score: 5/5 (plenty of activities offered for every age group)
6	Activity diversity	Score: 5/5 (the sidewalks are shaded, well-lighted at night and well-maintained: facilities are within walking distance from every house and there are plenty of shortcuts)	Score: 2/5 (the sidewalks are well-lighted and well-main-tained, but due to the high-rise buildings, there is a sense of overwhelming given by the blocks, traffic is also a concern in the locality)
7	Walkability		

these spaces for various activities leading to higher social interaction.

Thus, it is seen that most of the indicators of NUOS have significant correlations with the physical density variables as indicated in Table 4. This validates the conceptual framework between the two types of variables and points assertively towards the fact that there are significant relationships between the residential patterns (given by physical density variables in this case) and indicators of NUOS as intended to be shown by the pilot study.

A multiple regression analysis is carried out to ascertain the R^2 value that explains the percentage of variation in the indicators of NUOS due to the density variables. The model summary (refer Table 5) shows that 67.4% (adjusted R Square value) variation in aggregate value of NUOS is significantly due to the variations in the density variables. This assertively shows that “Physical Density has an impact on Nature and Use of Open Spaces”.

Results and Discussion

The correlation coefficient analyses show that significant relationships (both positive and negative) exist between the physical density variables and indicators of NUOS. People engage in community activities and group interaction because of the type and condition of open spaces. Activity intensity increases with increase in people density and building density. Activity diversity also shows an increasing trend with increasing residential density thus suggesting that more people engage in different activities and greater social interaction happens in higher density neighbourhoods. However, higher FARs and plot coverage reduce the public ground area per capita and paved road length per capita and aggravate congestion on roads which dampens people willingness to walk and thus negatively affects the walkability of the area. Other aspects like presence and condition of sidewalks, street lights, outdoor furniture, level of cleanliness, etc. determine peoples’ desire to reside, walk and utilize spaces. Good level of services and regular maintenance and upkeep of the residential areas ensure higher level of cleanliness as seen in the case studies. Proximity to daily needs, good condition of sidewalks and open spaces helps in creating walkable neighbourhoods.

The aggregate quality profiles help in comparatively analysing the commonalities and the differences in the indicators of NUOS. It is seen that Rangoli Gardens has slightly better overall nature and use of open spaces as compared to Urban Woods. A closer look at the quality profiles (Fig. 12) suggest that the types and condition of open spaces is much better in Rangoli Gardens thus resulting in higher scores of activity intensity and activity diversity as compared to Urban Woods. However, the lower level of cleanliness and

Fig. 7 a and b Impact of people density on type and condition of open spaces

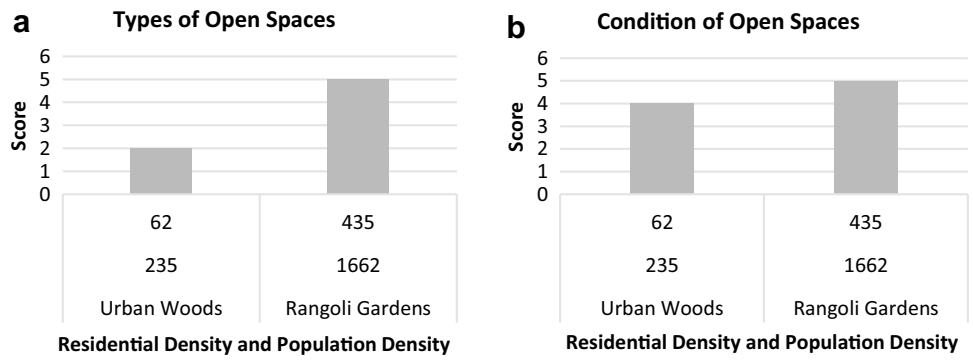


Fig. 8 a and b Impact of people density on cleanliness, activity intensity, activity diversity and walkability

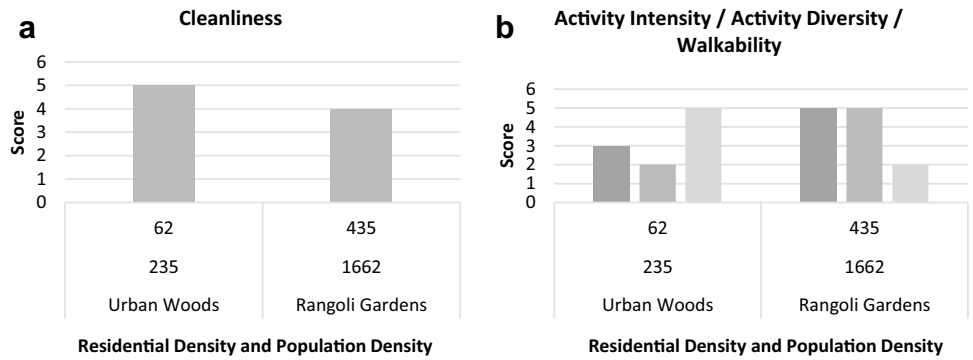


Fig. 9 a and b Impact of building density on type of open spaces, activity intensity and activity diversity

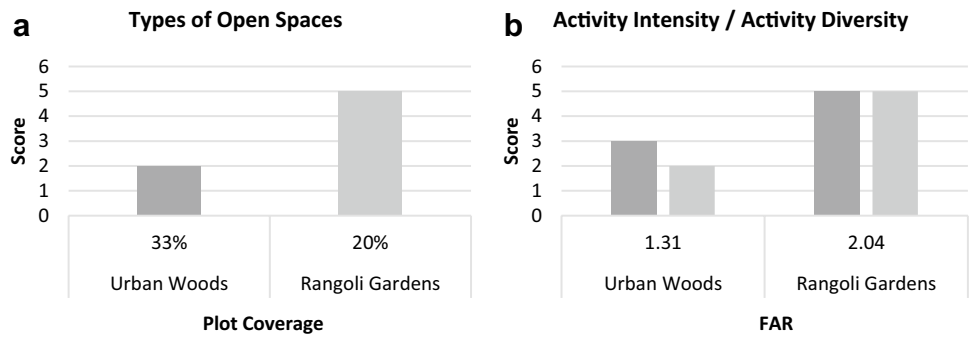


Fig. 10 a and b Impact of spatial density on walkability, activity intensity and activity diversity

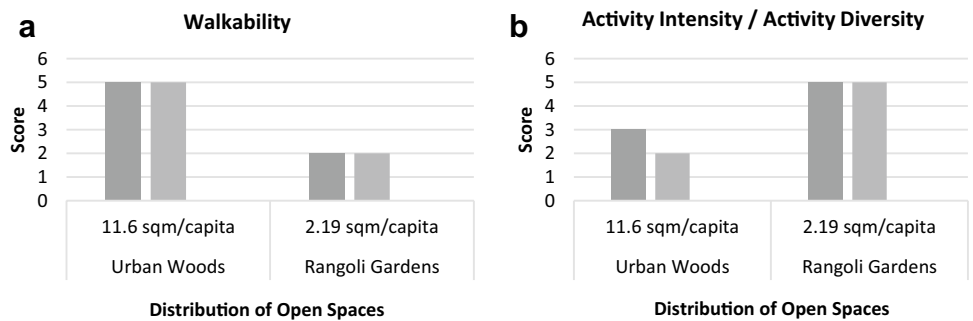


Fig. 11 a and b Impact of spatial density on use of open spaces

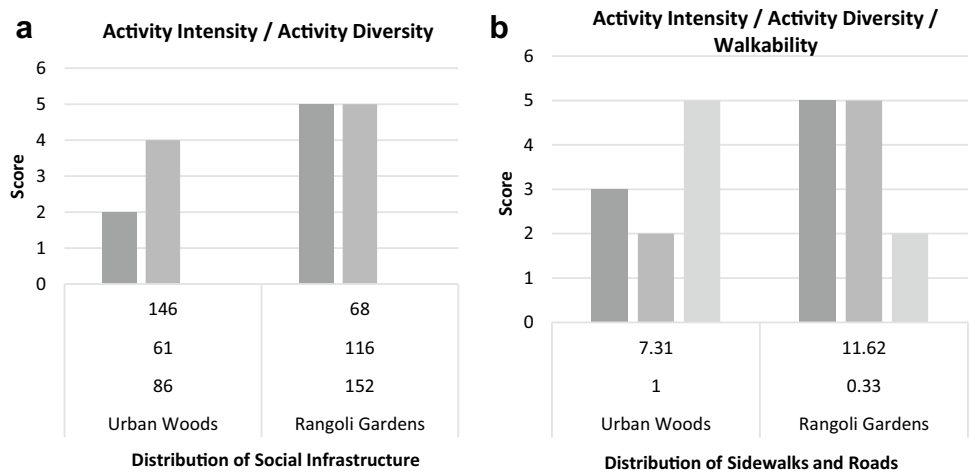


Table 4 Summary of correlation analyses

Physical density variables		Indicators of nature and use of open spaces (NUOS)						
		Type	Condition	Naturalness	Level of cleanliness	Activity intensity	Activity diversity	Walkability
People density	Population Density	.752**	.480**		-.278*	.532**	.445**	-.399**
	Residential Density	.695**	.312*		-.385**	.626**	.577**	-.490**
Building density	FAR					.549**	.515**	
	Plot Coverage	-.295*		-.635**		.000	.000	-.526**
Spatial density	Dist. of open spaces			.520**				.447**
	Dist. of roads and sidewalks			.434**		.506**		-.139*
	Dist. of Street lights							.751**
	Dist. Of Social Infrastructure		.474**		.302*	.655**	.550**	.340**
		.000		.015	.000	.000	.000	.000

Correlation coefficient > 40%—strong correlation

Correlation coefficient ≤ 40%—weak correlation

Empty cells—no apparent correlation

Italic: Positive correlation

Bold: Negative Correlation

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

naturalness in Rangoli Gardens has a negative impact on the walkability as compared to Urban Woods. This is also exacerbated due to the lower road length per capita and high building density in Rangoli Gardens.

The comparative chart also shows that there are some qualitative aspects that can be extracted from both neighbourhoods as possible strategies of improvement:

- i. Every well-planned neighbourhood should be designed with various types of open spaces that are suitable for different age groups and fulfil social and religious preferences of the inhabitants.
- ii. People need activity diversity and it can be achieved by the different types and distribution of open spaces, public buildings, etc. Adequate physical and social

Table 5 Regression analysis

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics					Durbin-Watson
					R square change	F change	df1	df2	Sig. F change	
<i>Model Summary^b</i>										
1	.827 ^a	.683	.674	.17904	.155	61.103	7	258	.000	1.435

^aPredictors: (Constant), population density, FAR, plot coverage, Dist. Of Open Spaces, Dist. Of Roads and Sidewalks, dist. Of street lights, dist. of social infrastructure

^bDependent variable: NUOS

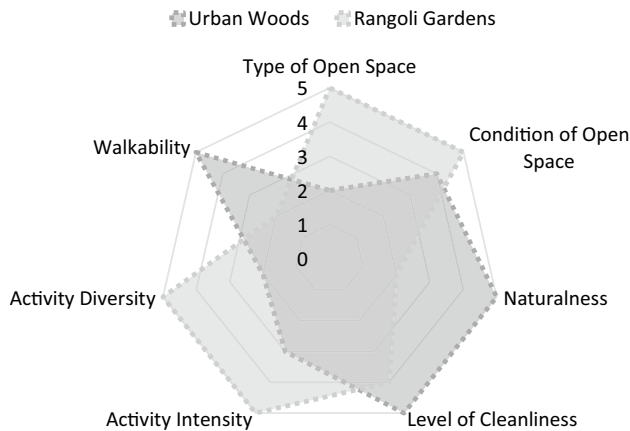


Fig. 12 Aggregate quality profile of urban woods and Rangoli gardens, Jaipur

infrastructure should be designed to meet the needs and aspiration of the residents. This will promote diversity and intensity of activities both being interdependent features.

- iii. It is important to assure naturalness and greenery throughout the area, not only in parks or playgrounds. More native trees like Neem (*Azadirachta indica*), Gulmohar (*Delonix regia*), Kadamba (*Neolamarckia cadamba*), etc. and shrubs should be planted along roads and sidewalks. This study has shown that naturalness and cleanliness affect the walkability more than any other aspect.
- iv. The cleanliness and good maintenance of the neighbourhood influences the physical and mental health of the residents hence proper management of the same by RWAs by engaging suitable agencies should be done immediately.

If the conditions mentioned above are respected by every planned residential area, the nature and use of open spaces is going to improve considerably. Additionally, as a consequence of improved health, life expectancy will become higher. When these strategies will be implemented

in important parts of the city, more areas are going to follow the example.

Conclusion

The present study shows that Nature and Use of Open Spaces varies with change in residential patterns given by different Density Variables. It has taken into consideration data collected not only from field research of the two chosen case study neighbourhoods, but also important published papers on quality of green open spaces and neighbourhood environment. The research approach helps to consider several density variables that can be controlled and modified during the planning and design phase to achieve better spatial quality. It is understood that with the increase in the number of people/dwelling units or in dense/compact neighbourhoods, variety of open spaces are required to cater to the needs of the people of different age groups. Spaces created within the living area must not only fulfil the requirements stated by law, but also the ones proclaimed by people. Design strategies and management measures need to be adopted to maintain the naturalness and cleanliness of such spaces.

Open spaces provide social and cultural benefits, promote interaction among people and add to the mental and physical well-being of residents in a neighbourhood in addition to environmental and aesthetic benefits. The activity intensity, diversity and walkability of neighbourhoods can be greatly enhanced by providing varied, adequate, safe and furnished open spaces, roads, sidewalks, social infrastructure, etc.

The study shows that significant relationships exist between physical density and indicators of NUOS further propelling one to identify the most important density variable impacting quality. It also helps to objectively define and assess a hitherto qualitative aspect like NUOS. It correspondingly holds scope to analyse NUOS further considering socio-economic factors and its impact on the type of facilities and amenities and resultant spatial quality in residential areas. Finally, it can be stated that the methodology developed can serve as a starting point for carrying out further study and research in different residential patterns found across Jaipur city and other cities that can help design

environmentally conducive neighbourhoods for future sustainable cities.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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