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The impact of pollution on plant biodiversity in Jaipur: A comparison between polluted and non-polluted areas

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Abstract
The current study aims to establish a connection between pollution levels as well as plant biodiversity in Jaipur, Rajasthan, by examining the plant species present in both polluted and non-polluted areas of the city. For this, the entire city of Jaipur was divided into several zones, followed by classification of these areas into polluted and non-polluted sites. The polluted sites were 12 in number and the highest plant biodiversity was found in Jhotwara (20) followed by RIICO, Malviya Nagar (20) > Kotputli (19) > Jaipur Rural (Bagru, Bindayaka, Dudu, Kartarpura, Phulera, Shahpura, and Sudarshanpur) (18) > Kaladera (16) > Bassi (16) > Sitapura (15) > Amer (10) > Ajmeri Gate (6) > Chandpole (4) > Transport Nagar (4) > Vishvakarma (2). Among the 7 non-polluted areas, the highest plant biodiversity was found in Mansarovar (9) followed by Gopalpura (9) > Vidhyadhar Nagar (8) > Vaishali Nagar (8) > Dungarpur (6) > Civil Lines (4) > Tilak Nagar (3). The study showed overall decline in plant biodiversity in polluted areas and highlights the ecological implications of these findings and proposes strategies for enhancing plant diversity in urban areas.

Keywords: Jaipur, pollution, decline in plant divrersity, sustainable development

Introduction

Jaipur, the capital city of Rajasthan, is growing rapidly into an urban centre owing to industrialization and urbanization. However, as a consequence of this development, the city faces the dual challenges of maintaining urban development while also ensuring environmental sustainability. Jaipur's rich history, vibrant culture, as well as increasing population have led to increased pressure on its natural resources. With increasing urbanization in Jaipur, there has been tremendous increase in air pollution from vehicles, industrial emissions, and the burning of fossil fuels, combined with poor waste management and industrial waste, all of which have led to a decline in the quality of the environment. This decline in environmental quality is most clearly observed in the reduction of plant biodiversity in the city's polluted areas, which are typically exposed to higher levels of air pollution, soil degradation, and poor water quality (Vezzani *et al.*, 2018; Bastviken *et al.*, 2023; Trap *et al.*, 2016) [22, 23].

Plants occupy a central stage in the hierarchial cycle of ecosyetm and have been bestowed with the much-needed function of performing photosynthesis and providing much needed oxygen to the environment as well as its dwellers. However, this attribute puts them at jeopardy, since they absorb all the harmful pollutants and obnoxious contaminants from the air. The situation is further exacerbated by sedentary nature of plants, owing to which, plants are unable to rescue themselves from the malicious effects of the obnoxious contaminants. Therefore, plants act as urban canopy and improve the aesthetic quality of the environment, mitigate the heat island effect, and contribute to human well-being by offering green spaces that promote physical and mental health. Not only this, plants play a critical role in any ecosystem by contributing to air purification, regulating climate, preventing soil erosion, and providing food and shelter for wildlife. However, the increasing urban population, in the form of air pollution from vehicular exhaust gases, water pollution and soil pollution, have in conjunction, led to decreased plant biodiversity in urban areas. As a direct consequence of this, certain species that are not well-adapted to polluted conditions become less prevalent, and sensitive native plants may be entirely displaced by hardy, pollution-tolerant species. This shift has contributed to a decrease in overall plant diversity, which has long-term implications for both urban ecosystems and the people who depend on them (Seyyednejad *et al.*, 2011; Zvereva *et al.*, 2008; Oksanen *et al.*, 2021; Lukina *et al.*, 2017) [13, 15, 19, 27].

The current study aims to investigate the relationship between pollution levels and plant biodiversity in Jaipur, specifically comparing plant species diversity in polluted and non-polluted zones of the city. This has been attempted by examining the plant life in various urban and semi-urban areas of Jaipur. The findings of the current study will provide us with an opportunity to explore the direct ecological consequences of urban pollution and identify potential solutions for improving biodiversity in these polluted urban environments.

Materials and Methods

1. Study Area

Jaipur is divided into regions with varying levels of pollution. For this study, we categorized areas into two main groups:

- **Polluted Areas:** Areas that experience high levels of pollution due to traffic congestion, industrial activities, and poor waste management.
- **Non-Polluted Areas:** Areas with lower pollution levels, often more green spaces, and cleaner air.

We collected data on the plant species in these areas from a combination of publicly available sources, local botanical studies, and field observations.

2. Data Collection

We documented the types of plants present in both the polluted and non-polluted zones. These data were gathered from government reports, local studies, and personal field surveys.

3. Data Analysis

We used species counts to compare plant diversity in the polluted and non-polluted zones.

Results

1. Plant Diversity in Polluted Areas

The current study highlights the stark variation in plant biodiversity in polluted and non-polluted areas of Jaipur. Among all the 12 polluted areas, the highest plant biodiversity was found in Jhotwara (20) followed by RIICO, Malviya Nagar (20) > Kotputli (19) > Jaipur Rural (Bagru, Bindayaka, Dudu, Kartarpura, Phulera, Shahpura, and Sudarshanpur) (18) > Kaladera (16) > Bassi (16) > Sitapura (15) > Amer (10) > Ajmeri Gate (6) > Chandpole (4) > Transport Nagar (4) > Vishvakarma (2)

The results revealed the following findings:

- **Chandpole:** The plant species found in Chandpole include ornamental plants like roses, tulips, lilies, and orchids, which add color and beauty to the area

- **Vishvakarma:** In Vishvakarma, the dominant species are Azadirachta indica (Neem) and Polyalthia longifolia (Ashoka), both of which are known for their resilience and tolerance to urban pollution.

- **Ajmeri Gate:** Ajmeri Gate is home to a variety of plants, including bamboo, money plants, and pothos, alongside ornamental species like roses, orchids, lilies, and tulips.

- **Transport Nagar:** The plant species in Transport Nagar consist mainly of fruit trees such as apple, peach, plum, and cherry trees, contributing to the area's greenery.

- **RIICO, Malviya Nagar:** RIICO and Malviya Nagar feature a wide range of plants, including marigolds, petunias, bougainvillea, roses, orchids, lilies, tulips, as well as fruit-bearing trees like mango, guava, pomegranate, citrus, apple, and fig. Other plants like neem, peepal, basil, mint, rosemary, and parsley also thrive in this area.

- **Jhotwara:** Jhotwara is known for its diverse plant life, including roses, orchids, lilies, and tulips, as well as vegetables like tomatoes and peppers. It also supports fruit trees such as citrus, apple, fig, peach, plum, and cherry, alongside hydrangeas, ferns, and spider plants.

- **Jaipur Rural (Bagru, Bindayaka, Dudu, Kartarpura, Phulera, Shahpura, and Sudarshanpur):** In the rural areas surrounding Jaipur, a variety of indigenous trees like Dhok or Dhokra, Adossa, Gurjan, Salar, Jhingha, Babul, Siris, Bar, Gular, Pipal, Shisham, Peelu, Hingota, Karaya, Khejra, Kair, and Jamun thrive in these areas.

- **Kotputli:** Kotputli hosts a combination of hardy trees like neem, dhak, kikar, and khejri, along with medicinal and edible plants such as lemongrass, aonla, pomegranate, bael, guava, lime, lehswa, and karonda. It also supports vegetables like tomatoes, chilies, carrots, peas, cluster beans, and watermelon.

- **Kaladera:** Kaladera is home to various ornamental plants like roses, orchids, lilies, and tulips, as well as native trees such as neem and mango. Other trees in the area include banyan, peepal, Indian almond, Indian mahogany, jamun, kadamb, kachnar, thor, ber, ker, khair, and bel.

- **Bassi:** Bassi features a mix of indigenous and ornamental species such as dhok, churel, butea, sisham, siras, bamboo, imli, kachnar, karanj, neem, awala, custard apple, gulmohar, and amaltas.

- **Amer:** Amer is known for its hardy plants like khejri, rohida, ber, ker, thorn, and foag, as well as other species like akra, jhaber, kachnar, churail, semal, peepal, bel, and amaltas.

- **Sitapura:** Sitapura has a variety of plants including ornamental species like roses, orchids, lilies, and tulips, along with trees like teak, salar, bamboo, dhokra, palash, khair, and babul. The area also supports crops such as Asian rice and decorative plants like garden croton, arrowhead plant, red frangipani, and Chinese hibiscus**.**

2. Plant Diversity in non-polluted Areas

The current study highlights the stark variation in plant biodiversity in polluted and non-polluted areas of Jaipur. Among all the 7 non-polluted areas, the highest plant biodiversity was found in Mansarovar (9) followed by Gopalpura (9) > Vidhyadhar Nagar (8) > Vaishali Nagar (8) > Dungarpur (6) > Civil Lines (4) > Tilak Nagar (3)

The results revealed the following findings:

- **Tilak Nagar:** Tilak Nagar is home to a few plant species, such as citrus trees, apple trees, and fig trees, which offer minimal yet essential greenery to the area.

- **Civil Lines:** Civil Lines features a combination of ornamental plants like roses, orchids, lilies, and tulips, which are known for their vibrant colors and ornamental value.

- **Mansarovar:** Mansarovar is rich in both ornamental and functional plants. Species include palm trees, flowering shrubs, bougainvillea, jasmine, basil, neem, lemongrass, and tulsi, contributing to both aesthetic and medicinal purposes.

- **Gopalpura:** Gopalpura features a variety of plants such as Asian rice, garden croton, arrowhead plant, red frangipani, and Chinese hibiscus, along with ornamental species like roses, orchids, lilies, and tulips.

- **Vaishali Nagar:** Vaishali Nagar is home to a mix of trees and ornamental plants, including Ashoka tree, lime plant, jackfruit plant, almond plant, along with roses, tulsi, Chinese hibiscus, and neem, providing a balanced combination of green cover and floral beauty.

- **Vidhyadhar Nagar:** In Vidhyadhar Nagar, native tree species such as moringa, kachnar, churail, semal, peepal, bel, rohida, and amaltas thrive, supporting local biodiversity and adding to the region's green cover.

- **Dungarpur:** Dungarpur hosts several indigenous trees, including mahua, teak, dhokra trees, neem, pipal, and babul, contributing to the area's natural vegetation and supporting local ecosystems.

Discussion

The findings of the current study clearly highlight the nefarious effects of pollution on plant biodiversity in Jaipur, Rajasthan. The study compares the plant diversity in polluted and non-polluted areas, revealing that pollution acts as a significant barrier to the growth and survival of many plant species, especially those that are native to the region. In the polluted areas of Jaipur, such as Chandpole, Vishvakarma, and Jhotwara, the plant diversity was noticeably limited. These zones, subjected to high levels of air pollution, vehicular emissions, as well as high amount of industrial activities, have shown a clear reduction in the number of plant species compared to less polluted regions. The plant species present in these polluted areas are predominantly hardy, pollution-tolerant varieties which are able to tolerate the harsh conditions of urban environments. The most commonly identified pollution tolerant species in these areas are Azadirachta indica (Neem), Polyalthia longifolia (Ashoka), and Bamboo, all of which are resilient to pollutants like particulate matter and toxic gases.

Apart from these pollution-tolerant species, certain ornamental plants such as roses, tulips, lilies, and orchids are found in the polluted areas. These ornamental species, though visually appealing, do not support the local ecosystem in the same way as indigenous species. In fact, after some time, these plants may not be able to thrive or even survive under the current pollution levels, especially if they are not adapted to local soil, water, and climate conditions. The reduction in plant biodiversity in polluted areas may have occurred due to several reasons, which include:

- **Air Pollution and Plant health:** Air pollution, mainly owing to vehicular emissions, industrial activities, and the burning of waste, is one of the most important contributors to the reduced plant diversity observed in the polluted areas of Jaipur. Presence of pollutants in the air such as particulate matter (PM2.5 and PM10), sulfur dioxide (SO2), nitrogen oxides (NOx), and ozone (O3) have been reported to cause significant damage to plant tissues, impairing photosynthesis and growth (Agarwal *et al.,* 2023; Ogwu *et al.,* 2024; Zvereva *et al.,* 2012; Sharma *et al.,* 2001; Singh *et al.,* 2010; Jain *et al.,* 2010) [14, 20, 21, 26]. Sensitive species, particularly native plants, are often unable to cope with the high concentrations of these pollutants, leading to poor growth and, in some cases, complete die-off. Polluted areas such as Chandpole, Vishvakarma, and Jhotwara, showed higher number of hardy species such as Neem (Azadirachta indica), Ashoka (Polyalthia longifolia), and Bamboo, all of which are relatively resistant to pollution. Although these plant species are capable of surviving under stressful conditions, they do not contribute to the ecological richness that is typically associated with native plant species. Furthermore, absence of plants such as Jamun, Mango, and Peepal further support the idea that pollution interferes with the survival of more sensitive plants **(**Domingo *et al.,* 2018; Diener *et al.,* 2021; Xu *et al.,* 2022; Rashid *et al.,* 2023**)** [24] [4, 18]. The absence of these trees can lead to a loss of essential ecosystem services such as air purification, carbon sequestration, and the provision of habitat for wildlife.

Furthermore, the study showed that non-polluted areas, where air quality is relatively better, a wider variety of plant species such as Teak, Mahua, Pipal, and Mango were observed. All these species play a crucial role in maintaining ecological balance by providing habitats for birds, insects, as well as other animals. Furthermore, the ability of these plant species to thrive in cleaner highlights the importance of reduced pollution in supporting plant biodiversity.

- **Soil and Water Contamination:** Apart from affecting the air quality, pollution also has significant impacts on soil as well as water quality, which in turn influence plant health **(**Gavrilescu *et al.,* 2021; Jayaraman *et al.,* 2021; Pedrinho *et al.,* 2024; Kolawole *et al.,* 202**)** [7, 10, 16]. Presence of high levels of industrial as well as vehicular pollution in areas contaminated with heavy metals, chemical runoff, and other pollutants contaminants disrupt the natural soil structure, reduce nutrient availability, and alter the pH balance, making it difficult for many plants to grow. In polluted zones such as RIICO and Malviya Nagar, the contamination of soil as well as water is particularly higher owing to the presence of industrial activities. The high concentration of pollutants in the soil as well as water systems leads to a reduction in the range of plant species that can survive. As a consequence of this, only a few pollution-tolerant plants, such as marigolds and petunias, are able to grow in these areas.

In contrast to this, the non-polluted areas of Jaipur are likely to have cleaner soils as well as water, both of which provide a more suitable environment for a wider range of plant species, particularly native species. The presence of Teak, Mango, and Mahua trees, along with medicinal plants like basil and pomegranate, indicates that these areas are better able to support plant life and contribute to the health of the ecosystem.

- **Impact of Urbanization and Habitat Fragmentation:** The conversion of natural land to commercial and industrial area has led to habitat fragmentation, leading to reduction in available space for plant life. In polluted areas, this effect is intensified by expansion of roads, buildings as well as other infrastructure, leading to reduced habitat availability for plant growth. In such areas, only the most resilient species, such as Neem and Bamboo, are able to survive in these disturbed environments. The loss of native vegetation also results in the loss of habitat for wildlife, including pollinators such as bees and butterflies, which rely on specific plant species for food and shelter **(**de Barros Ruas *et al.,* 2022; Fenoglio *et al.,* 2021; Hald-Mortensen *et al.,* 2023; Li *et al.,* 2022; Peng *et al.,* 2024; Yang *et al.,* 2024**)** [3, 6, 8, 17, 25]**.** On the other hand, non-polluted areas

like Dungarpur and Vaishali Nagar are likely to have larger, more intact habitats, which support a wider variety of plant species. These areas may also benefit from efforts to preserve and enhance green spaces, such as parks, gardens, and green corridors, which help maintain plant diversity and provide critical habitat for wildlife.

The decrease in plant biodiversity in polluted areas has far-reaching consequences, both for the local ecosystems as well as human health. Plants occupy the central stage at the homeostasis of the ecosystem and even minor alteration in plant health translates to major repercussions in the ecosystem. Moreover, plants have direct value for human health owing to their medicinal properties. For instance, plant species found in non-polluted areas of Jaipur, such as basil, tulsi, and lemongrass, have medicinal properties and contribute to overall well-being. Also, the presence of food-bearing plants such as pomegranate and guava provides local communities with fresh and nutritious produce. Decline in number of such useful plant species owing to pollution-induced effects will have major complications in the ecosystem functioning. Therefore, the findings of the current study highlight the urgent need for comprehensive measures to mitigate pollution and promote sustainable urban development.

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