

From Plants to Planet: A Review of the Emerging Role of Botany in Human Health, Climate Resilience and Sustainable Development

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Abstract

Plants are fundamental to human civilization, providing food, medicines, oxygen, fibres, raw materials and ecosystem services. Their importance extends to environmental quality, human health, livelihoods, culture and community resilience. With climate change, urbanization and biodiversity loss creating new challenges, Botany has an increasingly important role in addressing human and environmental needs.

Medicinal plants provide an important link between plant diversity and healthcare through their biologically active secondary metabolites and traditional uses. However, climate change, habitat degradation and unsustainable harvesting may alter their distribution, productivity and phytochemical composition. Urban green spaces, botanical gardens and community gardens also contribute to biodiversity conservation, climate adaptation, environmental quality and human well-being.

This review examines the relationship between plants, human welfare and environmental resilience, focusing on medicinal plants, climate change, urban green spaces, biodiversity conservation and community participation. It emphasizes integrating traditional knowledge with modern botanical research and sustainable conservation. A people-centered and interdisciplinary approach to Botany can transform plant knowledge into practical solutions for healthier, resilient and sustainable communities.

Keywords: Botany; medicinal plants; human well-being; climate change; urban green spaces; biodiversity; traditional medicine; ecosystem services; conservation; sustainable communities

Introduction

Plants form the biological foundation of terrestrial life and provide food, medicines, shelter, clothing, fuel, fibres and industrial materials. They also regulate carbon storage, nutrient cycling, soil formation, water regulation and habitat provision.

Traditionally, Botany has focused on morphology, anatomy, physiology, taxonomy, ecology and evolution. However, climate change, biodiversity loss, urbanization, pollution, food insecurity and growing healthcare demands require plant science to address wider social challenges.

Medicinal plants illustrate this changing role. Their secondary metabolites have long supported traditional healthcare and continue to attract pharmaceutical research. Environmental factors such as temperature, water availability, light, CO₂ and soil nutrients can influence their production (Jangpangi et al., 2025).

Climate change may therefore affect both the distribution and phytochemical characteristics of medicinal plants (Takubessi et al., 2025).

India is particularly important because of its rich biodiversity and long tradition of medicinal plant use. Recent research has examined Indian medicinal plants in relation to traditional uses, phytochemistry, pharmacology, quality control and conservation (Kumar et al., 2024). The WHO Global Traditional Medicine Strategy 2025–2034 further emphasizes evidence, safety, sustainability, biodiversity, cultural respect and community empowerment (WHO, 2025).

Urban vegetation provides another important pathway between Botany and human welfare. Parks, gardens, trees and community green spaces can provide cooling, biodiversity, recreation and health benefits (Nazish et al., 2024; Raza et al., 2024).

Objectives of the Review

The review aims to:

1. Examine the role of plants in human health and social welfare.
2. Review climate-change effects on medicinal plants and secondary metabolites.
3. Examine urban green spaces in relation to well-being and climate resilience.
4. Highlight medicinal plant conservation, particularly in India.
5. Examine community and institutional participation in conservation.
6. Identify research gaps and future opportunities.
7. Develop an integrated framework linking plant science, health, biodiversity and sustainable development.

Plants and Human Well-being

Plants contribute to human welfare through four major pathways:

- **Material benefits:** food, medicines, fibres, timber, oils, spices and industrial materials.
- **Healthcare benefits:** phytochemicals used in traditional medicine and investigated for pharmaceutical applications (Kumar et al., 2024).
- **Environmental benefits:** carbon sequestration, temperature regulation, soil conservation, water management and habitat formation (Zhang & Qian, 2024).
- **Psychological and social benefits:** recreation, relaxation, social interaction and contact with nature (Xie et al., 2024).

Thus, plants should increasingly be regarded as part of the public infrastructure supporting healthy communities.

Medicinal Plants: A Link Between Botany and Healthcare

Medicinal plants connect Botany with traditional knowledge, pharmacology and public health. They produce secondary metabolites such as alkaloids, flavonoids, phenolics, terpenoids, tannins, glycosides, saponins and essential oils, many of which possess biological activities of potential therapeutic value. India's Ayurveda, Siddha and Unani traditions demonstrate the importance of medicinal plants in healthcare (Kumar et al., 2024). However, increasing demand can result in overharvesting, habitat destruction and population decline. Sustainable cultivation and scientifically managed harvesting are therefore essential.

Climate Change and Medicinal Plants

Climate change is an important threat to medicinal plant resources. Major environmental factors include temperature, rainfall, drought, soil moisture, atmospheric CO₂, ultraviolet radiation, salinity, nutrient availability and extreme weather events.

Environmental stress can alter secondary metabolism. Moderate stress may stimulate certain protective metabolites, whereas prolonged or severe stress can reduce growth and productivity (Jangpangi et al., 2025). Therefore, changes in phytochemical composition may influence medicinal quality, although responses vary according to species, genotype, plant part, developmental stage and environmental conditions.

A. Climate Change and Species Distribution

Climate change can also alter the geographical distribution and habitat suitability of medicinal plants. A scoping review of 219 studies covering 367 medicinal plant species reported range shifts, changes in habitat suitability and potential extinction risks, along with important conservation gaps (Takubessi et al., 2025).

Conservation should therefore combine habitat protection, cultivation, seed banking, ex situ conservation, tissue culture, ecological restoration, sustainable harvesting and community participation.

B. Climate Change and Secondary Metabolites

Climate-related stress can increase or decrease phenolics, flavonoids, terpenoids and other secondary metabolites. An increase in one compound does not necessarily mean improved medicinal quality because other compounds, biomass or the overall phytochemical balance may change. Multi-component phytochemical assessment is therefore preferable to studying individual marker compounds alone (Jangpangi et al., 2025).

Traditional Medicine and the Global Context

The WHO Global Traditional Medicine Strategy 2025–2034 emphasizes:

1. Strengthening the evidence base.
2. Ensuring safe and effective traditional medicine through appropriate regulation.
3. Integrating safe and effective traditional medicine into health systems.
4. Promoting cross-sectoral value and community empowerment (WHO, 2025).

The strategy also recognizes sustainability, biodiversity, cultural rights, community engagement and health equity. For Botany, this means medicinal plant research should integrate **conservation, quality, safety, traditional knowledge, community welfare and environmental sustainability**.

Urban Green Spaces and Human Well-being

Urban green spaces include public parks, urban forests, institutional and botanical gardens, roadside plantations, community and school gardens, and green corridors.

They provide ecosystem services, recreational opportunities and potential health benefits. Evidence indicates positive associations between green-space exposure and several health and well-being outcomes, although evidence strength differs among outcomes (Xie et al., 2024; Raza et al., 2024).

Green spaces should therefore be viewed as one component of a broader healthy-environment strategy rather than a universal solution to health problems.

A. Urban Green Spaces and Heat Resilience

Urban heat is an important climate-related health challenge. Vegetation provides shade and influences loc-

al microclimates. Nazish et al. (2024) reported a general association between greater green-space availability and lower heat-related morbidity and mortality.

Urban vegetation can therefore serve as a nature-based climate adaptation strategy. Species selection should consider climatic suitability, water availability, root characteristics, canopy structure, biodiversity value, maintenance requirements, allergenic potential and long-term resilience.

B. Urban Biodiversity

Effective urban greening should focus not only on increasing vegetation but also on improving its ecological quality. Diverse plant communities can provide habitat, pollinator resources, shade, soil protection, carbon storage, educational opportunities and recreational benefits.

Native and locally adapted species can support local biodiversity, although carefully evaluated climate-resilient non-native species may also have limited roles. The guiding principle should be **ecological suitability with biodiversity safeguards**.

Community Gardens and Social Welfare

Community and medicinal plant gardens can support practical education, recreation, local food production, medicinal plant awareness, biodiversity conservation, knowledge exchange and community interaction.

Educational institutions can develop botanical gardens as **living classrooms** where students learn plant identification, propagation, conservation and ecological monitoring. Such spaces can simultaneously support education, biodiversity and community outreach.

Potential Functions of an Institutional Botanical Garden

Component	Educational Value	Social/Environmental Benefit
Medicinal plant garden	Ethnobotany and pharmacognosy	Medicinal plant awareness
Native plant section	Taxonomy and ecology	Local biodiversity conservation
Butterfly garden	Pollination biology	Pollinator support
Tree avenue	Dendrology	Shade and microclimate regulation
Herbarium	Plant identification	Biodiversity documentation
Nursery	Plant propagation	Conservation and outreach
Compost unit	Nutrient cycling	Sustainable waste management
Biodiversity register	Field research	Long-term campus monitoring

Plants, Biodiversity and Ecosystem Services

Plant diversity supports ecosystem functioning through multiple pathways:

Carbon cycle → Climate regulation

Root systems → Soil stability

Vegetation → Water regulation

Flowering plants → Pollinator support

Trees and shrubs → Habitat creation

Green spaces → Recreation and well-being

Urban vegetation should therefore be regarded as multifunctional ecological infrastructure rather than merely decorative landscaping (Zhang & Qian, 2024; Nazish et al., 2024).

Medicinal Plant Conservation

Medicinal plant conservation requires both **in situ** and **ex situ** approaches.

In situ conservation

Protects plants in their natural habitats while maintaining ecological interactions.

Ex situ conservation

Includes botanical gardens, seed banks, field gene banks, tissue culture, cryopreservation and controlled cultivation.

Cultivation can reduce pressure on wild populations but should maintain genetic diversity and appropriate phytochemical quality. GIS and species-distribution modelling can help identify present and future suitable habitats (Takubessi et al., 2025).

Traditional Knowledge and Ethical Considerations

Traditional knowledge is valuable for botanical research but should not be treated as an unrestricted resource. Ethnobotanical knowledge is often associated with specific communities and cultural contexts. Research should recognize knowledge holders and follow relevant ethical and legal requirements.

The WHO strategy recognizes Indigenous Peoples' rights, culture, biodiversity, sustainability and community engagement (WHO, 2025).

Future ethnobotanical research should therefore follow:

Documentation + Validation + Conservation + Benefit Sharing + Community Participation Research Gaps

Important gaps include:

1. Limited long-term experiments combining temperature, drought, CO₂ and other stresses.
2. Insufficient long-term monitoring of climate-related phytochemical changes.
3. Inadequate conservation assessment of many medicinal plants (Takubessi et al., 2025).
4. Need for region-specific climate vulnerability studies in India.
5. Limited evidence from low- and middle-income urban settings (Nazish et al., 2024).
6. Limited intervention-based research on changes to urban green spaces and health or educational outcomes (Raza et al., 2024).

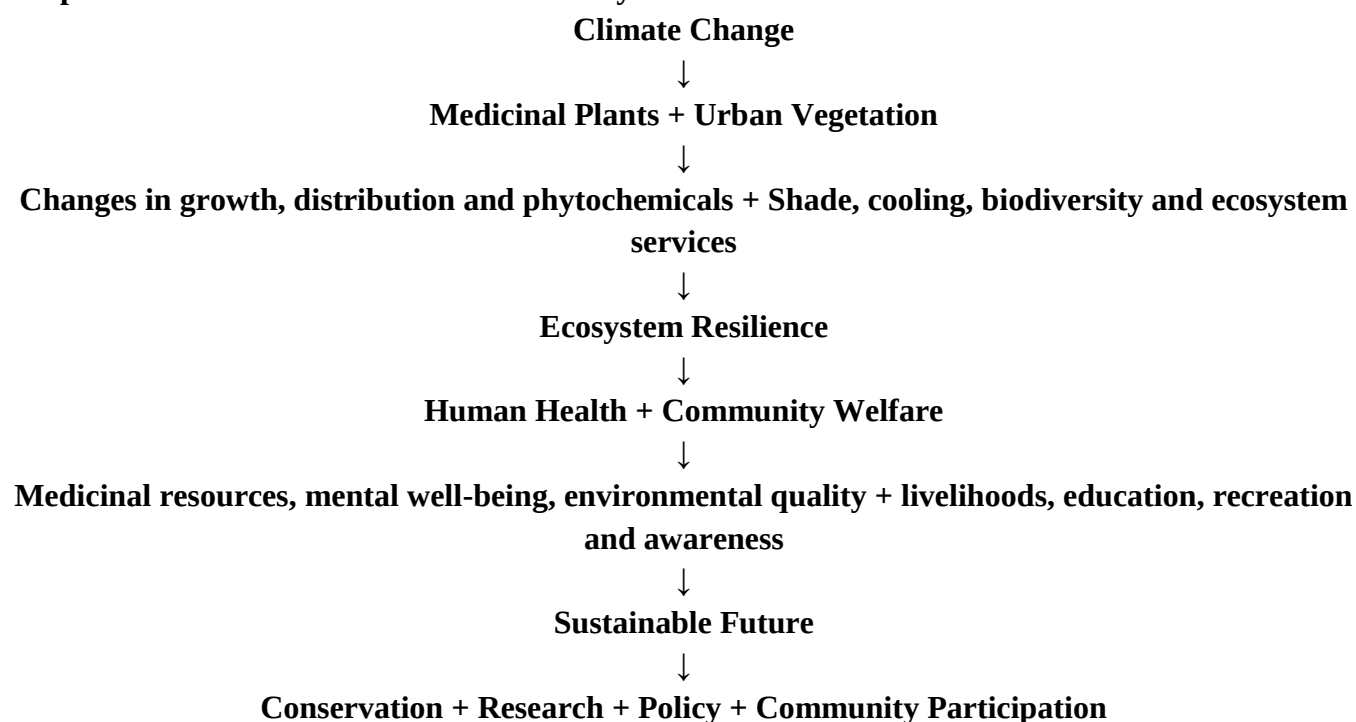
Future Research Priorities

Future Botany research should focus on:

1. **Climate-resilient medicinal plant cultivation** – identifying species and genotypes that maintain productivity and desirable phytochemical profiles.
2. **Multi-factor climate experiments** – studying heat, drought, elevated CO₂ and altered rainfall together.
3. **Phytochemical fingerprinting** – applying metabolomics to assess complete phytochemical responses.

4. **GIS-based conservation** – combining species distribution models, climate projections and field observations.
5. **Green-campus research** – using educational campuses to monitor biodiversity, phenology, carbon storage and pollinators.
6. **Community-based conservation** – involving local communities as active conservation partners.
7. **Plant–health research** – establishing stronger evidence on how specific green-space interventions affect health.

Proposed Plant–Health–Climate–Community Framework



The framework demonstrates that plants connect climate resilience and human welfare through healthcare resources, traditional knowledge, ecosystem services and healthier living environments. Conservation, research and community participation are essential for maintaining these benefits.

Novelty and Significance

This review brings together areas often studied separately: medicinal plant phytochemistry, urban green-space research, climate-related plant responses and ethnobotany.

It proposes that these should be viewed as interconnected components of **socially relevant Botany**:

Plant diversity → Ecological resilience → Human health → Community welfare → Sustainable development

This perspective is especially relevant to India because of its biological diversity, traditional medicinal knowledge and rapidly changing urban and rural environments.

Implications for India

India offers significant opportunities for socially relevant botanical research because of its medicinal plant traditions, biodiversity and diverse climatic regions. Priority areas include:

- Climate-resilient medicinal plants

- Ethnobotany and traditional knowledge documentation
- Conservation of threatened species
- Sustainable cultivation
- Urban biodiversity
- Medicinal plant gardens
- Green campuses
- Community-based conservation
- Nature-based climate adaptation

The WHO Global Traditional Medicine Centre in Jamnagar further strengthens India's role in traditional medicine research and knowledge exchange. Indian Botany departments can use this opportunity to develop interdisciplinary research linking plant science, healthcare, conservation and public welfare.

Conclusion

Botany has evolved beyond the traditional study of plant morphology, anatomy, taxonomy and physiology. Plants are fundamental to human health, environmental quality, biodiversity conservation, climate adaptation and community well-being.

Medicinal plants demonstrate the connection between botanical diversity and healthcare. Climate change can affect their distribution, growth and phytochemical composition (Jangpangi et al., 2025; Takubessi et al., 2025). Urban vegetation provides another pathway through which plants support biodiversity, environmental quality, climate adaptation and human well-being (Zhang & Qian, 2024; Xie et al., 2024), including potential reductions in heat-related health risks (Nazish et al., 2024).

The WHO Global Traditional Medicine Strategy 2025–2034 reinforces the importance of evidence, safety, sustainability, biodiversity, cultural respect and community participation (WHO, 2025).

The future of Botany should therefore be **people-centered, evidence-based and sustainability-oriented**. Contemporary plant science should ask not only *what a plant is and how it functions*, but also how botanical knowledge can conserve biodiversity, improve human well-being and build resilient communities.

Recommendations

1. Promote interdisciplinary Botany research involving ecology, pharmacology, public health, climate science and social sciences.
2. Strengthen medicinal plant conservation through combined in situ and ex situ approaches.
3. Develop climate-resilient cultivation protocols for important medicinal species.
4. Establish medicinal plant gardens in colleges and schools.
5. Develop biodiversity-rich institutional campuses using locally appropriate species.
6. Document traditional botanical knowledge ethically with recognition of knowledge-holding communities.
7. Expand GIS and species-distribution modelling for climate-vulnerable medicinal plants.
8. Conduct long-term phytochemical studies on climate-related changes in medicinal plant quality.
9. Increase research on urban greenery in Indian cities, particularly rapidly urbanizing and low-income communities.
10. Promote citizen science and community participation in biodiversity documentation and conservation.

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