PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 11(3): 450-459
https://doi.org/10.14719/pst.3778

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REVIEW ARTICLE

Plant diversity conservation issues and challenges: A review

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OPEN ACCESS

ARTICLE HISTORY

Received: 27 April 2024
Accepted: 10 July 2024

Available online
Version 1.0 : 25 July 2024
Version 2.0 : 31 July 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Behera S, Bhadra A. Plant diversity conservation issues and challenges: A review. Plant Science Today. 2024; 11(3): 450-459. https://doi.org/10.14719/pst.3778

Abstract

Significant conceptual changes have occurred over the past years in plant conservation, with major methodological advances incorporating modern techniques, technology, and disciplines. The global, national, and regional loss of biodiversity is a multifaceted issue affecting social, economic, organizational, political, scientific, and communicational scenarios. The identification of root causes is key to preventing biodiversity loss. India's diverse ecosystem supports various needs, including food, medicine, clothing, and shelter. Spatial biodiversity assessment is important for prioritizing and monitoring mechanisms and efforts in the context of land use, land cover change, unprecedented overexploitation, uncontrolled pollution, and alien species invasion. Odisha, an eastern Indian state, is rich in natural resources, with tropical moist, and dry deciduous forests covering remote areas of many districts, north-south-western hills, plateaus, and isolated pockets. Conservation efforts have expanded with protected areas, Red Lists, *ex-situ* facilities, wild plant accessions, and some developed species recovery programs. The conservation community is concerned about how to respond to the continuously depleting bioresources. Conservation prioritization focuses on protecting socioeconomically, medicinally, and environmentally significant species and living communities, regions of high species richness and endemism, and active functional ecosystems. The present review explores how to address sustainable biodiversity conservation practices and natural ecosystems aligning with UN Sustainable Development Goals No. 13 and 15.

Keywords

Plant diversity; ecosystem; conservation; sustainable development

Introduction

Plants are the living resources of an ecosystem playing a vital role in ecosystem balance. The diversity of plants determines the quality and quantity of resources present within a geographical boundary. Plant diversity has received less attention over time, being found to have many threatened, endangered, and extinct species. In modern society, increasing anthropogenic pressure of population growth and industries has put natural resources in rapid decline. Hence, plant diversity must be restored to prevent extinction and ensure sustainable use of plant materials for present and future generations. Globally, the rapidly declining biodiversity has several implications for ecosystem functioning and stability, and this impacts our way of life (1). Plant diversity with almost 500,000 species, serves human needs and plays a major role in the natural ecosystem. With the lack of evidence, many species are still unknown, which could be useful in the future and defence boundary to protect plants in the natural environment (2).

Materials and Methods

The research paper by Panda *et al.* (3) deals with the study of plant diversity, tree regeneration, seedlings, phenology, and fruiting by the Quadrates method. Regional floras such as Haines (1921-25), Gamble and Fischer (1915-1935); Saxena and Brahmam (1994-1996); Mooney (1950) were used for identifying plants. A field study was conducted by Pradhan *et al*. (4), to gather information on medicinal plants used in primary healthcare systems. Interviews with village medicine men and Kavirajs were conducted to identify plants used for various remedies. Spot identification was done with local experts and published flora. Literature was compiled from earlier books by Kirtikar *et al*., with plant names arranged alphabetically. The field study from 2014-2015 by Mahalik *et al*. (5) involved collecting data from 10m × 10m quadrates randomly placed at each study site. The data was analyzed for frequency, density, and dominance, and the Flora of Orissa was used to identify species. The vegetation data was also analyzed for relative density, frequency, and dominance by using a specific formula (5). The study by Reddy *et al*. collected phytosociological data from 100m × 100m quadrates and surveyed all trees of girth at breast height. Species were identified using the Flora of Presidency of Madras and the Flora of Tamil Nadu Carnatic. Shannon and Simpson's index by Magurran 1988, Hill diversity, and Sorensen's similarity indexes were used for species diversity and evenness. The floristic structure was studied using the Importance Value Index of Curtis and Mcintosh (1950) and the sum of Index calculation was by the Relative Basal Area, Relative Frequency, and Relative Density (6).

Literature analysis

'The Global Tree Search', a web-based tool, provides a comprehensive list of 58,497 tree species from around the world that can be used for the analysis, recording, and conservation of biodiversity and forests. Experts, scientific references, and plant databases provide updated information as botanists and taxonomists continue to catalog species diversity and understand relationships among species.

Sacred groves, conserved for religious beliefs, house RET (Rare, Endangered, and Threatened), and endemic plant species. A survey of eco-floristic nature in the Bamanghaty subdivision of Mayurbhanj district found 357 species with 63 families. Restoration of degraded groves requires raising awareness among villagers. Twelve species with strenuous effects on them are *Pterocarpus marsupium* Roxb. (Fabaceae), *Cassia fistula* L. (Fabaceae), *Madhuca indica* var. latifolia (Roxb.) (Sapotaceae), *Shorea robusta* Gaertn. F. (Dipterocarpaceae), *Ficus benghalensis* L. (Moraceae), *Ficus religiosa* (L.) (Moraceae), *Annona reticulata* Linn. (Annonaceae), *Terminalia tomentosa* Roxb (ex DC) (Combretaceae), *Bombax ceiba* L. (Malvaceae), *Azadirachta indica* L. (Meliaceae), *Schleichera oleosa* (Lour.) Oken. (Sapindaceae) and *Mangifera indica* L. (Anacardiaceae). Leguminosae has the highest number of 45 species. Other dominant families include Asteraceae, Euphorbiaceae, Rubiaceae, Acanthaceae, Convolvulaceae, Lamiaceae, Moraceae, Verbenaceae, and Scrophulariaceae (7).

Choudhury and Biswal (8) identified 323 angiospermic plant species in the Nandankanan sanctuary. A comprehensive assessment of floral diversity was conducted, revealing 704 species of plants with 491 genera. The angiospermic flora includes 531 dicots with 377 genera, 24 families, and 155 monocots.

An ethnobotanical survey conducted in Semiliguda block, Koraput district, Odisha, suggests traditional medicinal plant knowledge among native Godaba healers. The survey comprised 50 species, the majority of which were regular with the main family being Euphorbiaceae and Myrtaceae. New data on locally utilized plants indicates the Semiliguda block's unexplored study on medical ethnobotany. It has experienced a decrease in the number of traditional healers, and the younger generation may not be interested in carrying on these traditions (9).

A study that examined the floral diversity in a grassland community in Mayurbhanj, Odisha, found that a grassland community had 32 species, with Poaceae and Linderniaceae contributing the most. The remaining 15 families were Fabaceae, Cyperaceae, Euphorbiaceae, Lythraceae, Molluginaceae, Asteraceae, Phyllanthaceae, Rubiaceae, Poaceae, Convolvulaceae, Scrophulariaceae, Linderniaceae, Violaceae, Commelinaceae, and Acanthaceae (10).

In the northern region of India, a landscape-level plant diversity and population inventory were carried out, with a focus on dry and moist forests. A total of 882 species accounting for 532 genera and 129 families were recorded, including 263 tree species, 78 shrub species, 138 climber/ twinner species, and 403 herb species. The study included 444 transects that counted trees and assessed herb, shrub, and liana species. *Diospyros melanoxylon* Roxb., *Lannea coromandelica* (Houtt.) Merr., *Madhuca indica* Var. latifolia and *Shorea robusta* Gaertn. f were the most common tree species, with Euphorbiaceae, Rubiaceae, Fabaceae, and Combretaceae contributing the most species richness, stand density, and basal area (3).

Cultural and religious activities have long been a part of environmental conservation in the Koraput district of Odisha. The diversity and applications of ninety-four sacred plant species with sixty-three genera and forty-three families have been documented. The plants mostly belong to Caesalpiniaceae, Asteraceae, and Combretaceae families. The plants include forty-eight trees, twenty-six shrubs, and twenty-one herb species (11).

The paper discusses medicinal plant species in the Mandaragiri tribal region, highlighting their medicinal uses. It highlights the rarity of some species and the importance of conserving endangered ones. *Acacia nilotica* (L.) Wild. ex Delile, *Indigofera cassioides* Rottler ex DC., and *Woodfordia fruticosa* (L.) Kurz. are rare, where *Streblus asper* Lour., *Rauvolfia serpentina* L. Benth. ex Kurz., and *Santalum album* L. are included in the endangered category. The inhabitants rely on folk medicine due to poverty and traditional beliefs. Documentation of

medicinal plant availability is crucial for further ethno-medicinal studies. (4).

Traditional herbal medicine has a long history in India, which can help with scientific and cultural studies. Ethnobotanists can study wild plants and their medicinal properties with the help of diverse flora and indigenous tribes. Combining ethnobotanist knowledge with pharmacological findings can lead to productive drugs. India's flora is diverse, with 45,000 plant species and over 400 ethnic groups. 7.5% of the population consists of tribals, forest dwellers, and rural people with unique knowledge of plant resources. The study reports on 135 ethnomedicines used by Indian tribes in Andhra Pradesh, Bihar, Madhya Pradesh, Orissa, Tamil Nadu, Uttar Pradesh, and other eastern parts of India (12).

An ethnobotanical investigation in the Dhenkanal district of Odisha found that local inhabitants traditionally used 109 medicinal plants from 53 families. Out of these, the most common plant species uses were for gastrointestinal ailments - 34, anti-inflammatory and skin diseases - 20, rheumatism - 13, diabetes - 10, cardiovascular ailments - 11, and diuretics - 7. The most commonly used plant parts were leaves, roots, bark, seeds, and fruit for ethno medicines (13).

The Dhenkanal district tribal population relies on folk medicinal healers for treating ailments. A survey of 315 plant species from 25 tribes identified 26 useful for urinary tract infections (UTIs). Out of 265 ethnobotanical notings, 26 were found to be convenient for cystitis. The study suggests that ethnobotanical plants can be used to discover natural products for developing new pharmaceuticals, addressing major therapeutic needs (14).

The literature on lichens in Odisha reveals 252 species which includes 81 genera as well as 35 families. Graphidaceae dominates with 49 species, followed by Arthoniaceae, Pyrenulaceae, Parmeliaceae, Trypetheliaceae, Physciaceae, Teloschistaceae, Lecanoraceae, Pertusariaceae, Ramalinaceae, Caliciaceae, Thelotremataceae, and Lecidiaceae. Lichens are plentily available in 13 out of 30 districts in Odisha. Ganjam, Jharsuguda, and Mayurbhanj districts are well-explored (15).

A study was conducted on the floristic diversity of Northern Tropical Semi-Evergreen forests in the Dhenkanal district of Odisha from 2014-2016. Data was collected using 10mx10m quadrates, and analyzed for ecological and phytosociological purposes. A survey of 320 plant species from 295 genera and 74 families was conducted in the Herbarium (14). The majority of species were tree species - 78, grasses - 63, climbers - 42, herbs - 94, and shrubs - 38. The forest vegetation types depend on climate and soil. The region is divided into three floristic zones. The study reveals that Rubiaceae, Mimosaceae, Euphorbiaceae, Anacardiaceae, and Caesalpiniaceae are the most tree-dominant families among the recorded 74 families. In the herb community, Asteraceae dominate followed by Lamiaceae, Fabaceae, and Malvaceae. Euphorbiaceae, Rutaceae, Verbenaceae, and Apocynaceae are shrub-dominated families. Poaceae dominates within the grass community. The study found only five angiosperm species threatened in the study area, including *Piper longum, Gloriosa superba,* and *Pterocarpus santalinus* (5).

The study explores the ethnobotanical practices in the Rourkela City of Odisha, India. This focused on the application of locally available plants and the conservation of wild as well as cultivated species of plants. A field survey identified 154 plant species, 53 medicinal, 43 ornamentals, 33 edibles, and 23 weeds. The study highlights the importance of proper use of urban flora and the potential for ethnopharmacological applications in medicine. The findings highlight the rich biodiversity in rural and urban areas (16).

The study examined the floristic diversity of grassland in Gangraj village, Mayurbhanj district, Odisha, from June 2019 to December 2019. The community had 23 species, with 9 grasses and 14 non-grass species. The species were grouped into nine families: Rubiaceae, Poaceae, Phyllanthaceae, Onagraceae, Malvaceae, Fabaceae, Cyperaceae, Convolvulaceae, and Asteraceae. The Poaceae family contributed the most species, followed by Cyperaceae, Asteraceae, Fabaceae, Malvaceae, and Rubiaceae. The community was dominated by Poaceae (39.13%) and Cyperaceae (13.04%), with Asteraceae, Malvaceae, Rubiaceae, and Fabaceae contributing 8.69% each, and Convolvulaceae, Onagraceae, and Phyllanthaceae exhibiting the lowest contribution (17).

The study collected six new plant genera in the angiospermic flora of Odisha state, India, including *Calystegia sepium* (L.) R.Br. (Convolvulaceae), *Cymbalaria muralis* (Plantaginaceae), *Gloxinia perennis* (L.) (Gesneriaceae), *Fumaria indica* (L) (Papaveraceae), *Lobularia maritima* (L.) (Brassicaceae), and *Tacca leontopetaloides* (L.) Kuntze (Dioscoreaceae). As global plant diversity declines and species become threatened, these genera were discovered to be new records in the state (18).

The study investigated plant species diversity in a moist forest in the coastal Eastern Ghat of Odisha, specifically in the Balugaon Range. The study involved 15 treatments of 5 plant types and 3 altitudes, resulting in 246 recorded species. Sal (*Shorea robusta* Gaertn. f) is found to be an important species in Eastern Ghat forests (6, 19). This study investigated plant species diversity in a very moist forest in the coastal Eastern Ghat of Odisha, using nested sampling methods. From April 2018 to May 2019, 246 plant species were recorded, including 110 trees, 33 shrubs, 53 climbers, 38 herbs, and 12 grasses. Elevation-wise species composition, Importance Value Index, and Shannon-Wiener index of diversity were used to understand the forest structure and floristics (20).

The study by A. Bhadra *et al*. (21) recorded 232 plant species on the Gandhamardan hills, representing 8.5% of the total 2727 species in Odisha. These species are found in six forest types: tropical semi-evergreen, tropical dry deciduous, scrub-woodland, bamboo, scrub forest, and grassland of the Gandhamardan hill range. Tree, shrub, LTC (Lianas, Twinner, and Clinber), and herb species make

up 37.50%, 15.09%, 12.07%, and 35.34% of the total species recorded in the present study. The dominant families are Poaceae, Fabaceae, Rubiaceae, Euphorbiaceae, Acanthaceae, Lamiaceae, Cyperaceae, Moraceae, Rhamnaceae, and Apocynaceae.

Seventy woody plant species were assessed in the secondary deciduous forest of Chandaka Wildlife Sanctuary, Odisha, India, about diversity, stand structure, and population density. Based on the study findings, a significant correlation was found between basal area and the importance value index (IVI), which may prove useful for the conservation and management of biodiversity (22).

From 2015 to 2020, a taxonomic study of forest trees in Odisha revealed 501 species of wild and naturalized trees, representing 293 genera. The Fabaceae family had the most species along with the genus Ficus representing the most 21 species. Regionally threatened species were identified, which need conservation attention as soon as possible (23).

Recent studies in the Similipal Biosphere Reserve (SBR) have focused on trees and medicinal plants but have not explored climber diversity. The present study explores the floristic composition of 120 climbing plant species in the tropical forests of Similipal Biosphere Reserve. The most species-rich families are Fabaceae and Convolvulaceae, with the dominant genera Ipomoea. The diversity of climbing plants contributes significantly to forest biodiversity and ecosystem balance, and their use and sustainable management are crucial for the economic value contributed by biosphere reserves. This study aims to find climber diversity, their uses, habits, and climbing modes, providing valuable insights for understanding forest ecosystems and the conservation of climbers in tropical forests (24).

Tropical forest ecosystems are disturbed by forest degradation, forest fires, invasive species, and habitat fragmentation. These drivers help play investigating roles in the research of natural ecosystems. This will contribute to the development of strategies for forest conservation, global warming mitigation, and forest reduction. Urbanization, infrastructure development, and agricultural expansion in Odisha have resulted in significant deforestation, with 10 of 30 districts losing more than 10% of their forest cover (25).

Results

Plant Diversity in World

Over 422,000 seed-bearing plants are reported worldwide. More than 50,000 of those plants are used for medicines. Besides, 85% of traditional medicine practices in primary healthcare systems are of plant origin. China and India have the wealthiest range of registered medicinal plants, with 43% of Indian subcontinent plants having medicinal value (4).

Anthropogenic activities are causing a global decline in biodiversity, impacting ecosystem productivity and sustainability. Species losses are crucial for species conservation but also alter key processes. Research has focused on how multiple global change drivers affect biodiversity and ecosystem functions. Key threats include reactive nitrogen deposition from agricultural and industrial activities, climatic warming from greenhouse gas emissions, and rainfall regime changes (26).

In Linnaeus's time, tropical flora was considered small and uniform due to the widespread occurrence of common and ruderal species transported between European colonists. Hans Sloane found similarities among the floras of the East Indies, Portugal, Spain, and the West Indies. Modern biological classification originated in temperate regions with smaller and manageable flora, but not the overwhelming tropical diverse vegetation. Compiling detailed knowledge of botanical richness and floristic composition has been the main business of 20th and 21st century Botany. The total terrestrial plant diversity is estimated to be around 400,000 known species, with 15% still awaiting discovery. Vascular plants include 383,671 species; bryophytes include 20,240; and 7,486 are liverworts and hornworts. Pteridophytes and lycophytes make up 13,269 species. Seed plants have 370,492 species and flowering plants sum up 369,434 species (27).

The plant extinction rate is lowered through well-designed and monitored protected areas, and *ex-situ* conservation through living collections, seed banks, and cryogenic storage systems. The chief obstacles to the goal of zero global plant extinctions are that many plant taxa are unexplored and not described yet, and the absence of tropical taxa in *ex-situ* collections. These taxa cannot have targeted measures of protection because of the low percentage of known taxa that have been studied (28).

Plant Diversity in India

India's research on diversity includes floristic diversity, species richness, endemism, diverse ecosystems, angiosperms, vegetation patterns and phytogeographical analysis. India's diverse flora is attributed to its topological conditions, vast climatic variations, and diverse habitats that support various plant species. Angiosperms account for approximately 18,532 of the 49,003 plant species or 10% of all known flowering plants. In comparison to other angiosperm families, Leguminosae is the most abundant, followed by Poaceae, Orchidaceae, Asteraceae, and Rubiaceae (29). A national database on the richness of Indian plant species was investigated by Behera and Roy (2019). They offered a maiden and indicative richness map of angiospermic plants, with 7761 species from 15,565 nested quadrants across latitudinal and longitudinal gradients (30). Based on Singh *et al*. (2015), there are 4303 endemic angiosperm species with 3170 dicotyledon species belonging to 723 genera, 1133 species of monocots belonging to 254 genera, 1.5% contribution of pteridophytes, and a very low amount of gymnosperms endemic species during the estimation period (31). India has 18,666 angiosperm species, with 25.67% of them being endemic. There are 659 endemic bryophytes among the 2780 species. Algae account for 1960 species (32).

Plant Diversity in Odisha

Odisha is known for its diversity of ecosystems that extend from the northern plateau to the Eastern Ghats, the central table land with its river valley systems, and the coastal plains. It has an exceptional biodiversity heritage. The forest ecosystem is the main terrestrial biome and is home to the majority of the state's biodiversity. Recent surveys have unveiled the impressive presence of approximately 726 species of angiosperms belonging to 496 genera and 120 families (33). The flora of Orissa by Saxena and Brahmam (1996) recorded 2727 plant species in Odisha (34).

A total of 90 plant species placed within 85 genera and 44 families were documented with a vernacular name, habitat, scientific name, and family. 35 trees, 24 herbs, 10 climbers, and 24 shrubs are documented in the Koraput, and Khordha districts of Odisha (35). Odisha, located on the eastern coast of India, is surrounded by West Bengal, Jharkhand, Chhattisgarh, Telangana, and Andhra Pradesh. The geography of the state is divided into four regions: Coastal Plains, Central Table Land, Eastern Ghats, and Northern Plateau. These regions have Mangrove forests, salt-tolerant vegetation, rich in biodiversity, hosting a mix of deciduous and evergreen forests. The annual average temperature of 25°C – 28°C is the reason behind 1,200 mm to about 1,600 mm rainfall. The Forest Survey of India reported tree cover of the State is 5,004 Km^2 (36). Odisha's forest cover is classified as Very Dense, Moderately Dense, Open Forest, and Scrub, with *Shorea robusta* Gaertn. f, a major tree species, abundantly found. Western Odisha's diverse flora, including medicinal plants, orchids, and endemic species, thrives in its transitional tropical/ subtropical climate, characterized by a mix of deciduous and semi-evergreen forests.

Discussion

Need of Plant Diversity

Odisha bears significance in botanical organization and geobotany due to its geographic location, diverse geographical features, and proximity to different floristic zones that have an impact on floral composition. Floristic diversity is the total number of plants present in a specified geographical region. It is an important source of information for botanists, ecologists, gardeners, researchers, and the general public. It is quite helpful to conduct a floristic study in a certain location for everyone to get a deep understanding of the forest management and plant ecosystem of the region at present.

The vegetation of southern Odisha was not scientifically identified for a long time. The first survey was conducted by W. Roxburgh in 1820-1832 in his book “Flora Indica”, While J.D. Hooker’s “The Flora of British India” provided some collection. H.H. Haines covered more parts of Odisha in 1925 and recorded his findings in “Botany of Bihar and Orissa”. The Haines plant identification manual was used by taxonomists and researchers for over 60 years. H.F. Mooney added 153 new species to the list, covering Kalahandi, Bonai, and Keonjhar regions. Other notable floristic Surveyors include S.N. Bal (1942), G. Panigrahi (1963), M.K. Mishra (1979), M.B. Raizada (1948), S. Patnaik (1973) and B.P. Chaudhary (1982). Saxena and Brahmam conducted a comprehensive Floristic survey of Odisha, resulting in the “Flora of Orissa” (1996) (34). Other reports from the Botanical Survey of India, Universities, and other sources also contribute to the flora.

Plants on the other hand are far more vital to us. Plant products are necessary as they provide substances for humans and animals in addition to a wide range of other products and services. It is undeniable that plants have a significant role in biodiversity, providing habitat and food for any array of animal species that exist in the world. Besides agriculture, the plant produces medicine, lumber, and other products with commercial value. It is important to conserve plant diversity to protect these resources while also contributing to the economic development of the local community. Various species of plants contribute to the resilience of the ecosystem while facilitating the adaptation of the ecosystem to climate change.

Loss of Plant diversity

Habitat fragmentation, loss, degradation, destruction, resource overexploitation, alien species invasion, air pollution, Nitrogen deposition, and climate change are the drivers of the decline in plant diversity. Deforestation leads to forest land conversion to pasture land and commercial crops in tropical regions. Reduction in plant diversity promotes non-forest habitats which are threatened by agricultural development, and mining activities.

The continuous drop in biodiversity is widely acknowledged; more concerning, this trend shows no sign of abating; in fact, it may even worsen. Biodiversity loss causes less ecosystem production, diminishes nature’s resilience, and lowers ecosystem services and species interactions.

Conservation of Plant Diversity

Biodiversity conservation is a worldwide concern. Odisha’s unique biogeography and plant species may have global significance due to their unique characteristics. By protecting these species, we contribute to the worldwide effort to conserve biodiversity and sustain a healthy world for the sake of future generations. There is an urgent need for the conservation of plant diversity to ensure ecological balance, economic sustainability, cultural preservation, and the overall well-being of its people (36). The conservation and sustainable management of this diversity are crucial for maintaining the ecological balance and supporting the livelihoods of the local communities. The conservation of biological diversity is a two-way process, with *ex-situ* conservation occurring outside natural habitats like botanical gardens and *in-situ* conservation occurring inside natural habitats like national parks and sanctuaries. Traditional methods for sustainable forest development include declaring sacred grove forests, encouraging large-scale cultivation of valuable species, public awareness, social forestry programs, law enforcement, compulsory planting programs, and

agroforestry models. These methods aim to maximize productivity and sustainable utilization of forest resources, promoting agroforestry models and multipurpose tree species (37).

Conservation Techniques and Methods

Conservation is an interdisciplinary and deliberate effort to address biodiversity loss worldwide (Table 1). It is rooted in the Western worldview and assumes that human agency and technology together, can have a remedial effect on biodiversity loss. Technology states the knowledge accessible for a society to design, produce, maintain, and apply physical objects for sustainable development. The use of science and technology in conservation is a thrust area of research. This provides an opportunity to explore the complex linkage among science, societies, technology, and the natural world (38).

In plant conservation approaches, Biotechnology has the advantage of faster propagation and storage of germplasm, benefiting various species ineffective with seed-based techniques. However, success and social acceptance vary due to unclear perception, implementation, regulation, and funding processes (39, 40).

Biodiversity conservation is crucial for life's survival on Earth. The Convention on Biological Diversity (CBD, 1992) prioritizes biodiversity conservation. Orissa has identified six biodiversity granaries, including Bhitarkanika National Park, Chilika Lagoon, Deomali Hill, Gandhamardan Hill, Similipal Biosphere Reserve, and Mahendragiri Hill. Out of 2727 plant species according to Flora of Odisha (Saxena and Brahmam, 1996), 27 are endemic, mostly found in these granaries (34). The loss of biodiversity due to human exploitation, overpopulation, and natural hazards is a serious threat to sustainable development.

Odisha is home to a wide variety of plants. A large number of plants have been lost, and some endemic and endangered species have disappeared. Because of this, biodiversity conservation in this region is critical for the survival of species and the environment. The government and non-governmental organizations must take immediate action by designating forest areas as sanctuaries and reserve forests, and by encouraging seeds and vegetative propagation as a means of propagating plants.

The IUCN Red List is crucial for biodiversity conservation, but limited resources must focus on species vulnerability, biological distinction, ecosystems, and ecological, social, and economic worth (41). Threatened plant species are increasing as a result of several factors chiefly forest degradation, environmental pollution, species invasion, habitat loss, anthropogenic intervention, climate change, and resource overexploitation. Conservation planning has used a variety of techniques, including *ex-situ* methods, *in-situ* methods, biotechnological approaches, and government legal frameworks. Understanding the interactions between various plant species and human communities can help society's socioeconomic aspects.

Table 1. Major plant resource and diversity documentation centers across the world

Levels	Sl. No.	Name of Centres	Year of Establishment	References
World or Global	1	Royal Botanical Gardens, Kew, London, UK	1959	https://whc.unesco.org/en/list/1084/
	2	Museum National d'Histoire Naturelle, Paris, France	1994	https://plants.jstor.org/partner/P
	3	New York Botanical Garden, New York, USA	1891	https://www.nybg.org/
	4	Natural History Museum, London, England		https://www.nhm.ac.uk/our-science/services/collections/botany.html
	5	Harvard University Herbaria and Libraries	1842	https://huh.harvard.edu/
National or India	1	Central National Herbarium, BSI, Howrah	1890	https://bsi.gov.in/units-page/en?rcu=137,100
	2	CSIR- National Institute of Science Communication and Policy Research, New Delhi		https://niscpr.res.in/facilities/rmham
	3	CSIR-NBRI (National Botanical Research Institute), Lucknow	1932	https://nbri.res.in/r-d-areas/plant-diversity-systematics-and-herbarium/
	4	Institute of Forest Genetics and Tree Breeding, ICFRE, TamilNadu	1988	https://ifgtb.icfre.gov.in/
	5	Wildlife Institute of India, Dehradun, Uttarakhand	1982	https://wii.gov.in/herbarium
State or Odisha	1	Regional Plant Resource Centre, Bhubaneswar	1985	https://rprcbbsr.in/View/general_herbarium.aspx
	2	State Botanical Garden, Nandankanan, Odisha	1963	https://www.nandankanan.org/botanical-garden.php
	3	Utkal University, Bhubaneswar	1969	https://utkaluniversity.ac.in/departments/botany/
	4	CSIR- IMMT, Bhubaneswar	1964	https://www.immt.res.in/environment-sustainability-facilities
e-Resources	1	WCVP, http://wcvp.science.kew.org/		Govaerts, R., Nic Lughadha, E., Black, N., Turner, R., & Paton, A. (2021). The World Checklist of Vascular Plants, a continuously updated resource for exploring global plant diversity. *Scientific Data*, *8*(1), 215 (50).
	2	IPNI, http://www.ipni.org		
	3	WCSP, http://wcsp.science.kew.org/)		

in-situ and *ex-situ* Methods

Biodiversity encompasses various levels of variation in the natural world, including genetic, species, and ecosystem diversity. It has various environmental, cultural, social, economic, medical, scientific, educational, and aesthetic values. However, biodiversity is being lost rapidly due to natural and anthropogenic factors. Threats include agricultural expansion, overexploitation, urbanization, pollution, forest fires, exotic species invasion, Genetically Modified Organisms (GMOs), and global climate change. To maintain biodiversity, complementary *in-situ* and *ex-situ* conservation approaches (Fig. 1), prioritizing ecosystems, species, and populations, promoting indigenous resource management, local involvement, and adequate resources are essential (42).

In-situ conservation is the process of maintaining or recovering viable species populations in their natural habitats, particularly for domesticated or cultivated species. The main goal is to protect, manage, and monitor these populations to maintain natural evolutionary processes and generate new variations in the gene pool. This process relies on identifying habitats, protecting both species and habitats and addressing threats to threatened species (43).

The conservation of plant species *in-situ* involves maintaining protected areas and addressing species and population levels. Despite efforts to conserve species, only a small percentage of threatened species are protected, largely by a few countries. The Convention on Biological Diversity's planning fails to coordinate actions, leading to confusion (44).

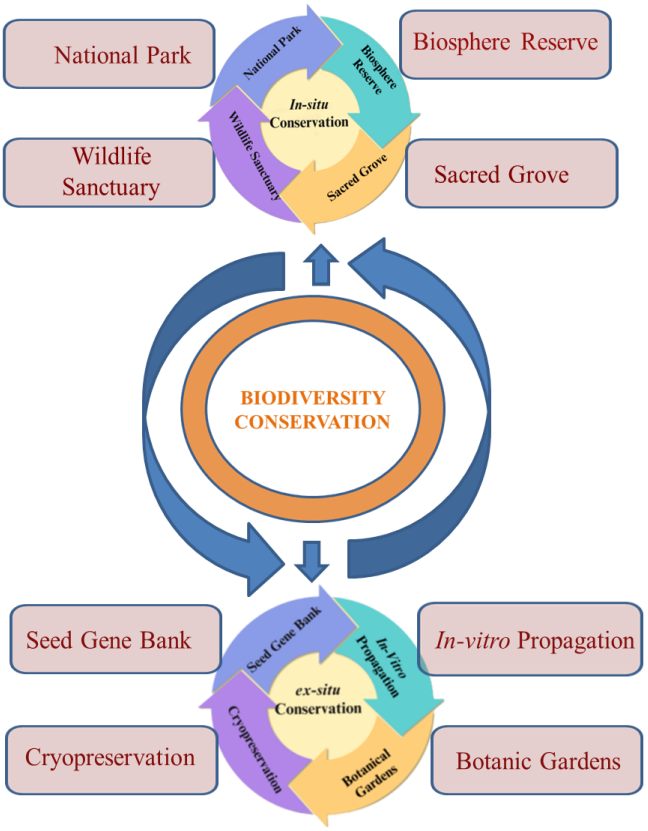

Fig. 1. Biodiversity Conservation Methods.

Botanic gardens manage 30% of all plant species diversity and conserve over 41% of threatened species. However, they are disproportionately temperate, with 93% of species in the northern hemisphere. Botanic gardens are addressing the threat of extinction, but only 10% of the network capacity is dedicated to the conservation of threatened species. Botanic gardens play a fundamental role in plant conservation, but actions to enhance future biodiversity conservation are needed. Botanic gardens play a crucial role in conserving plant diversity and preventing species extinctions. The first Botanic Gardens Conservation Strategy was published in 1989, and the Global Strategy for Plant Conservation (GSPC) was adopted in 1998. The GSPC outlines sixteen targets, including knowledge, conservation, sustainable use, awareness, and capacity-building activities. Botanic gardens are key to achieving GSPC Target 8, which requires at least 75% of threatened plant species in *ex-situ* collections and 20% for recovery and restoration programs by 2020 (45).

Plant resources are crucial for human survival and development, but they are threatened by human and natural disturbances. *Ex-situ* conservation is essential to protecting these resources. Botanical gardens and germplasm banks protect over 105,634 plant species, with China's botanical gardens and banks preserving 60% of the total. Scientific research and resource utilization are crucial for strengthening *ex-situ* conservation. The report suggests a nationwide management mechanism for *ex-situ* plant conservation, strengthening the national botanical garden system, and improving laws and regulations. We should enhance its *ex-situ* conservation efforts by collaborating with scientific research, knowledge dissemination, ecological recreation, and resource utilization. Utilizing new technologies like citizen science, the internet, big data, and Artificial Intelligence (AI) can benefit society. More funding is needed for capacity building, including a skilled staff team, standards preparation, germplasm exchange platforms, backup banks, and safe preservation. They should also establish international cooperation mechanisms, participate in international conventions and agreements, and promote the Belt and Road Initiative. This will improve botanical gardens' *ex-situ* conservation, capacity building, and environmental impact (46).

In vitro Methods

Protocols of *in vitro* propagation were introduced for numerous valuable, rare, and endangered plant species (47). *In vitro* conservation methods vary based on storage duration. Short-term methods aim to reduce growth and increase subculture intervals. Long-term methods use cryopreservation at ultra-low temperatures, like liquid nitrogen, to prevent cellular divisions and metabolic processes. These techniques require minimal maintenance and small-volume sample protection.

Cryopreservation Technique

Some materials, such as seeds or buds, can be cryopreserved without further processing. However, because most cryopreservation systems contain a large

amount of cellular water, they are vulnerable to freezing injury. To prevent ice crystallization, cells are artificially dehydrated. Traditional cryopreservation techniques involve freeze-induced dehydration, whereas newer techniques use vitrification to convert water to an amorphous phase (48).

Research Gaps and Future Concerns

Out of the 50,000 plant species used for medicinal purposes globally, 13% belong to angiosperms (49). More than 8,000 plant species are used in traditional and modern medicine in India. However, 90% of these plants are collected from the wild, with 70% involving destructive and unsustainable extraction. Overexploitation, destructive collection methods, and anthropogenic pressure pose major threats to medicinal plants. Sustainable harvesting requires a multi-disciplinary approach considering ecological, biological, socio-cultural, and economic aspects (50). Anthropogenic factors, invasive plant species, and the declining abundance of climbing species like *Aristolochia indica* L., *Asparagus racemosus* L., and *Gymnema sylvestre* R. Br. are major threats to the local biodiversity of Odisha. To ensure the long-term survival of climbing plants, local people must be educated on their conservation, and a multi-pronged approach should be taken, including habitat protection, restoration, invasive species management, and collaboration among stakeholders (51). Traditional knowledge of plants is essential for nutrition, herbal medicine, perfumery, and cosmetics. Multidisciplinary research is being carried out worldwide to develop innovative and marketable ideas and products. Conservation and sustainable utilization of bioresources are crucial for future generations and the existence of earth society. However, measures are inadequate in conserving biodiversity, especially for Rare, Endangered, and Threatened (RET) listed plant species, highlighting the need for conservation (52). Traditional conservation ethics safeguard plant diversity and natural resources, but there is little global support for modern methods, even though local communities are key players (53). The study by Adhikari *et al*. (2010) focuses on the conservation and sustainable utilization of medicinal plants in nearby areas, highlighting their status, altitudinal range, nativity, parts used, uses in ailments, and conservation efforts (54).

Conclusion

Identifying exceptional plant species is crucial for developing an *ex-situ* conservation strategy. Seed banking efforts may not accommodate exceptional cases of species. Therefore, curated living and cryo-collections must work alongside seed banks. This definition and baseline list can focus on conservation interventions, aligning with international initiatives like the Sustainable Development Goals (SDG 13 and SDG 15) and the Global Strategy for Plant Conservation. Prioritizing conservation actions for threatened or high conservation concern species helps identify gaps in knowledge and track progress. Numbers of sacred groves in Odisha require continued inventory and research for conservation and eco-restoration. Undocumented groves need documentation for better conservation. Further research on ecology and socioeconomic mechanisms associated with natural resources is to be understood and implemented in biodiversity conservation. Forests are vital for the tribal people and local communities, requiring conservation prioritization and active support. Indigenous Knowledge (IK) complements scientifically-based systems, often combining traditional and new methods specific to a site, culture, and project. It improves communication among farmers, extension agents, and scientists, and provides the basis for grassroots-level decision-making at the community level through Indigenous organizations, associations, and time-specific technologies.

Acknowledgments

The authors acknowledge the support from Centurion University of Technology and Management.

Authors' contributions

The first author collected literature, and data, wrote the article, and formatted the article according to the Journal; and the second author contributed to the editing, revision, plagiarism compliance, and checking.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None.

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