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Research Article

Exploring Urban Greenery: A Case Study of Roadside Trees in Pokhara Metropolitan City

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Abstract

Roadside trees play a crucial role as important components of urban greenery, significantly enhancing the overall quality of cities and ultimately contributing to the quality of life for residents and visitors alike. This study examines the condition, maintenance, and proximity of roadside trees to electric wire corridors in Pokhara Metropolitan City, Nepal. This study employs field surveys, categorization based on tree attributes, and mapping techniques to analyze the distribution and characteristics of roadside trees. Out of approximately 1500 trees initially collected, 1435 were processed for further analysis. Trees were classified by species, height, condition, and the presence of fencing or resting structures (Chautaro), with proximity to electric wire corridors also assessed. Findings reveal a significant presence of trees in good condition, predominantly Dhupi, Kapur and Ashoka species, with a notable percentage requiring maintenance. A substantial number of trees were found in close proximity to electric wires, posing potential hazards. Mapping techniques facilitated visualizing the spatial distribution of trees, aiding in urban planning and management strategies. The study underscores the importance of sustainable urban greening practices and the need for proactive measures to address challenges related to tree maintenance and safety in urban environments like Pokhara Metropolitan City. This study emphasizes the pivotal role of roadside trees in enhancing the aesthetic appeal and quality of city life, positioning them as decisive factors in shaping urban environments and fostering a welcoming atmosphere for residents and visitors.

Keywords

Roadside Trees, Urban Greenery, Pokhara, GPS Survey, Chautaro

1. Introduction

Urban greenery, encompassing various elements such as parks, gardens, and street trees, constitutes an integral aspect of urban landscapes worldwide [1, 2]. Among these elements, roadside trees hold a particular significance due to their strategic placement along urban streets and roads [3, 4]. Urban greenery, including roadside trees, plays a pivotal role in enhancing the environmental quality, aesthetic appeal, and overall livability of cities [5, 6]. This paper seeks to explore the importance of urban greenery, focusing specifically on roadside trees, within the context of Pokhara Metropolitan City, Nepal.

The presence of urban greenery, including roadside trees, contributes significantly to the creation of healthier and more sustainable urban environments [7, 8]. These trees serve as natural air purifiers by absorbing pollutants such as carbon dioxide, sulfur dioxide, and particulate matter, thereby im-

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proving air quality and mitigating the adverse effects of urban pollution [9, 10]. Furthermore, roadside trees act as natural noise barriers, dampening traffic noise and creating more tranquil urban spaces conducive to human well-being [11, 12]. Their cooling effect through shading and evapotranspiration helps mitigate the urban heat island effect, reducing temperatures in built-up areas and enhancing thermal comfort for residents [13, 14]. Beyond their environmental benefits, roadside trees also play a crucial role in enhancing the social and economic fabric of cities [15, 16]. They contribute to the creation of visually appealing urban landscapes, fostering a sense of place and identity within communities [17]. Studies have shown that access to green spaces, including streets lined with trees, correlates positively with residents' mental health and overall quality of life [18, 19]. Moreover, urban greenery, including roadside trees, has been linked to increased property values and economic vitality, attracting businesses, residents, and visitors to urban areas [20, 21].

In the context of other cities globally, the types of trees planted along urban streets vary depending on factors such as climate, soil conditions, and local preferences [22, 23]. Common species of roadside trees include deciduous and evergreen varieties, native and non-native species, and trees with varying growth habits and canopy sizes [24, 25]. For instance, cities in temperate climates may feature a mix of broad-leaved deciduous trees such as maples, oaks, and elms, renowned for their vibrant foliage colors in autumn. In contrast, cities in subtropical or tropical climates may favor evergreen species like palms, ficus, and eucalyptus, prized for their year-round greenery and shade-providing qualities.

Regardless of the specific species planted, the presence of roadside trees in urban environments contributes to creating healthier cities. Their benefits extend beyond mere beautification to encompass crucial ecological, social, and economic functions essential for building sustainable and resilient urban communities [26]. As such, understanding the management practices and community perceptions surrounding roadside trees is paramount for fostering their long-term health and maximizing their contributions to urban ecosystems. In this context, the case study conducted in Pokhara Metropolitan City offers valuable insights into the challenges and opportunities associated with urban greenery management, with a specific focus on roadside trees.

Study Area

Pokhara city is taken as the study area of our project. Pokhara city is the headquarter of Kaski district of Nepal. Its latitude and longitude are 28°12'34.1964"N and 83°57'34.2648"E respectively. It is the country's largest Metropolitan city in terms of area and second largest in terms of population. It is also known as the city of lakes and one of the most appropriate touristic destinations of Nepal. The average temperature of Pokhara Metropolitan is 21.5°C that makes the city mild, pleasant and climatically suitable for the tourist.

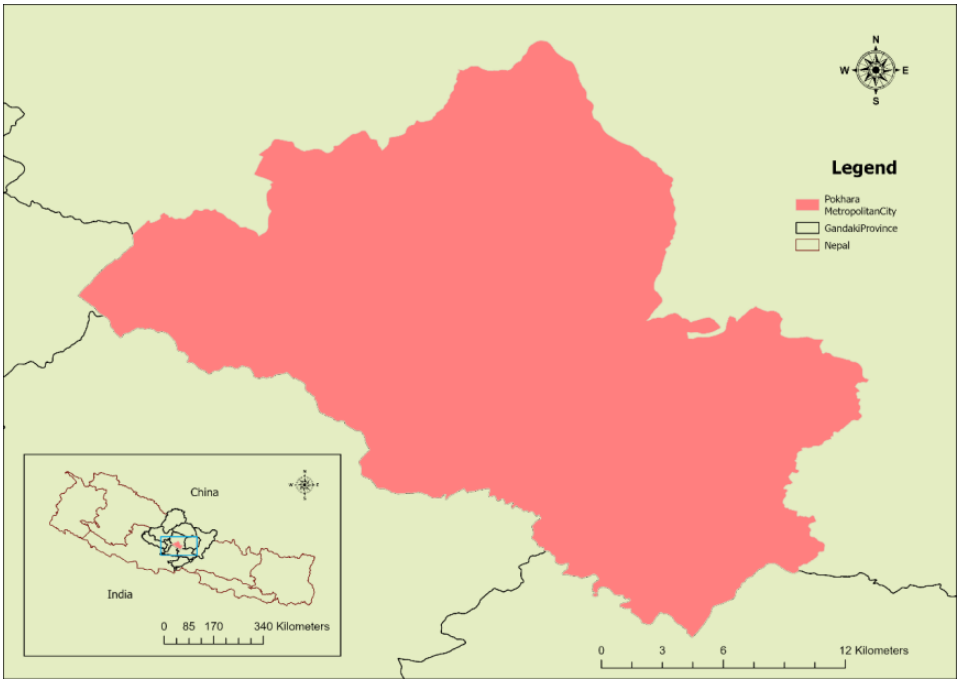

Figure 1. *Study Area Map of Pokhara Metropolitan City.*

Pokhara holds significant importance as a tourism capital not only within Nepal but also on an international scale. Renowned for its breathtaking natural beauty, Pokhara is nestled amidst the majestic Annapurna and Dhaulagiri mountain ranges, with the serene Phewa Lake adding to its charm. This picturesque city serves as a gateway to popular trekking des-

tinations such as the Annapurna Circuit and the Annapurna Base Camp, attracting trekkers and adventure enthusiasts from around the globe. Beyond its natural allure, Pokhara offers a plethora of tourist attractions and activities. Visitors can explore the vibrant Lakeside area, bustling with restaurants, cafes, and shops offering a diverse range of cuisine and handicrafts. The city is also home to cultural landmarks such as the Bindyabasini Temple, and the World Peace Pagoda, which provide insights into Nepal's rich cultural heritage. Moreover, Pokhara serves as a hub for outdoor adventures, including paragliding, zip-lining, boating, and mountain biking, making it a haven for thrill-seekers and nature lovers alike. The city's mild climate, scenic landscapes, and hospitable atmosphere contribute to its reputation as a must-visit destination in Nepal. Given Pokhara's status as a tourism capital and its significance as a gateway to the Himalayas, the management of urban greenery, including roadside trees, is crucial for enhancing the city's aesthetic appeal, environmental quality, and overall visitor experience. As such, understanding the characteristics and management practices of roadside trees within Pokhara Metropolitan City is essential for promoting sustainable tourism and preserving the city's natural beauty for future generations.

The study area encompasses various road sections within Pokhara Metropolitan City, located in the Kaski District of the Gandaki Province in Nepal. Notable places within this area include Bagar, Mahendrapool, Naya Bazar, Mustang Chowk, Rastra Bank Chowk, the Lakeside area, Hallan Chowk, Zero Kilometer, Shrijana Chowk, and Bindyabasini Chowk.

Table 1. *Location information of study area.*

Country	**Nepal**
Province	Gandaki
District	Kaski
Metropolitan	Pokhara
Road Sections	Bagar – Mahendrapool – Naya Bazar – Mustang chowk – Rastra Bank Chowk – Lake side area Hallan Chowk – zero km – Shrijana chowk – Bindyabasini chowk

2. Methodology

The methodology employed for this study involved a comprehensive approach to data collection, transfer, analysis, and map preparation to assess the attributes of roadside trees in Pokhara Metropolitan City. The data collection process began with the utilization of the kobocollect mobile application, which facilitated the systematic recording of point data for each tree's location and other relevant attributes. These attributes included latitude, longitude, altitude, address, the name of the tree, presence of fencing, diameter measurement, tree category, estimated height, presence of chautaro (traditional resting place), proximity to electric wires, overall tree condition, and photographic documentation.

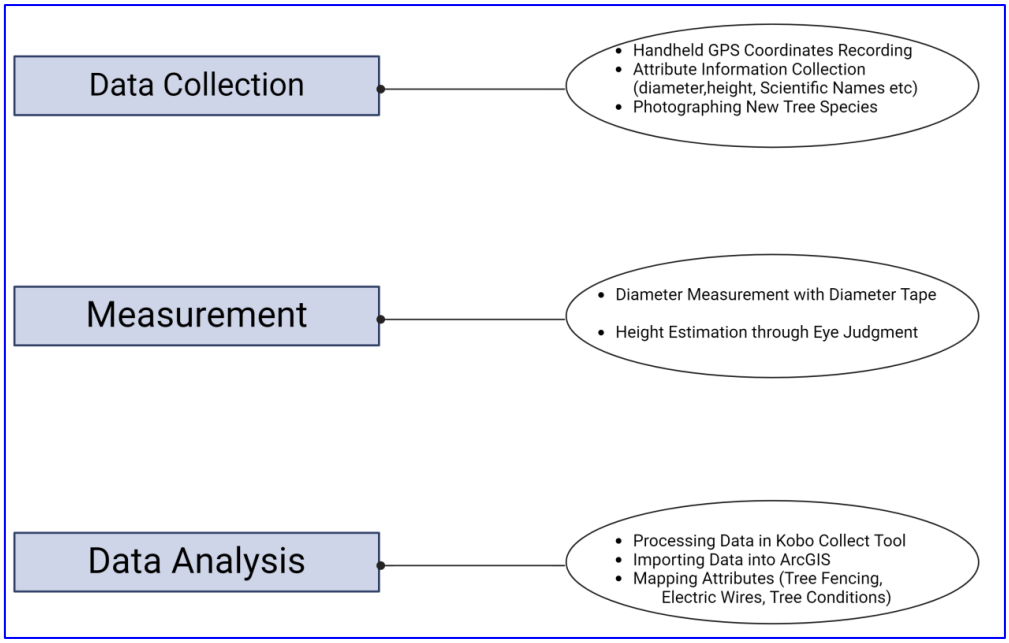

Figure 2. *Overview of Methodology.*

To ensure accurate measurements, handheld GPS devices were used to record the geographic coordinates (latitude and longitude) of each roadside tree. Additionally, the diameter of each tree was measured using a diameter tape, providing

precise measurements for further analysis. However, due to practical constraints, tree height was estimated through visual assessment, relying on eye judgment to determine approximate heights.

The data collected through kobcollect were then transferred to the KoboToolbox server and subsequently downloaded in .csv format for further processing. This process facilitated efficient data management and analysis. The collected data, including tree species, scientific names, and attribute information, were imported into ArcGIS 10.8 in .shp format using export tools.

Once imported into ArcGIS, the data were utilized to prepare thematic maps depicting various attributes such as tree species distribution, presence of fencing, proximity to electric wires, and overall tree condition. These maps provided visual representations of the spatial distribution and characteristics of roadside trees within Pokhara Metropolitan City.

The entire survey process, including data collection, transfer, and analysis, took approximately one week to complete. This time-frame allowed for thorough data collection and analysis while ensuring the accuracy and reliability of the findings.

In summary, the methodology employed in this study encompassed a systematic approach to data collection, transfer, analysis, and map preparation, facilitating a comprehensive assessment of roadside trees in Pokhara Metropolitan City. Through the utilization of advanced tools and techniques, this study aimed to provide valuable insights into the distribution, characteristics, and management of urban greenery within the study area.

3. Result

3.1. Datasets Preparation

After processing and cleaning the collected data, a final table summarizing the attributes of roadside trees in Pokhara Metropolitan City was created. The table provides detailed information on each tree, including its geographical coordinates, altitude, address, tree species, diameter, height, presence of fencing, proximity to electric wires, overall condition, and scientific name. This comprehensive dataset allows for a detailed analysis of the distribution, characteristics, and management status of roadside trees in the study area.

Below is a sample excerpt from the final table:

Table 2. *Sample of road side trees with location information and key attributes.*

S.N.	Latitude	Longitude	ScientificName	Fencing	Categorey	Chautaro	Electricwire	Condition
1	28.24189	83.98877	*crapemyrtles*	Yes	Small	Yes	Yes	Good
2	28.23377	83.99022	*Nyctanthes arbor-tristis*	No	Medium	Yes	No	Good
4	28.23078	83.99127	*Cinnamomum camphora*	No	Medium	No	Yes	Good
5	28.24173	83.98874	*Schizolobium parahyba*	No	Medium	No	No	Good
6	28.23073	83.99127	*Schizolobium parahyba*	No	Medium	Yes	Yes	Good
7	28.23061	83.99131	*Cinnamomum camphora*	No	Medium	Yes	Yes	Good
8	28.24099	83.98879	*Schizolobium parahyba*	Yes	Medium	Yes	Yes	Good
9	28.23078	83.99128	*Cinnamomum camphora*	Yes	Small	No	No	Good
10	28.23075	83.99119	*Cinnamomum camphora*	No	Medium	No	Yes	Good

This final table serves as a valuable resource for understanding the spatial distribution, species composition, and management status of roadside trees in Pokhara Metropolitan City.

3.2. Key Attribute Visualization

Bar diagrams and charts were generated to provide graphical representations of specific attributes and trends related to roadside trees. These visual aids included diagrams depicting the height categories, tree species composition, fencing coverage, and the prevalence of trees near electric wires.

Scientific Name

With the assistance of friends from forestry college and utilizing the internet, the scientific names of each species were identified, along with their local names and photos.

The bar diagram in Figure 3 indicates that there are approximately 288 Juniperus indica, followed by 253 *Cinnamomum camphora*, and 226 *Saraca asoca*. Additionally, 316 trees were recorded as "others," consisting of Areca catechu (39), Ficus religiosa (35), *Cinnamomum tamala* (32), among others.

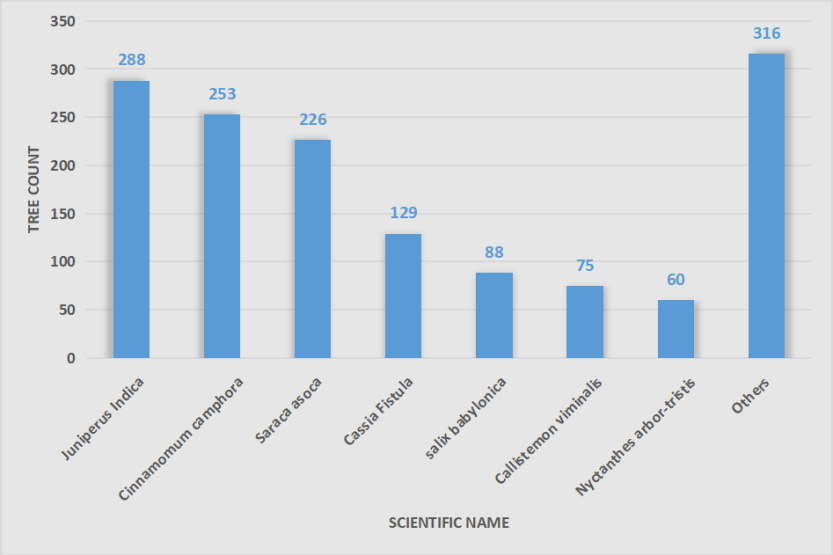

Figure 3. *Bar Diagram showing number of trees Vs scientific name.*

Height Categories:

In order to gain insights into the height and its impact on the surrounding environment, we categorized the height into three groups: small, medium, and large. Trees with a height below 3 meters are classified as small. Trees with a height above 3 meters and below 10 meters are categorized as medium, while trees above 10 meters are classified as large.

The pie chart in Figure 4 illustrates that around 635 trees fall into the small category, with the majority being pine trees. Additionally, 652 trees fall into the medium category, with the highest number being ashoka trees. Finally, 142 trees, including sacred trees like pipal and bar, are categorized as large.

Table 3. *Local name of Road Side Trees o left and Scientfic name on right*

Local Name	Scientific Name
Dhupi	*Juniperus Indica*
Kapur	*Cinnamomum camphora*
Ashoka	*Saraca asoca*
Baar	*Ficus benghalensis*
Pipal	*Ficus religiosa*

Presence of Fencing

In our study, we defined a fence as a structure enclosed by a round metal bar or wooden structure.

Out of 1435 trees surveyed, approximately 58% were provided with fencing, with the majority enclosed by a round metal structure, as depicted in Figure 5. It was observed that the fencing and plantation activities were predominantly carried out by youth clubs and NGOs located in Pokhara on significant occasions. On the other hand, around 42% of the trees were not provided with fencing. Most of these unfenced trees are 8 meters or taller in height and are widely spread. Several of these trees are already in contact with electric wires, posing a potential hazard.

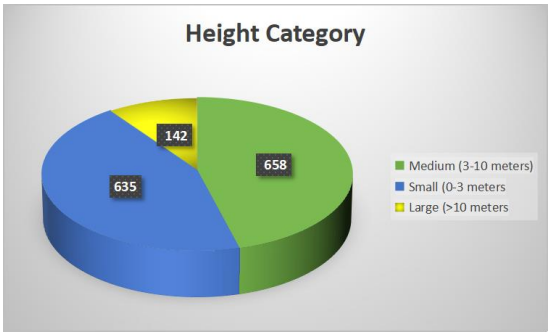

Figure 4. *3D: Pie Chart showing the number of trees Vs height categorized in small, medium and large.*

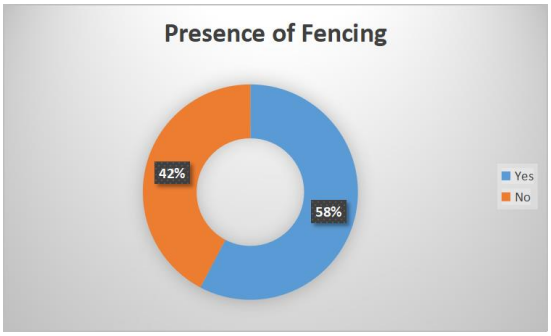

Figure 5. *Doughnut-chart showing Number of Trees VS Presence of Fencing.*

Overall Condition

In our study, we also categorized trees according to their appearance, distinguishing between trees in good condition, those requiring further maintenance, those that have been chopped down, and dead trees. Four categories were created based on tree condition.

The pie chart in Figure 6 illustrates that out of 1435 trees surveyed:

1) 1229 trees were in good condition, indicating that they were well-shaped, well-watered, and had a healthy green appearance.
2) Approximately 9% (136 trees) required further maintenance, suggesting the need for trimming and additional watering.
3) 56 trees were chopped down, evidenced by long stems with few green leaves and clear visible chop marks.
4) 14 out of 1435 trees were dead and must be replaced by new plants.

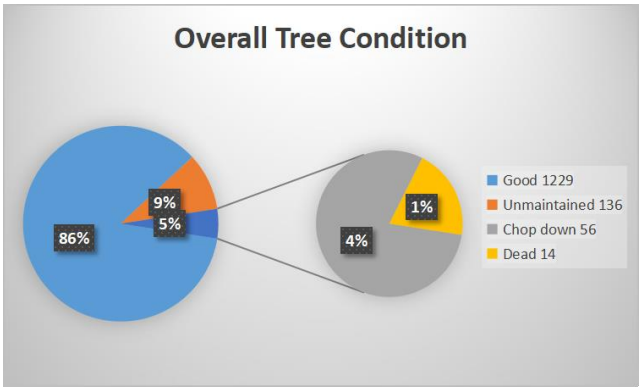

Figure 6. *Pie of Pie-chart showing overall condition of trees and their percentage out of 100.*

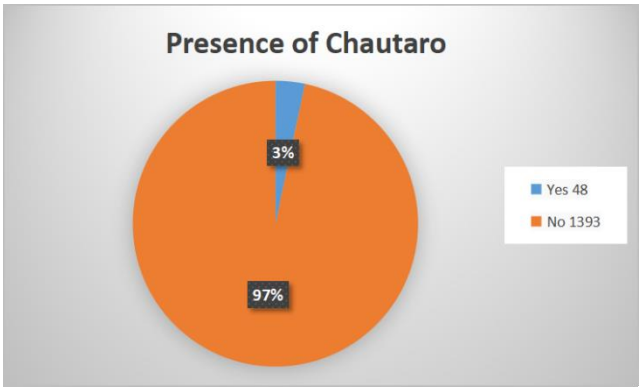

Figure 7. *Pie-chart showing Number of Trees Vs Presence of chautaro's.*

Presence of Chautaro

"Chautaro" typically refers to a raised platform or pedestal often found in traditional Nepali architecture. It's commonly used as a place for resting, socializing, or conducting community activities. Chautaro are usually made of stone or concrete and may have trees planted around them.

The pie chart in Figure 7 indicates that around 3% of the 1435 trees surveyed, totaling 48 trees, have structures such as concrete, metal, or wooden seating areas where people can sit and relax for some time. These resting places, known as "Chautaro," are scattered throughout all areas of Pokhara.*Proximity to Electric Wires*

In most cities in Nepal, roadside trees are often planted directly below the electric wire corridor. While trees like pine may not pose a hindrance to the electric wire corridor, trees like Ashoka and kapur, over time, may grow in height and eventually come into contact with the electric wires. In our survey conducted in the roads of Pokhara, we observed a large number of trees in close proximity to the electric wires, with some already touching them, and a few growing taller than the electric wires.

The pie chart in Figure 8 illustrates that out of the 1435 trees counted:

- 18% (256 trees) were found to be touching electric wires.
- Although 1179 trees were not touching electric wires, nearly forty percent of them were in close proximity to the electric wires and may come into contact with them within a year or so.

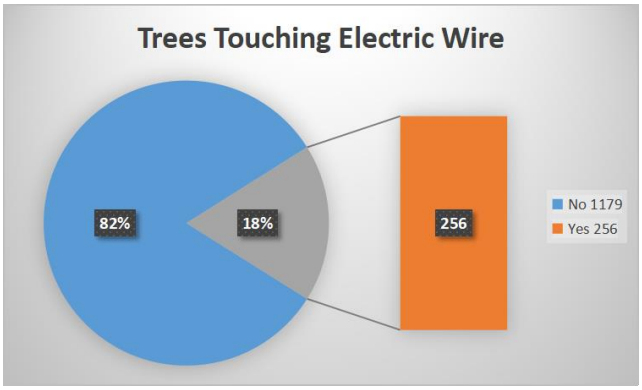

Figure 8. *Bar of Pie-chart showing Number of Trees touching electric wire.*

3.3. Map Preparation

Following the creation of the final table summarizing the attributes of roadside trees in Pokhara Metropolitan City and key attribute visualization in bar diagrams and charts, the datasets was utilized to generate thematic maps. Thematic maps were constructed using ArcGIS software at a scale of 1:1000 to illustrate the spatial distribution of various attributes, including tree species distribution, presence of fencing, proximity to electric wires, and overall tree condition.

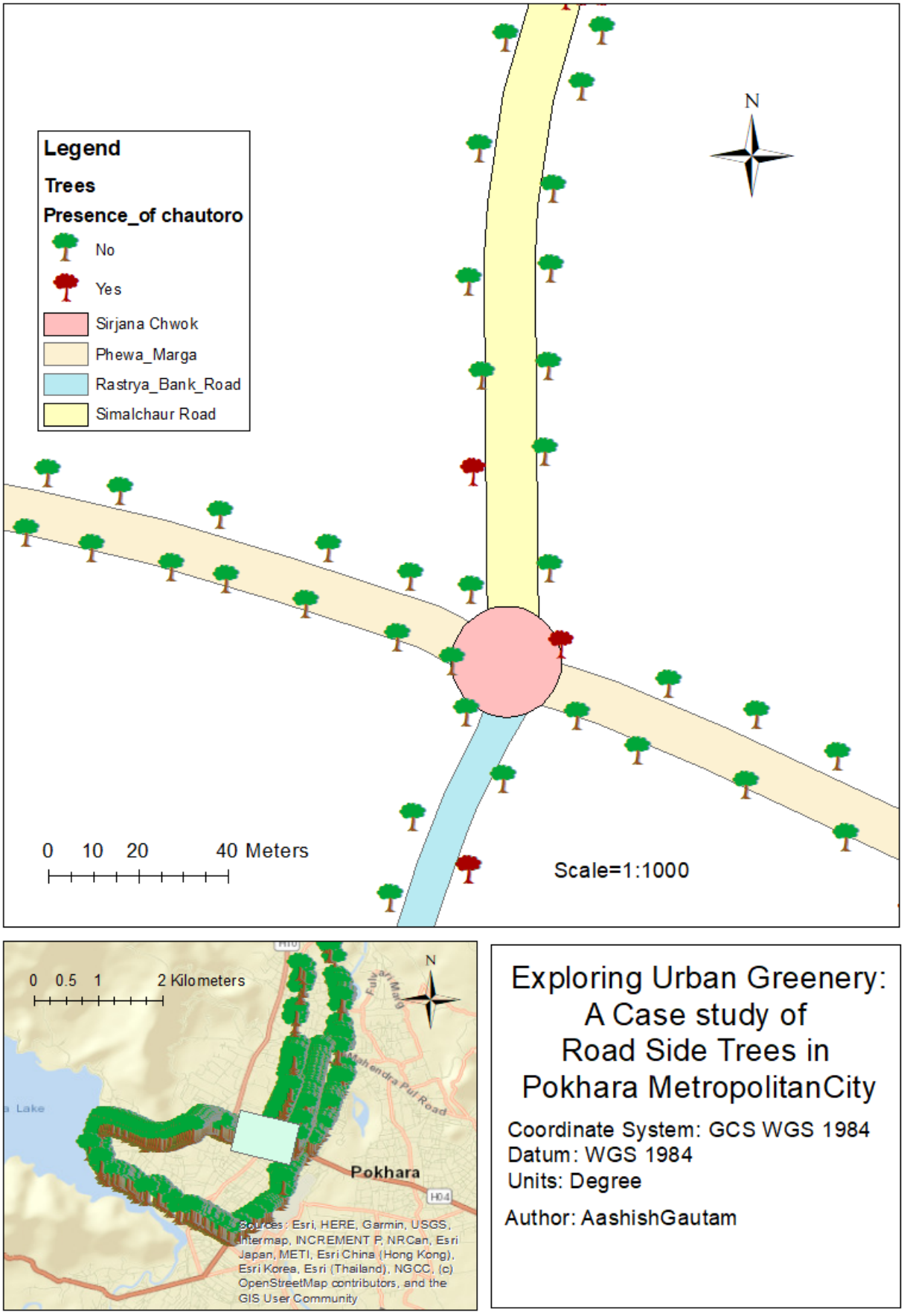

Figure 9. *Map of Roadside Trees in Pokhara Metropolitan City, with trees having chautaro represented by light brown color.*

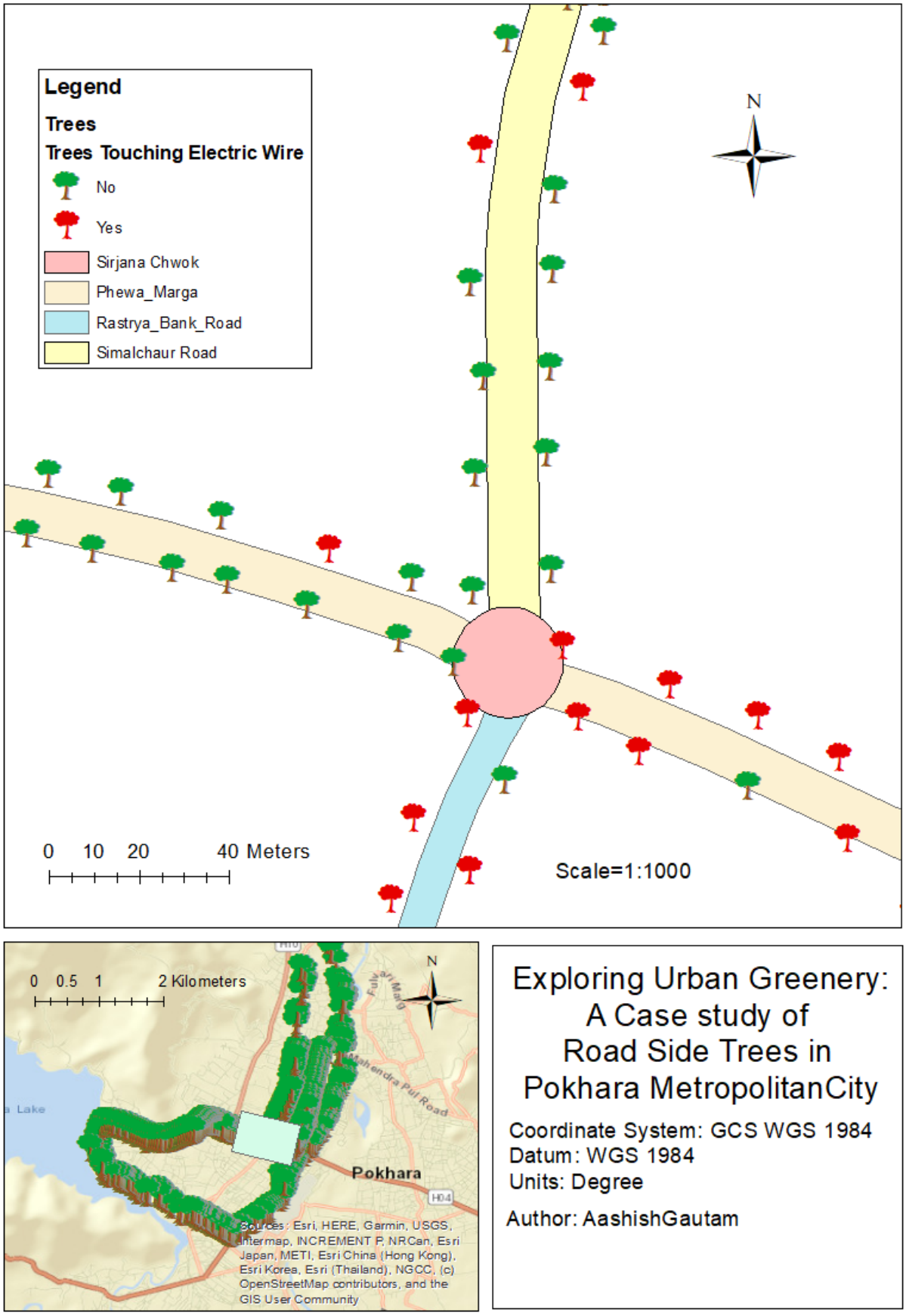

Figure 10. *Map of Roadside Trees in Pokhara Metropolitan City, with trees touching electric wires represented by red color.*

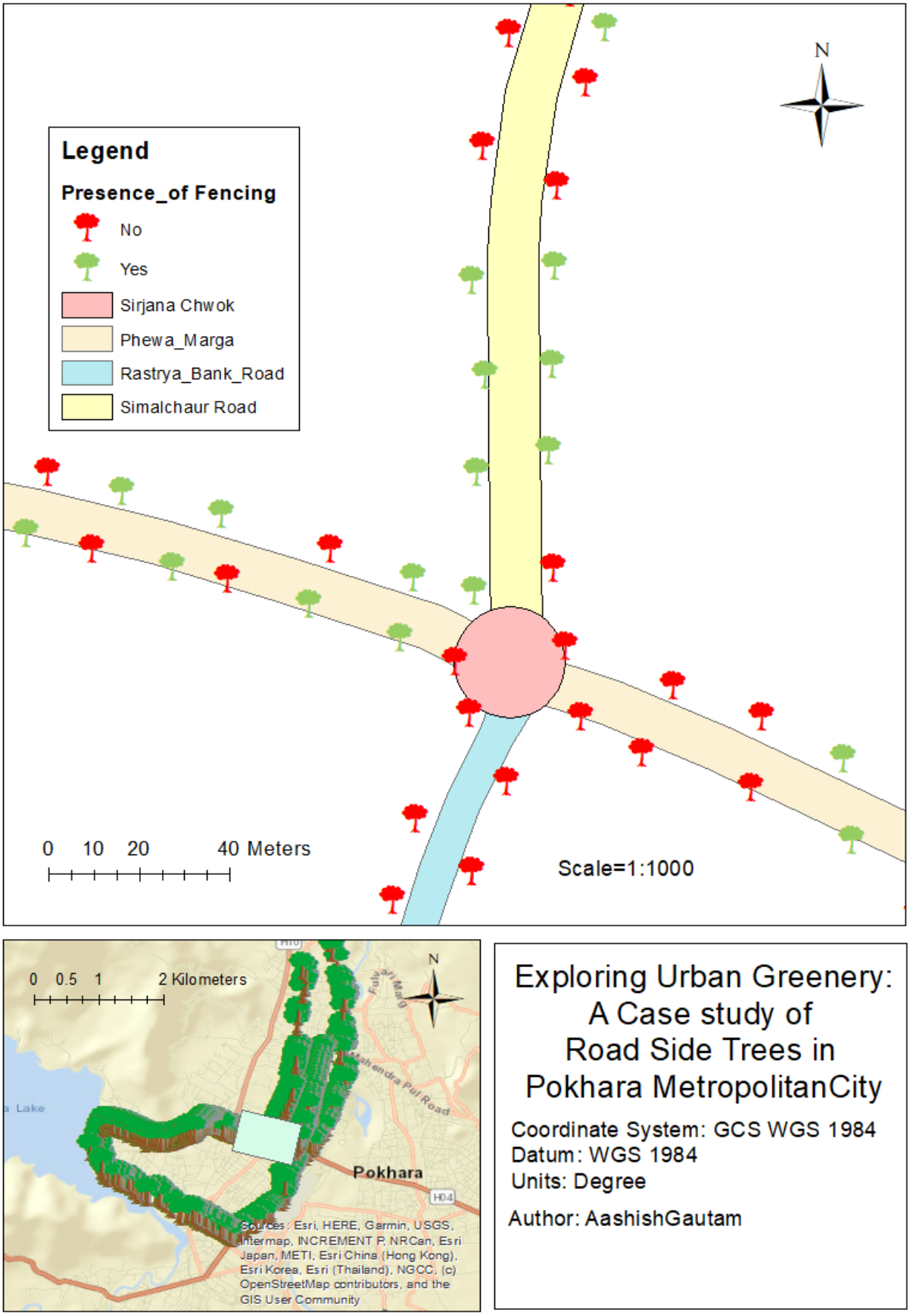

Figure 11. *Map of Roadside Trees in Pokhara Metropolitan City, with trees having fencing represented by red color.*

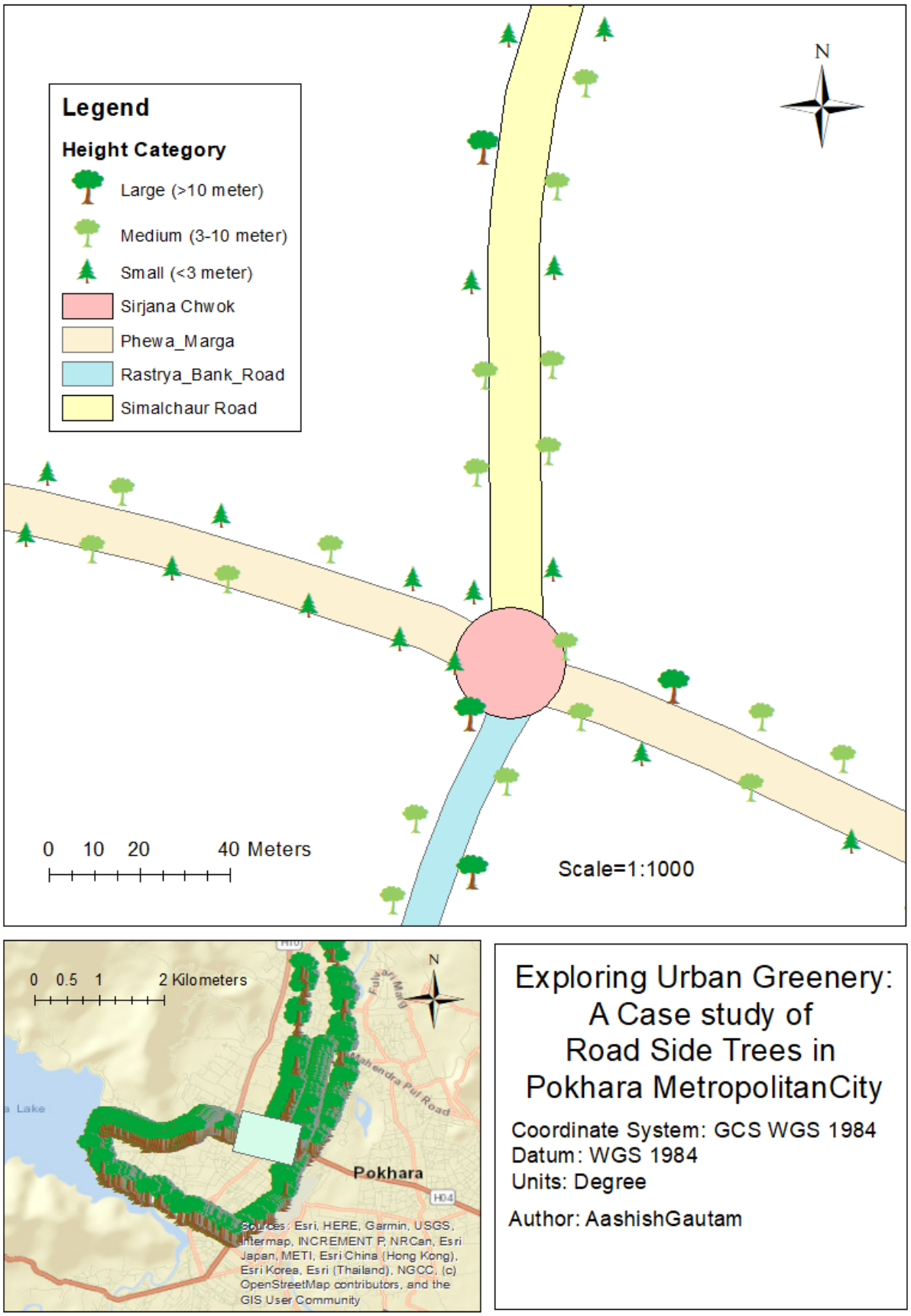

Figure 12. *Map of Roadside Trees in Pokhara Metropolitan City, with trees divided into category of large, medium and small for height of trees >10 meter, 3-10 meter and <3 meter respectively.*

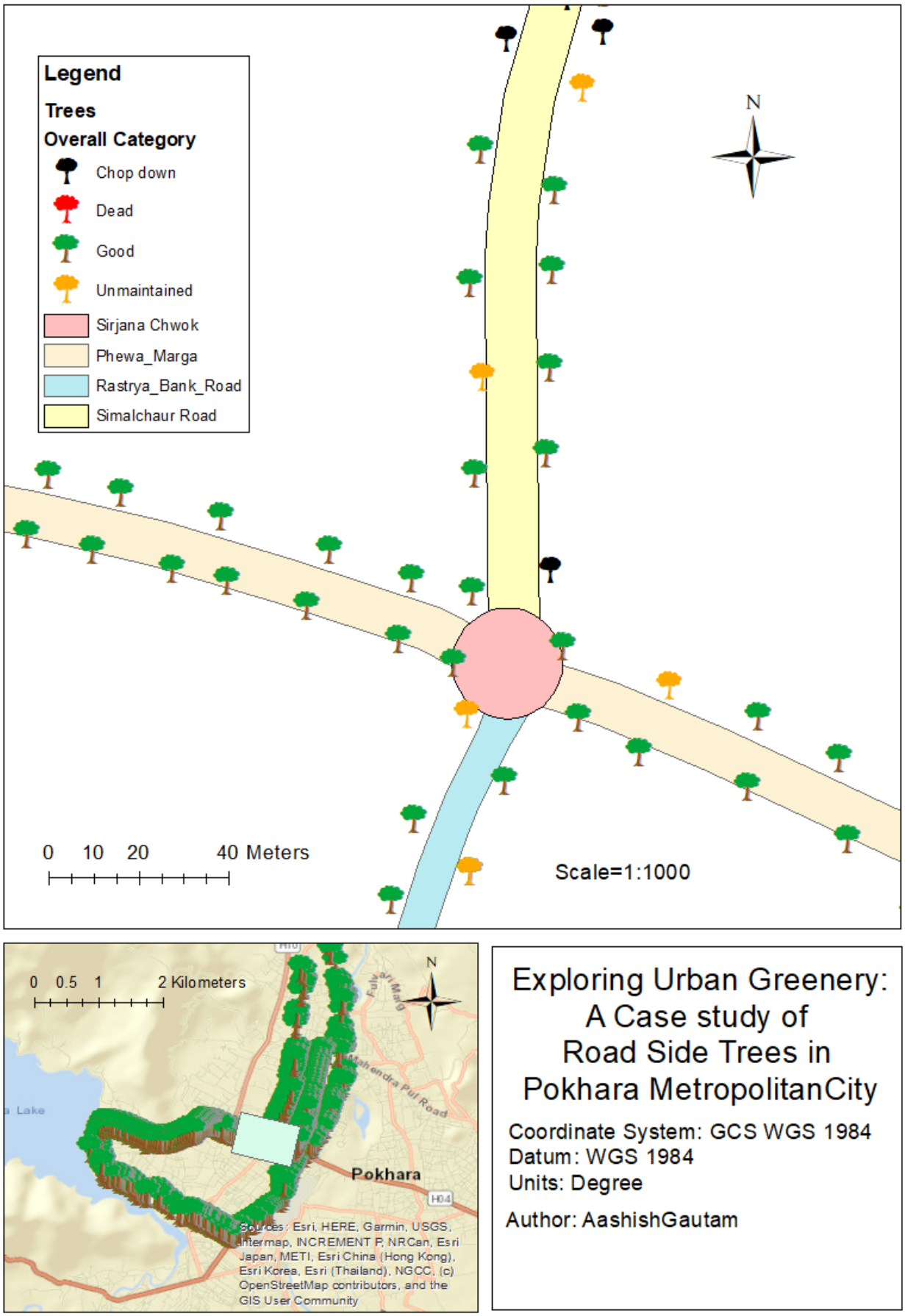

Figure 13. *Map of Roadside Trees in Pokhara Metropolitan City, with trees divided into Good, Unmaintained, Dead and Chopdown.*

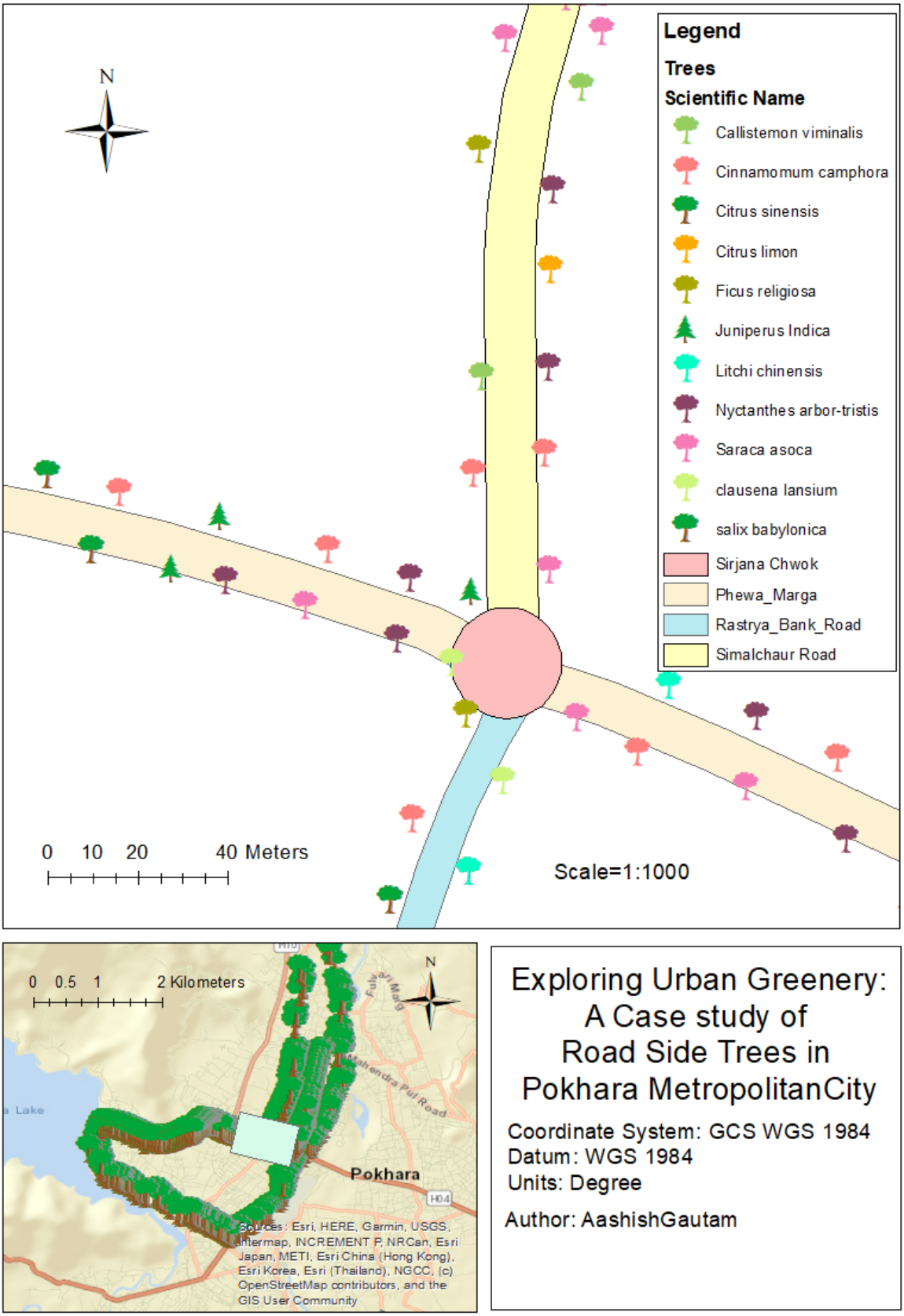

Figure 14. *Map of Roadside Trees in Pokhara Metropolitan City, divided according to their scientific name.*

Overall, the combination of the final table, thematic maps, bar diagrams, charts, and statistical analyses provided a comprehensive overview of the attributes and management status of roadside trees in Pokhara Metropolitan City. These results contribute valuable insights into the urban greenery landscape, aiding in the development of informed management strategies for main-

taining and enhancing the city's roadside tree ecosystem.

4. Conclusion

The assessment of roadside trees in Pokhara Metropolitan City has provided valuable insights into their distribution, characteristics, and management status. Through the systematic collection of data and analysis of attributes such as tree species, diameter, height, fencing, and proximity to electric wires, several key findings have emerged.

Firstly, the study revealed a diverse range of tree species present along urban streets and roads, contributing to the aesthetic appeal and environmental quality of the city. However, challenges such as inadequate fencing and trees touching electric wires were observed, posing safety concerns and inconvenience to local residents.

Secondly, the assessment highlighted the importance of effective management strategies for roadside trees to ensure their health, safety, and contribution to urban ecosystems. Sustainable management practices, including regular maintenance, proper fencing, and addressing safety hazards such as trees touching electric wires, are essential for preserving the urban greenery landscape and enhancing the livability of Pokhara Metropolitan City.

5. Recommendations

Based on the findings of the study, the following recommendations are proposed:

Regular Maintenance: Implement regular maintenance programs to ensure the health and vitality of roadside trees. This includes pruning, watering, and pest control measures to mitigate disease and promote healthy growth.

Proper Fencing: Install and maintain adequate fencing around roadside trees to protect them from damage caused by vehicles, pedestrians, or animals. Proper fencing also enhances the safety of pedestrians and nearby structures.

Addressing Safety Hazards: Take immediate measures to address safety hazards such as trees touching electric wires. Collaborate with local utility providers to relocate or trim trees to mitigate safety risks and alleviate concerns of nearby residents.

Community Engagement: Engage with local communities, including residents and business owners, to raise awareness about the importance of roadside trees and solicit their input in tree management initiatives. Address concerns and seek collaborative solutions to enhance the urban greenery landscape while addressing safety and aesthetic issues.

Continued Monitoring and Evaluation: Establish a monitoring and evaluation framework to assess the effectiveness of management strategies implemented for roadside trees. Regular monitoring of tree health, growth, and safety will inform adaptive management practices and ensure the long-term sustainability of urban greenery in Pokhara Metropolitan City.

It is noteworthy that during the data collection process, locals residing in areas with shops and houses nearby expressed concerns about roadside trees touching electric wires. Their feedback underscores the importance of addressing safety hazards and community concerns in the management of roadside trees, emphasizing the need for collaborative efforts between local authorities, utility providers, and residents to ensure the well-being of both trees and the surrounding community.

Abbreviations

CSV	Comma Separated Values
GCS	Geographic Coordinate System
GPS	Global Positioning System
WGS	World Geodetic System

Author Contributions

Aashish Gautam is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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