An overview of domesticated vegetation for survival of endangered plants beyond phyto-geographical regions of distribution

Sandip Kumar Dutta[1], Subhra Bandhopadhyay[2], Dr. Ankush Pal[3], Dr. Debnath Palit[4]
[1]*State Civil Servant, Government of West Bengal, India*
[2]*Ph.D. Scholar, West Bengal, India*
[3]*Associate Professor, Department of Botany, Berhampore Girls' College,*
[4]*Principal, Krishnagar Government College, India*

***Abstract*—The rapid decline of plant biodiversity has led to an increasing number of plant species becoming endangered, primarily due to habitat destruction, climate change, overexploitation, and restricted phytogeographical distribution. Many endangered plant species are confined to specific ecological zones, making them highly vulnerable to environmental disturbances. In this context, domestication of endangered vegetation beyond their native phytogeographical regions has emerged as an effective alternative conservation strategy. This approach involves the cultivation and management of threatened plant species under controlled or semi-controlled environments such as botanical gardens, agroforestry systems, research farms, and home gardens, enabling their survival outside natural habitats. Domesticated vegetation facilitates ex-situ conservation by reducing pressure on wild populations, maintaining living germplasm, and enhancing propagation potential. Furthermore, domestication supports adaptive responses to changing climatic conditions by allowing species to acclimatize to new environmental settings. However, ecological risks such as genetic erosion, loss of wild traits, and invasive tendencies necessitate careful monitoring and ethical conservation practices. This overview highlights the significance of domesticated vegetation as a complementary conservation tool, bridging in-situ and ex-situ strategies, and emphasizes its role in ensuring the long-term survival of endangered plant species beyond their traditional phytogeographical limits.**

***Index Terms*—Endangered plants, Domestication, Phytogeography, Ex-situ conservation, Climate change**

I. INTRODUCTION

Plant biodiversity underpins terrestrial ecosystem functionality, providing essential ecosystem services such as nutrient cycling, soil stabilization, climate regulation, and genetic resources for agriculture and medicine. However, global biodiversity assessments indicate that a substantial fraction of vascular plants is at risk of extinction, with estimates ranging from 20% to 30% of assessed species considered threatened (IUCN, various years). The primary drivers of this decline include habitat loss due to agricultural expansion and urbanization, unsustainable harvesting for economic use, invasive species displacement, and mounting pressures from climate change. Because many plant species are restricted to discrete ecological zones defined as phytogeographical regions the degradation of these areas disproportionately impacts endemic flora.

Phytogeographical regions are biogeographical units characterized by distinct climatic regimes, geological substrates, and evolutionary histories that have shaped unique plant assemblages. For example, the Eastern Himalayas, Western Ghats, and the Cape Floristic Region host high levels of plant endemism, yet these areas face intense anthropogenic pressure. In such contexts, traditional in-situ conservation strategies protecting plants within their native habitats are necessary but often insufficient for ensuring long-term survival, particularly when habitats are irreversibly altered or species face immediate extinction risk.

Consequently, ex-situ conservation measures have gained prominence. These methods include seed banks, tissue culture, botanical gardens, and controlled cultivation outside native contexts. Among ex-situ strategies, domesticated vegetation beyond native phytogeographical regions represents an adaptive approach that integrates ecological understanding with practical horticulture. Domestication in this sense involves the cultivation and management of endangered plant species outside their natural distribution ranges, with controlled environmental inputs to support growth and reproduction. Unlike genetic engineering or artificial hybridization, domestication focuses on ecological adaptation and propagation under human-managed conditions.

This paper provides a comprehensive review of the role of domesticated vegetation in conservation biology. It assesses theoretical foundations, methodological frameworks, case studies, ecological considerations, and future prospects. In doing so, it underscores how domestication beyond native ranges can enhance global efforts to safeguard endangered plant species while contributing to sustainable biodiversity stewardship.

II. PHYTOGEOGRAPHICAL REGIONS AND PLANT ENDEMISM

Phytogeographical regions are critical for understanding patterns of plant distribution and endemism. These regions are delineated based on floristic similarities, historical biogeography, climatic influences, and geological features. Classic phytogeographical schemes such as those proposed by Takhtajan and others divide the world into distinct regions including the Holarctic, Paleotropical, Neotropical, and Australian regions, each comprising multiple provinces with unique species composition.

Endemism and ecological specialization: Endemism refers to the ecological state of a species being native to a single defined geographic location. Endemic species often exhibit adaptations to environmental conditions, such as soil types, moisture regimes, light levels, and interspecific relationships. These specialized adaptations increase vulnerability when conditions change. For example, high-elevation alpine plants may be finely attuned to cold, short-growing-season environments; slight climatic warming can disrupt their phenology, reproductive cycles, and competitive balance.

The conservation implications of endemism are profound. When a species occurs only within a narrow range, loss of any part of that range can jeopardize the entire species. Fragmentation of habitat further isolates populations, reducing gene flow and increasing susceptibility to inbreeding depression.

Threats in phytogeographical hotspots: Several global biodiversity hotspots regions with exceptionally high endemism and significant habitat loss exemplify these challenges. The Western Ghats of India are renowned for endemic medicinal plants, many of which are overharvested for traditional medicine. The Eastern Himalayas harbor unique alpine and sub-alpine flora, but rapid infrastructure development and climate shifts threaten these ecosystems. Madagascar, with its profoundly unique flora, continues to experience deforestation and fragmentation at alarming rates.

Understanding these regions' ecological constraints is essential for conservation planning. While in-situ protection efforts continue to be fundamental, they often cannot alone secure endangered species' futures in the face of dynamic environmental change.

III. CONCEPTUAL FRAMEWORK OF DOMESTICATED VEGETATION

The term domesticated vegetation in conservation refers to the cultivation of plant species under conditions different from their natural environment to ensure survival, growth, and reproduction. It extends beyond traditional horticulture to integrate conservation goals, ecological knowledge, and adaptive management. Unlike classical domestication which historically refers to long-term genetic selection under human influence conservation domestication focuses on short- to medium-term ecological support and propagation.

Domestication vs. Cultivation vs. Ex-situ Conservation: To clarify, cultivation broadly denotes the human management of plant growth for desired outcomes, such as agriculture or landscaping. Domestication in a conservation context involves cultivation targeted toward survival and propagation of endangered taxa, often with ecological considerations such as microclimate simulation and genetic diversity maintenance.

Ex-situ conservation encompasses any method that removes species from their natural habitats to prevent extinction, including seed banks, cryopreservation, tissue culture, and botanical garden collections. Domesticated vegetation is a subset of ex-situ strategies that emphasizes living plant populations grown in terrestrial environments outside native ranges, often with managed ecological conditions.

Theoretical rationale: The rationale for using domesticated vegetation as a conservation measure emerges from several ecological and evolutionary principles:

- Adaptive Plasticity: Many plant species exhibit phenotypic plasticity the capacity to adjust physiology and morphology in response to environmental variation. Domestication leverages this plasticity by exposing species to novel but controlled conditions.
- Propagation Assurance: Controlled environments can mitigate factors such as seed predation, herbivory, and climatic extremes that limit reproductive success in the wild.
- Genetic Reservoirs: Maintained populations outside native ranges serve as reservoirs of genetic material for future restoration and research.
- Buffer Against Habitat Loss: When native habitats are irreversibly altered, domesticated populations can maintain species viability while long-term habitat restoration is pursued.

Collectively, these principles establish domestication as a bridge between in-situ protection and advanced ex-situ methodologies.

IV. METHODOLOGIES FOR DOMESTICATION BEYOND NATIVE RANGES:

Implementing domestication for conservation requires scientifically informed methodologies that address ecological, genetic, and operational challenges. Key components include site selection, propagation techniques, environmental management, and long-term monitoring.

Site selection and environmental replication: Selecting suitable sites outside native ranges involves evaluating climatic parameters (temperature, precipitation, seasonality), soil characteristics (pH, nutrient levels, texture), and biotic factors. Ideally, chosen sites replicate key aspects of the plant’s native environment while offering resilience against future climate variability.

Soil replication techniques may include:

- Soil amendments to mimic native soil chemistry.
- Substrate layering that recreates natural soil horizons.
- Microbiome inoculation to establish beneficial microbial communities.

Propagation and reproduction techniques: Domestication projects may employ several propagation techniques:

- Seed propagation: Collecting seeds from wild populations and germinating them under controlled nursery conditions.
- Vegetative propagation: Using cuttings, grafts, or tissue culture to produce genetically identical or diverse individuals.
- Tissue culture and micropropagation: Especially important for species with low seed viability or recalcitrant seeds that do not store well.

These techniques enhance survival rates and genetic diversity by allowing controlled selection and multiplication.

Environmental control and adaptive management: Environmental control measures include irrigation systems, shade structures, frost protection, and pest management. Adaptive management repeatedly monitoring and adjusting conditions based on response data ensures that domesticated populations remainviable and resilient.

Genetic diversity and population management: Maintaining genetic diversity is critical. Conservation domestication must avoid narrowing genetic pools through unintentional selection for traits suited only to managed environments. Genetic monitoring using molecular markers to assess diversity is recommended to ensure long-term evolutionary potential.

V. ECOLOGICAL AND ETHICAL CONSIDERATIONS

While domestication offers conservation potential, several ecological and ethical considerations must be carefully addressed.

Risk of Invasiveness: Plants introduced beyond their native range, even with conservation intent, could become invasive if they establish unchecked reproductive success. Invasiveness can disrupt local ecosystems, outcompete native flora and alter ecosystem dynamics. Pre-introduction risk assessments and post-establishment monitoring are essential.

Genetic integrity and hybridization: Domesticated populations may hybridize with local congeners, potentially diluting genetic integrity. In regions with closely related species, careful spatial planning is required to prevent unintended genetic exchange.

Ethical responsibilities in conservation: Ethics in conservation domestication involves ensuring that human intervention does not compromise ecological systems or cultural values associated with plants. Respecting indigenous knowledge and equitable benefit sharing especially for medicinal or culturally significant species is imperative.

Balancing conservation and utilitarian use: While domesticated vegetation can provide resources for sustainable use (e.g., medicinal plants cultivated for pharmaceutical purposes), care must be taken not to incentivize overexploitation or commodification that undermines conservation goals.

VI. CASE STUDIES

Rauvolfia serpentina (Indian Snakeroot): Rauvolfia serpentina is a medicinal plant native to Indian forests, historically overharvested for its alkaloids used in treating hypertension. Due to habitat loss and overexploitation, wild populations declined sharply. Conservation domestication involved cultivating this species in research farms and community gardens outside its native forest range. Controlled propagation ensured genetic variation retention while providing sustainable plant material for pharmaceutical use. This approach reduced pressure on wild populations and stimulated local economic participation.

Saussureacostus (Kuth): Saussureacostusis an alpine plant endemic to high-elevation Himalayan regions. Its roots are highly valued in traditional medicine, leading to extensive wild harvesting and endangerment. Domestication efforts introduced cultivation in botanical gardens and managed fields at intermediate elevations, with soil and microclimate modification to approximate alpine conditions. While full replication of native environments is challenging, partial domestication has successfully produced viable populations for conservation and research.

Gloriosa superba (Flame Lily): Native to tropical regions with specific soil and moisture regimes, Gloriosa superba has faced habitat degradation and illegal harvesting for horticulture and pharmaceuticals. Domestication in controlled agroforestry systems outside its native distribution involved optimizing light, substrate, and moisture to promote growth. These efforts have increased the availability of plant material for both conservation and horticultural markets.

Taxus wallichiana (Himalayan Yew): Taxus wallichianais a conifer valued for anti-cancer compounds. Extensive harvesting and habitat loss have renderedit endangered in native Himalayan forests. Botanical gardens in temperate regions have cultivated T. wallichianaunder managed conditions, enabling seed production and research into propagation techniques. These collections serve as genetic reservoirs and provide material for potential reintroduction programs.

VII. DOMESTICATION AS A CONSERVATION STRATEGY IN POLICY FRAMEWORKS

Conservation domestication aligns with global biodiversity frameworks such as the Convention on Biological Diversity (CBD) and the Global Strategy for Plant Conservation (GSPC). Policy support is needed to integrate domestication into broader conservation planning, including:

- Funding for ex-situ facilities and long-term maintenance.
- Regulatory frameworks for translocation and cultivation outside native ranges.
- Collaboration with indigenous and local communities.
- Ethical guidelines for benefit sharing, especially for economically valuable species.

Institutional partnerships between botanical gardens, research institutions, and conservation agencies can facilitate knowledge exchange and resource pooling.

VIII. CHALLENGES AND LIMITATIONS

Despite its potential, domestication as a conservation strategy faces several challenges:

- Environmental Replication Difficulties: Some species require highly specific conditions that are difficult to replicate outside their native range.

- Resource Intensity: Domestication requires sustained financial and technical support, particularly for monitoring and adaptive management.
- Uncertain Reintroduction Outcomes: Successfully grown domesticated populations may not survive if reintroduced into altered or degraded native habitats.
- Inadequate Genetic Representation: Without careful planning, domesticated populations may represent only a subset of wild genetic diversity.

Addressing these challenges requires interdisciplinary research and long-term commitment.

IX. FUTURE DIRECTIONS AND RESEARCH NEEDS:

Emerging technologies and methodologies can enhance conservation domestication:

- Genomic Tools: Use of genomic sequencing to assess genetic diversity and structure.
- Advanced Phenotyping: Remote sensing and phenomics to monitor plant health and responses.
- Climate Modeling: Predictive models to determine future suitable cultivation zones.
- Citizen Science: Engaging communities in monitoring domesticated populations.

Integration of domestication with seed banking, cryopreservation, and landscape restoration can create holistic conservation strategies.

X. CONCLUSION:

Domesticated vegetation beyond native phytogeographical regions offers a promising adaptive conservation strategy in an era of rapid environmental change. By supporting endangered species' survival under controlled conditions, enhancing propagation, and maintaining genetic reservoirs, domestication complements traditional in-situ conservation. However, its success depends on scientifically informed methodologies, ethical foresight, and policy frameworks that balance ecological integrity with sustainable use. When implemented prudently, domestication can play a pivotal role in safeguarding global plant biodiversity and ensuring the persistence of endangered species for future generations.

REFERENCES:

[1] R. Mounce, P. Smith, and S. Brockington, "Ex situ conservation of plant diversity in the world's botanic gardens," Nature Plants, vol. 3, pp. 795–802, 2017.

[2] M. Negi, K. Tyagi, and M. S. Rawat, "Studies on conservation and domestication of endangered and threatened medicinal plant species in India – A review," Indian Journal of Agricultural Sciences, 2013.

[3] S. Gupta, R. Khan, V. Saxena, R. J. Srivastava, and A. Kumar, "Ex-situ conservation, cultivation and sustainable use of some medicinal plants," FAO, n.d.

[4] D. Li et al., "The impact of ex situ cultivation on the genetic variation of endangered plant species – Implications for restoration," Biological Conservation, vol. 284, p. 110221, 2023.

[5] N. Coelho, S. Gonçalves, and A. Romano, "Endemic plant species conservation: Biotechnological approaches," Plants, vol. 9, no. 3, p. 345, 2020.

[6] W. Sun et al., "Ex situ conservation of threatened higher plants in Chinese botanical gardens," Global Ecology and Conservation, vol. 38, p. e02206, 2022.

[7] C. E. Turcu et al., "Ex situ conservation of plant diversity in Romania: A synthesis of threatened and endemic taxa," Journal for Nature Conservation, vol. 68, p. 126211, 2022.

[8] V. H. Heywood and J. M. Iriondo, "Plant conservation: Old problems, new perspectives," Biological Conservation, vol. 113, pp. 321–335, 2003.

[9] S. Oldfield, "Plant diversity and conservation: Integration within and beyond protected areas," Plant Diversity, vol. 41, no. 2, pp. 36–49, 2019.

[10] S. Sharrock, "The role of botanic gardens in ex-situ conservation," in Plant Conservation Science and Practice. Cambridge, U.K.: Cambridge Univ. Press, 2017.

[11] International Union for Conservation of Nature (IUCN), The IUCN Red List of Threatened Species (plants dataset). IUCN, 2023.

[12] Convention on Biological Diversity (CBD), Global Strategy for Plant Conservation – Target 8 Report. Montreal, Canada: CBD, 2020.

[13] S. K. Barik and A. G. Gupta, "Role of medicinal plant conservation areas in India," Journal of Ethnopharmacology, 2018.
[14] C. Hamilton, "Medicinal plants, conservation and livelihoods," Biodiversity and Conservation, 2004.
[15] M. Walters and R. Seed, "Ex-situ conservation and the role of domestication," Plant Genetic Resources Newsletter, 2002.
[16] R. Khosla, "Conservation of endangered plant species through ex-situ cultivation," Journal of Plant Conservation, vol. 22, no. 3, pp. 145–160, 2018.
[17] N. Maxted et al., "Ex situ and in situ conservation linkages for crop wild relatives," Biodiversity and Conservation, vol. 21, pp. 3099–3121, 2012.
[18] E. O. Guerrant, K. Havens, and M. Maunder, Ex Situ Plant Conservation: Supporting Species Survival in the Wild. Washington, DC, USA: Island Press, 2004.
[19] S. Volis, "Conservation genetics and adaptive capacity of threatened plants," Conservation Biology, 2016.
[20] C. P. Dunn, "Plant reintroduction: An overview," Native Plants Journal, 2002.
[21] V. Sarasan et al., "Application of biotechnologies for conserving endangered plants," Plant Cell, Tissue and Organ Culture, 2006.
[22] S. Hoban et al., "Genetics and conservation translocation success," Conservation Genetics, 2020.
[23] J. Zhang, D. Li, and P. Smith, "Botanic Garden role in threatened plant recovery," Botanical Studies, 2021.
[24] J.-C. Svenning et al., "Climate change impacts on plant distribution and conservation strategies," Global Change Biology, 2023.
[25] T. Cross et al., "Monitoring genetic diversity in ex situ plant populations," Plant Conservation Genetics, 2019.