Impact of Soil pH on Vegetation Distribution in New Delhi City Based on Remote Sensing

Supriyo Acharya, Summer Research Scholar, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, New York

Dr. Rajiv Narula, Assistant Professor, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, New York

A B S T R A C T

The research analyzes how plants and soil pH relate within New Delhi City (India). The researcher employed remote sensing (RS), ArcGIS, and literature review to systematically analyze the effects of soil pH on the different types of plant life there. Overall, the researcher found that most of the soil within New Delhi City is either acidic or neutral. Where there are acidic soils occur primarily in a hill region that has a lot of evergreen broadleaf trees and coniferous trees. Areas with very strong (highly) acid soil contain primarily plants that are tolerant of acidic conditions, such as rhododendrons and tea. Neutral and somewhat alkaline soils support a wider range of trees and crops than acidic soils. In addition, the study describes the adaptability of various types of plant species to a particular kind of soil pH, and therefore serves as an important scientific resource for preserving the environment and land use planning in New Delhi City. The researcher indicates that developing and implementing good soil management and improvement practices can positively influence the selection process for plants, assist in the restoration of degraded ecological areas, as well as promote sustainable development within the newly developed regions of India.

Keywords: Soil pH, ArcGIS; Vegetation distribution, Sustainable development

Introduction

Soils have pH levels, or degree of acidity and alkalinity, which indicate the chemical properties of the soil and largely dictate how plants, nutrients and microbes interact within a given area. When soil pH changes, it directly impacts how much water and nutrients a plant can absorb, thus changing what plant species will occur in an area, which will ultimately affect the ability of an ecosystem to remain stable [1-3]. Understanding how the soil pH on a particular location and the distribution of the plants in that location are related is important in terms of managing ecosystems, as well as planning land use sustainably [4-6]. The pH of soils on earth ranges from very acid to very alkaline and influences the different types of plant communities which can grow there [6, 7]. In acid soils, where there is an abundance of hydrogen ions in solution, the roots of the plant will limit their absorption of nutrients and should wilt due to the presence of toxic materials, such as aluminum; while alkaline soils will fix nutrients, thus rendering other necessary nutrients in solution unavailable to plant roots. Chemical constraints are inhibiting plants from growing, which also leads to the altering of the microbial activity in the soil, which in turn leads to deficiencies in soil fertility and stability [8-13].

Studies conducted in India have demonstrated distinct regional variations in plant communities associated with differing soil types. Regions with acidic soils in southern India support acid-tolerant plants such as tea and rhododendron trees [14], whereas northern Indian deserts with alkaline soils support grasses adapted to higher soil pH levels (e.g., northern Bombay) [15]. Globally, established patterns exist between soil pH, vegetative positioning, and distribution. Furthermore, human-induced changes, such as intensive fertilization and land use changes, have contributed to soil acidification in multiple areas of the world, resulting in plant species distribution and ecosystem functioning changes (e.g., long-term nitrogen fertilizer use in India causes less microbial activity and lower pH; vegetable cropping at high intensity causes a decline in soil fertility and lower pH) [16-18]. Advancement in technology has provided new ways to analyze soil-vegetation relationships at a regional level with improved use of remote sensing and geographic information systems (GIS). The use of ArcGIS has improved researchers' ability to combine soil property data with vegetation indices derived from satellite images and thus to evaluate spatial patterns of soil pH differences and their effect on the types of vegetation present which will help identify areas for ecological restoration and land management purposes [19-21]. Through this study, it conducts an investigation about how soil pH relates spatially to vegetation

distribution in New Delhi City, India using remote sensing data in conjunction with ArcGIS analysis. This study identifies the pH characteristics of regional soils and their corresponding vegetation types, thus providing scientific evidence to optimize land use, as well as, to guide ecological restoration strategies and aid in achieving sustainable development in Delhi.

Materials and Methods

Study Area

Geographic Location and Natural Conditions

New Delhi is the capital city of India and is located in the northern part of the country within the Delhi National Capital Territory.

- Latitude: 28.61° N
- Longitude**:** 77.21° E
- It lies on the Indo-Gangetic Plain, one of the most fertile and densely populated regions of India.
- The city is situated on the western bank of the Yamuna River.
- It is bordered by the state of Haryana on three sides and Uttar Pradesh to the east. (**Fig.1**)

The terrain of New Delhi is generally flat to gently undulating**.**

- The Aravalli Ridge, an extension of the Aravalli Range, runs through the city and forms its main natural elevation.
- The Yamuna floodplain forms a low-lying fertile region on the eastern side.

New Delhi experiences a humid subtropical climate with extreme seasonal variations. Summer (April–June): Very hot and dry; temperatures often exceed 40°C**.** Monsoon (July–September): Heavy rainfall due to the Southwest Monsoon. Winter (December–February): Coo**l** with temperatures sometimes dropping to 4–5°C**.** Average annual rainfall: 700–800 mm**.**

The soil is mainly alluvial, deposited by the Yamuna River. Natural vegetation includes tropical thorn forest and scrub vegetation, though much of it has been replaced by urban development.

Important green areas include parks and forest zones such as Ridge Forest. The city also has several artificial lakes and wetlands that support local biodiversity.

Winter moths are December, January, and February – Cool weather, at times as low as 4-5 degrees. Average Annual Rainfall: 700 to 800 mm. The soil in the area is mostly alluvial, deposited by the Yamuna river. The natural vegetation in the area consists of tropical thorn forests and scrub vegetation, although this has also changed due to urban development. The green areas in the city include parks and forest areas such as the Ridge Forest. (**Fig.** *2*).

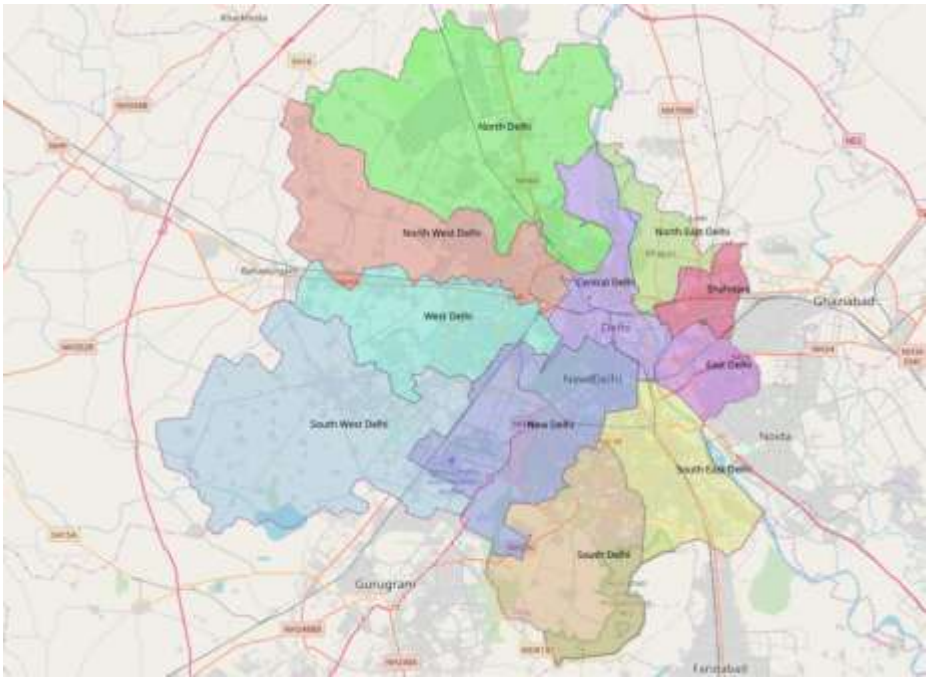

Fig. 1. Administ*rative map of New Delhi.*

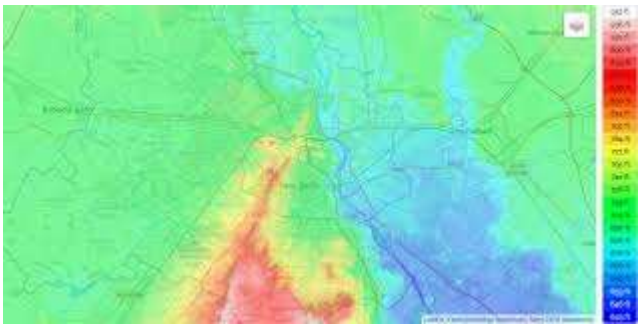

Fig. 2. Elevation map of New Delhi City.

Soil Types and Distribution

The soil types of New Delhi City are closely aligned with the topography of the area, where most low altitudes have naturally occurring Entisols and Alluvial soils (which are good for supporting agricultural crops of rice), mud (i.e., wetlands) and rivers that are moderately acidic and nutrient dense (which support aquatic/wetland vegetation). In contrast, soils in the mountainous areas have lower fertility, including semi-hydromorphic and anthropogenic (human-created, man-made) soils, and are better suited for mountain vegetation due to their low fertility. Soils also interact with elevation, as low-lying fertile soils are generally more conducive for growing crops, while high land areas provide habitats for mountain vegetation. (**Fig. 3**).

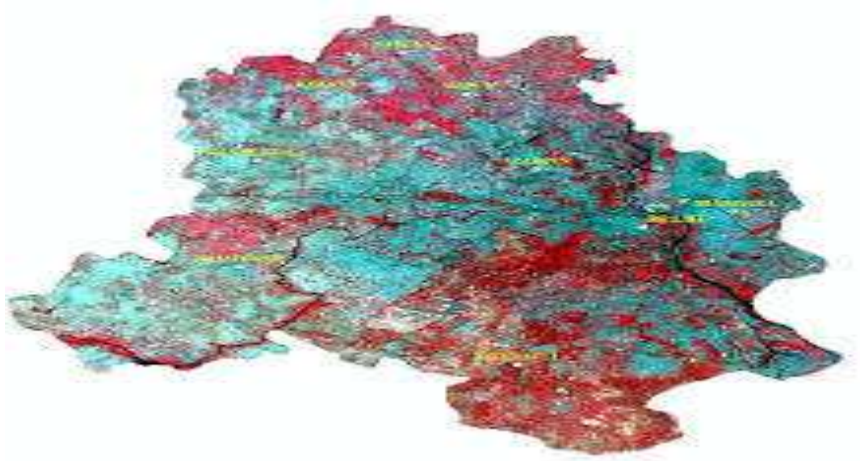

Fig. 3**.** Soil type distribution in New Delhi City.

Major Vegetation Types

New Delhi City hosts diverse vegetation types, including tropical and subtropical species, influenced by climate, soil, and topography. Common types are evergreen broadleaf forests, coniferous trees, bamboo forests, and shrublands. Low-altitude zones are dominated by evergreen broadleaf species such as Ficus, Arjuna and Neem. Mid- to high-elevation areas are mainly coniferous trees, including Blue Pines and Chir Pinus. Bamboo forests are widespread in humid areas, while acid-tolerant species like Rhododendron thrive in acidic soils. Vegetation distribution closely corresponds to soil pH and elevation, reflecting typical subtropical forest ecosystems (**Table 1**).

Table 1. Analysis of Soil pH and Vegetation Type Adaptability in New Delhi City.

Soil pH range	The corresponding vegetation type	Vegetation characteristics	Dominant species	Growth	Adaptability to soil pH
Strongly acidic soil (pH < 4.5)	Peepal , broad-leaved forests, ferns	The root system is developed, drought tolerant and barren	Jamun, Blue pine	Grows well in mountainous and hilly areas	Able to adapt to lower pH levels
Weakly acidic soil (pH 4.5 ~ 5.5)	Bamboo forest, shrubs	It likes a humid environment and has a dense root system	Tea tree, bamboo	It is common in humid mountains, lower forests and low mountainous areas	Adapt to slightly acidic to moderately acidic soil environments
Neutral soil (pH 5.5 ~ 7.0)	grassland and farmland plants	Most of them are deep-rooted plants, with strong adaptability and rapid growth	Early ripening grass and dogtail grass	Grows well in lowland and plains areas	It has good adaptability to neutral soils, but its growth is limited in overly acidic or alkaline soils

Climate and Hydrological Environment

New Delhi City's subtropical humid climate features hot, humid summers and mild winters. Annual mean temperature ranges from 18–22°C, with annual rainfall of 1,700–2,000 mm concentrated in spring and summer. Major rivers, including the Ganges, Yamuna, and Sahibi provide abundant water resources. This climate and hydrological environment support both vegetation growth and agriculture.

Data Sources

- **Soil data:** HWSD v1.2, FAO Coordinated World Soil Database, FAO soil portal.
- **Vegetation type spatial distribution, soil type data, field mapping tables, TIFF files:** Resource and Environmental Science Data Center (https://www.resdc.cn/data.aspx?DATAID=122).

Methods Overview

This study analyzed the spatial relationship between soil pH and vegetation types in New Delhi City using literature review, remote sensing imagery, and ArcGIS spatial analysis. Soil pH values were categorized as strongly acidic (<4.5), acidic (4.5–5.5), neutral (5.5–7.0), slightly alkaline

(7.0–8.0), and strongly alkaline (>8.0). Vegetation data were overlaid with soil pH data for spatial, cluster, and outlier analyses. Results guided soil management and vegetation protection recommendations.

Vegetation Classification and Distribution Analysis

Vegetation types include grasslands, shrublands, evergreen broadleaf forests, coniferous forests, and other types. Low-altitude areas are dominated by evergreen broadleaf forests (Pilkhan, Arjuna and Neem), mid- to high-elevation zones by coniferous plants (Chir Pine and Blue Pine), and humid valleys by bamboo forests alternating with grasslands and shrubs. Vegetation distribution is closely linked to elevation, soil pH, and climate, with acid-tolerant shrubs like Peepal and Jamun dominating highland or poor-soil areas (**Fig.** *4*).

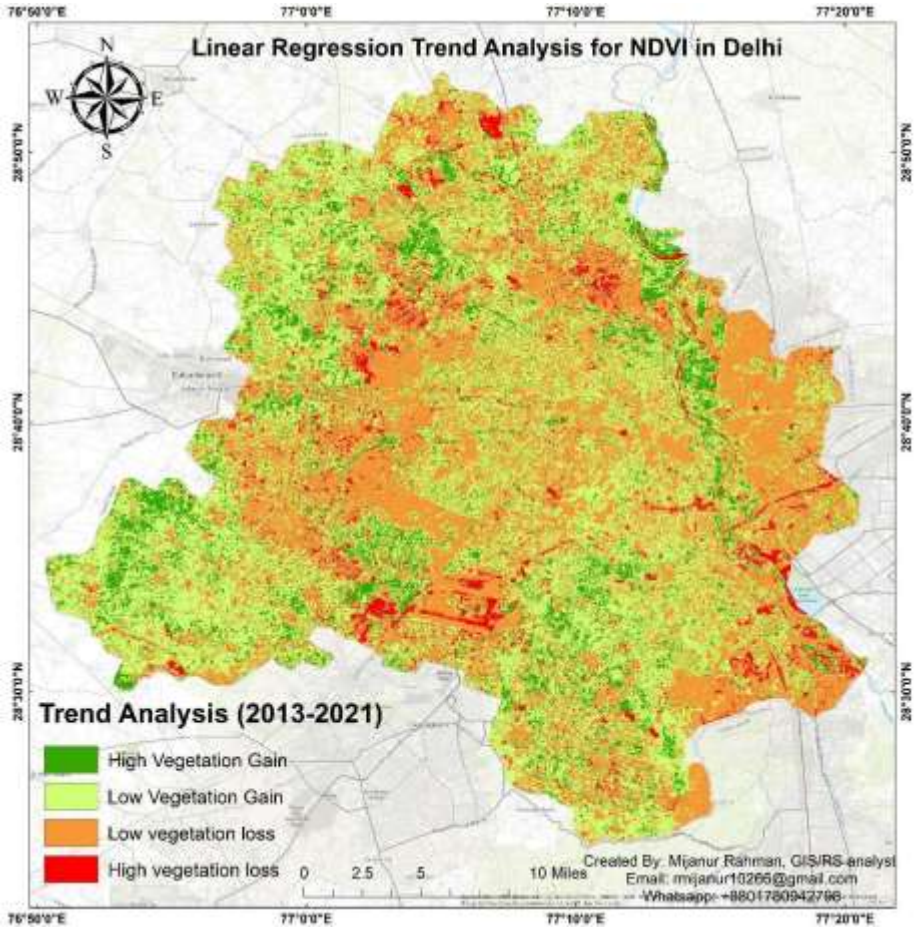

Fig. 4. Vegetation type distribution in New Delhi City.

Data Preprocessing and Quality Control

HWSD soil data were imported into ArcGIS along with county-level administrative boundaries to extract the New Delhi City region. Shapefile files were generated, and soil pH values were selected and extracted using mask analysis.

Spatial Overlay, Cluster, and Outlier Analysis

Selected pH data were reclassified, overlaid with vegetation layers, and verified by comparing attribute tables. Raster-to-point conversion was applied to vegetation layers, followed by spatial autocorrelation analysis to assess patterns and visualize distribution.

Results

Spatial Distribution of Soil pH

New Delhi City soils exhibit distinct regional pH variation, predominantly acidic (pH 5.2–6.9). Urban and surrounding areas are slightly acidic (pH 5.6–6.6). Acidic soils mainly occur in low hills and mid- to high-elevation zones, influenced by rainfall, organic matter, and dense vegetation. Some areas in the northeast and river valleys have near-neutral or slightly alkaline soils (pH ≈ 7.0), suitable for plants with broader pH tolerance. Strongly acidic soils (<5.6) appear on mountain ridges or dry zones, potentially limiting agricultural productivity (**Fig. 5**).

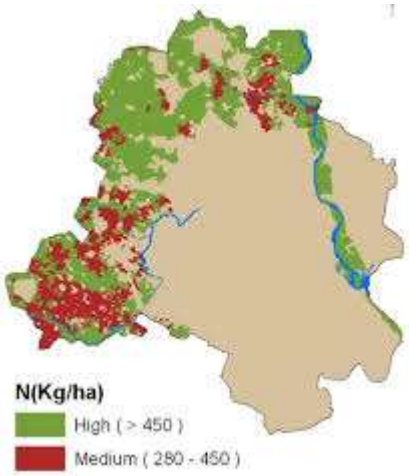

Fig. 5. Soil pH classification in New Delhi City

Vegetation Distribution under Different Soil pH Conditions

Weighted overlay analysis showed acidic soils dominate (pH 4.0–6.5), mostly in western and southern regions. Mid-northern regions have near-neutral soils. Evergreen broadleaf forests thrive in acidic to weakly acidic soils, while coniferous forests and shrublands dominate moderately pH-neutral hills and mountains. Areas with pH 6.0–7.5 support diverse vegetation with high suitability scores. Strongly acidic zones favor acid-tolerant species, and micro-alkaline soils in the northeast match alkaline-tolerant vegetation.

Correlation Analysis between Soil pH and Vegetation

Soil pH strongly correlates with vegetation type. Acidic soils support evergreen broadleaf and coniferous forests. In low-altitude humid areas, evergreen broadleaf species dominate, while high-altitude areas are dominated by conifers. Strongly acidic soils (<5.6) favor acid-tolerant species (Rhododendron, Camellia). Near-neutral soils (≈7.0) support more diverse vegetation, including fruit trees and crops. Cluster and outlier analyses revealed central and northwest regions dominated by dense grasslands and shrubs, while eastern neutral areas have denser broadleaf and coniferous forests

Discussion

The spatial distribution of soil pH in New Delhi City exhibits clear regional variation, with most areas dominated by acidic soils (pH 5.2–6.9), particularly in low mountain hills and mid-to-high elevation zones. These acidic soils provide favorable conditions for the growth of evergreen broadleaf forests and coniferous forests. In low-altitude humid areas, species such as Amaltas, Semal, and Kachnar are prevalent, thriving in organic-rich, moderately acidic soils. Conversely, at higher elevations where soil acidity is stronger, coniferous species such as Zyzyphus and Cynodon are predominate, adapted to drier and more nutrient-poor conditions. Areas with strongly acidic soils (pH < 5.6) are dominated by acid-tolerant species such as Peepal and Jamun, whereas regions with near-neutral or slightly alkaline soils (pH ≈ 7.0) support a more diverse range of vegetation, including both evergreen broadleaf and coniferous species, as well as fruit trees and crops. These patterns clearly indicate that soil pH is a critical factor shaping the spatial distribution of vegetation types in New Delhi City.

The study also highlights the combined influence of elevation, soil type, and climate on vegetation distribution. Acidic soils are most common in low-mountain and mid-to-high elevation areas, while neutral to slightly alkaline soils occur primarily in northeastern and valley regions, supporting diverse plant communities. Weighted overlay and clustering analyses further confirmed that vegetation density and type are closely aligned with soil pH, with areas of extreme acidity or alkalinity showing localized anomalies in vegetation distribution. This emphasizes the importance of considering soil chemical properties in ecological planning and land management.

From an ecological and agricultural perspective, the results provide practical insights for soil management and vegetation protection. Acidic soils can be amended using lime or other soil conditioners to increase pH and improve fertility, facilitating the growth of crops and acid-tolerant plants. In neutral or slightly alkaline soils, diverse vegetation planting can optimize land use and enhance ecosystem stability. Additionally, monitoring soil pH and adjusting management practices accordingly is recommended to maintain long-term soil and vegetation health. Ecological restoration and soil erosion prevention are particularly important in strongly acidic or high-elevation regions to protect vegetation and preserve ecosystem stability.

This study has certain limitations. Soil pH data may be influenced by sampling time and location, which could affect representativeness. Remote sensing-based vegetation classification may introduce boundary errors or misclassifications due to limitations in image resolution. Moreover, while ArcGIS allows detailed spatial analyses, it cannot fully account for complex interactions among soil properties, climate variability, and land use, which may also influence vegetation patterns.

Compared to previous domestic and international studies, the observed relationships between soil pH and vegetation types are generally consistent. In southern India, acidic soils favor acid-tolerant species, while alkaline soils dominate in northern arid regions, affecting grassland vegetation. Globally, soil pH is recognized as a key factor influencing plant distribution and nutrient uptake, with many studies in Europe, North America, and Australia emphasizing its ecological significance. This study contributes to regional knowledge by integrating ArcGIS spatial analysis and remote sensing data to provide a detailed assessment of New Delhi City's soil-vegetation relationships, although improvements in temporal and spatial data coverage and consideration of additional environmental variables remain necessary.

Conclusion

This study demonstrated that soil pH is a key factor influencing vegetation distribution in New Delhi City. Acidic soils support evergreen broadleaf and coniferous forests, while strongly acidic areas favor acid-tolerant species (Peepal and Jamun). Neutral to slightly alkaline soils enable more diverse plant growth, including fruit trees and crops.

ArcGIS-based spatial analysis accurately mapped soil-vegetation relationships, guiding soil management and vegetation protection. Recommendations include:

1. Soil Management: Amend acidic soils with lime to improve fertility; encourage diverse planting in neutral or slightly alkaline areas; monitor pH for adaptive management.
2. Vegetation Protection: Restore ecosystems in strongly acidic or high-altitude areas; prevent soil erosion; maintain vegetation stability to enhance biodiversity.
3. Overall, soil pH shapes the spatial distribution of vegetation in New Delhi City. Appropriate soil management and vegetation protection can enhance ecological stability, sustainable land use, and agricultural planning.

References

1. Abd Latif Z., S. N. A. Aman and R. Ghazali (2011). Delineation of tree crown and canopy height using airborne LiDAR and aerial photo. 2011 IEEE 7th International Colloquium on Signal Processing and Its Applications.doi:10.1109/cspa.2011.5759902

2. Bhalla P. and P. Bhattacharya (2015). Urban Biodiversity and Green Spaces in Delhi: a case study of new settlement and Lutyens' Delhi. Journal of Human Ecology, 52(1-2), 83-96

3. Bharathkumar L. and M. A. Mohammed-Aslam (2015). Crop pattern mapping of tumkur taluk using NDVI technique: a remote sensing and GIS approach. Aquatic Procedia, 4, 1397-1404. doi: 10.1016/j.aqpro.2015.02.181

4. Chikr El-Mezouar, M., N. Taleb, K. Kpalma K. and J. Ronsin, 2010. A high-resolution index for vegetation extraction in IKONOS images. Remote Sensing for Agriculture, Ecosystems, and Hydrology XII. doi:10.1117/12.866187

5. Elmqvist T., M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. L. McDonald, ... & C. Wilkinson. (2013). Urbanization, biodiversity and ecosystem services: challenges and opportunities: a global assessment (p. 755). Springer Nature. doi.org/10.1007/978-94-007-7088-1

6. Gosain A. K., P. K. Khandelwal and S. Kulshrestha (2009). Urban floods: Case study of Delhi. Disaster Dev, 3, 15.

7. Panwar H. and M. Dhote (2022). Degraded Land Management in Urban Areas: The Case of Biodiversity Parks in Delhi. In Sustainable Urbanism in Developing Countries (pp. 291-304). CRC Press.

8. Sinha G.N. (Ed.) (2014). An Introduction to the Delhi Ridge. Department of Forests & Wildlife, Govt. of NCT of Delhi, New Delhi. xxiv+154 pp.

9. Teodorescu G. (2010). Climate change impact on urban ecosystems and sustainable development of cities in Romania. WSEAS Transactions on Environment and Development, 2(6), 103-112.

10. Tiwari S., A. K. Srivastava, D. S. Bisht, T. Bano, S. Singh, S. Behura, ... and B. Padmanabhamurty (2009). Black carbon and chemical characteristics of PM10 and PM2. 5 at an urban site of North India. Journal of Atmospheric Chemistry, 62(3), 193-209.

11. UN (2018). The World's Cities in 2018: Data Booklet, Statistical Papers - United Nations (Ser. A), Population and Vital Statistics Report, UN, New York doi.org/10.18356/c93f4dc6-en

12. Vliet W. V. (2002). Cities in a globalizing world: from engines of growth to agents of change. Environment and Urbanization, 14(1), 31-40. doi.org/10.1177%2F095624780201400103