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Green corridors as nature-based solutions for pollution, climate and connectivity: A comprehensive review

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ABSTRACT

Rapid urban expansion, rising pollution levels and widespread habitat fragmentation have intensified pressure on natural ecosystems worldwide. Green corridors ranging from ecological, urban, transport, bluegreen and energy networks provide an essential strategy for reconnecting landscapes, improving environmental quality and strengthening climate adaptation. India's long tradition of roadside planting, along with contemporary efforts such as the National Green Highways Mission (NGHM), illustrates the critical role of vegetated corridors in mitigating air pollutants, lowering noise, reducing heat stress and enhancing overall road safety. Studies highlight that species like Calliandra hybrida, Nerium oleander, Thevetia peruviana, Yucca filamentosa, Berberis thunbergii, Saraca asoca and Ficus elastica maintain strong physiological resilience under heavy vehicular emissions. Additionally, green belts contribute to significant carbon storage, support microclimatic cooling and even influence driver emotions through canopy form and landscape composition. Overall, the evidence demonstrates that well-designed green corridors supported by scientific species selection and thoughtful spatial planning are vital for enhancing biodiversity, improving human comfort and advancing sustainable transportation infrastructure.

Keywords: *Green Corridor, Roadside Vegetation, Highway Landscaping, Pollution Mitigation, Noise Abatement, Air Quality Improvement, Thermal Comfort, Carbon Sequestration, APTI, API, Plant Stress Physiology, Species Selection.*

1. Introduction

Our Earth, once adorned with vast natural landscapes and rich biodiversity, has undergone unprecedented degradation due to human activities, particularly over the last century. Rapid industrialisation, unplanned urban expansion and relentless exploitation of natural resources have severely altered the ecological balance. As cities expand and industries grow, environmental pollution has emerged as a critical global issue. The overuse of open spaces, the soaring number of automobiles and continuous demographic pressure have further accelerated the decline in environmental quality. Natural habitats are shrinking at alarming rates and ecological connectivity is increasingly being fragmented. Globally, plant diversity is facing a severe crisis. One in every five plant species is at risk of extinction, largely as a result of habitat destruction, deforestation, rapid urbanisation and climate change. Transportation networks themselves play a significant role in biodiversity decline approximately 2.66% of global species are threatened by transportation and service corridors, while roads and railways alone affect nearly 684 species (2.35%) worldwide [18].

Such statistics highlight the magnitude of ecological disruption driven by human movement and infrastructure development. These alarming trends reveal an urgent need for adopting sustainable and ecologically sensitive approaches that can restore environmental health while supporting human development. Integrating nature-based solutions into urban and rural planning such as green corridors, green highways and ecological linkages has become essential for maintaining biodiversity, reducing pollution, mitigating climate change and improving the overall quality of life. As landscapes continue to fragment, establishing connected green networks offers a promising strategy to protect ecosystems, enhance resilience and ensure a sustainable future for both people and the planet.

2. History

In the historical era, Avenue planting in India has a long history. Emperor Ashoka (3rd century BCE) promoted tree planting along roads and in cities for shade, beauty and public welfare, earning the title "Father of Arboriculture in India." He also developed parks and gardens lined with avenues of trees such as banyan, peepal and mango many of which still survive [17].
During the Mughal era, tree-lined avenues were central to elaborate gardens, blending shade, beauty and a connection to nature. In the British colonial period, avenue planting became part of urban beautification, with banyan, peepal and mango again being common choices, many of which continue to thrive today [17].

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3. Green Corridor

The idea of green corridors came from Olmsted's "Parkways" in the United States and Ebenezer Howard's "Garden City" in England in the early 20th century. Green corridors are linear open spaces, such as farmland, parks, natural or semi-natural areas, interwoven within or outside of urban areas to protect the environment and landscape [2].

4. Types of Green Corridor

4.1 Ecological green corridor

These are natural or semi-natural passageways that connect isolated patches of vegetation and allow movement of wildlife to maintain biodiversity.

Purpose

- Facilitate wildlife movement and gene flow
- Prevent habitat fragmentation
- Enhance biodiversity conservation
- Improve ecosystem resilience to climate change

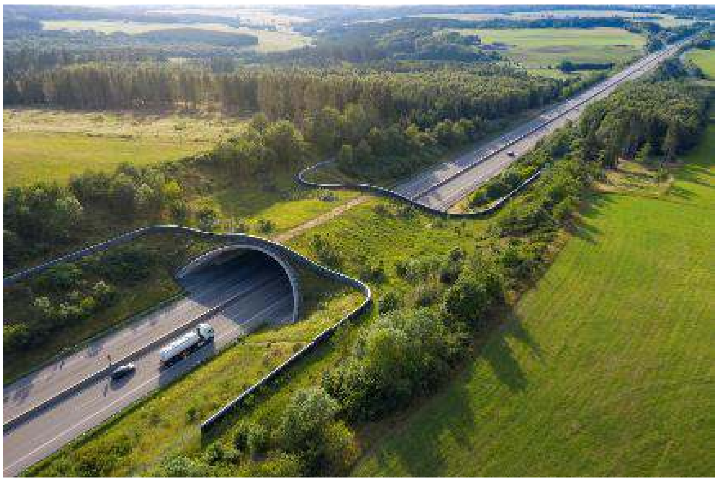

Fig. 1: Ecological green corridor

4.2 Urban Green Corridors

Urban green corridors are planned green networks within city environments, created to improve ecological quality, beautify landscapes and support healthy human living.

Purpose

Reduce Urban Heat Island (UHI) effect
Improve air quality by filtering pollutants
Provide non-motorized mobility routes (walking/cycling)
Enhance psychological well-being of urban residents

Examples

- Green belts and urban forests
- Tree-lined streets
- Greenways
- Park connectors

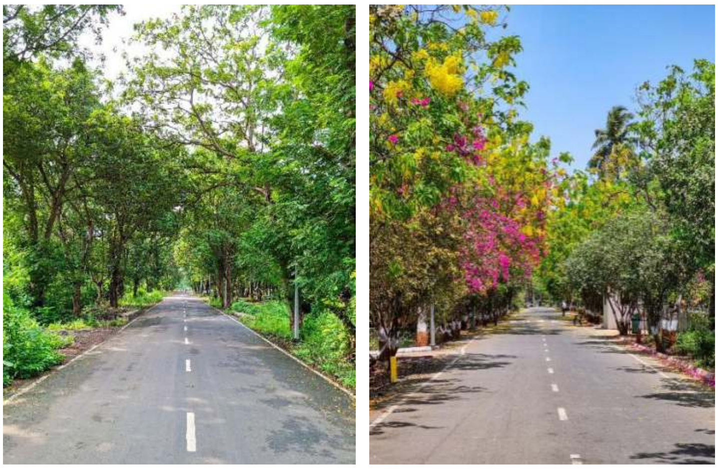

Fig. 2: Tree lined streets

4.3 Blue Green Corridors

Blue–green corridors integrate water bodies (blue) and vegetation (green) to create multifunctional ecological landscapes.

Purpose

- Natural flood mitigation
- Improve water quality
- Enhance aquatic terrestrial biodiversity
- Provide recreational spaces like riverfronts

Examples

- Sabarmati Riverfront, Ahmedabad
- Wetland–green belt networks in European sustainable cities
- Mangrove–green buffer systems in coastal areas

Fig. 3: Sabarmati Riverfront, Ahmedabad

4.4 Green Energy Corridors

These are not vegetation-based but infrastructure corridors designed for renewable energy transmission.

Purpose

- Integrate renewable energy (solar, wind, hydro, tidal) into national grids
- Reduce fossil fuel dependence
- Enable long-distance movement of green electricity

Examples

- Lakadia-Vadodara Transmission Project (LVTPL)

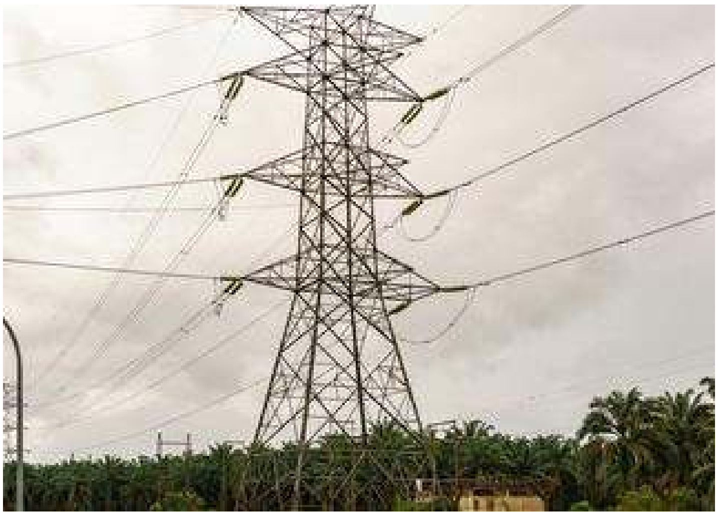

Fig. 4: Lakadia-Vadodara Transmission Project

4.5 Transport Green Corridors

Transport green corridors integrate sustainable landscaping, reduced emissions and eco-friendly infrastructure along roads, highways and railways.

Purpose

- Reduce total logistics-related carbon emissions
- Improve roadside air quality, noise buffering and aesthetics
- Provide shade and lower road temperatures
- Prevent soil erosion and enhance road safety [1]

Examples

- Green corridor along highway

Fig. 5: Green corridor along highway

5. National green highway mission

The National Green Highways Mission (NGHM*),* launched in July 2015 by the *Ministry of Road Transport & Highways (MoRTH), Government of India*, is a nationwide initiative aimed at transforming India's highways into environment friendly and sustainable green corridors. The mission focuses on planting trees and developing green belts along national highways to improve environmental quality while supporting socio-economic development. It encourages the active participation of local communities, farmers, NGOs, private sectors, government institutions and forest departments, ensuring that the greening process becomes both inclusive and sustainable. The purpose of NGHM is not only beautification but also environmental protection. Roadside plantations help reduce air pollution, absorb dust, control noise levels, stabilise soil on highway embankments and provide shade, which ultimately lowers road surface temperature. Green strips along highways also help in glare reduction, act as windbreaks and contribute to safer driving conditions. In addition, the mission aims to generate local employment opportunities by involving communities in plantation and long-term maintenance activities. Through these objectives, NGHM integrates ecological conservation with national infrastructure development, making highway expansion more sustainable and climate-resilient.

6. Basics of landscaping highways

Landscaping along highways is a vital component of sustainable road infrastructure, as it enhances environmental quality, improves road safety and contributes to the long-term ecological functioning of transportation corridors. As outlined in the PPT, highway landscaping begins with the strategic planning of the Right of Way (ROW), which includes both the Landscape Maintenance Zone (LMZ) a safety buffer extending from the road edge and the Vegetation Zone, where structured planting is implemented. The LMZ width varies with road speed to ensure adequate recovery space for vehicles, while intersection landscaping must maintain vegetation below 2 feet to preserve visibility and ensure road safety. Proper horizontal (18 inches) and vertical (17 feet) clearance for vegetation is essential for safe vehicle movement. Beyond safety, landscaping serves multiple ecological purposes: it reduces air and dust pollution, provides shade, functions as a windbreak, mitigates noise and prevents soil erosion along embankments. These benefits align with global studies showing that roadside vegetation can significantly reduce particulate matter, moderate microclimates and enhance visual comfort. In highway landscaping, the placement of vegetation must be carefully coordinated with the installation of road signs to ensure that plants do not obstruct sightlines and that all traffic signs remain clearly visible from the required viewing distance. Road signs are designed to communicate essential information such as warnings, regulations and directions and their effectiveness depends on unobstructed visibility. Therefore, landscaping guidelines specify that trees, shrubs and groundcovers should be selected and positioned in a way that maintains a clear zone around signs, preventing leaves, branches, or trunks from blocking the driver's field of vision. Shrubs used in medians or roadside strips should be low-growing and regularly pruned to avoid blocking the line of sight. This approach ensures that road signs remain legible from a sufficient distance allowing drivers enough reaction time while still achieving the ecological and aesthetic goals of highway landscaping. Ultimately, harmonising vegetation placement with sign visibility creates a safer, more readable and visually appealing roadway environment.

7. Criteria for selection of plant species for highway side vegetation[7]

1	Size and growth habit	Tree species with appropriate sizes and growth habits that won't obstruct sightlines, utility lines or cause obstructions to traffic are preferred.
2	Native and local species	Native or locally adapted tree species are often favoured as they are more likely to be well-suited to the local environment, support local ecosystems and require less maintenance.
3	Adaptability	Species that can tolerate local climate, soil conditions and pollution levels are chosen for roadside planting to ensure their survival and long-term health.
4	Maintenance requirements	Species that have manageable maintenance requirements in terms of pruning, disease resistance and pest control are preferred for roadside planting.
5	Wind resistance	Consider the tree species' ability to withstand high winds and storms without significant damage.
6	Non-invasive roots	Species with non-invasive root systems are chosen to avoid potential damage to sidewalks, pavements and underground utilities.
7	Canopy density	Consider the density of the tree's canopy to determine the amount of shade it will provide and its impact on visibility for drivers and pedestrians.
8	Soil requirements	Consider the tree species' soil preferences, including soil type, pH levels and drainage capacity.
9	Aesthetic value	Consider the tree species' visual appeal, including its foliage, flowers, bark texture and seasonal interest, to enhance the aesthetic quality of the roadside.
10	Wildlife support	Select tree species that provide food, shelter and nesting opportunities for birds, insects and other wildlife, contributing to urban biodiversity.
11	Cultural significance	Assess the cultural or historical significance of the tree species to the local community or region.
12	Stakeholder input	Consider input from relevant stakeholders, including local communities, urban planners and landscape architects, to incorporate preferences, cultural values and specific project goals.
13	Longevity	Assess the tree species' expected lifespan to ensure long term benefits and minimize the need for frequent replacements.
14	Urban tolerance	Evaluate the tree species' ability to withstand urban conditions, such as pollution, compacted soil and limited root space.
15	Pest and disease resistance	Select tree species that have natural resistance or tolerance to common pests and diseases prevalent in the area.

8. Benefits of Green Corridor

Roadside trees provide numerous benefits to both the environment and the community. Roadside trees act as natural air filters, absorbing pollutants such as carbon dioxide, nitrogen dioxide and particulate matter from vehicle emissions [8,10,12]. Through the process of photosynthesis, trees convert carbon dioxide into oxygen, helping to improve air quality and reduce the impacts of air pollution. Roadside trees can act as a barrier, helping to reduce traffic noise by absorbing and deflecting sound waves. They contribute to creating a quieter and more peaceful environment for residents, pedestrians and other road users. Trees planted along roadsides enhance the visual appeal of an area, adding greenery and natural beauty to the landscape. They contribute to a sense of place and improve the overall aesthetics of the community. Trees planted along roadsides enhance the visual appeal of an area, adding greenery and natural beauty to the landscape. They contribute to a sense of place and improve the overall aesthetics of the community. The root systems of roadside trees help stabilise the soil and prevent erosion along roadways. They hold the soil in place, reducing the risk of sediment runoff into water bodies and maintaining the integrity of road embankments. Trees planted along roadways can serve as a natural buffer, separating pedestrians from vehicle traffic and providing shade and shelter. They can help define and improve the safety of pedestrian pathways and encourage walking and cycling. Roadside trees can provide a calming and soothing effect, reduce stress levels and enhance the overall quality of life for people living and working in the area. Roadside trees provide habitat and food sources for birds, insects and other wildlife [5,11]. They contribute to urban biodiversity by supporting a range of species and ecological interactions.

9. Air Pollution Resistant Tree in Urban Landscaping [15]

Pollutant	Tolerant Tree Species	
Sulfur di-oxide	*Albizia lebbeck*	*Lagerstroemia flosregineae*
	Ailanthus excelsa	*L. thorelli*
	Alstonia scholaris	*Mimusops elengi*
	Azadirachta indica	*Parkinsonia aculeate*
	Casuarina equisetifolia	*Polyalithia longifolia*
	Delonix regia	*Terminalia arjuna*
	Ficus religiosa	*Ulmus parviflora, Jacq*
NO and NO_2	*Fugus orientalis*	*Alnus spp.*
	Quercus robur	*Sambucus nigera*
	Robinia Psudocacia	
O_3	*Acer platanoides*	
	A. negundo	
Hydrogen floride	*Ailanthus excelsa*	*Juniperus spp.*
MIC gas	*Dracaena spp.*	*Polyalithia longifolia*
	Syzygium cumini	*Ficus bengalensis*
	Mangifera indica	*Callistemon viminalis*
	Phoenix spp.	*Cassia siamea*
Fluorides	*Ficus elastica*	*Althaea officinalis*
	Crataegus dodada	*Diospyros virginiana*
	Ulmus parviflora	*Picea glauca*
	Gleditschta triacanthos	*Paulownia spp.*
	Ailanthus excelsa	
Chlorides	*Ficus carica*	*Mangifera indica*
	Thuja sp.	*Althaea officinalis*
	Cedrus deodara	*Thevetia peruviana*
	Ulmus parviflora	*Paulownia sp.*
	Gleditchia tricanthos	*Picea glauca*
Smoke and Dust Particulates	*Acacia nilotica*	*Punica granatum*
	Ficus bengalensis	*Dalbergia sissoo*
	Zizyphus mauritiana	*Albizia lebbeck*
	Prosopis juliflora	*Tecomela undulata*
	Cordia obliqua	*Tecoma stans*
Combined gaseous pollutants (Emission of oxides sulfur, Nitrogen and Carbon from petrochemical and thermal power plant)	*Acacia nilotica*	*Ficus bengalensis*
	Albizia lebbeck	*Ficus religiosa*
	Butea monoperma	*Madhuca indica*
	Dalbergia sissoo	*Moringa oleifera*
	Emblica officinalis	*Zizyphus mauritiana*
	Eucalyptus citriodora	
Combined odorous pollutants (Hydrogen silphide, Ammonia, Acetaldehyde, Methyl mercaptan, CH_4)	*Bushes*	*Acacia farnesiana*
	Melaleuca	*Pine*
	Cedar	*Junipers*
	Eucalyptus	*Tulsi*
	Turmeric	*Vetiver*
	Nerium	*Pongamia pinnata*
	Bamboo	*Casuarina*
	Neem	

Trees Species prevent Dust Pollution

cacia auriculiformis	*Eucalyptus citriodora*	*Melia azedarach*
Albizia lebbeck	*Eugenia cuspidate*	*Millettia ovalifolia*
Alstonia scholaris	*Ficus benjamina*	*Millingtonia hortensis*
Bombax ceiba	*F. religiosa*	*Pongamia pinnata*
Cassia fistula	*Grevillea robusta*	*Syzygium cumini*
C. javanica	*Jacaranda mimosifolia*	*Tamrindus indica*
Cordia dichotoma	*Kigelia pinnata*	*Terminalia arjuna*
Dalbergia sissoo	*Lagerstroemia speciosa*	*Toona ciliate*
Erythrina variegate	*Madhuca indica*	*T. microcarpa*

Trees Species prevent Noise Pollution

Alstonia scholaris	*Lagerstroemia speciosa*
Azadirachta indica	*Madhuca indica*
Butea monospermum	*Mangifera indica*
Erythrina variegate	*Morus alba*
Eucalyptus citriodora	*Pterosprmum acerifolium*
Grevillea robusta	*Syzygium cumini*
Kigelia pinnata	*Terminalia arjuna*

10. Discussion

Dust Accumulation and Glare Interruption Capacity of Roadside Shrub Species

Trees planted along highways serve as vital ecological buffers that intercept and filter airborne pollutants, acting as natural purifiers capable of capturing dust, smoke and vehicular emissions such as SO_2, NO_2 and CO. Their dense canopies not only trap harmful particulates but also help reduce noise levels, moderate ambient temperatures and diminish the intensity of headlight glare, thereby enhancing visibility and improving overall road safety for motorists. The significance of such vegetation is evident from research conducted along the central verge of NH-8 near Navsari, India, where the physiological responses of eight ornamental shrub species exposed to high vehicular pollution were compared with those grown under lower-pollution conditions. Parameters such as plant height, branching, leaf size, flowering behaviour, dust accumulation, glare interruption capacity and peroxidase activity and consistently found that pollutant exposure leading to suppressed growth and reduced flowering due to continuous contact with SO_2, NO_2, CO and heavy particulate loads. Despite these stresses, species such as *Calliandra hybrida*, *Nerium oleander* and *Thevetia peruviana*. While *Calliandra hybrida* demonstrated remarkable tolerance, exhibiting minimal reductions in growth and retaining high efficiency in trapping dust and mitigating glare, more sensitive species like *Cassia bicapsularis* showed pronounced declines in physiological vigour and overall performance, underscoring the need for selecting pollution-resistant species for roadside landscaping to maintain ecological function under heavy traffic loads [14].

Carbon Sequestration Potential of Roadside Trees

Beyond their role in pollution attenuation, roadside vegetation categorised as Trees Outside Forests (TOF) plays an important role in climate regulation, particularly through carbon sequestration, as these vegetative belts significantly increase local green cover and serve as effective carbon sinks. Green belts along highways often accumulate large quantities of carbon, with sequestration strongly associated with biomass rather than species diversity or tree density, highlighting the importance of robust, high-biomass plantings. Strengthening, expanding and periodically monitoring these green corridors can meaningfully contribute to reducing atmospheric CO_2 concentrations while providing additional ecological benefits, such as enhanced biodiversity, reduced pollution loads, improved rainfall regulation and increased groundwater recharge. The carbon storage capacity of highway vegetation shows that species like *Delonix regia* and *Dalbergia sissoo* store the highest carbon content, while *Erythroxylon monogynum* exhibits an exceptional annual sequestration capacity of approximately 0.62 tons of CO_2 per year, making these species particularly valuable for long-term atmospheric carbon reduction strategies [16].

Role of Vegetative Strips in Highway Noise Abatement

Vegetation belts also contribute significantly to noise abatement, with sparse-to-moderate vegetative barriers reducing noise levels by up to 50%, although results indicate that excessive vegetative density may lead to diminishing returns in noise reduction capacity. Noise attenuation is influenced by several structural factors, including trunk diameter and setback distance, but the greatest benefit is typically achieved within a 5-meter-deep vegetative strip, beyond which additional setback offers minimal improvement. When combined with the psychological comfort provided by natural vegetation, such green barriers outperform artificial noise barriers in both acoustic and perceptual terms [13].

Influence of Tree Configuration on Roadside Thermal Environment

Roadside microclimate is likewise influenced by tree arrangement, as areas flanked by dense vegetation exhibit significant temperature reductions often exceeding 2 °C accompanied by measurable increases in relative humidity. Denser tree crown configurations consistently yield cooler microclimates, with strong correlations between ambient temperature, humidity and the linear continuity of tree crowns. Simulations have further shown that continuous rows of closely spaced trees with dense foliage can reduce surface temperatures by up to 1.41 °C, indicating that tree quantity and spacing have greater influence on thermal regulation than foliage density alone and providing important guidance for designing climate-responsive roadside environments [9].

Psychological Impacts of Roadside Tree Canopies on Driver Emotion and Safety

In addition to their environmental roles, roadside trees influence driver psychology, as different canopy shapes evoke varying emotional responses while, some forms induce feelings of serenity, amazement, relaxation, excitement and joy, others may trigger fear, stress, anger, anxiety, or confusion. These findings emphasise that species selection should consider not only ecological and functional performance but also its potential influence on driver behaviour and road safety [6].

Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) as Tools for Selecting Roadside Vegetation

Air pollution tolerance in ornamental plants can be assessed through physiological indicators such as relative water content, leaf pH, chlorophyll concentration and ascorbic acid levels, which reveal clear differences in species resilience under polluted conditions. Shrubs often outperform trees, with species like *Yucca filamentosa* and *Berberis thunbergii* showing strong biochemical stability and high APTI values, while more sensitive species exhibit pigment loss and reduced metabolic activity. Integrating APTI with the Anticipated Performance Index (API) provides a more comprehensive evaluation by combining these physiological markers with morphological and socioeconomic traits, consistently identifying species such as *Saraca asoca*, *Ficus elastica*, *Aucuba japonica* and *Ficus religiosa* as highly pollution-tolerant and suitable for highway greenbelt development. Together, these insights support more effective roadside vegetation planning aimed at maximising pollution mitigation, enhancing microclimatic benefits and improving long-term ecological performance [3,4].

Conclusion

Green corridors played a vital role in maintaining ecological balance and improving the quality of urban life. They connect fragment habitats, reduce pollution, regulate climate and provide spaces for recreation and well-being. Species like *Nerium oleander* cv. Roseum and *Calliandra hybrida* demonstrated unique dust loading and glare-reducing capacities. Tree canopy shapes strongly influenced drivers' emotions as conical forms enhanced comfort and reducing stress. The selection of the right tree species at the roadside was also a crucial factor to be considered to avoid vehicle crashes. *Yucca filamentosa* and *Berberis thunbergii* show strong biochemical stability and high APTI values. *Saraca asoca* and *Ficus elastica* emerged as the most pollution tolerant and best-performing plants, respectively. Beyond psychological benefits, roadside trees also provide substantial ecological services like mitigating noise, managing temperature and sequestering significant amounts of carbon dioxide. Thus, selecting and managing suitable species with dense canopies and strategic spacing maximized ecological, aesthetic and psychological benefits, making roadside greenery an effective natural solution for pollution control, climate mitigation and improved driving environments.

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