# AREA AND LOCATION BASED STUDY OF URBAN GREEN SPACES: A GIS-BASED ANALYSIS IN THE CITY OF PUNE, MAHARASHTRA

A Thesis Submitted To

Savitribai Phule Pune University

In Partial Fulfilment of the Requirements For

The Degree Of

PG BSc (Applied) in GIS & Remote Sensing

Submitted by

Tushar Balasaheb Kothule (22071010)

Under the Guidance of

Ms. Priyanka Hingonekar

Assistant Professor

Department of Geography (Geoinformatics)

Savitribai Phule Pune University

Department of Geography (Geoinformatics)

Savitribai Phule Pune University

Pune - 411007

Maharashtra, India

(30 April 2023)

# SAVITRIBAI PHULE PUNE UNIVERSITY

## DEPARTMENT OF GEOGRAPHY

Ganeshkhind
Pune - 411 007 (INDIA)
Telephone:
Office
EPABX: 020-25601364 / 65
Head: 020-25601363
Fax: 020-25693370

Email ID:
bhoogol@unipune.ac.in

Date: 30/04/2023

## CERTIFICATE

This is to certify that the project work entitled ***"Area and Location Based Study of Urban Green Spaces: A Gis-Based Analysis in The City of Pune, Maharashtra"*** has been carried out by ***Mr. Tushar Balasaheb Kothule*** under the guidance of Ms. Priyanka Hingonekar, during the academic year 2022-2023 for the partial fulfillment of the degree of PG BSc (Applied) GIS and Remote Sensing.

Place: Pune
Date: 30/04/2023

**Ms. Priyanka Hingonekar**
Assistant Professor,
Department of Geography,
Savitribai Phule Pune University,
Pune – 411 007.

# SAVITRIBAI PHULE PUNE UNIVERSITY

## DEPARTMENT OF GEOGRAPHY

Ganeshkhind
Pune - 411 007 (INDIA)
Telephone:
Office
EPABX: 020-25601364 / 65
Head: 020-25601363
Fax: 020-25693370

Email ID:
bhoogol@unipune.ac.in

Date: 30/04/2023

## CERTIFICATE

This is to certify that the project work entitled ***"Area and Location Based Study of Urban Green Spaces: A Gis-Based Analysis in The City of Pune, Maharashtra"*** has been carried out by ***Mr. Tushar Balasaheb Kothule*** under the guidance of Ms. Priyanka Hingonekar, during the academic year 2022-2023 for the partial fulfillment of the degree of Master of Science in Geoinformatics.

Place: Pune
Date: 30/04/2023

**Dr. Sudhakar Pardeshi**
Professor and Head,
Department of Geography,
Savitribai Phule Pune University,
Pune – 411 007.

**Savitribai Phule Pune University**

**Department of Geography**

**Declaration**

I, Tushar Balasaheb Kothule, bearing Examination/Roll No. 22071010, bonafide student of the Department of Geography (Geoinformatics), Savitribai Phule Pune University hereby declare that the project titled '**AREA AND LOCATION BASED STUDY OF URBAN GREEN SPACES: A GIS-BASED ANALYSIS IN THE CITY OF PUNE, MAHARASHTRA**', has been carried out and composed by me.

I do hereby declare that the thesis submitted is original and is the outcome of the independent investigations/research carried out by me. This work has not been submitted to any other University or Body in quest of a degree, diploma or any other kind of academic award.

I do hereby further declare that the text, diagrams or any other material taken from other sources (including but not limited to books, journals and the web) have been acknowledged, referred and cited to the best of my knowledge and understanding.

Date: 30/04/2023

Signature of the student

**To my entire family, for their constant love, support, and sacrifices that have made this academic achievement possible.**

# ACKNOWLEDGMENTS

Throughout every step of writing this thesis, I received a lot of support and encouragement.

First, I would like to express my sincere appreciation to my supervisor, Ms. Priyanka Hingonekar, for his assistance at each stage of the project. My academic study has benefited significantly from your expertise and broad experience.

I would like to express my sincere gratitude to Dr. Sudhakar Pardeshi, Head of the Department for giving me this opportunity and support which was influential in shaping my knowledge.

I would also like to thank my teachers Dr. Swapnil Vyas, Mr. Ravindra Medhe, and Mr. Ramesh Nannaware for giving me the insights I needed to make the right decisions and write my dissertation successfully. I want to thank you for your patience and support.

I would additionally like to convey my sincere thanks to my parents for their assistance and encouragement during my education. And the very end, I would like to thank Rushikesh, Mayuri, and Charul for their generosity and for spending such a special amount of time with me in the lab and social situations.

# CONTENTS


| | |
|---|---|
| **Contents** | **I.** |
| **List of Tables** | **III.** |
| **List of Figures** | **IV.** |

## Chapter 1: Introduction

| | | |
|---|---|---|
| 1.1 | Introduction | 2 |
| 1.2 | Conceptual Background | 4 |
| 1.3 | The Significance of Green Spaces | 5 |

## Chapter 2: Literature Review

| | | |
|---|---|---|
| 2.1 | Review of Literature | 8 |

## Chapter 3: Materials and Methods

| | | |
|---|---|---|
| 3.1 | Data used | 11 |
| 3.2 | Study Area | 12 |
| 3.3 | Aims and objectives | 13 |
| 3.4 | Methodology | 14 |
| 3.4.1 | The Measure of per Capita Urban Green Spaces | 14 |
| 3.4.2 | The Measure the accessibility of UGS (parks) | 15 |

## Chapter 4: Results and Discussion


| | | |
|---|---|---|
| 4.1 | Urban Green Spaces in Pune | 18 |
| 4.1.1 | UGS in Bhavani Peth Ward | 19 |
| 4.1.2. | UGS in Kasba Vishrambagh Ward | 20 |
| 4.1.3. | UGS in Dhole Patil Road Ward | 21 |
| 4.1.4. | UGS in Ghole Road Ward | 22 |
| 4.2 | The proximity of UGS (Parks) | 24 |
| 4.2.1. | Accessibility of UGS (Parks) in Bhavani Peth ward | 24 |
| 4.2.2. | Accessibility of UGS (Parks) in Kasba Vishrambagh ward | 25 |
| 4.2.3. | Accessibility of UGS (Parks) in Dhole patil Road ward | 26 |
| 4.2.4. | Accessibility of UGS (Parks) in Ghole Road ward | 27 |


## Chapter 5: Conclusions


| | | |
|---|---|---|
| 5.1 | Conclusions | 30 |
| 5.2 | Limitations of the study | 31 |
| 5.3 | References | 32 |

# List of Tables


| Sr. No. | Titles | Page No. |
|---|---|---|
| 3.1 | The representation of Data and Sources. | 11 |
| 3.2 | Level-1 classification of an image into two broad regions: non-UGS and UGS. | 15 |
| 4.1 | The tabular representation of per capita UGS in Pune and all four wards. | 23 |
| 4.2 | The tabular representation of parks (UGS) in Pune and all four wards. | 28 |

# List of Figures


| Sr. No. | Titles | Page No. |
|---|---|---|
| 3.1 | Study Area Map | 12 |
| 4.1 | Urban Green Spaces in Pune | 18 |
| 4.2 | UGS in Bhavani Peth Ward | 19 |
| 4.3 | UGS in Kasba Vishrambagh Ward | 20 |
| 4.4 | UGS in Dhole Patil Road Ward | 21 |
| 4.5 | UGS in Ghole Road Ward | 22 |
| 4.6 | Accessibility to parks in Bhavani Peth | 24 |
| 4.7 | Accessibility to parks in Bhavani Peth | 25 |
| 4.8 | Accessibility to parks in Dhole patil Road | 26 |
| 4.9 | Accessibility to parks in Dhole patil Road | 27 |

# CHAPTER 1

# INTRODUCTION

# CHAPTER 1

## 1.1 INTRODUCTION

The Census of India, 2011 revealed that 31.16% of the country's population resided in urban areas. In absolute terms, it accounted for 37 crore population. Population growth and high densities in cities can adversely impact natural and environmental resources. Preservation of vegetated areas or green spaces improves the quality of life by providing residents with natural settings for leisure and recreation and by safeguarding the quality of basic resources such as air and water. Adequate tree cover is an essential link in the bio-diversity chain.

A study published in the journal Environmental Health Perspectives found that "access to green space was associated with a lower risk of mental health problems, particularly anxiety and depression." (Gascon et al., 2015). Urban green spaces play a vital role in the physical and mental well-being of city residents. "The availability of green space was positively associated with physical activity levels in urban residents" (Kaczynski et al., 2014). "A study published in the Journal of Epidemiology and Community Health found that living in a neighborhood with more green space was associated with lower rates of cardiovascular disease" (Richardson et al., 2013). They provide a place for relaxation, recreation, and socialization, as well as contribute to the ecological health of the city. However, the accessibility of these spaces is often unequal across urban areas, and some neighborhoods may have limited access to green spaces.

Geographic Information Systems (GIS) technology provides a useful tool for analyzing urban green space accessibility, allowing researchers to identify underserved areas and inform policy decisions for improving access. This research focuses on the city of Pune in India, using GIS-based analysis to assess the accessibility of urban green spaces for residents. The study aims to analyse the area-based measures and accessibility or location-based measures of green space. The area-based measures of green spaces account for the distribution and green space per person. And accessibility or location-based measures account for the distance between residences and the nearest parks (green space) within a defined area, typically expressed in meters or kilometres.

Urban green spaces are essential for maintaining the physical and mental well-being of city residents. They provide spaces for relaxation, recreation, and socialization, as well as contribute to the ecological health of the city. However, the accessibility of these spaces is

often unequal across urban areas, and some neighborhoods may have limited access to green spaces. This disparity in access to green spaces can contribute to social and health inequalities, particularly in low-income communities, which often have fewer opportunities to access these spaces.

Pune is a rapidly growing city located in the western part of India. The city is known for its rich cultural heritage, educational institutions, and growing IT sector. The city has also witnessed significant urbanization over the last few decades, leading to an increase in urbanization and urban sprawl. This rapid urbanization has led to a significant reduction in green spaces, posing a serious challenge to the city's ecological health and the well-being of its residents. Thus, understanding the accessibility of urban green spaces in Pune is crucial to developing strategies for promoting healthy and sustainable urban environments.

The study uses satellite data to identify and map urban green spaces in the city. The study also uses the parks data of Pune Municipal Corporation (PMC), population density, land use, and transportation infrastructure to model the accessibility of green spaces for residents. The study also examines the spatial distribution of green spaces and their accessibility, identifying areas that are underserved and over-served in terms of green space accessibility.

The findings of this study will be useful for policymakers, urban planners, and community groups in Pune and other cities facing similar challenges in providing equitable access to urban green spaces. The study provides a spatial distribution of per capita UGS and an analysis of green space accessibility, identifying areas that require more attention in terms of improving access. Ultimately, the study aims to contribute to the development of a sustainable and liveable urban environment in Pune and beyond.

## 1.2 CONCEPTUAL BACKGROUND:

UGS has different definitions depending on the context and purpose of the studies. The first definition of UGSs in this study considers; "Urban Green Spaces (UGS) constitute parks, gardens and recreation venues, informal green spaces such as a river or sea fronts, greens spaces surrounding historical sites, railway corridors and indigenous vegetation types. Urban habitats such as derelict industrial sites and overgrown gardens have also been considered as UGS" (Venn & Niemela, 2004). "Urban green space is defined as land that consists mainly of unsealed, permeable, soft surfaces such as soil, grass, shrubs and trees. In other words, green space is a plot of undeveloped land separating or surrounding areas of intensive residential use that is maintained for recreational enjoyment." (Dunnett, May 2002). "Urban green spaces can also be defined as public and private open spaces in urban areas, primarily covered by vegetation, which are directly (e.g., active or passive recreation) or indirectly (e.g., positive influence on the urban environment) available for the users." (Manlun, 2003). Urban Green Space is a sum of green paved, open and burial places, sports grounds, private gardens, formal and informal green forests, road verges, derelict land, and horticulture within a city (Duan et al., 2018; Wang & Akbari, 2016).

Several studies were conducted to identify the targets regarding UGS. The World Health Organization has set a minimum target of 9 m² and an ideal value of 50 $m^2$ of UGS per capita (World Health Organization, 2010). Whereas European cities have different targets regarding the minimum surface of UGS per capita. In German cities, targets related to green supply per capita vary between 6 and 15 $m^2$ per resident (für Landespflege, 2006). The residents of a large city, such as Berlin, should have access to UGS of a minimum of 0.5 ha at a distance of 500 m from their residence and to 6 $m^2$ of UGS per capita (Kabisch et al., 2015).

The World Health Organization (WHO) recommends that everyone should have access to green spaces within a 5-minute walk (about 400 meters) from their home, which translates to a coverage of about 0.5 hectares of green space per 1,000 people. This recommendation is based on evidence that access to green spaces within a short walking distance can provide significant health benefits, including improved physical activity levels, reduced stress, and improved mental health. Other research suggests that the optimal distance between residential areas and parks depends on the size and type of the park. A study conducted in Stockholm, Sweden found that smaller neighborhood parks (less than 1 hectare) should be located within 300 meters of residential areas, while larger regional parks (over 10 hectares) can be located

up to 2 kilometres away from residential areas (source: B. C. Nordh, "The importance of proximity to green spaces - a comparative study of different user groups' preferences in the Stockholm urban region", Urban Forestry & Urban Greening, 2009). Another study conducted in Portland, Oregon, USA found that the ideal distance between residential areas and parks depends on the size of the park and the density of the surrounding population. For small neighborhood parks (less than 1 hectare), the recommended distance is within 400 meters of residential areas, while for larger regional parks (over 10 hectares), the recommended distance is up to 2.5 kilometres away from residential areas (source: M. J. Zhang, et al., "The spatial distribution of parks and their proximity to physical activity facilities in Portland, Oregon", Journal of Public Health Management and Practice, 2018).

Overall, the recommended distance between residential areas and parks varies depending on several factors, and there is no one-size-fits-all answer. However, the WHO recommendation of access to green spaces within a 5-minute walk (about 400 meters) from homes is a good starting point for ensuring that everyone has access to the health benefits of green spaces.

### 1.3 THE SIGNIFICANCE OF GREEN SPACES:

Urban green space is essential to the sustainability, good health, and efficiency of energy in our cities. Urban Green Spaces are required to be properly planned, created, developed, and managed/maintained to be accessible in terms of both space and population coverage. Urbanisation in India will undoubtedly continue unabatedly. Urban green areas produce a wide range of ecosystems that are crucial to human well-being, and human activities influence how these ecosystems behave.

1. Improved Mental Health: Access to urban green spaces has been linked to improved mental health outcomes. Access to UGS has also been linked to improved mental health outcomes. Exposure to nature has been shown to have a positive effect on mood and can help to reduce symptoms of depression and anxiety.
2. Reduced stress and anxiety: UGS can help to reduce stress and anxiety levels. Exposure to nature has been shown to have a calming effect on the body and mind, which can help to reduce stress levels.

3. Reduced Air Pollution: Urban green spaces can help to reduce air pollution by absorbing pollutants and improving air quality. UGS can help to improve air quality by absorbing pollutants such as carbon dioxide, nitrogen dioxide, and particulate matter. They can also release oxygen into the atmosphere, which is essential for human health.

4. Increased Physical Activity: Urban green spaces can encourage physical activity, which is associated with numerous health benefits. UGS can encourage physical activity by providing opportunities for walking, cycling, and other outdoor activities. Regular physical activity has numerous health benefits, including reducing the risk of obesity, diabetes, and other chronic conditions.

5. Enhanced Biodiversity: Urban green spaces can support biodiversity by providing habitats for a variety of plant and animal species. UGS can provide habitats for a wide range of plant and animal species, including those that are not typically found in urban areas. This can help to maintain biodiversity in the urban environment and promote ecosystem services such as pollination and pest control.

6. Increased social interaction: UGS can provide opportunities for social interaction and community building. Public green spaces such as parks and playgrounds can serve as gathering places for neighbours and friends, promoting social cohesion and a sense of community.
7. Increased property values: UGS can increase property values for nearby properties. Studies have shown that properties located near UGS tend to have higher property values than properties located farther away.
8. Reduced energy costs: UGS can help to reduce energy costs by providing shade and cooling in the summer, which can reduce the need for air conditioning. Trees and other vegetation can also provide insulation in the winter, reducing the need for heating.

UGS has many economic benefits that are essential for promoting economic development and reducing costs associated with infrastructure, health care, and energy. These benefits highlight the importance of incorporating green spaces into urban planning and development to promote economic sustainability and resilience.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Review of Literature

‘Assessment of changes in urban green spaces of Mashad city using satellite data’ A Spatio-temporal study of Urban green spaces was done in Mashad city in the year of 1987 and 2006. After doing a comparative study of 19 years it was seen that there is significant decrease had occurred in the extent of urban green spaces because of rapid urbanization. (Rafiee, R., Mahiny, A. S., & Khorasani, N.,2009)

‘Evaluating the Urban Green Space benefits and functions at macro, meso and micro level: a case of Bhopal City’ research was done in Madhya Pradesh, Bhopal, the hypothesis of this study was that the benefits and functions of urban green space differ at various spatial levels. Bhopal City was selected as a case example to evaluate the extent of green space benefits and functions. The study examines qualitative and quantitative aspects of urban green spaces in terms of their benefits to users. (Rao, P., & Puntambekar, K.,2014)

‘Access to Urban Green Space in Cities of the Global South: A Systematic Literature Review’ A study mainly focused on access to urban green space (UGS) based on socioeconomic status in Global South countries found that inequities for UGS quantity (high-SES people are advantaged in 85% of cases) and UGS proximity (74% of cases). Inequities were less consistent for UGS quality (65% of cases). The research also found that UGS inequities were consistent across African, Asian, and Latin American cities. (Rigolon, A., Browning, M. H. E. M., Lee, K., & Shin, S.,2018)

‘NDVI Threshold-Based Urban Green Space Mapping from Sentinel-2A at the Local Governmental Area (LGA) Level of Victoria, Australia’ In this research, they developed a three-level hierarchical mapping of urban green space using the Normalized Difference Vegetation Index (NDVI) on Sentinel-2A Earth Observation data. We also developed the Urban Green Space Index (UGSI) and Per Capita Green Space (PCGS) to provide insights on the association of demography with urban green infrastructure using urban spatial analytics. (Jagannath Aryal et al., 2022)

‘Proximity to Urban Parks and Mental Health’ This research was done in Los Angeles for finding the relationship between proximity to urban parks and psychological distress. The research found that residential distance from parks is significantly related to mental health, with the highest MHI-5 scores found among residents within 400m walking distance from the park. The association between distance and mental health decreases significantly beyond

400m, independent of the number of visits and physical activity minutes. (Roland Sturm and Deborah Cohen, 2014)

‘Access to green areas and the frequency of visits – A case study in Helsinki’ The research is particularly focused on examining whether the presence of green spaces and other factors that enhance accessibility in residential areas have any impact on the frequency of recreational activities that take place close to people's homes. The result of this study shows that the availability of ample green spaces and the convenience of accessing them within a short distance from residential areas have a positive correlation with the frequency of visits made by residents of Helsinki. (N. Marjo et al., 2007),

‘An integrated simulation approach to the assessment of urban growth pattern and loss in urban green space in Kolkata, India: A GIS-based analysis’ This study aimed to investigate the impact of land use and land cover (LULC) changes on the reduction of urban green spaces (UGS) in Kolkata, using a multi-temporal land-use transition scenario. And study the availability of per capita UGS in Kolkata. The study found that urban expansion led to a gradual reduction of green areas, with built-up areas encroaching upon them the most. The availability of urban green spaces was analyzed using PCG, revealing that most wards fell below the WHO's recommended minimum requirement of per-capita green space. (Santanu Dinda et al., 2021)

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1. Data Used:

The study is mainly done on secondary data. The data involves satellite data, demographic data, park data and road network data.

As per the census 2011, Pune is composed of 76 general electoral wards. These wards were converted into 14 administrative wards by Pune Municipal Corporation (PMC). These boundaries are considered for the study. Out of those 14 wards Bhavani Peth, Kasba Vishram Bagh, Ghole Road, and Dhole Patil Road are taken for study. The park data is also taken from Pune Municipal Corporation (PMC).

Sentinel 2 satellite image data which is having 10 m spatial resolution has been used for calculating NDVI. The ward-wise population data is taken from the Pune Census 2011. The road network data is used and taken from Open Street Map (OSM). The data and their source are shown in the below Table. There are other dada has been used for ground truthing such as google earth pro and google maps.

**Table No. 3.1: The representation of Data and Sources.**

| | Data | Sources |
|---|---|---|
| 1. | Ward map and administrative boundary | Pune Municipal Corporation (PMC) |
| 2. | Satellite Imagery - Sentinel-2 | Copernicus Open Access Hub. (scihub.copernicus.eu) |
| 3. | Demographic information, such as population data. | Census of India (censusindia.gov.in) |
| 4. | Park Data | Pune Municipal Corporation (PMC) (https://www.pmc.gov.in/en/garden-list) |
| 5. | Road network Data | Open Street Map (OSM) (www.openstreetmap.org) |
| 6. | Google image | Google Earth Pro |

Source: Computed by the researcher based on data.

## 3.2. Study Area:

Pune city is located in the central part of the Maharashtra state at an altitude of 560 m above mean sea level. Pune city lies between latitudes 18° 25'N and 18° 37' N and longitudes between73° 44' E and 73° 57' E and covers an area of 250.56 sq. km. Pune is one of the fastest-growing cities in India. It is considered one of the eight megacities of India. It has emerged as an important city for education, Information Technology hub and manufacturing hub. As per the census 2011, the population of Pune is over 3 million composed of 76 general electoral wards. These wards were converted into 14 administrative wards by Pune Municipal Corporation (PMC).

The study area for this research comprises four wards in Pune, namely Bhavani Peth, Kasba Vishram Bagh, Ghole Road, and Dhole Patil Road. As shown in the map these wards are located in the central part of the Pune city. These wards have been chosen due to their high population density, location, rapid urbanization, and potential for significant demand for urban green spaces. Additionally, these wards represent a mix of residential, commercial, and industrial areas, providing a diverse range of environments for the study.

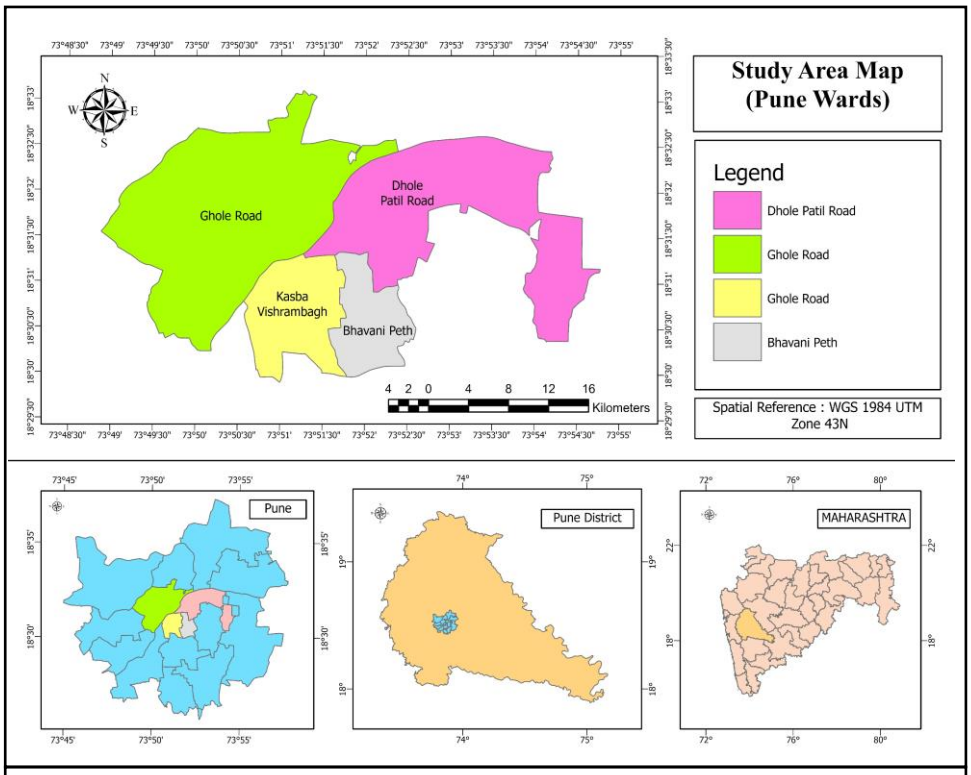


**Figure No. 3.1: Study Area Map**

## 3.3. Aim and Objective: -

To study the urban green spaces in Pune city. The main aim of the study is to analyse the area-based measures and accessibility or location-based measures of green spaces within the study region. The area-based measures of green spaces account for the distribution and green space per person. And accessibility or location-based measures account for the distance between residences and the nearest green space within a defined area, typically expressed in meters or kilometres. To carry out this study, it may be useful to have the following specific objectives.

**Objectives –**

1. To study the per capita UGS in Pune and Pune's four wards Bhavani Peth, Kasba Vishram Bagh, Ghole Road, and Dhole Patil Road.

2. To study the accessibility of UGS (Parks) to residential regions in the study area.

## 3.4. Methodology:

According to the aim and objectives of this study, the methodology has been created. To study the above objective, the data is gathered from secondary sources. The data are compiled and organized in a logical way to achieve the results. With the use of appropriate statistical tools, the acquired data from the field and offices were assembled and analysed.

In this study, to measure the urban green space in the Pune city wards, remote sensing data is used and GIS techniques are used. The software used for the analysis of this research is ArcGIS Pro. A pixel-based technique is applied in this research. The pixel-based technique will calculate the relevant NDVI value for each individual pixel without taking into account nearby pixels. This is done in order to account for all potential small urban green areas within the research area. After doing the NDVI classification a reclassification will take place, reclassifying all pixels in the groups: The NDVI is broadly divided into two categories one is non-urban green spaces and Urban green spaces, consisting of sparse vegetation and dense vegetation.

### 3.4.1. The Measure of per capita Urban Green Spaces:

First, we download the Sentinel-2A dataset from the Copernicus Open Access Hub. However, cloud coverage is one of the problems that come during the acquisition of satellite images. For this, a limit of the cloud coverage range from 0 to 10 in is applied. Then the Normalized Difference Vegetation Index (NDVI) is used to calculate the UGS. This index is defined as follows:

$$NDVI = (NIR - RED) / (NIR + RED)$$

***For the sentinel-2 image, Band 8 is NIR and Band 4 is RED***

Where ‘NIR’ stands for the near-infrared wavelength and ‘RED’ stands for the reflectance of visible red wavelengths. The NDVI in this research will be used to measure the amount of green space as well as the density of this green space (Earth Observatory, 2000). The result of this calculation will end up in the range between -1 and 1. The negative values are generally bodies of water, concrete, or sandy soils while the positive values are generally vegetation including crops, trees, shrubs and grass fields (Huang et al, 2021).

Second, we categorize the target image into the vegetation as UGS (such as trees, bushes, etc.) and non-vegetation as non-UGS (such as built-up, water, etc.) categories. For this, the threshold of NDVI values as suggested by the previous studies and methods. To this end, by using the NDVI threshold value on each pixel in the target image, we divided the image into two broad regions. As an example, we have presented the Level-1 classification of the City of Pune. The non-vegetation such as built-up, and water have an NDVI value of less than 0.19, whereas the vegetation region containing green cover such as ground, bush, trees, etc. has a higher than 0.19 NDVI value.

| Category | Threshold |
|---|---|
| Non-UGS (Non-vegetation) | −1.00 to 0.2 |
| UGS (Vegetation) | 0.2 to 1.00 |

**Table No. 3.2:** Level-1 classification of an image into two broad regions: non-UGS and UGS.

Third, after having the classified image we calculate the accuracy of the data. For that, we created 100 accuracy assessment points all over the study area using equalized stratified random method. After getting the table and adding ground truthing data points for created points we calculate the accuracy of the classified data. The kappa coefficient of the data is 0.61, indicating moderate agreement beyond chance, and the overall accuracy of the data is 92%, meaning that the model correctly classified 92% of the observations.

At last, we used the raster to polygon tool for calculating the area of Urban green spaces for per capita UGS. Then the area of UGS (vegetation) is calculated in sq. meters. Then the formula is used to calculate the per capita UGS. This formula is defined as given below:

**per capita UGS = Total area of green space (sq. m) / Total Population of the study area.**

After having the area of UGS and the population data of the study area calculation of per capita UGS is done. Using the above formula, the calculation for per capita UGS for Pune and its four wards have done.

### 3.4.2 The Measure of Accessibility to UGS (parks):

At first, using the Pune Municipal Corporation (PMC) parks data and its location the parks were digitized on Google Earth Pro. For proper location and better results, different Google Map base layers were used. After doing digitization this point data was added in ArcGIS Pro for further processes.

Second, adding the data into ArcGIS, it was converted from KML file format to .SHP file format. After adding the boundary, park and road network data the proximity tool was used to measure the accessibility. In the proximity tool, multiple buffer tool was used for creating 400 and 500-meter buffer around the park's location. And the appropriate color scheme was applied for a better visual representation of the buffer. At last, the final map layout was created for further analysis and interpretation.

# CHAPTER 4

# RESULTS AND DISCUSSION

**Results:**

Per capita urban green spaces in Pune refers to the amount of green space available per person in the city of Pune, India. This can include parks, gardens, forests, and other areas of vegetation that are accessible to residents of the city. Interpreting the per capita urban green spaces in Pune and Pune's wards can provide insights into the availability of green spaces in the city and the level of access that residents have to these spaces. It can also help to identify areas of the city that may be lacking in green space and where efforts could be made to improve access to these areas.

### 4.1. UGS in Pune:

The results of the analysis of the UGS in Pune are shown below in Figure no 4.1. For this map, the green color is showing UGS and the light brown color is showing the non-UGS of the region.

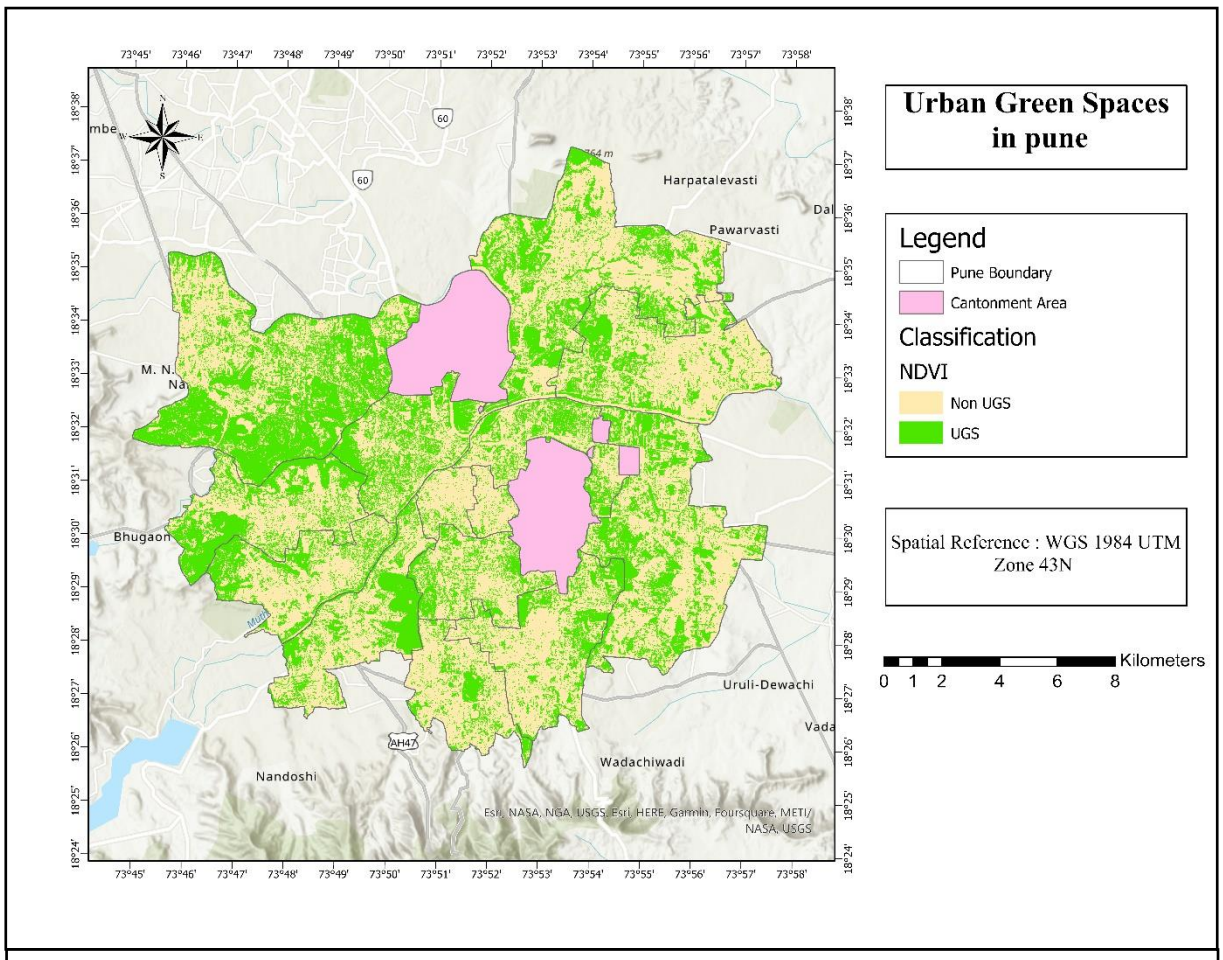


**Figure No. 4.1: Urban Green Spaces in Pune (2023)**

After interpretation of figure no. 4.1, one can see that the central part of Pune city is having comparatively low urban green spaces (Vegetation). The more one moves away from the city center the higher the associated NDVI value becomes because of the availability of hills, farms, open areas, and sparse urban areas.

As per the city development plan of Pune (2012) in 1987, the urban area of Pune was 138.36 Sq.km with an addition of 23 villages in 2001; the area has increased to 243.84 Sq.km. The UGS area which we calculated for Pune city is 104038700 sq. meters and as per the census 2011 the total population of Pune was 3132143. After applying the per capita UGS formula which is per capita *UGS = 104038700 /3132143*, the outcome is 33. 21 sq. m green area per person. This means that if we consider the entire Pune city on average, each person in Pune has access to 33.21 square meters of urban green space.

### 4.1.1. UGS in Bhavani Peth Ward:

Bhavani Peth ward is located in the central part of Pune city and it is a comparatively older part than the outside region of Pune. As one can see in Figure 4.2 the UGS is sparsely distributed in the ward. As it is a central part of the city most of the area is covered by build-up area.

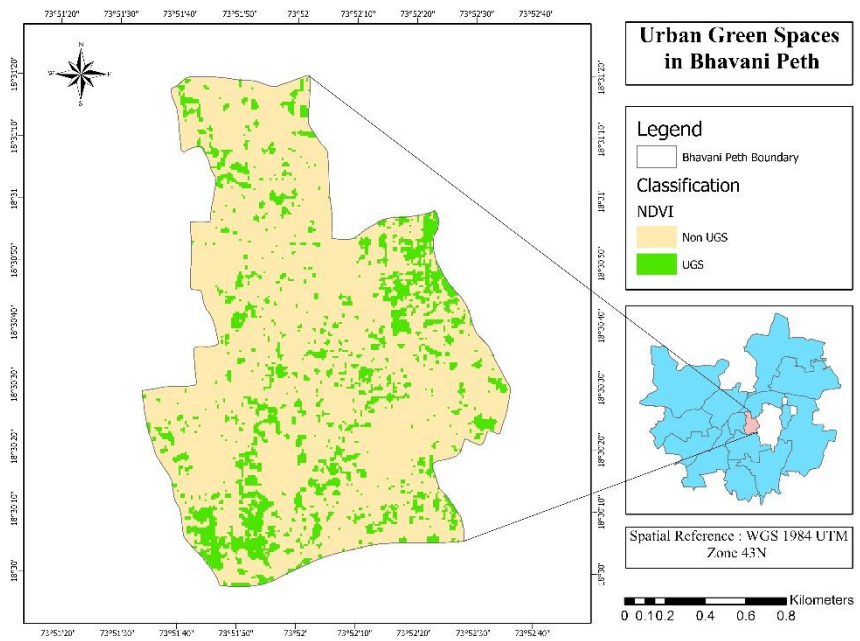


**Figure No. 4.2: UGS in Bhavani Peth Ward**

The total population of Bhavani Peth is 191787 people and the total urban green space area is 439424.1 square meters. To calculate the per capita urban green space in the Bhavani Peth ward area, we would divide the total green space area by the population:

439424.1 sq. m / 191787 residents = 2.3 sq. m per capita

This means that on average, each resident in Bhavani Peth has access to 2.3 square meters of urban green space.

### 4.1.2. UGS in Kasba Vishrambagh Ward:

Kasba Vishrambagh ward is also situated in the central part of Pune city and it is also older than the outside region of Pune. As one can see in the figure no. 4.3 the UGS is sparsely distributed and most of the UGS is found in the western and southern parts of the ward. As it is a central part of the city most of the area is covered by settlements.

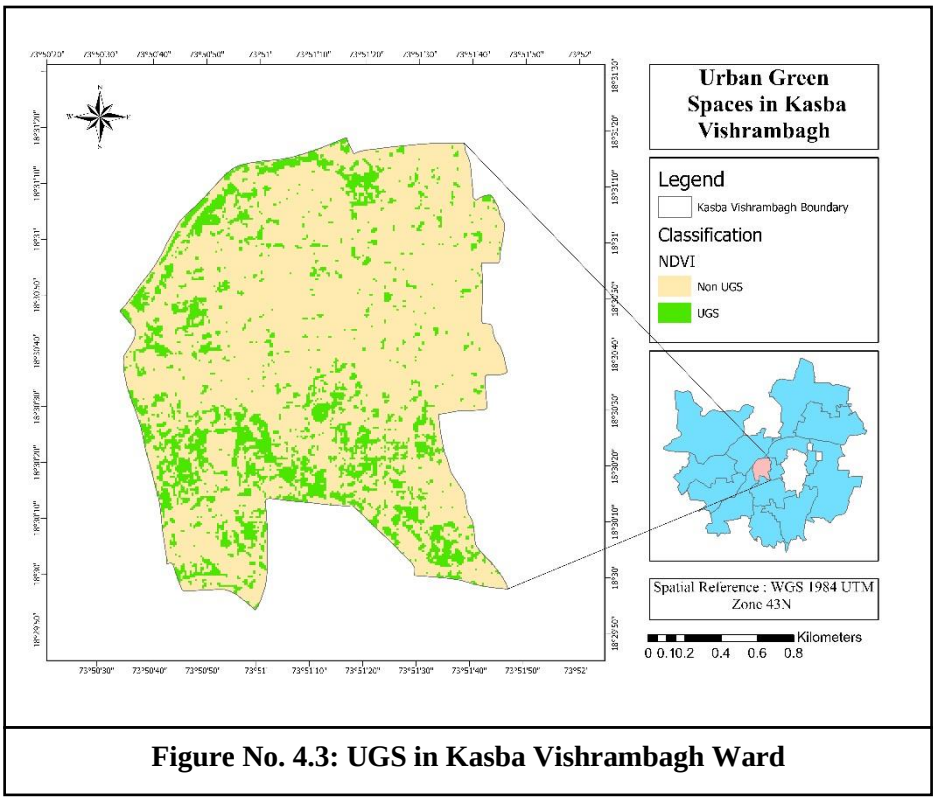


**Figure No. 4.3: UGS in Kasba Vishrambagh Ward**

The total population of Kasba Vishrambagh is 222648 people and a total urban green space area of 661519.4 square meters. To calculate the per capita urban green space in Kasba Vishrambagh ward, we would divide the total green space area by the population:

661519.4sq. m / 222648 residents = 2.9 sq. m per capita

This means that on average, each person in Kasba Vishrambagh has access to 2.9 square meters of urban green space. Compared to the Bhavani Peth ward the UGS is slightly high in Kasba Vishrambagh ward.

### 4.1.3. UGS in Dhole Patil Road Ward:

Dhole Patil Road ward is located near the center of Pune city. As one can see in Figure 4.4, the UGS is densely distributed in the northern and eastern regions of the ward. The western part is having comparatively low and sparse UGS because it is very near to the central region of Pune.

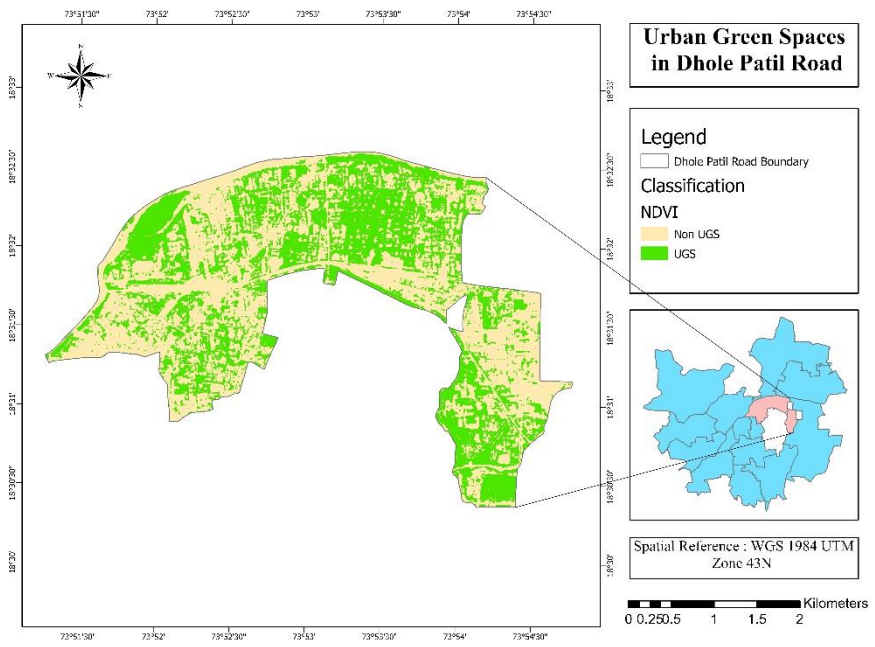


**Figure No. 4.4: UGS in Dhole Patil Road Ward**

The total population of Ghole Road is 171756 people and a total urban green space area of 4579855 square meters. To calculate the per capita urban green space in Dhole Patil Road, we would divide the total green space area by the population:

4579855 sqm / 171756 peoples = 26.66 sq. m per capita

This means that on average, each resident in Dhole Patil Road has 26.66 square meters of urban green space. Compared to the Bhavani Peth and Kasba Vishrambagh this wards the having high UGS availability.

### 4.1.4. UGS in Ghole Road Ward:

Ghole Road ward is located slightly away from the center of Pune city. As one can see in the figure no. 4.5, the UGS is densely distributed in all regions and a high density of UGS is found in the western and north-eastern parts of the ward. The eastern part is having comparatively low UGS because it is very near to the central region of Pune.

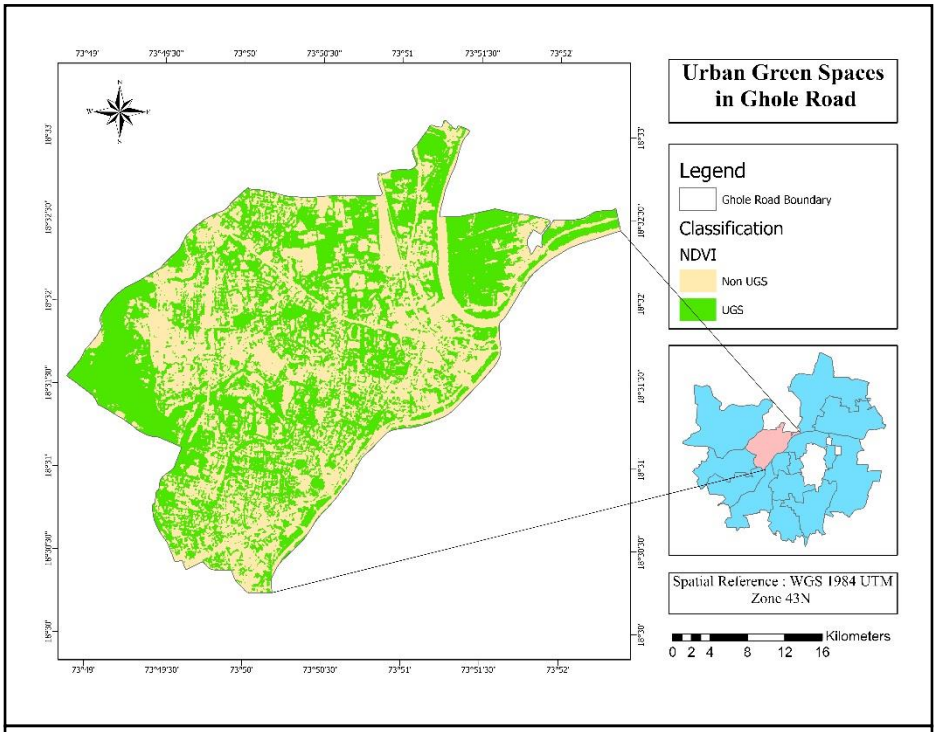


**Figure No. 4.5: UGS in Ghole Road Ward**

The total population of Ghole Road is 155307 people and a total urban green space area of 7390008 square meters. To calculate the per capita urban green space in your study area, we would divide the total green space area by the population:

7390008 sq. m / 155307 peoples = 47.6 sq. m per capita

This means that on average, each person in Ghole Road has 47.6 square meters of urban green space. Compared to the Bhavani Peth, Kasba Vishrambagh and Dhole Patil Road wards the UGS is very high in this ward.

**Table No. 4.1: The tabular representation of per capita UGS in Pune and all four wards.**

| ***Wards*** | ***Green Spaces area in sq. meter*** | ***Total population*** | ***The per capita UGS sq. meter per capita*** |
|---|---|---|---|
| Bhavani Peth | 439424.1 | 191787 | 2.3 |
| Kasba Vishrambagh | 661519.4 | 222648 | 2.9 |
| Dhole patil Road | 4579855 | 171756 | 26.66 |
| Ghole Road | 7390008 | 155307 | 47.6 |
| **Pune** | **104038700** | **3132143** | **33.21** |

Source: Computed by the researcher based on analysed data.

A high per capita urban green space in Pune indicates that there is a greater amount of green space available per person, which can have a positive impact on the health and well-being of residents. This can include providing opportunities for physical activity, reducing stress levels, and improving air quality.

Conversely, a low per capita urban green space in Pune may indicate that there is limited access to green space, which could have negative impacts on the health and well-being of residents. This may be particularly concerning in densely populated urban areas where residents may have limited access to outdoor spaces.

Overall, the interpretation of per capita urban green spaces in Pune is important in understanding the availability and accessibility of green spaces in the city, and in identifying opportunities to improve the health and well-being of residents through increased access to these areas.

### 4.2. The proximity of UGS (Parks)

The term "proximity" to Urban Green Spaces (UGS) or parks refers to how close they are to the people who use them, whether it's their home or workplace. The closer a park is to where people live or work, the more likely they are to use it frequently. People who can access parks within 300-400 meters are more likely to use them regularly than those who have to travel further. Having easy access to UGS has numerous health and social benefits. People who live near parks tend to be more physically active, experience less stress, and have better mental health than those who live far away. They are also more likely to connect with their community and socialize with their neighbours.

#### 4.2.1. Accessibility of UGS (Parks) in Bhavani Peth ward:

In Fig. no. 4.6, using a multi-ring buffer the distance is defined. The yellow color is indicating the proximity of 400 m from the parks. And red color is indicating the proximity of 500 m from the parks and in the center parks points number are showing the area of the parks.

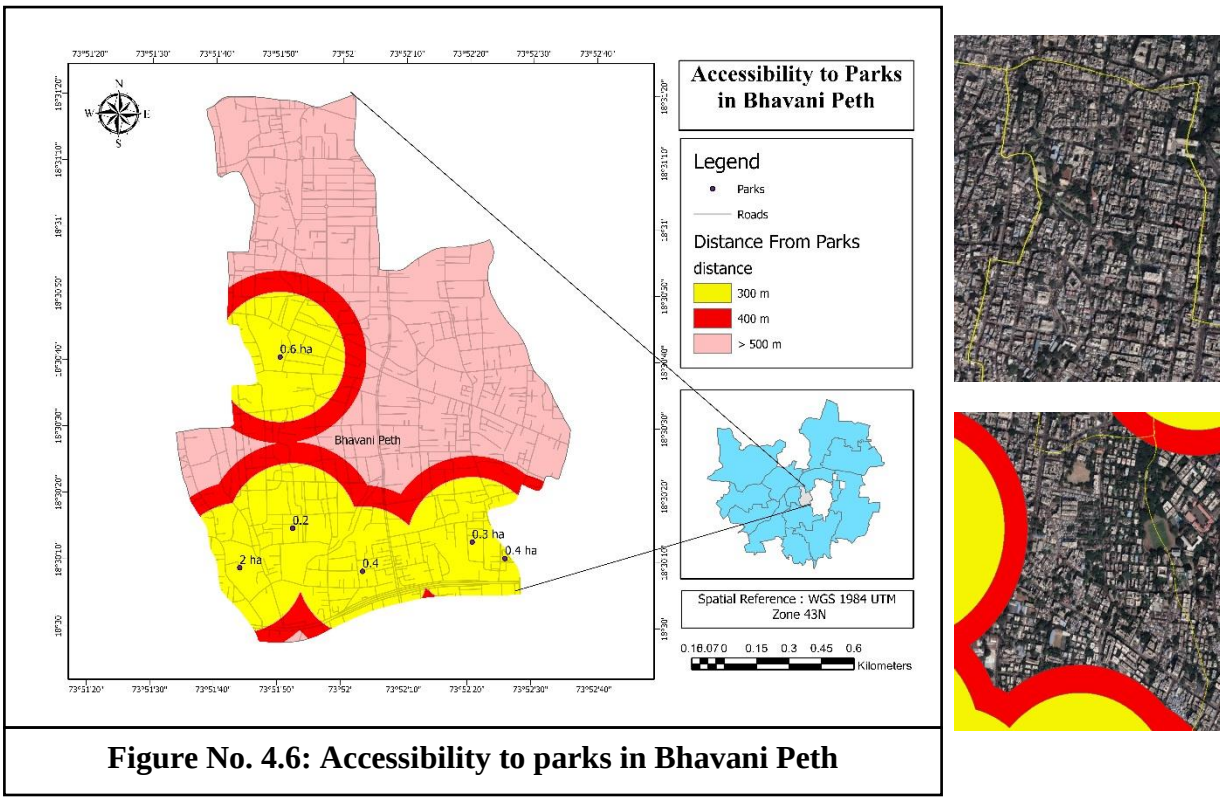


**Figure No. 4.6: Accessibility to parks in Bhavani Peth**

In Bhavani Peth, there are a total of 6 parks available. As one can see that out of that six parks four parks are located in the southern part of the ward and one park is located in the western region of the ward. Except for one park, all the parks are coving less than 1 hectare

of the area. As one can see that the distribution of the parks in Bhavani Peth is showing that out of 6 parks 5 parks are located in the southern region of the ward. The analysis is showing that Bhavani Peth is having an unequal distribution of parks as most of the parks are located in the southern region in a clustered form.

In the satellite image, one can see that there is a dense residential area in the northern and eastern regions without the accessibility of parks of 400 to 500 m near homes and offices. These two regions are not fitting in criteria for accessibility of parks of a distance of 400 to 500 m distance.

### 4.2.2. Accessibility of UGS (Parks) in Kasba Vishrambagh ward:

In Kasba Vishrambagh ward, there are a total of 8 parks available. As one can see in fig.no 4.7 that out of the eight parks, five parks are located in the southern part of the ward and three parks are located in the northern region of the ward. Out of eight, four parks are covering an area of more than 1 hectare.

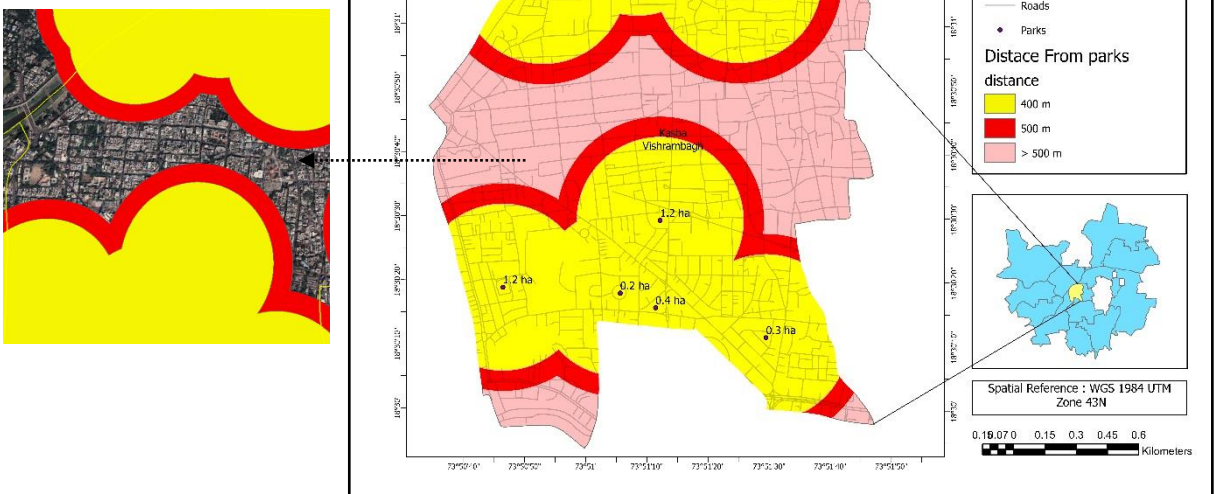


**Figure No. 4.7: Accessibility to parks in Bhavani Peth**

The analysis is showing that Kasba Vishrambagh is not having almost an equal distribution of parks all around the ward. As most of the parks are located all around the ward region except the central part of the ward.

In the satellite image, one can see that there is a dense build-up area is there in the central part of the ward without the accessibility of parks about 400 to 500 meters near residents and offices. This region is not fitting in criteria for accessibility of parks of a distance of 400 to 500 m distance. We can also see that there is a dense network of roads in the central part, which indicates that the area is well in use and should have small parks.

### 4.2.3. Accessibility of UGS (Parks) in Dhole patil Road ward:

In the Dhole patil Road ward, there are a total of 12 parks available. As one can see that out of those twelve parks 5-6 parks are located in the central region of the ward and three parks are located in the northeastern region of the ward. Out of twelve, five parks are spread over an area of 1 or more than 1 hectare.

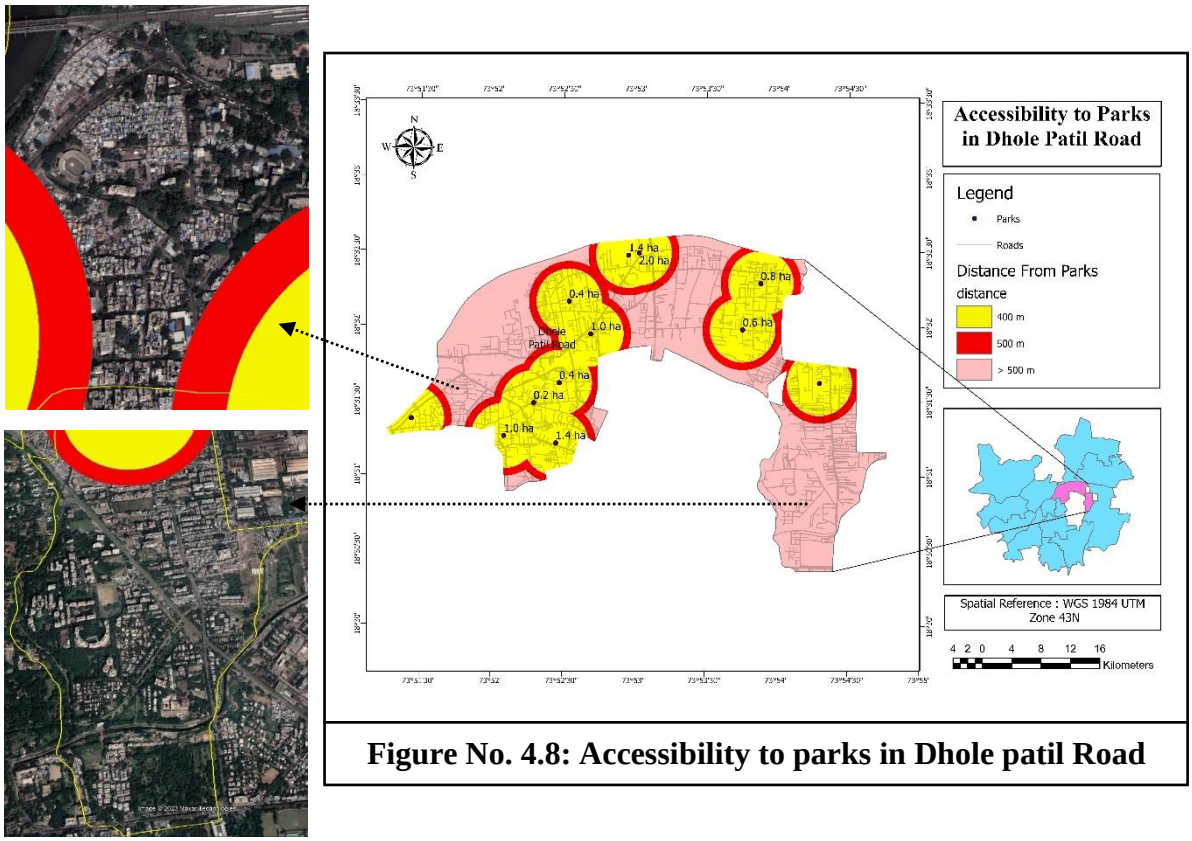


**Figure No. 4.8: Accessibility to parks in Dhole patil Road**

The result is showing that Dhole Patil Road is not having an equal distribution of parks all around the ward. As most of the parks are located in central and northeastern parts of the ward. The number of parks in the eastern part is only three and all three parks are spread over an area of less than 1 hectare. And in the western part, there is a cluster of parks with coving more than 1 hector area.

In the satellite image, one can see that there is a slum area in the western region and a mix of residential and industrial areas in the southeastern region of the ward without the accessibility of parks about 400 to 500 meters. These regions are not fulfilling the criteria for accessibility of parks of a distance of 400 to 500 m distance.

### 4.2.4. Accessibility of UGS (Parks) in Ghole Road ward:

In the Ghole Road ward, there are a total of 16 parks are there for many purposes. As one can see that out of those sixteen parks ten parks are located in the central and western region of the ward, two parks are located in the northeastern region and three parks are located in the southern region of the ward. Out of sixteen, six parks are spread over an area of 1 or more than 1 hectare. Half of the parks are larger than 1 hector areas.

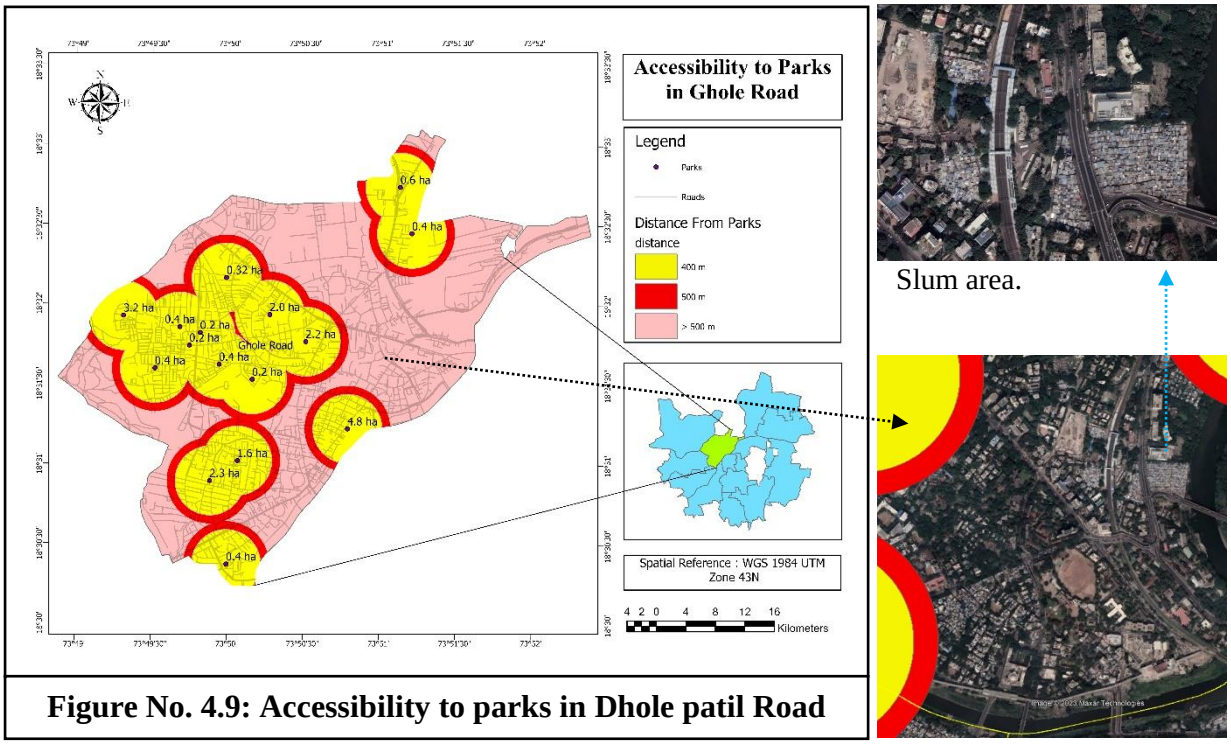


**Figure No. 4.9: Accessibility to parks in Dhole patil Road**

The map is showing that Ghole Road ward is also an unequal distribution of parks all around the ward. As most of the parks are located in central and western parts of the ward. The number of parks in the southern part is only three. And in western and central parts there is a cluster of parks and some of them with coving more than 1-hectare area.

In the satellite image, one can see that there is a slum area on the right side of the road in the eastern of the ward without the accessibility of parks about 400 to 500 meters. this region is not fulfilling the criteria for accessibility of parks of a distance of 400 to 500 m distance.

**Table No. 4.2: The tabular representation of parks (UGS) in Pune and all four wards.**

| No. | Wards | Total Number of Parks | Number of Parks having an area less than a hectare | Number of Parks having an area of more than 1 hectare |
|---|---|---|---|---|
| 1. | Bhavani Peth | 6 | 5 | 1 |
| 2. | Kasba Vishrambagh | 8 | 4 | 4 |
| 3. | Dhole patil Road | 12 | 7 | 5 |
| 4. | Ghole Road | 16 | 10 | 6 |

Source: Computed by the researcher based on PMC data.

The above table indicates that the wards which are located in the central part of the Pune Bhavani Peth and Kasba Vishrambagh are having fewer numbers of parks (considering the area factor the area is also small as compared to other wards) compared to Dhole Patil Road and Ghole Road wards. And compared to Dhole Patil Road and Ghole Road wards, Bhavani Peth and Kasba Vishrambagh wards have less number of Parks having an area of more than 1 hectare.

# CHAPTER 5

# CONCLUSIONS

## Conclusions:

In conclusion, the findings of the research have provided valuable knowledge and understanding of the subject matter and have relevant implications for future research and practical applications.

A study examines per capita UGS in a pune and its central 4 wards areas. And find out that overall Pune City is having a satisfactory UGS but is still not able to achieve the WHO ideal value which is 50 square meters per capita. As one moves towards a micro level such as ward study the situation is very different. Bhavani Peth and Kasba Vishrambagh are only having less than 3 sq. meters per capita UGS, these wards failed to match the WHO minimum level of UGS which is 9 sq. m per capita. It highlights that at a micro level special central part of the Pune City, the per capita UGS is very low.

To interpret the accessibility of UGS (Urban Green Spaces) or parks in Pune wards, we have analysed the distribution and accessibility of parks within four wards. The distribution and accessibility of urban green spaces (UGS) or parks in Pune's wards were analysed in our study. The research found that parks were unevenly distributed throughout the four wards examined. There were instances where parks clustered in certain areas, leaving other regions without any green spaces. Additionally, many parks were not located within 400-500 meters of residential areas, limiting their accessibility to residents.

The study also revealed disparities in park accessibility across different socio-economic groups. For instance, low-income areas had fewer parks. However, most residential areas were located within a 400–500-meter buffer zone around each park, indicating that many residents had easy access to green space. This highlights the need for more parks or green corridors near the slum areas in this ward to ensure that all residents have equal access to green space. It also revealed that central region wards like Bhavani Peth and Kasba Vishrambagh had few parks covering an area of more than 1 hectare, while wards further away from the city center had a higher number of parks covering an area of more than 1 hectare.

## Limitations of the Study:

**Variability in definitions:** There is no universally accepted definition of UGS, and different studies may use different criteria to define UGS. This can lead to inconsistent or incompatible results, and make it difficult to compare UGS studies across different regions or countries.

**Focus on quantity over quality:** Some definitions of UGS may focus solely on the quantity of green space, such as the area of parks or forests, without considering the quality or accessibility of UGS. This can result in an incomplete understanding of the benefits and limitations of UGS for different user groups and ecosystem services.

**Seasonal variation:** The amount of UGS may vary seasonally due to changes in weather conditions and vegetation cover. This can make it challenging to compare UGS across different seasons and accurately estimate the overall accuracy of UGS. This can make it difficult to accurately estimate the amount and distribution of green space across seasons, which can limit the ability to compare and generalize findings from UGS studies.

**The spatial resolution of data:** Higher spatial resolution satellite data can provide more accurate and detailed information about UGS, such as the size, shape, and distribution of green spaces. This can improve the accuracy of UGS mapping and monitoring efforts. low spatial resolution satellite data may not be able to detect small UGS features such as individual trees, and small patches of green space. This can lead to inaccurate results of UGS in a study area.

**measurement of accessibility:** There is no definite accepted definition of accessibility to UGS, which can lead to inconsistencies and inaccuracies in study findings. Some studies may define accessibility based on distance or travel time to the nearest UGS, while others may consider factors such as the quality and quantity of UGS amenities.

## References:


Braçe, O., Garrido-Cumbrera, M., Foley, R., Correa-Fernández, J., Suárez-Cáceres, G., & Lafortezza, R. (2020). Is a View of Green Spaces from Home Associated with a Lower Risk of Anxiety and Depression? International Journal of Environmental Research and Public Health, 17(19), 7014. doi. 10.3390/ijerph17197014.

Rafiee, R., Mahiny, A. S., & Khorasani, N. (2009). Assessment of changes in urban green spaces of Mashad city using satellite data. International Journal of Applied Earth Observation and Geoinformation, 11 431–438.

Aryal, J., Sitaula, C., & Aryal, S. (2022). NDVI Threshold-Based Urban Green Space Mapping from Sentinel-2A at the Local Governmental Area (LGA) Level of Victoria, Australia. Multidisciplinary Digital Publishing Institute, 11, 315. doi.org/10.3390/land11030351.

Kondo, M. C., Fluehr, J. M., McKeon, T., & Branas, C. C. (2018). Urban green space and its impact on human health. International Journal of environmental research and public health, 15(3), 445.

Neuvonen, M., Sievänen, T., Tönnes, S., & Koskela, T. (2007). Access to green areas and the frequency of visits – A case study in Helsinki. Urban Forestry & Urban Greening, 6(4), 235-247. doi.org/10.1016/j.ufug.2007.05.003.

Rao, P., & Puntambekar, K. (2014). Evaluating the urban green space benefits and functions at macro, meso and micro level: a case of Bhopal City. International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 6, June - 2014

Sturm, R., & Cohen, D. (2014). Proximity to urban parks and mental health. Journal of Mental Health Policy and Economics, 17(1), 19-24.

Rigolon, A., Browning, M. H. E. M., Lee, K., & Shin, S. (2018). Access to urban green space in cities of the Global South: A systematic literature. International Journal of Engineering Research & Technology (IJERT), *2*(3), 67

Dinda, S., Chatterjee, N. D., & Ghosh, S. (2021). An integrated simulation approach to the assessment of urban growth pattern and loss in urban green space in Kolkata, India: A GIS-based analysis. Journal of Ecological Indicators, doi.org/10.1016/j.ecolind.2020.107178.

Shishegar, Nastaran (Jan 2013). "The Impact of Green Areas on Mitigating Urban Heat Island Effect: A Review". The International Journal of Environmental Sustainability. 9 (1): 119–130. doi:10.18848/2325-1077/CGP/v09i01/55081.

Francis, Jacinta; Giles-Corti, Billie; Wood, Lisa; Knuiman, Matthew (December 2012). "Creating a sense of community: The role of public space". Journal of Environmental Psychology. 32 (4): 401–409. doi: 10.1016/j.jenvp.2012.07.002.

Rigolon, Alessandro; Németh, Jeremy (25 July 2018). "What Shapes Uneven Access to Urban Amenities? Thick Injustice and the Legacy of Racial Discrimination in Denver's Parks". Journal of Planning Education and Research. 41 (3): 312–325. doi:10.1177/0739456X18789251. S2CID 149537951.

Francis, Jacinta; Giles-Corti, Billie; Wood, Lisa; Knuiman, Matthew (December 2012). "Creating a sense of community: The role of public space". Journal of Environmental Psychology. 32 (4): 401–409. doi: 10.1016/j.jenvp.2012.07.002.

Wen, Ming; Zhang, Xingyou; Harris, Carmen D.; Holt, James B.; Croft, Janet B. (19 January 2013). "Spatial Disparities in the Distribution of Parks and Green Spaces in the USA". Annals of Behavioral Medicine. 45 (S1): 18–27. doi:10.1007/s12160-012-9426-x. PMC 3590901. PMID 23334758.

A. Samuel. (2022). Exploring Urban Green Space Provision and Inequalities with Accessibility in The Accra Metropolitan Area (Master's thesis). Wageningen University, Netherlands.