**Medicinal Plants the Nature’s Pharmacy:** **Challenges and Progress in Conservation**

***A Review Article***

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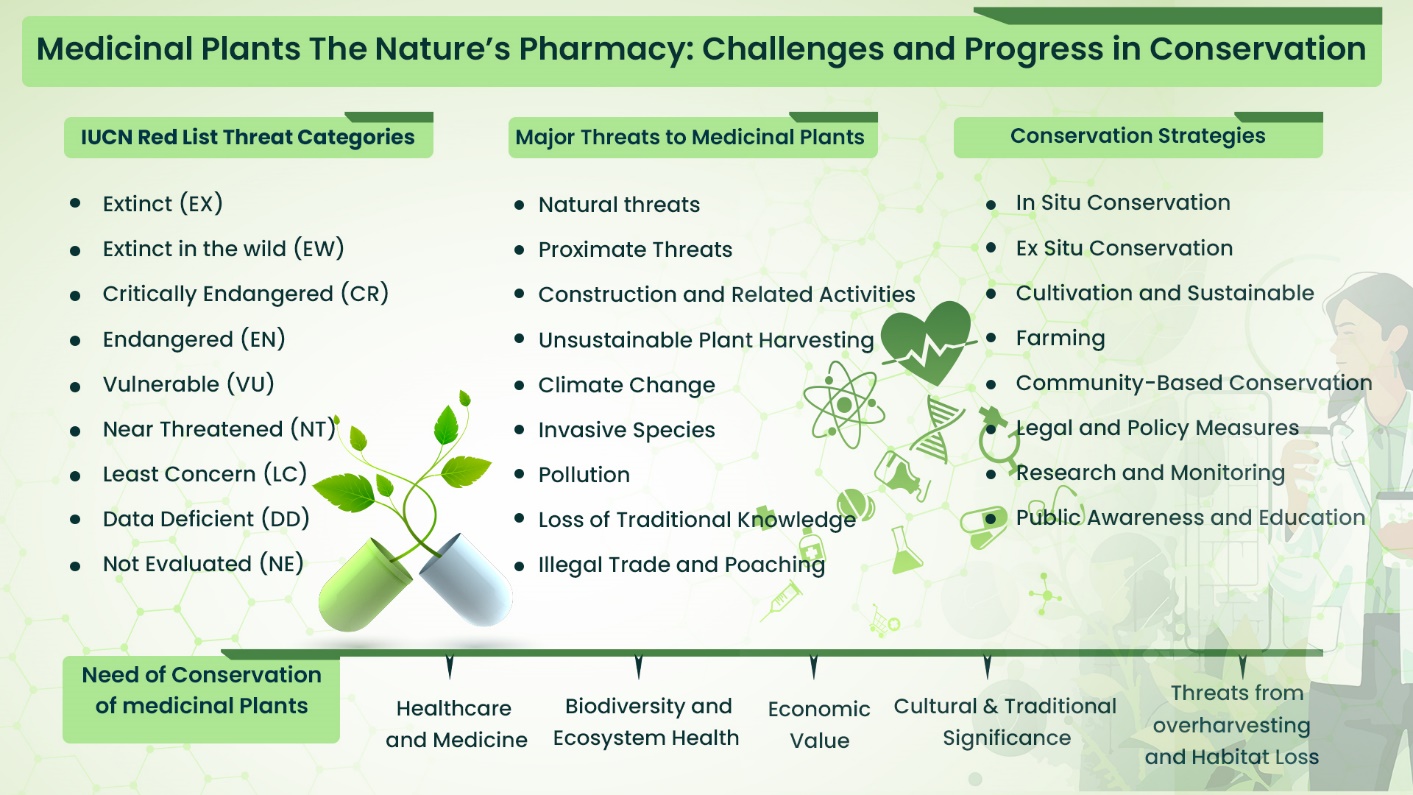
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**Abstract**

Medicinal plants continue to play a vital role in healthcare systems worldwide, offering a rich source of bioactive compounds that support both traditional therapies and the discovery of modern drugs. This review brings together recent evidence on their ecological value, pharmacological potential, and socio-economic importance, while drawing attention to the urgent challenges posed by habitat destruction, overharvesting, and climate change. Current findings indicate that many species face rapid decline, threatening not only biodiversity but also the continuity of indigenous knowledge and community livelihoods. To address this, the review discusses sustainable conservation measures such as in situ and ex situ protection, domestication and cultivation practices, community-led initiatives, and the application of modern biotechnological tools for genetic resource preservation. By integrating these approaches, conservation can ensure a steady supply of plant-derived resources, maintain cultural traditions, and open new pathways for therapeutic innovation.

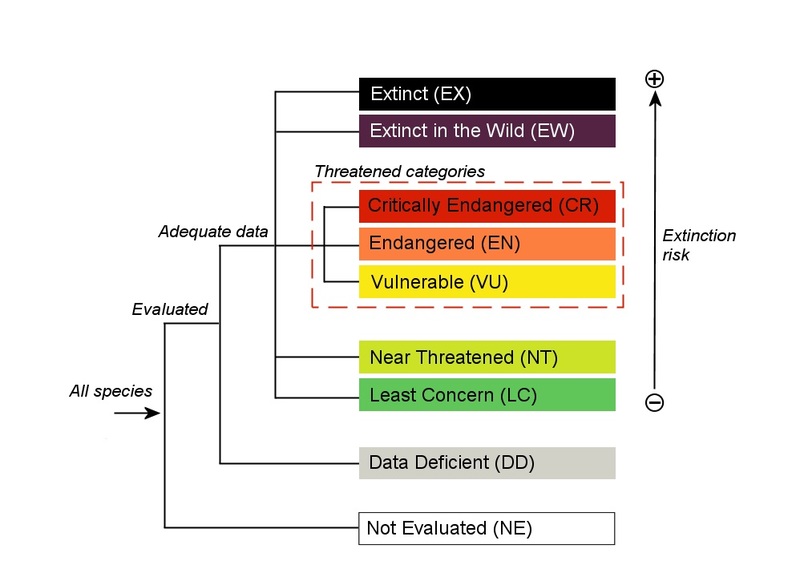
**Keywords:** Medicinal plants, conservation strategies, phytochemicals, sustainability, biodiversity, drug discovery

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**Graphical Abstract**

**1.0 Introduction**

Natural resources are naturally occurring materials, such as plants, water, minerals, and soil, that can be directly used or managed for the benefit of human societies. Their conservation and sustainable use are essential to ensure their ongoing access and availability for future generations. Increasing human interactions lead to the loss of plant resources by causing their habitat loss, species loss, degradation and fragmentation. Nature has bestowed India with an enormous wealth of medicinal plants, due to which the country is often referred as ‘Medicinal Garden’ or ‘Botanical Garden’ of the world (1)**.** Comment given by Wood ‘The race to save biodiversity is being lost, and it is being lost because the factors contributing to its degradation are more complex and powerful than those forces working to protect it.’ (2)The conservation of plant diversity has received considerably less attention than the conservation of animals, perhaps because plants lack the popular appeal of many animal groups (3). As a result, plant conservation is greatly under-resourced in comparison with animal conservation (4).



**Figure.1 IUCN Red List threat categories and their risk level (Reference: IUCN 2022)**

With an increasing sense of urgency, resources conservation is required and needful steps have to be taken to conserve the resources for future generations and proper functioning of our ecosystem.

India is floristically rich and is globally recognized as one of the 12 megadiversity countries (5) accompanied by 10 biogeographic regions (6) along with more than 40 sites that are well-known for their genetic diversity and high endemism, in their updated list of Earth’s biodiversity hotspots, involved 2 from India.

In this review emphasis is given for conserving the medicinal plants, because they are the foundation of traditional and modern medicine. [Many pharmaceuticals are derived from plant compounds, and preserving these plants ensures we continue to have access to potential new treatments and cures](https://www.mdpi.com/2071-1050/16/14/5841) (7). Moreover, Medicinal plants contribute to the overall biodiversity of ecosystems. Protecting them helps maintain ecological balance and supports the health of other species within the ecosystem. Thus, there arises a need for healthy populations of medicinal plants that will contribute to the stability of ecosystems, which in turn supports soil health, water quality, and climate regulation. One of the most important aspect of conserving medicinal plants is that it will assist in economic stability as medicinal plants can be a source of income for local communities through sustainable harvesting and cultivation. This economic benefit can incentivize conservation efforts (Wani et al 2021) (8). Conserving these plants helps preserve cultural knowledge and practices that have been passed down through generations and medicinal plants will also play a role in food security and nutrition, providing essential nutrients and health benefits to communities

**2.0** **Major Threats to Plant Resources-**

Our planet has different types of climatic and altitudinal variations along with undulating topography and various kind of ecological habitats. These conditions attributed in development of rich flora of different kind of medicinal plants which serve as raw material for pharmaceutical industries and traditional medicine systems. With the growing pressure for medicinal plants, most of which is still experienced by wild collection, consistent pressure is generated on the existing resources which finally leads to the reduction of some forest species and also at the same time the forest land suffers the loss of its natural fora at an alarming rate (9).

In order to control this situation, various steps have been taken such as commercial cultivation and habitat conservation, to set up the natural reserves and to implement the laws for exporting the plants which should be kept under control (10). With increasing awareness people became more aware regarding health and medications they use. Now a day’s people rely on herbal medicines. The use of medicinal plants is growing speedily globally with the growing pressure for natural health products, herbal drugs, and secondary metabolites of medicinal plants (11,12). Loss of habitat, degradation, fragmentation, invasive species, pollution, overexploitation for byproducts and adverse climatic changes are some major threats to plant diversity. Now a days many plant species are on the urge of extinction. On global scale plant conservation is a tedious task.it can be managed by proper awareness, knowledge, planning, implementation and back-up for filling the gaps. Due to habitat destruction and overharvesting, approximately 15,000 species are at risk of extinction, and with the growing human population and plant utilization, around 20% of the wild resources have almost already been depleted (13,14).With the rapid loss of biodiversity and habitat destruction, the threat of vanishing of medicinal plants has been increased globally, and this menace has been well-known for decades particularly in India, Nepal, Tanzania, Uganda, and China (11,15,16).Top of FormBottom of Form

Major threats to plant resources, especially medicinal plants, include the following:

**Natural Threats** – Many types of natural threats like land slide, volcanic eruptions, hurricanes, climatic changes cause loss of plant species growing in that particular area. In last few decades due to increase in temperature and other factors there has been increase in forest fires that is destroying large areas of vegetation, leading to the loss of plant resources. Climate change and land-use changes have made some areas more prone to frequent and intense wildfires.

**Proximate Threats** – Loss of habitat is very important proximate threat for plant extinction. There are some other threats also exist like land use in various ways also cause loss of plant diversity. Expansion of agriculture, intensification of agriculture, degradation of cultivated land, inappropriate way of grazing, burning, hunting, afforestation with exotic species. The conversion of diverse ecosystems into agricultural lands, especially for monoculture crops, reduces plant diversity and contributes to habitat loss. Monocultures also increase vulnerability to pests, diseases, and climate fluctuations.

**Construction and related activities** – urban expansion and other construction, mining and quarrying. Moreover, Deforestation, urbanization, logging, and infrastructure development has lead to the loss of natural habitats, which threatens plant populations. Forests, wetlands, and grasslands, which harbor diverse plant species, are particularly vulnerable to Habitat Destruction. Rapid road construction, mining, and industrial development lead to habitat fragmentation, reducing plant populations and disrupting ecosystems.

**Unsustainable Plant Harvesting** – Harvesting of trees for timber, wood for furniture and other purposes and harvesting for their products also causing their depletion because harvesting rates are greater than recovery rates. Over-harvesting and unsustainable harvesting of medicinal plants, often driven by high demand in local and global markets, has also lead to a rapid decline in plant populations, making it difficult for them to regenerate

**Climate Change**: Changes in temperature, rainfall patterns, and extreme weather events impact plant growth, flowering, and seed production. Climate change also alters ecosystems, making it harder for plants to adapt and survive in their native habitats.

**Invasive Species** – There are many invasive species which do not allow other important plants to grow and they disappear from their habitat. Non-native plant species can invade and outcompete native plants for resources such as water, nutrients, and sunlight. This competition can lead to the decline or extinction of indigenous plant species.

**Pollution**: Industrial activities, agricultural runoff, and the use of pesticides and herbicides can contaminate soil and water, affecting plant health and growth. Air pollution can also impact photosynthesis and overall plant vitality.

**Loss of Traditional Knowledge**: As indigenous communities face displacement or adopt modern lifestyles, traditional knowledge about medicinal plants and their conservation is at risk of being lost, leading to a decline in the sustainable use of these resources.

**Illegal Trade and Poaching**: The black-market trade in rare and endangered plants, often driven by the high value placed on certain species for medicinal, ornamental, or culinary purposes, poses a significant threat to plant conservation.

Addressing these threats requires a combination of Conservation-Efforts, sustainable harvesting practices, policy regulations, community involvement, and the integration of traditional knowledge with modern conservation strategies.

**3.0 Conservation of Medicinal Plants**

A natural resource is one that is offered by nature without any human involvement. The soil, minerals, forests, water, etc. are examples of a county’s natural resources. Complexity and costs of managing sustainable use of wild populations increase markedly with an increasing number of uses and resource users. The conservation of biodiversity is a global issue, often predicated by governments and communities on the intrinsic value of biodiversity (17). There is also awareness that biodiversity can provide financial returns (18). These values were traditionally tied to ethnobotanical uses of biodiversity for food, fiber, medicines and cultural reasons (19). The present-day cry of environmental degeneration, fragmentation, ecological genocide, genetic erosion, and extinction as well as destruction of our biological heritage is the result of inaction (20). As per Ayurvedic Pharmacopoeia of India, around 396 plant species are used in different Ayurvedic formulations. Out of these, 30 species have been included in the Red Data Books of Indian Plants published by the BSI to prioritize them for conservation (Table1).  
Conservation of medicinal plants is today’s utmost requirement because of their multipurpose use in herbal medicines, pharmaceuticals and cosmetics. Many of them are on the urge of extinction or already extincted. Medicinal plants and their natural habitats are threatened due to overexploitation. The conservation of the endangered medicinal plant species in their natural habitats and to achieve their sustainable exploitation in less vulnerable areas is our utmost goal (21).

**Table 1.** Updated list of medicinal plants under the category (medicine: plants and animals) in different threat categories as per IUCN (Original Source: IUCN 2020, Taken From - 22).

| **Critically Endangered (CR) Aconitum chasmanthum Stapf ex Holmes, Aquilaria malaccensis Lam. = A. agalocha Roxb.ex DC., Ceropegia odorata Nimmo ex J. Graham, Chlorophytum borivilianum Sant., Commiphora wightii (Arn.) Bhandari, Gentiana kurroo Royle., Gymnocladus assamicus Kanjilal, Lilium polyphyllum Don., Nardostachys jatamansi DC., Paphiopedilum druryi (Bedd.) Stein., Saussurea costus (Falc.) Lipsch., Tribulus rajasthanensis Bhandari & Sharma, Utleria salicifolia Bedd., Valeriana leschenaultia DC.** |
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| **Endangered (EN)**  Aconitum heterophyllum Wall., Angelica glauca Edgew., Cinnamomum wightii C.F.W.Meissn, Coffea arabica L., Commiphora stocksiana Engl., Coptis teeta Wall., Curcuma caulina J. Graham, Cycas beddomei Dyer., Cycas circinalis L., Decalepis hamiltonii Wight & Arn., Dysoxylum malabaricum Bedd., Gymnema khandalense Santapau, Humboldtia vahliana Wight, Illicium griffithii Hook. F. & Th., Iphigenia stellata Blatter, Lamprachaenium microcephalum Benth., Nepenthes khasiana Hook.f., Pimpinella tirupatiensis Bal. & Sub., Piper barberi Gamble., Pterocarpus indicus Willd., Shorea tumbuggaia Roxb., Syzygium alternifolium (Wt.) Wall., Taxus contorta Griff., Taxus wallichiana Zucc. |
| **Vulnerable (VU)**  Aconitum violaceum Jacq. EX Stapf, Anacyclus pyrethrum (L.) Lag., Boesenbergia siphonantha (King ex Baker) M.Sabu, Prasanthk. & Škornick., Boswellia ovalifoliolata Bal & Henry., Calophyllum apetalum Willd., Cayratia pedata Juss. ex Gagnepain, Cephalotaxus mannii Hook. f., Cinnamomum macrocarpum Hook., Cinnamomum sulphuratum Nees., Curcuma pseudomontana J. Graham, Cycas nathorstii J. Schust., Diospyros candolleana Wight, Diospyros paniculata Dalz., Dipterocarpus alatus Roxb. & G. Don, Dipterocarpus costatus Gaertn. f., Dipterocarpus gracilis Blume, Etlingera fenzlii (Kurz) Škorničk. & M.Sabu, Garcinia indica (Dup.) Choisy, Hopea odorata Roxb., Hydnocarpus pentandrus (Buch.-Ham.) Oken, Ilex embelioides Hook. f., Jatropha nana Dalzell & A. Gibson, Magnolia nilagirica (Zenker) Figlar, Malaxis muscifera (Lindley) Kuntze, Myristica dactyloides Gaertn., Nilgirianthus ciliates (Nees) Bremek., Ochreinauclea missionis (Wall.ex G.Don) Ridsdale, Phyllanthus indofischeri Bennet., Piper pedicellatum C. DC., Rhynchosia heynei Wight & Arn. = Rhynchosia coodoorensis Bedd., Salacia oblonga Wall., Santalum album L., Terminalia pallida Brandis, Vanda spathulata (L.) Spreng. |
| **Near Threatened (NT)**  Albizia thompsonii Brandis, Allium roylei Stearn, Cupressus cashmeriana Royle ex Carriere, Dioscorea hamiltonii Hook. f., Dipterocarpus tuberculatus Gaertn. f., Mangifera andamanica King, Pterocarpus marsupium Roxb., Pterocarpus santalinus L.f. |
| **Least Concern (LC)**  Abelmoschus crinitus Wall., Abelmoschus ficulneus (L.) Wight & Arn. ex Wight, Acacia aneura F. Muell ex Benth., Acacia auriculiformis A. Cunn. ex Benth., Acacia nilotica (L.) Willd. ex Delile, Acanthus ebracteatus Vahl, Acanthus ilicifolius L., Acanthus volubilis Wall., Acer caesium (Reinw. Ex Blume) Kosterm, Acer laevigatum Wall., Acer pseudoplatanus L., Acmella paniculata (Wall. ex DC.) R.K.Jansen, Acorus calamus L., Acorus gramineus Aiton, Adenosma indianum (Lour.) Merr., Adenostemma viscosum J.R.Forst. & G. Forst., Adiantum capillus-veneris L., Aegiceras corniculatum (L.) Blanco, Aeschynomene indica L., Alangium salviifolium (L. f.) Wangerin, Alchornea rugosa (Lour.) Müll.Arg., Alisma plantago-aquatica L., Alnus nepalensis D.Don, Alnus nitida (Spach) Endl., Alocasia fornicate (Roxb.) Schott, Alocasia odora (Lindl.) K.Koch, Alpinia nigra (Gaertn.) Burtt, Alternanthera sessilis (L.) R.Br. ex DC., Alysicarpus bupleurifolius (L.) DC., Ammannia auriculata Willd., Ammannia baccifera L., Amorphophallus paeoniifolius (Dennst.) Nicolson, Andira fraxinifolia Benth., Aphanamixis polystachya (Wall.) R.Parker, Archidendron ellipticum (Blanco) I.C.Nielsen, Artocarpus hirsutus Lam., Arundo donax L., Astragalus tribuloides Delile, Avicennia marina (Forssk.) Vierh., Azadirachta indica A.Juss., Azolla pinnata R. Br., Bacopa monnieri (L.) Wettst., Baphia nitida Lodd., Barringtonia acutangula L. Gaertn., Barringtonia racemosa (L.) Spreng., Bauhinia acuminata L., Bauhinia purpurea L., Beilschmiedia roxburghiana Nees., Berberis aristata DC., Betula alnoides Buch.-Ham. ex D.Don, Betula utilis D.Don, Biancaea decapetala (Roth) Alston = Caesalpinia decapetala (Roth) Alston, Bidens cernua L., Bidens tripartita L., Bischofia javanica Blume = Bischofia javanica var. toui (Decne.) Müll.Arg., Boesenbergia rotunda (L.) Mansf. = Boesenbergia pandurata (Roxb.) Schltr., Bolboschoenus maritimus (L.) Palla, Brachiaria mutica (Forssk.) Stapf, Brachiaria reptans (L.) C.A.Gardner & C.E.Hubb, Bridelia stipularis (L.) Blume = Bridelia scandens (Roxb.) Willd., Caesulia axillaris Roxb., Cajanus scarabaeoides (L.) Benth. = Atylosia scarabaeoides (L.) Benth., Calophyllum inophyllum L., Camellia kissii Wall., Cananga odorata (Lam.) Hook.f. & Thomson, Capparis spinosa L., Carex filicina Nees., Carex phacota Spreng., Caryota urens L., Cassia javanica L., Casuarina equisetifolia L., Catabrosa aquatica (L.) P.Beauv., Celtis australis L., Cenchrus hordeoides (Lam.) Morrone, Centella asiatica (L.) Urb. = Hydrocotyle asiatica L., Centipeda minima (L.) A.Braun & Asch., Centrostachys aquatic (R.Br.) Moq., Cerasus cerasoides (Buch.-Ham. ex D.Don) S.Ya.Sokolov = Prunus cerasoides Buch.-Ham. ex D.Don., Ceratopteris thalictroides (L.) Brongn., Chamaecrista absus (L.) H.S.Irwin & Barneby = Cassia absus L., Chlorophytum tuberosum (Roxb.) Baker, Christia vespertilionis (L.f.) Bakh.f., Chukrasia tabularis A.Juss., Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm, Colocasia esculenta (L.) Schott, Colvillea racemosa Bojer, Commelina benghalensis L., Commelina clavata C.B.Clarke, Commelina diffusa Burm.f., Commelina erecta L., Commelina imberbis Ehrenb. ex Hassk., Cordia dichotoma (Ruiz & Pav.) Gürke = Cordia bifurcata Roem. & Schult., Cotinus coggygria Scop., Cressa cretica L., Crinum viviparum (Lam.) R.Ansari & V.J.Nair, Crotalaria albida Roth, Crotalaria assamica Benth. = Crotalaria burmannii DC., Crotalaria micans Link = Crotalaria dombeyana DC., Crotalaria paniculata Willd., Crotalaria quinquefolia L., Croton argyratus Blume, Cryptocoryne ciliate (Roxb.) Fisch. ex Wydler, Cryptocoryne retrospiralis (Roxb.) Kunth, Curanga amara Juss. = Picria fel-terrae Lour., Curcuma haritha Mangaly & M.Sabu, Curcuma inodora Blatt., Cyanotis arcotensis R.S.Rao, Cyanotis axillaris (L.) Schult. F. = Cyanotis axillaris (L.) D.Don ex Sweet., Cyathocline purpurea (Buch.-Ham. ex D.Don) Kuntze., Cynometra ramiflora L., Cyperus alopecuroides Rottb., Cyperus articulatus L., Cyperus cephalotes Vahl., Cyperus compressus L., Cyperus cyperoides (L.) Kuntze, Cyperus difformis L., Cyperus diffuses Vahl, Cyperus distans L.f., Cyperus dives Delile, Cyperus esculentus L., Cyperus exaltatus Retz., Cyperus haspan L., Cyperus iria L., Cyperus laevigatus L., Cyperus platyphyllus Roem. & Schult., Cyperus pumilus L. = Pycreus pumilus (L.) Nees., Cyperus stoloniferus Retz., Cyperus tuberosus Rottb. = C. rotundus L., Delonix elata (L.) Gamble = Poinciana elata L., Desmodium adscendens (Sw.) DC., Desmodium barbatum (L.) Benth., Desmodium elegans DC., Desmodium microphyllum (Thunb.) DC.. = Leptodesmia microphylla (Thunb.) H. Ohashi & K. Ohashi (IPNI), Dichrostachys cinerea (L.) Wight & Arn, Dicranopteris linearis (Burm. f.) Underw., Drosera burmanni Vahl., Drosera indica L., Drosera peltata Thunb., Echinochloa colona (L.) Link, Echinochloa picta (K.D.Koenig) P.W.Michael, Eclipta prostrata Kehraj., Eclipta alba (L.) Hassk., Elaeagnus rhamnoides (L.) A.Nelson. = Rhamnoides hippophae Moench., Eleocharis acicularis (L.) Roem. & Schult., Eleocharis geniculata (L.) Roem. & Schult., Eleusine indica (L.) Gaertn, Engelhardtia roxburghiana Lindl., Enhalus acoroides (L.f.) Royle, Enydra fluctuans DC., Epaltes divaricata (L.) Cass., Ephedra foliata Boiss. ex C.A.Mey., Ephedra intermedia Schrenk & C.A.Mey., Ephedra kardangensis P.Sharma & P.L.Uniyal, Ephedra major Host, Epilobium hirsutum L., Epilobium latifolium L., Erythrina variegata L., Ethulia conyzoides L.f., Euryale ferox Salisb., Excoecaria agallocha L., Fimbristylis dichotoma (L.) Vahl, Floscopa scandens Lour., Fraxinus floribunda Wall., Fuirena umbellata Rottb., Gloriosa superba L., Gmelina arborea Roxb., Gmelina asiatica L., Gmelina elliptica Sm. = G. villosa Roxb., Gnetum gnemon L., Gnetum montanum Markgr., Gnetum ula Brongn. = G. pyrifolium Miq. Ex Parl., Gordonia obtusa Wall. ex Wight, Grangea maderaspatana (L.) Poir., Grewia asiatica L., Grewia villosa Willd., Harpullia arborea (Blanco) Radlk., Helicia nilagirica Bedd., Heliciopsis terminalis (Kurz) Sleumer = Helicia terminalis Kurz, Heliotropium ovalifolium Forssk. = Euploca ovalifolia (Forssk.) Diane & Hilger, Hemarthria compressa (L.f.) R.Br., Hemisteptia lyrata Fisch. & C.A.Mey., Heritiera littoralis Aiton, Hibiscus tiliaceus L., Homonoia retusa (Graham ex Wight) Müll.Arg., Homonoia riparia Lour., Hoppea dichotoma Willd, Hydrilla verticillata (L.f.) Royle, Hydrocotyle sibthorpioides Lam., Hydrolea zeylanica (L.) Vahl, Hygrophila auriculata (Schumach.) Heine., Hygrophila pinnatifida (Dalzell) Sreem., Hygrophila polysperma (Roxb.) T.Anderson, Hygrophila salicifolia (Vahl) Nees., Hygrophila schulli M.R.Almeida & S.M.Almeida = H. auriculata (Schumach.) Heine., Indigofera linifolia (L. f.) Retz., Indigofera oblongifolia Forssk., Indigofera trita L. f., Ipomoea aquatica Forssk., Ipomoea cairica (L.) Sweet, Ipomoea coptica (L.) Roth ex Roem. & Schult., Iris pseudacorus L. = Limnirion pseudacorus (L.) Opiz, Ixora grandifolia Zoll. & Moritzi, Juglans regia L., Juncus decipiens (Buchenau) Nakai, Juncus effuses L., Juniperus communis L., Knema globularia (Lam.) Warb., Kyllinga brevifolia Rottb., Kyllinga bulbosa P.Beauv., Kyllinga nemoralis (J.R.Forst. & G.Forst.) Dandy ex Hutch. & Dalziel., Lagenandra ovate (L.) Thwaites, Lagenandra toxicaria Dalzell, Lasia spinosa (L.) Thwaites, Lemna minor L., Leptochilus decurrens Blume, Lespedeza cuneata (Dum.Cours.) G.Don, Limnophila aromatica (Lam.) Merr., Limnophila indica (L.) Druce, Limnophila polystachya Benth., Limnophila repens (Benth.) Benth., Limnophila rugosa (Roth) Merr., Limnophyton obtusifolium (L.) Miq., Lindernia anagallis (Burm.f.) Pennell, Lindernia antipoda (L.) Alston, Lindernia ciliate (Colsm.) Pennell, Lindernia crustacea (L.) F.Muell. = Torenia crustacean (L.) Cham. & Schltdl., Lindernia oppositifolia (L.) Mukerjee, Lindernia procumbent (Krock.) Philcox, Lindernia pusilla (Willd.) Bold., Lindernia ruellioides (Colsm.) Pennell, Liquidambar excelsa (Noronha) Oken = Altingia excelsa Noronha, Lobelia heyneana Schult., Ludwigia hyssopifolia (G.Don) Exell, Ludwigia octovalvis (Jacq.) P.H.Raven., Ludwigia perennis L., Lygodium microphyllum Link. = L. japonicum (Thunb.) Sw., Magnolia baillonii Pierre, Magnolia champaca (L.) Baill. ex Pierre = Michelia champaca L., Magnolia oblonga (Wall. ex Hook.f. & Thomson) Figlar, Malus baccata (L.) Borkh., Marsilea minuta L., Marsilea quadrifolia L., Mecopus nidulans Benn., Medicago sativa L., Meistera masticatorum (Thwaites) Skornick.& M.. F. Newman, Melia azedarach L., Melicope lunu-ankenda (Gaertn.) T.G. Hartley, Mentha arvensis L., Menyanthes trifoliate L., Merremia gangetica Cufod., Mimusops elengi L., Monochoria hastate (L.) Solms, Monochoria korsakowii Regel & Maack, Monochoria vaginalis (Burm. f.) C. Presl, Mucuna bracteata DC., Musa acuminate Colla, Musa balbisiana Colla, Myriophyllum indicum Willd., Myriophyllum oliganthum (Wight & Arn.) F. Muell., Myriophyllum tuberculatum Roxb., Myriophyllum verticillatum L., Nageia wallichiana (C.Presl) Kuntze, Nasturtium officinale R.Br., Neottia acuminate Schltr., Nephrolepis undulate (Afzel. ex Sw.) J. Sm., Nerium oleander L., Nymphaea alba L., Nymphaea nouchali Burm.f., Nymphaea pubescens Willd., Nymphaea tetragona Georgi, Nymphoides hydrophylla (Lour.) Kuntze, Oenanthe javanica (Blume) DC., Oldenlandia diffusa (Willd.) Roxb., Osmunda hugeliana C.Presl, Osmunda regalis L., Ottelia alismoides (L.) Pers., Oxystelma esculentum (L. f.) Sm., Palaquium obovatum (Griff.) Engl., Parkia timoriana (DC.) Merr., Paspalidium flavidum (Retz.) A.Camus, Paspalum conjugatum P.J.Bergius., Paspalum distichum L., Paspalum scrobiculatum L., Peltophorum africanum Sond., Persicaria amphibian (L.) Delarbre, Persicaria barbata (L.) H. Hara, Persicaria glabrum (Willd.) M.Gómez, Persicaria lapathifolia (L.) Delarbre, Persicaria strigosa (R.Br.) Nakai, Phragmites australis (Cav.) Trin. ex Steud., Phyla nodiflora (L.) Greene, Phyllodium pulchellum (L.) Desv., Pistacia khinjuk Stocks, Pistia stratiotes L., Plantago major L., Polygonum punctatum Elliott, Pometia pinnata J.R.Forst. & G.Forst., Pongamia pinnata (L.) Pierre, Potamogeton crispus L., Potamogeton nodosus Poir., Potamogeton perfoliatus L., Potamogeton pusillus L., Potentilla supine L., Prunella vulgaris L., Psidium guajava L., Psidium guineense Sw., Pterospermum diversifolium Blume, Quercus acutissima Carruth., Quercus glauca Thunb., Ranunculus sceleratus L., Rhynchosia minima (L.) DC., Sagittaria guayanensis Kunth, Sagittaria trifolia L., Schima khasiana Dyer, Schima wallichii Choisy, Scleria lithosperma (L.) Sw., Scyphiphora hydrophylacea C.F.Gaertn., Sesbania bispinosa (Jacq.) W.Wight, Silene vulgaris (Moench) Garcke, Sirhookera lanceolata (Wight) Kuntze, Smithia sensitive Aiton, Sonneratia alba Sm., Sonneratia apetala Buch.-Ham., Spathodea campanulata P.Beauv., Spatholobus parviflorus (DC.) Kuntze, Sphaeranthus africanus L., Sphaeranthus amaranthoides Burm.f., Sphaeranthus indicus L., Sphaeranthus senegalensis DC., Spirodela polyrhiza (L.) Schleid., Tacca leontopetaloides (L.) Kuntze, Tephrosia tinctoria Pers., Tephrosia villosa (L.) Pers., Terminalia calamansanai (Blanco) Rolfe., Terminalia catappa L., Thespesia populnea (L.) Sol. ex Corrêa, Toona ciliata M.Roem., Toona sinensis (Juss.) M.Roem., Toona sureni (Blume) Merr., Trapa natans L., Trema orientale (L.) Blume, Triadica cochinchinensis Lour., Trifolium pretense L., Typha angustifolia L., Typha domingensis Pers., Typha elephantine Roxb., Typha orientalis C.Presl, Typhonium flagelliforme (Lodd.) Blume, Ulex europaeus (Lodd.) Blume, Uraria picta (Jacq.) DC., Utricularia aurea Lour., Utricularia bifida L., Vallisneria natans (Lour.) H.Hara, Vallisneria spiralis L., Vanda tessellate (Roxb.) Hook. ex G.Don, Veronica anagallis-aquatica L., Vigna angularis (Willd.) Ohwi & H.Ohashi, Vitex glabrata R.Br., Vitex quinata (Lour.) F.N.Williams, Wedelia chinensis (Osbeck) Merr., Wurfbainia villosa (Lour.) Skornick. & A.D.Poulsen, Xylia xylocarpa (Roxb.) Taub., Xyris complanata R.Br., Xyris indica L., Zanthoxylum armatum DC., Zeuxine strateumatica (L.) Schltr. |
| **Data Deficient (DD)**  Abrus fruticulosus Wight & Arn., Amomum sericeum Roxb., Asparagus filicinus Buch.-Ham. ex D.Don., Coscinium fenestratum (Goetgh.) Colebr., Dioscorea wightii Hook.f., Ephedra khurikensis P.Sharma & P.L.Uniyal, Fraxinus micrantha Lingelsh., Limnophila pulcherrima Hook.f., Millettia fruticosa (DC.) Baker, Platanus orientalis L., Zingiber zerumbet (L.) Roscoe ex Sm. |

Authority and appropriate synonyms as per The Plant List ([www.theplantlist.org](http://www.theplantlist.org/)), International Plant Names Index (IPNI; [www.ipni.org](http://www.ipni.org/)) and India Biodiversity Portal (indiabiodiversity.org)

For conservation of plants especially medicinal plants effective strategies should be implemented. Integrated methods of conservation as well as sustainable harvesting methods, developing local awareness are also required for conservation of medicinal plants. The conservation of medicinal plants can be approached by implementation of scientific techniques along with social awareness and actions.

There are three scientific techniques of conservation of medicinal plants.

**3.1 Legislation –**

In India, existing forestry-related laws primarily address the conservation of medicinal plants rather than establishing policies specifically devoted to medicinal flora. With the following laws and policies offering direct or indirect protection to wild medicinal plants, the Indian government has taken a number of steps to preserve these resources:

i. Indian Forest Act, 1927  
ii. Wildlife (Protection) Act, 1972  
iii. Forest (Conservation) Act, 1980  
iv. Environment (Protection) Act, 1986  
v. National Forest Policy, 1988  
vi. Biological Diversity Act, 2002  
vii. Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

The export of 29 species of medicinal plants is regulated under the EXIM Policy, and a dedicated Wildlife Crime Control Bureau has been established to curb illegal trade and smuggling of medicinal flora.

**Legal and Policy Measures for Conservation**

* Law and Regulation: Enforcing laws to save endangered species, limit the illicit trade in medical plants, and regulate harvesting methods.
* CITES (Convention on International commerce in Endangered Species): This convention oversees and controls global commerce to prevent overexploitation of medicinal plant populations.
* Intellectual Property Rights (IPR): Using IPR frameworks to protect indigenous and local populations' traditional knowledge while guaranteeing fair benefit sharing.

3.2 **In-situ conservation –**

Conservation of a given species in its natural habitat or in the area where it grows naturally is known as in-situ conservation. ii. It includes Gene bank/Gene sanction, Biosphere reserves, national parks, sacred sites, Sacred grooves etc. iii. It is only in nature that plant diversity at the genetic, species and eco-system level can be conserved on long-term basis. It is necessary to conserve in distinct, representative biogeographic zones inter and intra-specific genetic variation. (23). Indigenous plants and natural communities can be preserved by in -situ conservation. In addition, in situ conservation increases the amount of diversity that can be conserved (24) and also strengthens the link between resource conservation and sustainable use (25). Establishment of biosphere reserves, national parks, wild life sanctuaries, sacred groves and other protected areas forms examples of ‘in-situ’ methods of conservation (23). Most medicinal plants are endemic species, and their medicinal properties are mainly because of the presence of secondary metabolites that respond to stimuli in natural environments, and that may not be expressed under culture conditions (26,27). In situ conservation of whole communities allows us to protect indigenous plants and maintain natural communities, along with their intricate network of relationships (28). In-situ conservation efforts worldwide have focused on establishing protected areas and taking an approach that is ecosystem-oriented, rather than species-oriented (29). Successful in -situ conservation depends on rules, regulations, and potential compliance of medicinal plants within growth habitats (30) (31). Throughout the globe in situ conservation has concentrated on building protected areas and adopting an ecosystem-based approach, rather than on species (32).

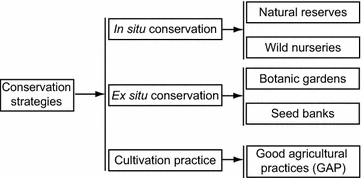
**Natural reserves** - The degradation and destruction of habitats is a major cause of the loss of medicinal plant resources (33). Natural reserves are protected areas of important wild resources created to preserve and restore biodiversity (34). Conserving medicinal plants by protecting key natural habitats requires assessing the contributions and ecosystem functions of individual habitats (35).

**Wild Nurseries-** A wild nursery is established for species-oriented cultivating and domesticating of endangered medicinal plants in a protected area, natural habitat, or a place that is only a short distance from where the plants naturally grow (36,37,38)Although the populations of many wild species are under heavy pressure because of overexploitation, habitat degradation and invasive species, wild nurseries can provide an effective approach for in situ conservation of medicinal plants that are endemic, endangered, and in-demand (39,40).Some complementary methods of in-situ conservation are also in practice-

* **On-farm conservation**: On-farm conservation involves the maintenance of traditional varieties by farmers in agroecosystems. A major focus for the conservationist or development practitioner will be to encourage the farmer to continue cultivation of traditional varieties and this may be achieved by niche marketing, seed shows, participatory traditional variety improvement or even financial incentives (41).
* **Home gardens** are found in both rural and urban areas in predominantly small-scale subsistence agricultural systems (42). Relying on research and observations on home gardens in developing and developed countries in five continents, Ninez formulated the following definition (43). The household garden is a small-scale production system supplying plant and animal consumption and utilitarian items either not obtainable, affordable, or readily available through retail markets, field cultivation, hunting, gathering, fishing, and wage earning.
* **Zero energy input-based** concept of Para frost conservation is existing in the Himalayan region naturally. This area is covered with snow.

**3.3 Ex- situ conservation-**

This is the conservation outside the native habitat. It gives protection to populations in danger of destruction, replacement or deterioration. Ex situ conservation is not always sharply separated from in situ conservation, but it is an effective complement to it, especially for those overexploited and endangered medicinal plants with slow growth, low abundance, and high susceptibility to replanting diseases (44,45,46). Ex situ conservation aims to cultivate and naturalize threatened species to ensure their continued survival and sometimes to produce large quantities of planting material used in the creation of drugs, and it is often an immediate action taken to sustain medicinal plant resources (47,48). Approaches to ex situ conservation include methods like seed storage, DNA storage, pollen storage, in vitro conservation, field gene banks and botanical gardens (49). Field gene banks provide easy access to conserved material for use, they run the risk of destruction by strategies using the tools of biotechnology are increasingly being applied towards conservation of plant genetic resources. These include (a) in vitro conservation (b) in vitro propagation and re- introduction of plants to their natural habitats, and (c) molecular marker technology. Several in vitro techniques have been developed for storage of vegetatively propagated and recalcitrant seed producing species (50). In general, they fall under two categories: (i) slow growth procedures, where germplasm accessions are kept as sterile plant tissues or plantlets on nutrient gels; and (ii) cryopreservation, where plant material is stored in liquid nitrogen. Slow growth procedures provide short- and medium-term storage options, while cryopreservation enables long- term storage of the plant material (51).



**Figure. 2  Schematic representation of different conservation strategies**

**Reference - (52)**

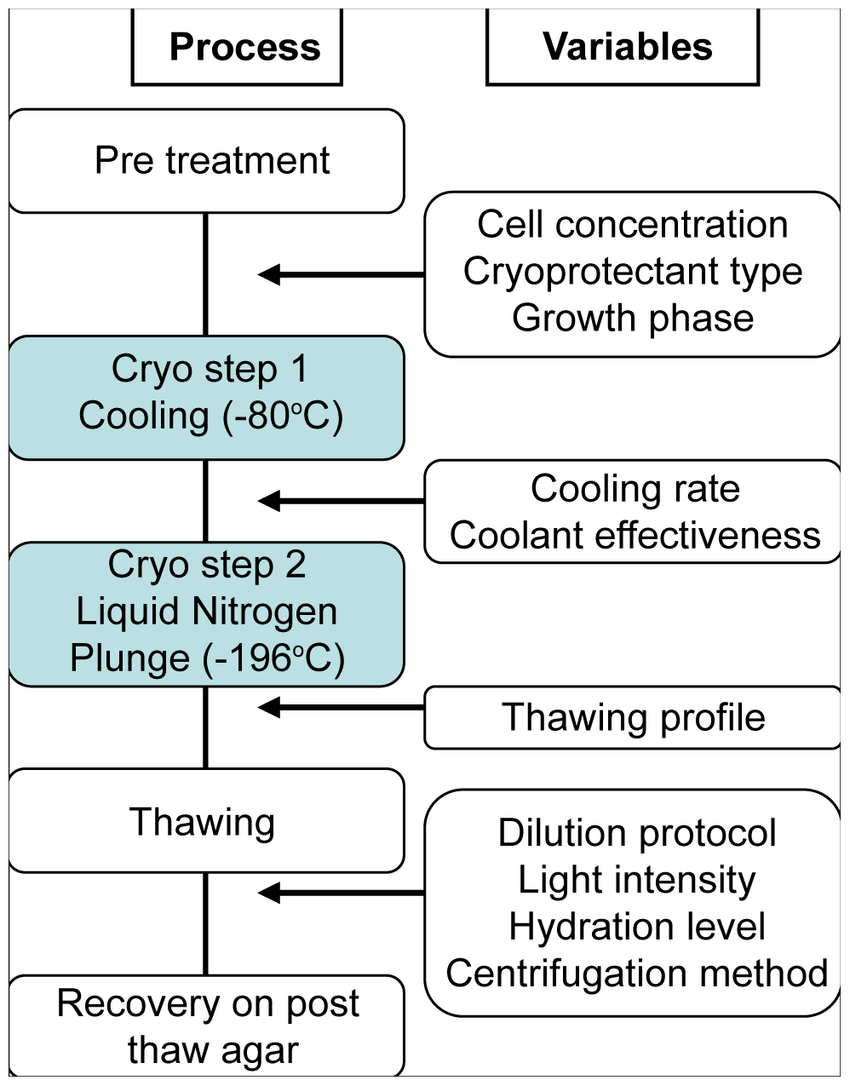
* **Field gene bank (field repository/clonal repository)**

1. (Gene Bank: Storage in the form of seed (Base collection at -20°C; Active collection at +4°C to l0°C). The three national gene banks have been established in India for ex situ conservation of medicinal and aromatic plants.
2. National Bureau of Plants Genetic Resources (NBPGR), New Delhi, under ICAR.
3. Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, Uttar Pradesh, under the Council of Scientific Industrial Research (CSIR), Ministry of Science and Technology, Government of India.
4. Tropical Botanical Gardens Research Institute, (TBGRI), Palode, Thiruvananthapuram (Kerala).
5. The conservation of genetic variability of cultivated plants and their wild relatives is the sole responsibility of the National Bureau of Plant Genetic Resources (NBPGR) that operates under the Indian Council of Agricultural Research (ICAR), Department of Agricultural Research and Education (DARE) (23).



**Figure -3 Field Gene Bank**

* **National active germplasm sites** - The national active germplasm sites (NAGS) are the integral component of the network. There are presently 40 NAGS, which are based at ICAR institutes, (crop-based institutes for a specific crop or a group of crops) and SAUs. These are integral part of national plant biodiversity conservation network. The NAGS are entrusted with the responsibility of multiplication, evaluation, maintenance and the conservation of active collection and their distribution to bonafide users both at the national and international levels. These active/ working collections are stored in modules maintained at +4°C and 35- 40 per cent relative humidity (RH). Under these temperatures, seeds are expected to remain viable for 15 to 50years. For medium term storage, seed moisture content is brought down to 8 to 10 per cent. The NBPGR has a network of II regional stations located in different agroclimatic zones of the country to support the active germplasm conservation activities of the regions.
* **Cryopreservation- “**Cryopreservation” is defined as the viable freezing of biological material and their subsequent storage at ultra-low temperatures (- 196C)” using liquid nitrogen.
* **Seed preservation:** The seeds have been grouped broadly into two categories, based on their response to dehydration (53). A majority of them are desiccation tolerant, called ‘Orthodox’ and hence can be stored for longer durations. The second group of plant species are called ‘Recalcitrant’, whose seeds suffer injury on their drying and therefore cannot be stored at subzero temperatures (23).
* **Pollen preservation:** Pollen storage was mainly developed as a tool for controlled pollination of synchronous flowering in plants, especially in fruit tree species. In addition, pollen storage has also been considered as an emerging technology for genetic conservation (54,55,56). Pollen can easily be collected and cryo-preserved in large quantities in relatively small spaces.



**Fig. 4 Showing different steps of cryopreservation**

**Reference: (57)**

* **In-vitro conservation and future prospects** - The essential prerequisites for an in vitro conservation programme are creation of special. facilities (culture rooms with controlled environment, artificial lights, laminar airflow cabinets, autoclave, etc. and trained scientists and technicians.Any in vitro conservation programme primarily comprises two stages, first is in-vitro multiplication to make large number of plants, and second is in vitro storage. The material can be stored in the form of meristems, shoot tips, axillary buds, embryos, callus and cell suspension. In vitro gene banks are easy to maintain and often inexpensive provided effective storage systems are developed.
* **DNA storage (Conservation at -20°C)-** Storage of DNA is widely applicable simple to carry out as well as the storage of DNA seems to be relatively easy and cheap. With the help of genetic engineering, it became possible to break down the barriers of transferring genes among species and genus. The development of genetic engineering has led to the feasibility of large-scale biosynthesis of natural products, and advancements in tissue culture and fermentation of medicinal plants have opened new avenues for the large scale and highly efficient production of desirable bioactive compounds. Tissue culture (including plant cell and transgenic hairy root culture) is a promising alternative for the production of rare and high-value secondary metabolites of medical importance (58). Micropropagation via tissue encapsulation of propagules can not only facilitate storage and transportation, but also promotes higher regeneration rates (59). When the amounts of normal seeds are insufficient for propagation, synthetic seed technology, defined as artificially encapsulated somatic embryos (or other tissues) could be used for cultivate in vitro or ex vitro, is a feasible alternative (60,61). Furthermore, breeding improvements can be carried out using molecular marker-based approaches applied at the genetic level, and the time required for breeding may be significantly shortened .

**4. Other approaches-**

#### **4.1 Community-Based and Socio-Cultural Approaches to Conservation**

#### For generations, traditional knowledge has been passed on from the elders to the younger members of a community. This forms the basis for the medicinal plant conservation work being done by these communities. The role of local communities, with the invaluable traditional knowledge they hold, in conserving medicinal plants is truly a case of placing the right persons in the right position to carry out the work. Indeed, communities work effectively and efficiently when they do so in a territory that they claim and wherein they can govern the resources. They have ways of governing resources that draw upon their traditional and customary knowledge and that work for them, for the generation of local livelihoods.

#### **4.2 Cultivation and Sustainable Farming Practices**

#### Cultivated plants reduce the pressure on wild plant populations and provide reliable sources of raw materials. To ensure the continued availability of these plants, their cultivation must be systematic. And that means sustainable. So, what does sustainable mean, in this context? It means farming strategies that: are economically viable; do not over-rely on external inputs; do not degrade essential ecosystem services; do not harm human health; do not compromise the ability of future generations to meet their needs; and do not eliminate or threaten the plants. Growing medicinal plants under farm conditions permits a steady and sustainable supply, thereby reducing the need to exploit fragile natural habitats. Medicinal plants are grown next to food crops or trees in agroforestry models. These next-generation farming systems create ecological niches; the systems—like natural settings—are diverse and resilient. Practices associated with organic farming protect plants, people, and the environment from harmful chemicals. They ensure that the quality of the plants being grown is not only high but also as close to nature as possible. This farm-to-table ethos fortifies the environmental balance that is currently so tenuously held.

#### **4.3 Community-Based Conservation**

#### When local communities are active participants instead of passive beneficiaries, conservation becomes much more effective. Including local communities makes conservation not only ecologically sustainable but also socially sustainable. Building capacity and providing training gives communities the skills and resources to run conservation programs. Traditional knowledge is an essential element of cultural heritage; it helps conserve not only the culture but also plant species, in a sustainable way. C. Michie and C. Smith argue that it is imperative to integrate this knowledge into the modern scientific disciplines if either are to understand the complete picture of the biology of the plants and their sustainable use and conservation. Here are some excerpts from their article, "Going Cowboy: How does Traditional Knowledge Navigate Plant Conservation and Sustainable Utilization?" Access to profits, royalties, or resource-based incentives is part of the benefit-sharing mechanisms that help build trust and encourage the long-term stewardship of biodiversity.

#### **5. Research, Monitoring, and Awareness**

Research in plant biology, reproductive ecology and phytochemistry is essential to better underpin conservation practices. Documentation of ethnobotany and monitoring of wild populations make a significant contribution in understanding the status and pressures on species. All kind of research, awareness initiatives, the trainings and then more responsible consumer choices could be many significant helps for a much more sustainable use of medicinal plants.

**5.1 Research and Monitoring**

Study of Plant Biology and Ecology: To study the growth characteristics, reproductive strategies, and ecological requirement of the medicinal plants to formulate proper conservation strategies. Ethnobotanical Documentation, recording traditional knowledge about the used medicinal plants to preserve local culture and significance of species. Population and Habitat Monitoring: monitoring of medicinal plant populations and their habitats to identify emerging threats in time for corrective actions

**5.2 Public Awareness and Education**

Outreach: Education of communities, policy makers and stakeholders about the potential ecological and medicinal value of these plant species. Capacity Building Workshops, training sessions for farmers, harvesters and communities on sustainable cultivation and harvesting techniques. Driving Responsible Use: Create Demand for sustainable products and encourage imparting support to ethical practising enterprises. This will lead to the establishment of a holistic approach for medicinal plant conservation by incorporating scientific research, traditional knowledge, education as well as sustainable practices. It helps save those species from extinction in the long run as well as biodiversity, and eventually preserves human communities that depend on them. By combining these strategies, we can create a comprehensive approach to conserving medicinal plants, ensuring their availability for future generations while supporting biodiversity and the well-being of communities that rely on them.

**Conclusion**

Wild Medicinal plants conservation is a holistic approach that combines in-situ and ex situ methods for the establishment of biodiversity-friendly legislation, community participation and scientific application. In so doing the ritual of conservation woven with ecological preservation and socio-economic benefits serves dual interests that will ensure the long-term availability of medicinal plants to benefit mankind as a whole while at the same time stopping from extinction valuable biological resources inherently rich in both biodiversity and cultural heritage. Large number of conservation strategies, management and sustainable utilization methods are followed for Medicinal plants cultivation but few percentages of success have achieved.

**Recommendations-**

Scientists and policymakers should also put more emphasis on developing new mechanisms and policies to protect our remaining wild medicinal plants today in order to preserve them for future generations.

Disclaimer (Artificial intelligence)

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. ChatGpt

2.QuillBot

3.

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