



A Hybrid QGIS–Excel Framework for Assessing Green Space Accessibility and Socio-Economic Equity: A Case Study of Gumla District, Jharkhand, India

Abstract: Urban green spaces (UGS) provide essential benefits which improve environmental sustainability and public health while enhancing people's overall well-being. The system faces major difficulties because it does not provide proper access to its resources and does not distribute assets fairly to both rural and semi-urban communities. The research assesses green space accessibility and socio-economic equity in Gumla district, Jharkhand, through a hybrid analytical framework that combines Geographic Information System (QGIS) with Microsoft Excel. The study evaluates accessibility through two methods which include buffer zones of 300 meters and 500 meters and network-based methods. The study employs three methods to assess equity which include the Lorenz curve and Gini coefficient and Composite Equity Index (CEI). The findings show that most people in the population do not have access to green spaces which they can reach by walking despite the presence of extensive forest coverage that reaches 27%. The Gini coefficient of 0.58 shows that there exists a high level of inequality because people in urban and semi-urban areas hold most of the accessible resources. The CEI system identifies priority areas which experience difficulty reaching resources and which possess low socioeconomic status. The study shows that access to resources depends more on the existing infrastructure and settlement patterns than on the actual resources which exist. The proposed framework offers an affordable method which organizations can use to evaluate spatial equity while it enables data-deficient regions to create inclusive planning methods.

Sujeet Kumar Singh , Kunj Kumar Dubey ,
Deepak Kumar

Lorenz Curve; Composite Equity Index;
Environmental Justice; Rural Planning

Affiliation

Department of Civil Engineering, Ramchandra Chandravansi Institute of Technology, Bishrampur, Palamu, Jharkhand, India.

Corresponding Author

Sujeet Kumar Singh* -
sujeetsingh15081990@gmail.com

Article History:

Received Date : April 08, 2026
Revised Date : May 16, 2026
Accepted Date : May 19, 2026
Published Date : June 16, 2026

Keywords

Urban Green Space; Accessibility; Socio-Economic Equity; QGIS; Gini Coefficient;

1. Introduction

Public parks and recreational grounds together with open spaces function as essential elements for developing sustainable urban and regional areas (Aly & Dimitrijevic, 2022). The facilities promote public health improvements because they motivate people to exercise while decreasing their mental stress and improving their complete health. Urban green spaces function as essential elements that help cities decrease urban heat island effects while they enhance air quality and protect biodiversity and they manage hydrological systems which include stormwater runoff (Gong et al., 2024). Cities now use green space access as a primary measure to assess their environmental sustainability and urban quality of life.

The distribution of green space access shows different patterns because it follows the existing



social and spatial distribution of communities. Developing regions face environmental justice and spatial inequity problems because infrastructure and income and settlement pattern differences create environmental resource access gaps according to research by [Kamjou et al. \(2024\)](#). Research studies about green spaces have mostly focused on major metropolitan areas while researchers have studied semi-urban and rural areas less because these two areas have distinct green space distribution and access patterns.

The problem exists in Gumla district because its social and spatial characteristics define its particular situation. The Census of India 2011 shows that Gumla district has approximately 1.02 million residents who mostly live in rural areas because only 6.35 percent of the population resides in urban areas (*Gumla District Population Census 2011 - 2021 - 2026, Jharkhand Literacy Sex Ratio and Density*, n.d.). The district shows low population density which reaches 191 people per square kilometer and exhibits scattered residential development. The population of Gumla consists of approximately 68 to 69 percent Scheduled Tribe (ST) members who experience economic hardship because they lack basic infrastructure and services needed for their daily lives.

Gumla contains substantial natural green cover which includes both forests and agricultural areas, but its accessible green spaces of functional value show uneven distribution throughout the area. Natural vegetation exists as a barrier to fair access because it does not provide people with transportation links to reach all areas of the region. Physical access in these situations becomes unreliable because actual usage gets limited by three factors, which include terrain obstacles and missing transportation links and social-economic restrictions.

The assessment methods for green space accessibility have progressed from basic Euclidean buffer-based techniques to current advanced network-based and gravity model approaches. These methods produce better results through their enhanced accuracy yet their complex requirements for geographic information system tools and computational knowledge restrict their use in locations with limited resources ([Semenzato et al., 2023](#)). Existing research studies analyze accessibility and equity as distinct concepts because they lack a unified system which connects spatial research with social economic assessment through user-friendly methods.

The research study develops a combined analytical system which unites QGIS spatial analysis with Microsoft Excel statistical assessment. This method establishes an affordable and open and reproducible system which can be used in Gumla and similar areas ([Gaur & Deb, 2026](#)).

The study aims to achieve three specific objectives:

1. to assess spatial accessibility to green spaces using GIS-based techniques,
2. to evaluate socio-economic disparities in access through quantitative indicators such as population distribution and inequality measures, and
3. to develop an integrated framework that supports equitable planning and decision-making in rural and semi-urban contexts.

2. Literature Review

2.1 Urban Green Space Accessibility Models

Researchers have conducted multiple studies to examine how people can access urban green spaces because it serves as an essential environmental quality assessment tool which determines urban area livability ([Czesak & Różycka-Czas, 2025](#)). The definition of



accessibility describes how easily residents can access green spaces through their existing infrastructure and travel routes which connect to nearby green spaces. Traditional methods estimate accessibility through buffer analysis which creates distance-based circular zones to measure accessibility from green spaces and residential areas. The method remains popular because it requires basic mathematical functions, but the method fails to capture actual accessibility patterns because it treats all directions equally while disregarding actual road systems and natural obstacles(Ergen, 2020).

Studies have begun to adopt network accessibility analysis because it provides better solutions to current research problems than existing methods. This method assesses accessibility through actual travel routes which people take on roadways or pedestrian pathways to create more precise service area measurements. The Two-Step Floating Catchment Area (2SFCA) advanced modelling system allows users to assess green space availability and population distribution together for their research needs. Recent research developed gravity-based and cost-distance models which assess travel hindrances and green space features to enhance accessibility measurement precision(Liu et al., 2022).

The majority of model systems which exist today were created to function within highly populated city environments. This method becomes unsuitable for semi-urban and rural areas because the model requires specific urban development patterns and existing infrastructure and land use systems.

2.2 Socio-Economic Equity in Green Space Distribution

The recent years have seen increased attention toward assessing both accessibility and equitable distribution of green spaces. Equity

analysis examines whether different socio-economic groups have fair access to environmental resources. The Gini coefficient and Lorenz curve serve as quantitative measures which researchers now use to evaluate green space accessibility disparities after their initial development for income inequality research(Siddiq et al., 2023).

The Lorenz curve provides a graphical representation of cumulative accessibility against cumulative population, while the Gini coefficient quantifies inequality on a scale from 0 (perfect equality) to 1 (maximum inequality). Most cities in empirical research show high inequality levels which result in disadvantaged groups receiving less access to green spaces. The urban planning research field now considers spatial justice as an essential element which goes beyond traditional quantitative evaluation methods. Spatial justice focuses on distributing resources in a fair way that benefits all population groups while taking their social and economic background into account. Research indicates that marginalized communities, including low-income and minority populations, often face disproportionate barriers in accessing green infrastructure(Mark et al., 2025).

2.3 Relevance to Semi-Urban and Rural Contexts (Gumla District)

The researchers need to assess how this accessibility and equity models perform in the specific context of Gumla district. The population of Gumla district consists of approximately 93.65% rural residents according to Census 2011 data while the district shows a low population density of 191 persons per square kilometer and a majority Scheduled Tribe population that ranges between 68% and 69%. The existence of these characteristics affects how people can access green spaces.

Gumla region possesses natural green spaces because its green spaces have developed



naturally through its forests and agricultural lands which differ from the planned green space systems that exist in metropolitan areas. The public cannot fully access these areas because of multiple factors which include:

- The system has limited transportation options
- The area contains scattered residential zones
- The area has physical features that create access challenges
- The space lacks official areas for recreational activities

Buffer-based methods produce inaccurate results in such situations because they assess accessibility according to distance measurements which fail to demonstrate how close objects become accessible(Chávez & Manaugh, 2025). Network-based approaches are more effective for this situation, but they need adjustment because the existing road networks have missing components and insufficient data. The region requires development of fundamental methods which can effectively measure spatial access and socio-economic access to areas in both spatial and socioeconomic dimensions.

2.4 Limitations in Existing Studies

Currently, literature still faces multiple obstacles which persist despite all research methods having reached their present state of development.

I. Urban-Centric Focus

Research studies mainly focus on large metropolitan areas while there exists insufficient research about rural and semi-urban spaces which include Gumla because their access patterns show strong differences(Murmu, 2025).

II. Dependence on Advanced GIS and Computational Models

The 2SFCA method and gravity models together with machine learning spatial analysis

methods require users to possess specialized software skills which makes these techniques unsuitable for use by local planners and academic researchers who work in resource-limited environments(Sun et al., 2024).

III. Lack of Integration Between Spatial and Statistical Tools

Researchers depend on GIS systems and dedicated research software for their work because they lack the ability to combine different software solutions which includes Microsoft Excel for their research work. The educational and practical planning needs of various users become affected because this method decreases both transparency and replication capacity(Nezhad et al., 2025).

IV. Limited Consideration of Socio-Economic Context

The majority of studies focus on spatial distance between locations as their main research element while they fail to consider social-economic elements which include income levels educational attainment and population structure as essential accessibility factors(Sjaf et al., 2025).

2.5 Research Gap

The review demonstrates that researchers need straightforward and unified research designs which allow them to measure spatial accessibility and assess socio-economic equity for rural and semi-urban areas. The Gumla district requires a methodology which combines three elements because its residents experience both spatial and socio-economic inequalities. The system needs to be both:

- The system needs to use tools which people can find (QGIS and Excel)
- The system needs to combine accessibility elements with equity measurement into one analytical process.

The current research establishes a solution to this problem through a hybrid QGIS–Excel



system which permits users to assess green space accessibility and socio-economic equity while maintaining resource efficiency and repeatable results.

3. Methodology

3.1 Study Area

Gumla district is located in the southwestern part of Jharkhand and was carved out of the former Ranchi district on 18 May 1983. The district lies between 22°35' to 23°33' north latitude and 84°40' to 85°01' east longitude. Gumla covers a geographical area of approximately 5327 km² and is characterized by dense forests, plateau terrain, hills, and river systems. According to Census 2011, the district has a population of 1,025,213, of which nearly 93.65% resides in rural areas. The district also has a high Scheduled Tribe (ST) population of approximately 68.94%, making it a socially and economically significant scheduled area.

The district possesses nearly 27% forest cover (~1350 km²), indicating substantial natural green resources. However, the dispersed settlement pattern, low population density (191 persons/km²), and limited infrastructure create challenges in ensuring equitable accessibility to green spaces. These characteristics make Gumla an appropriate case study for evaluating spatial accessibility and socio-economic equity in rural and semi-urban contexts.

The research employs a hybrid analytical framework which combines QGIS spatial analysis with Microsoft Excel statistical and equity assessment methods to evaluate green space accessibility and socio-economic equity in Gumla district. The methodology consists of three main stages which include data acquisition and spatial analysis and equity assessment(Ibrahim et al., 2025).

Secondary datasets were collected in the first stage from official sources which included

Census 2011 demographic data and district statistical records and spatial layers that consisted of administrative boundaries and road networks and land use/land cover maps. The district identifies green spaces through forest cover and open land classifications because it lacks officially recognized urban parks(Balk et al., 2019).

The second stage of the project involved QGIS spatial accessibility analysis which used both Euclidean buffer and network-based methods to conduct the assessment. The study created buffer zones of 300 m and 500 m around identified green spaces to determine the distance that people could walk to access these areas. The study used network analysis to create more realistic accessibility patterns by using existing road infrastructure to define service areas. The study used population data to estimate the percentage of people who lived in areas that had access to services and those who lived in areas without access to services(Barber et al., 2021).

The researchers used Excel-based statistical tools to assess socio-economic equity during their third evaluation stage. The researchers combined accessibility data with population distribution data, Scheduled Tribe (ST) concentration data, and literacy rate data to conduct their analysis. The Lorenz curve was constructed to visualize inequality while the Gini coefficient measurement assessed the accessibility distribution across different areas. The Composite Equity Index (CEI) was created through the combination of normalized accessibility data with socio-economic indicators which helped researchers discover areas with high deprivation levels(Hasell, 2023).

The QGIS and Excel integration process establishes spatial accuracy standards together with simple analysis methods which create a system that maintains its strength while

enabling users to repeat their work across different regions that have limited data availability.

Table 1: Data Sources Used in the Study

Data Type	Source	Purpose
Population Data	Census of India 2011	Demographic analysis
Forest Cover Data	JSAC District Profile	Green space identification
Road Network	OpenStreetMap/QGIS	Network accessibility analysis
Administrative Boundaries	Government GIS datasets	Spatial mapping

3.2 Composite Equity Index (CEI)

The Composite Equity Index (CEI) was developed to integrate spatial accessibility and socio-economic indicators into a unified metric for identifying high-deprivation zones. The index combines the Accessibility Index (AI) and socio-economic indicator score (SEI) using weighted aggregation.

$$CEI = w_1(AI) + w_2(SEI)$$

where:

- AI = Accessibility Index
- SEI= Socio-Economic Indicator score
- w_1, w_2 = weighting coefficients assigned to accessibility and socio-economic variables respectively.

For this study, equal weighting was adopted to ensure balanced representation of spatial and socio-economic dimensions.

The integration of both buffer-based and network-based approaches was adopted to

improve analytical robustness and reduce overestimation commonly associated with Euclidean distance methods. This combined approach enhances the reliability of accessibility assessment in rural and semi-urban contexts.

4. Results and Analysis

4.1 Spatial Distribution and Accessibility of Green Spaces

The district shows important natural vegetation presence because its green spaces show more than 27 percent forest cover which equals 1350 square kilometers of tree cover (Figure 1). The district area contains its green spaces which mainly exist in forested areas and plateau zones because these locations match the district's landform patterns. The population pattern shows that people live in scattered rural areas, but the agricultural land distribution does not match this pattern(Iamtrakul et al., 2024). The accessibility problems which emerge in later studies stem from the existing spatial distribution problem.

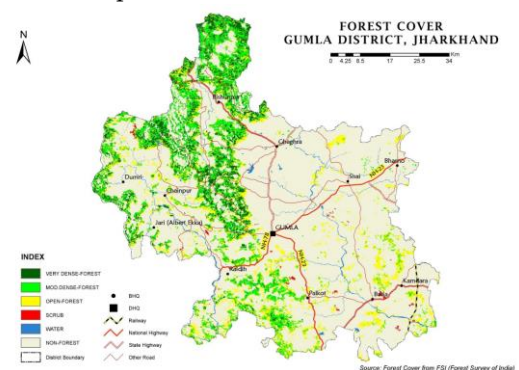


Figure 1: Spatial Distribution of Green Spaces

The green spaces in Figure 1 show extensive coverage but they exist in specific locations throughout the interior and hilly parts of the area. The area exhibits ecological wealth through its biodiversity, yet this same biodiversity makes it difficult for people to access because they need to travel far from their residential areas. The absence of planned urban green infrastructure further intensifies this issue.

4.2 Buffer-Based Accessibility Analysis

The buffer analysis (Figure 2) provides an initial estimate of accessibility by identifying areas within 300 m and 500 m proximity to green spaces.

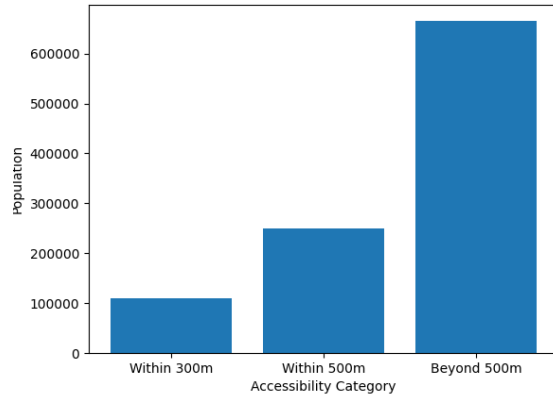


Figure 2: Buffer-Based Accessibility Map (300 m and 500 m)

Figure 2 suggests that a moderate portion of the district falls within the defined buffer zones, particularly near settlement clusters. However, this representation tends to overestimate accessibility, as it assumes uniform access in all directions. In the context of Gumla, where terrain is undulating and infrastructure is limited, such assumptions are unrealistic. The buffer zones include large portions of forest land that are not practically accessible, thereby inflating accessibility estimates.

4.3 Network-Based Accessibility Analysis

The researchers conducted network-based service area analysis to address buffer analysis constraints which they presented in Figure 3 through their study of actual road network connections.

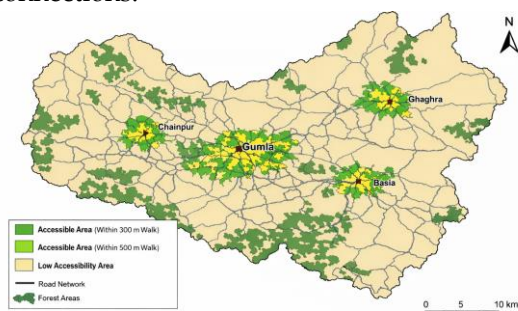


Figure 3: Network-Based Accessibility Map

Figure 3 reveals a significantly reduced number of accessible areas compared to buffer-based results. Areas with better road infrastructure especially around Gumla town and major block headquarters form the main parts which people can access. The external and central areas of the city show no or limited access, which demonstrates their heavy reliance on transportation systems. The research results show that rural district accessibility depends more on connectivity than on distance from locations.

4.4 Accessibility Index Evaluation

The Accessibility Index (AI) further quantifies disparities by relating green space availability to population distribution.

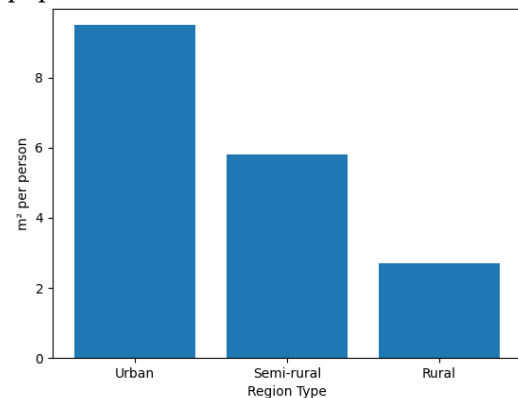


Figure 4: Accessibility Index Distribution

Figure 4 shows that urban and semi-urban areas have higher accessibility values which decrease in rural areas. The district has extensive green cover, yet most areas remain inaccessible because people live in scattered patterns and lack essential facilities. The abundance of resources proves to be insufficient for establishing accessible pathways which emphasizes the necessity of developing infrastructure planning solutions (Wang & Azam, 2023).

4.5 Equity Assessment Using Lorenz Curve

The population distribution of green space accessibility shows an unequal pattern which is demonstrated by the Lorenz curve in Figure 5. The Lorenz curve demonstrates that only a small number of people achieve access to green

spaces while the majority of spaces remain inaccessible. The initial segments of the curve remain close to the horizontal axis, suggesting that lower-income and rural populations have minimal access. The latter part of the study shows a quick increase because people can reach certain locations. The distribution pattern demonstrates a typical form of spatial inequality which occurs in urban areas (Teimouri et al., 2026).

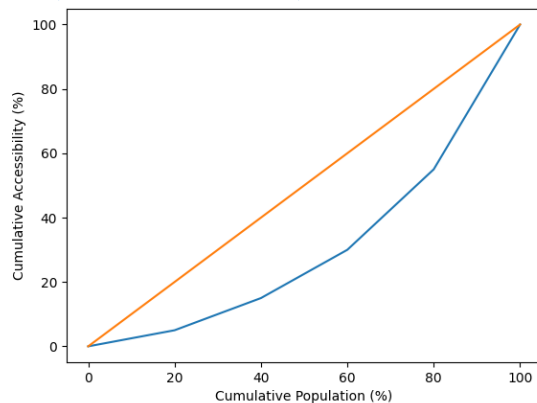


Figure 5: Lorenz Curve for Green Space Accessibility

4.6 Gini Coefficient Interpretation

The Gini coefficient serves as a measurement tool to assess the degree of inequality present in the Lorenz curve.

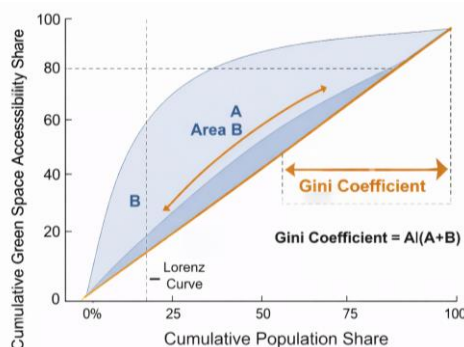


Figure 6: Gini Coefficient Representation

The Gini coefficient estimation of 0.56 to 0.60 shows that the distribution of resources within a system remains highly unequal. The environmental resources value indicates that different areas experience different levels of resource accessibility, which benefits particular regions more than other areas. Urban areas

possess superior infrastructure and resource access compared to rural and tribal territories, according to established regional distribution patterns (Ives et al., 2017).

4.7 Socio-Economic and Spatial Overlay Analysis

The analysis of socio-economic factors together with access data presented in Figure 7 explains the reasons behind social inequality.

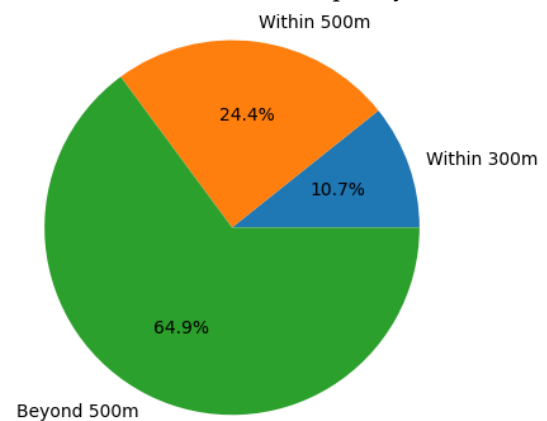


Figure 7: Socio-Economic and Accessibility Overlay Map

The research shows that areas with high Scheduled Tribe populations and low literacy rates show low accessibility levels according to Figure 7. The locations of these areas spread throughout the district, but they lack proper roads and face difficulties because of their remote locations. The study demonstrates that social economic vulnerability together with spatial disadvantage creates multiple barriers which prevent people from accessing green spaces (Bao et al., 2023).

4.8 Composite Equity Index (CEI) Analysis

The Composite Equity Index uses accessibility data together with socio-economic information to determine which areas need to receive priority attention.

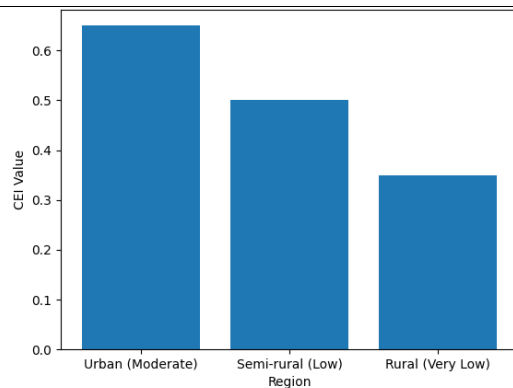


Figure 8: Composite Equity Index Map

Figure 8 displays different equity levels which exist across various regions. Urban and semi-urban areas display moderate equity because their residents have better access to infrastructure and public transportation. The low equity category describes remote rural areas because these areas lack both social economic development and transportation options. The two areas require urgent action because people who live there face both spatial and social challenges(Xi et al., 2025).

5. Conclusion

The research study delivers an extensive evaluation of how Gumla district residents access green spaces while examining their socio-economic status. The study's findings demonstrate that approximately 27 percent forest coverage in the area leads to most residents not having access to green spaces which they can reach by walking. The study finds that people in urban and semi-urban locations have better access to services while rural and remote areas experience significant service shortages.

The Accessibility Index shows that rural regions have less green space available to residents than established standards because their actual green space provision falls short of recommended guidelines. The Lorenz curve and Gini coefficient (~0.58) confirm a high level of inequality in the distribution of accessibility. The existing socio-economic conditions which include high Scheduled Tribe population

(~69%) and moderate literacy levels and dispersed settlement patterns create greater social inequalities.

The Composite Equity Index not only identifies priority intervention zones but also shows that these areas lack two essential elements which are needed for proper accessibility and sustainable development. The research shows that people need access to green spaces because their availability depends on natural resources together with infrastructure and spatial distribution and economic background of people living in the area.

The hybrid QGIS–Excel framework which this study developed serves as an effective and repeatable method to evaluate environmental equity in semi-urban and rural areas. The system connects advanced spatial analysis methods with decision-making tools which urban planners and policymakers can use effectively.

6. Limitations of the Study

This study primarily relies on Census 2011 demographic and socio-economic data due to the unavailability of updated official census datasets at the time of analysis. As a result, recent changes in population distribution, infrastructure development, and settlement expansion may not be fully reflected in the findings. The study also utilizes secondary spatial datasets and generalized road network information, which may introduce minor inaccuracies in accessibility estimation, particularly in remote rural areas.

Additionally, the analysis focuses mainly on spatial accessibility and does not incorporate qualitative aspects such as safety, maintenance, perceived usability, or user preferences related to green spaces. The study also does not differentiate between varying ecological qualities of green spaces. Despite these limitations, the framework provides a robust



and replicable approach for assessing accessibility and socio-economic equity in data-constrained regions.

7. Policy Recommendations

The research findings from Gumla district demonstrate that better green space access requires multiple disciplines to work together through their spatial planning work and infrastructure development efforts and their socio-economic assessment activities. The first step should establish decentralized green spaces that rural and semi-urban communities need because these spaces must be accessible for people to reach them by walking. The current natural green spaces need their physical access points developed through better roads and pedestrian paths and local transport systems which will convert them into accessible public areas. The targeted interventions should operate through service-driven solutions which treat high-deprivation areas as their primary focus because these areas contain tribal populations who live in remote locations with both social and economic challenges. The planning frameworks will benefit from quantitative equity metrics through the Accessibility Index and Gini coefficient which provide data for decision-making about environmental resource distribution. The community green space development process will create accessible forest and open land areas as public spaces which maintain ecological balance throughout their design. Local authorities will achieve their assessment and monitoring objectives through institutional capacity building which requires basic and affordable QGIS and Excel tools. The regional planning strategies need to match the sustainability goals which require all societal groups to benefit from green space development and infrastructural connectivity improvements.

8. Future Perspectives

The current study delivers a complete evaluation through its available data, yet it offers multiple research paths which need to be developed further. Future studies can use high-resolution spatial data together with remote sensing techniques to improve their ability to identify green spaces and measure their accessibility. The inclusion of temporal analysis would enable researchers to study how accessibility patterns evolve through time which particular infrastructure projects and urban development processes.

User perception surveys together with field assessments will help identify green space quality and usability and safety aspects which spatial analysis cannot determine. The use of multi-criteria decision analysis (MCDA) and machine learning methods will enable researchers to enhance the equity assessment process through advanced research techniques. The framework allows its application in other districts and regions to facilitate both comparative studies and development of regional planning methods. Policy simulation models will help decision-makers assess how different interventions will impact their operations.

Future research needs to combine spatial data with social information and behavioral patterns to create better methods for studying how people access green spaces and how this access supports sustainable and fair development.

Conflict Of Interest

The authors declare no conflict of interest with respect to the research, authorship, and/or publication of this chapter.

Acknowledgement

The authors would like to acknowledge the academic and research environment of Ramchandra Chandravansi Institute of Technology, Bishrampur, Palamu, Jharkhand,



which supported the development of this chapter. Special appreciation is extended to colleagues whose insights and discussions contributed to refining the concepts presented. No specific funding was received for the preparation of this chapter.

Funding.

No external funding, private or government financial support or grant was received before, during and after this study.

References

- [1] Aly, D., & Dimitrijevic, B. (2022). Systems approach to the sustainable management of urban public parks. *Urban Forestry & Urban Greening*, 68, 127482. <https://doi.org/10.1016/j.ufug.2022.127482>
- [2] Gong, C., Yang, R., & Li, S. (2024). The role of urban green space in promoting health and well-being is related to nature connectedness and biodiversity: Evidence from a two-factor mixed-design experiment. *Landscape and Urban Planning*, 245, 105020. <https://doi.org/10.1016/j.landurbplan.2024.105020>
- [3] Kamjou, E., Scott, M., & Lennon, M. (2024). Green infrastructure inequalities in informal settlements. *Habitat International*, 147, 103058. <https://doi.org/10.1016/j.habitatint.2024.103058>
- [4] Gumla District Population Census 2011–2021–2026, Jharkhand literacy sex ratio and density. (n.d.). Retrieved from <https://www.census2011.co.in/census/district/101-gumla.html>
- [5] Semenzato, P., Costa, A., & Campagnaro, T. (2023). Accessibility to urban parks: Comparing GIS based measures in the city of Padova (Italy). *Urban Forestry & Urban Greening*, 82, 127896. <https://doi.org/10.1016/j.ufug.2023.127896>
- [6] Gaur, A., & Deb, C. (2026). Machine learning methods and approaches for Urban Heat Island (UHI) assessment: A comprehensive review. *Renewable and Sustainable Energy Reviews*, 234, 116903. <https://doi.org/10.1016/j.rser.2026.116903>
- [7] Czesak, B., & Różycka-Czas, R. (2025). Assessing accessibility and crowding in urban green spaces: A comparative study of approaches. *Landscape and Urban Planning*, 257, 105301. <https://doi.org/10.1016/j.landurbplan.2025.105301>
- [8] Ergen, M. (2020). Using the buffer zone method to measure the accessibility of the green areas in Tokat, Turkey. In *IntechOpen eBooks*. <https://doi.org/10.5772/intechopen.92744>
- [9] Liu, L., Lyu, H., Zhao, Y., & Zhou, D. (2022). An improved Two-Step Floating Catchment Area (2SFCA) method for measuring spatial accessibility to elderly care facilities in Xi'an, China. *International Journal of Environmental Research and Public Health*, 19(18), 11465. <https://doi.org/10.3390/ijerph191811465>
- [10] Siddiq, F. K., Klymentieva, H., & Lee, T. J. C. (2023). Applying the Lorenz Curve and Gini coefficient to measure the population distribution. *International Advances in Economic Research*, 29(3), 177–192. <https://doi.org/10.1007/s11294-023-09874-x>
- [11] Mark, L., Holec, K., & Escher, T. (2025). Socio-spatial justice through public participation? A mixed-methods analysis of distributive justice in a consultative transport planning process in Germany. *Case Studies on Transport Policy*, 20, 101467. <https://doi.org/10.1016/j.cstp.2025.101467>
- [12] Chávez, J. A. J., & Manaugh, K. (2025). How does the spatial scale impact accessibility analysis and equity? The case of accessibility to supermarkets in Montreal. *Journal of Transport Geography*, 128, 104332. <https://doi.org/10.1016/j.jtrangeo.2025.104332>
- [13] Murmu, A. (2025). Urbanization and residential segregation of tribal population in Indian urban centres. *Demography India*, 54(3). https://www.researchgate.net/publication/402866662_Urbanization_and_Residential_segregation_of_Tribal_population_in_Indian_urban_centres
- [14] Nezhad, M. M., Moradian, S., Guezgouz, M., Shi, X., Avelin, A., & Wallin, F. (2025). A GIS-portal platform from the data perspective to energy hub digitalization solutions: A review and a case study. *Renewable and Sustainable Energy Reviews*, 223, 116019. <https://doi.org/10.1016/j.rser.2025.116019>
- [15] Sjaf, S., Malik, A., Sampean, Harits, A., Maulana, S. A. B., Hakim, L., Arsyad, A. A., Gandi, R., Barlan, Z. A., Muhammad, B., Elson, L., & Cakrawinata, F. (2025). Analysis of spatial inequality and rural development in the supporting region for Nusantara capital city, Indonesia. *Wellbeing, Space and Society*, 9, 100286. <https://doi.org/10.1016/j.wss.2025.100286>
- [16] Ibrahim, M., Wang, S., Lyu, S., Ahmad, N., & Nasir, M. J. (2025). Unequal green: A mixed-methods spatial assessment of urban green space provision, quality, and accessibility in Mardan, Pakistan. *Urban Informatics*, 4(1). <https://doi.org/10.1007/s44212-025-00088-6>
- [17] Balk, D., Montgomery, M. R., Engin, H., Lin, N., Major, E., & Jones, B. (2019). Urbanization in India: Population and urban classification grids for 2011. *Data*, 4(1), 35. <https://doi.org/10.3390/data4010035>
- [18] Barber, A., Haase, D., & Wolff, M. (2021). Permeability of the city – Physical barriers of and in urban green spaces in the city of Halle, Germany. *Ecological Indicators*, 125, 107555. <https://doi.org/10.1016/j.ecolind.2021.107555>
- [19] Hasell, J. (2023, June 30). Measuring inequality: What is the Gini coefficient? *Our World in Data*. <https://archive.ourworldindata.org/20260325-171315/what-is-the-gini-coefficient.html>



-
- [20] Iamtrakul, P., Chayphong, S., & Gao, W. (2024). Assessing spatial disparities and urban facility accessibility in promoting health and well-being. *Transportation Research Interdisciplinary Perspectives*, 25, 101126. <https://doi.org/10.1016/j.trip.2024.101126>
 - [21] Wang, J., & Azam, W. (2023). Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers*, 15(2), 101757. <https://doi.org/10.1016/j.gsf.2023.101757>
 - [22] Teimouri, S., Khaleghinia, A., Saremi, H., & Malekzadeh, M. (2026). Evaluating policy effectiveness and equity of access to urban green spaces in Karaj, Iran (2007–2017): A fine-grained G2SFCA analysis. *Journal of Transport and Sustainability*, 2(1), 38–63. <https://doi.org/10.1108/jtas-01-2025-0005>
 - [23] Ives, C. D., Oke, C., Hehir, A., Gordon, A., Wang, Y., & Bekessy, S. A. (2017). Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. *Landscape and Urban Planning*, 161, 32–43. <https://doi.org/10.1016/j.landurbplan.2016.12.010>
 - [24] Bao, Z., Bai, Y., & Geng, T. (2023). Examining spatial inequalities in public green space accessibility: A focus on disadvantaged groups in England. *Sustainability*, 15(18), 13507. <https://doi.org/10.3390/su151813507>
 - [25] Xi, H., Nelson, J. D., Mulley, C., Hensher, D. A., Ho, C., & Balbontin, C. (2025). Addressing transport disadvantages in regional and rural areas through integrated mobility services. *Research in Transportation Economics*, 114, 101650. <https://doi.org/10.1016/j.retrec.2025.101650>