



Biodiversity Loss: Threats and Conservation Strategies

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ABSTRACT

The global population is expanding day by day, the increase in food demand by the growing population poses serious environmental challenges. To satisfy the increasing food supply, a shift in conventional agriculture was observed that lead to expanded agricultural land uses with reduced wildlife and biodiversity. Deterioration of agricultural land has caused overexploitation of forest land by converting natural habitats into managed systems. Life has originated billions of years ago. Since then, there is a continual extinction of over 90% of the species due to various factors such as increased human population, unsustainable resource consumption, habitat fragmentation, habitat degradation, alien species invasion, pollution, monoculture practices, climate change, loss of forest cover etc. Food, fodder, fuel, medicines, wood, crop plants are some of the natural resources received from the environment. Biodiversity also provides an ecosystem, social, and spiritual services to mankind. We must realize the significance of biodiversity on earth as a valuable resource that can help in developing new products for generations. A consensus has been developed to adopt a holistic view of biodiversity for its conservation and sustainable utilization. Numerous techniques have been proposed and implemented for the conservation of biodiversity and its genetic resources. Since we are dependent on nature for our livelihood, this review paper aims to address the biodiversity and its threats along with some conservation strategies which are not adopted on a large scale.

Keywords: Keystone; habitat destruction; invasive species; reproductive biology.

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INTRODUCTION

The world's human population is increasing day by day and it will reach ~ 8.9 billion in the next few decades leading to an increase in the food requirement. To generate additional food for an increasing population, there is an essential requirement to expand agricultural land by converting forests.^{1,2} Deterioration of agricultural land has resulted in widespread impairment and overexploitation of forest land. In the period 1990–2015, The Global Forest Resources Assessment 2015 observed a reduction in forest area from 129 million hectares to 4 billion hectares.³ This causes an increase in biotic and abiotic stresses (isolation, inbreeding, competition, predation, parasitism, and disease) for plants.^{4,5} The world's biologically rich and unique habitats are experiencing a high degree of species extinctions due to various anthropogenic activities such as rapid urbanization, deforestation, burning of fossil fuel, and industrialization. These environmental changes affect the ecological and evolutionary process and ultimately result in species extinction, population and decline in global

biodiversity.⁶⁻⁸ The major problem lies in the fact that the distribution of biodiversity is not even throughout the geographical areas of the world, wherein certain areas are more diverse than others. The uneven distribution of biodiversity on earth has resulted in a delineation of 36 hot spots of biodiversity. They possess 1,500 endemic species and have lost 70 % or more species of their habitat.⁹ Biodiversity is lost at higher rates than those in the fossil record.¹⁰ IUCN (2004), based on assessments of 38,047 species observed, a reduction in plant genetic resources, with animal species (7,266) and plant species (8,321) placed in the category of threat (Vulnerable, endangered, or critically endangered).¹¹ According to IUCN (2020) > 120,000 species are listed in the Red data book with ~ 32,000 species under threatened with extinction category.^{12,13} Biodiversity loss by altering the composition of biological communities causes species extinction and also leads to the decline in ecosystem functioning.^{14,15} The species represented by small populations may become endangered due to genetic erosion, fragmentation, pollution, and human impact. The facilities offered by biodiversity are eventually undervalued by society in terms of the distribution of benefits and its long-term sustainability.^{8,16,17}

1.1 Biodiversity and its richness

The diversity of life forms in an ecosystem is referred to as biodiversity. It constitutes various species of organisms, such as plants, animals, and micro-organisms, and the genes they contain and the ecosystems they form.



According to Heywood and Baste (1995), “biodiversity” is defined as the number, variety, and variability of living organisms in a given ecosystem.¹⁸ The biodiversity cannot be solely expressed in numbers, as it also depends on the ecological structure of an area. Whittaker (1972) recognized three different types of diversity that have been defined as alpha, beta, and gamma diversity.¹⁹ Diversity within each geographical group corresponds to alpha diversity, the proportion of diversity due to differences among geographical populations corresponds to beta diversity, and the total diversity within plants corresponds to gamma diversity.²⁰

Biodiversity can be explained at three levels genetic, species, and ecosystem diversity. Genetic variability in the individuals of a species is known as genetic diversity. Due to numerous genes, every individual in a species differs widely from other individuals in its genetic makeup. The variability in the genes within a population can be estimated due to the number of polymorphic genes and the number of alleles for each polymorphic gene.²¹ For a healthy breeding population, genetic variability is an essential feature as lesser variation results in inbreeding of species, resistance to disease and parasites, and non-flexibility in coping with environmental challenges. This will ultimately contribute to anomalies and lead to species extinction.^{22,23}

The number of plants and animal species present in a region constitutes species richness that varies from region to region. The tropical rainforests support the diversity of living organisms as compared to desert ecosystems. Hotspots are determined based on species metrics. The areas that are abundant in species diversity, endemic species and the number of rare or threatened species are called ‘hotspots’ of diversity.²⁴ In species diversity, niche and habitat are the primary elements used for the representation of ecological diversity. Species diversity is the key feature for diversity measures used in research and biodiversity conservation. It involves consideration of two important features of a community that are species richness and evenness or equitability.²⁵ The major problem associated with the calculation of the species richness is that the number of species observed usually increases with the number of individuals sampled, and the number of individuals increases with the size of the sampling unit. Species diversity influences the ecosystem's functioning by affecting the productivity and stability of the system.²⁶

Ecosystem diversity is the third type of diversity that focuses on the diversity within and between the ecosystems. An ecosystem is the result of biological, climatic, geological, and chemical constituents in a particular field, such as forests, grasslands, deserts, mountains, aquatic ecosystems (rivers, lakes, oceans, marine, freshwater), and wetland ecosystems.²⁷ The species plays an important role in the ecosystem and if it is exploited or overused loses its productivity and gets deteriorated. The destruction of the ecosystem changes

both intra and interspecies biodiversity. The assessment of biodiversity at the ecosystem level is difficult due to biotic and abiotic components' dynamism.²⁸

The species diversity and genetic diversity within a plant species can affect the community and ecosystem functioning, but the consequences of biodiversity loss are difficult to analyze based on either level of diversity alone.^{29,30} The impact of a different diversity has been indicated in the Cedar Creek Natural History Area grassland experiments in Minnesota.³¹ The knowledge of genetic, species, and ecosystem diversity and its distribution is essential for its conservation. The threats to biodiversity have been discussed and verified in many books, journals, articles, newspapers either separately or concretely. However, through this review paper, we are trying to discuss the threats along with various conservation strategies that are already in use, but not adopted on a large scale. There is a need to address these threats and find out the measures which need to be adapted to reduce the impacts of these major threats on biodiversity. The conservation strategies for biodiversity are essential for present and future human well-being.

1.2 Biodiversity Threats

The three dimensions of biodiversity are currently exhausted at a higher rate as a result there is a great concern regarding biodiversity loss.³² Due to the increasing human population, rich and unique habitats are being degraded and fragmented. The various threats are human population, habitat loss, invasive alien species, climate change, pollution, eutrophication, overfishing, soil erosion, soil degradation, poverty and loss of green forest.³³⁻³⁵

1.2.1 Human Population

The world's population would reach beyond the level of 8.9 billion (UN, 2004) by 2050s. As a population is expanding extensively, the current practice could lead to the conversion of another 1 billion hectares of natural habitat into agricultural land. The world population explosion has resulted in increased per capita demand for food, timber, wood fuels, fodder, biomass, decorations, shelter, and clothes. This has caused severe repercussions on nature, vegetation, forest cover, and biodiversity. This exerts pressure on the limited land that will lead to doubling/tripling of nitrogen and phosphorus usage and 3 fold increase in pesticide usage. The disproportionate use of chemical fertilizers and pesticides in soil results in soil degradation and erosion.³⁶

The use of fire to clear forests, ground debris for agriculture showed a major influence on the forests as it allows other invasive species to invade and out-compete them for light and nutrients. These forest fires are more damaging for native plant species. The appearance of fire-tolerant trees species in these forests such as *Acacia catechu*, *Carrya arborea*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Tectona grandis*, *Terminalia spp*, and *Xylocarpa* in these forests is a shred of evidence that these tree species are competent to withstand fire and acts as a



fire indicator.³⁷ Fire suppression and drainage are the main reasons for *Sarracenia* and *Drosera* spp decline in the southeastern United States.³⁸

Due to human interference, various trees such as *Myristica fatua*, *Cranther acarnalica*, *Semacarpus auriculata*, and the palm *Pinanga dicksonii* have disappeared along with swamps.³⁷ Unique landscape elements, *Myristica* swamps in the Western Ghats of India, have now been practiced for rice cultivation. Human activities such as monoculture practices, dams, and alterations of the natural environment are also accountable for the decline of trees diversity. Over the last two centuries monocultures practices of trees of *Acacia pycnantha*, *Anacardium excelsum*, *Cedrela odorata*, *Eucalyptus obliqua*, *Cinchona officinalis*, *Eucalyptus obliqua*, *Hevea brasiliensis* and *Syzygium aromaticum* have removed extensive patches of natural forests throughout the greater part of the world.³⁹ Drought is another constituent that severely impacts natural aquatic ecosystems caused by direct and indirect anthropogenic modifications to streams. The drought condition causes groundwater loss causing, plants unable to sustain in the ecosystem.⁴⁰ In a race of development, we have altered our natural environment to an extent, today we face lots of consequences as an invasion of alien species, climate change, pollution, and fragmentation. The natural system modifications, residential and commercial developments are all closely associated obstacles that resulted in threatened or extinction of species.

The vegetation structure and species composition are the key factors for determining vegetation disturbance and its restoration. The human interference showed direct correlation with vegetation coverage.⁴¹ Plant behaviour also get altered by human impact, as some species show great attention initially, some acclimatize, whereas others remain native in their responses. The behavioural change alters the whole component of the community. The research studies shows there will not be a single species by 2100 whose behaviour has not somehow been affected by it.^{42,43} Thus, there is a requirement to identify imperilment situations for the management priorities of species.

1.2.2 Habitat loss and fragmentation

Global biodiversity loss is primarily due to the degradation and destruction of natural habitats. Habitat loss alone is not a single process and is always associated with fragmentation. Various natural, and anthropogenic activities, land use pattern alteration have caused fragmentation or loss of habitats.²³ Constant transformation of natural habitat into isolated and smaller fragments with spatially distributed patches is known as habitat fragmentation.⁴⁴ The fragmentation has the capacity to cause persistent damages to the entire forest ecosystem causing long-term damage in the functioning of remaining fragments that result in species extinctions.⁴⁵ The exploitation of croplands, pastures, plantations, and urban areas, has caused alterations in ~ 50% of our natural vegetation.⁴⁶ The world forests tree cover has declined extensively of its geographic area, as against the

recommended requirement for contributing ecological stability. This affects endemic species and causes the complete elimination of entire taxonomic groups.⁴³ These changes eliminate the population and disrupt their behavioral response to the environment, mutualism, and pollinators. To understand the relationships between habitat distribution and species richness, identification of discrete habitat patches is necessary. The patterns of habitat fragmentation consequences are inherently hierarchical in nature.^{47,48} The habitat fragmentation induces various climatic (wind exposure and higher light penetration) and micro-environmental alterations (higher evaporation rates), which affects the whole ecosystem functioning. It modifies the dispersal patterns and distances that favors the native species. Habitat fragmentation also results in lower visitation rate and seed set as compared to non-fragmented habitats. There are lots of indication that suggests a global drop in pollinators due to fragmentation.^{49,50} The conservation of biodiversity is an essential process as the products and services received by flora and fauna are numerous. Thus, there is an imperative requirement to conserve the habitat and restrict habitat fragmentation for the living organisms to provide different types of ecological functions that will be profitable for an ecosystem.

1.2.3 Invasive Alien Species (IAS)

After habitat destruction, Invasive alien species are considered as third major threat for species extinction by scientists and policymakers which demands to be addressed to achieve its goal "to halt the decline of biodiversity". These species cause irreversible destruction to the native flora and fauna resulting in a change in the entire ecosystem. Invasive alien species are also known as non-indigenous/non-native species which affects the habitat, where they have been introduced outside their natural distribution, intentionally or unintentionally. These species are competent in propagating and are not native to that particular ecosystem in which they are found.^{51,52} It is also considered as a threat to native species causing negative impacts on socio-ecological systems. These invasive species can be considered as chemical pollutants causing biological pollution.⁵³ The biological invasion leads to the magnificent development of alien species in different regions of the world. The most common and extensively studied invasive species are *Caulerpa taxifolia* (Vahl) C. Agardh and *Ageratum conyzoides*, *Mikania micrantha*, *Galinsoga parviflora*, *Eupatorium adenophorum*, *Lantana camara*, *Eupatorium odoratum*, *Mikania cordata* and *Parthenium hysterophorus*.^{39,54,55}

The invasive species are causal drivers of biodiversity loss and not merely the passengers.⁴² These species causes alteration in the habitat and community structure of native species.^{43,56} In the 1970s, *Mytilus galloprovincialis*, Mediterranean mussel was unintentionally introduced to the west coast of South Africa and was deliberately introduced to the south coast for mariculture purposes where it becomes invasive and outcompeting local



mussels.^{57,58} To restrict the introduction of alien species that threaten ecosystems, the conference of parties to CBD called upon governments (CBD, 1992).⁵⁹ The prevention of alien species introduction is the responsibility of the government that needs scientific, administrative, and political coordination. However, efforts made are not up to the mark and still need policies concerning the use and management of invasive species.⁶⁰ Invasions are not directly related to climate but promote the establishment and spreading of invasive species in ecosystems. The invasive species showed a decline and even destruction of several marine ecosystems including pathogen loss.^{43,62}

1.2.4 Climate change

Climate change and increasing temperature alter other environmental factors such as precipitation, sea-level, and rainfall regimes that cause land degradation, pollution, invasive species, and overexploitation. Various man made activities led to habitat destruction which affects the distribution of species in terrestrial and aquatic ecosystems.⁶²⁻⁶⁴

Climate change is recognised as one of the major factor causing biodiversity loss by Intergovernmental Panel on Climate Change (IPCC). Large-scale natural disturbances due to climate change such as wildfires, cyclones, and floods will become more common in the future.^{65,66} It causes major disturbances on habitats and ecosystem functioning. The various biological processes such as biota, and inter-specific interactions are considered as the major cause for species extinctions.^{63,67-69} The anthropogenic and industrial activities lead to a rise in earth temperature due to the emission of greenhouse gases. Since the 1970s, the temperature rise has resulted in intense and longer droughts period across the world in tropical and subtropical regions causing a population decline.^{70,71} According to Thomas *et al.* (2004) revealed that in the next 50 years, climate change could be one of the major reason for the extinction of more than a million terrestrial species.⁷² Greenhouse gas emissions cause a rise in sea level between 0.18 and 0.38 m to 0.26-0.59 m, causing physical disturbance, storm, coastal erosion, acidification and salinization of soil.⁷⁰ These alterations affect the marsh habitats that are considered as vulnerable and ecologically valuable areas of biodiversity.^{73,74} According to Wernberg and Goldberg (2008), an increase in wave energy resulted in the fragmentation of seaweed canopy along with the adverse effects on local diversity and productivity of the community.⁷⁵ An increase in ocean temperature affects herbivores and their foraging activities.^{76,77} The temperature rise also results in the spreading of various pathogens, which enhances their virulence and decreases the resilience of host organisms in macroalgae.⁷⁸ Across the world, countries like New Zealand and Japan observed a massive decline (40-100 %) of kelps *Ecklonia radiata* and *Laminaria religiosa* due to the outbreaks of disease.⁷⁹⁻⁸¹

Climate change causes a long-term alteration in precipitation. The high rate of precipitation switches the boundaries of ecosystems, can expand while others get declined. Many species have moved poleward from their habitat and their migration varies strongly amongst different species. The reproductive phase varies in some regions causing alteration in the duration of species reproduction.⁶⁵ Climate change also alters the rainfall patterns, as low rainfall regions receive less rainfall, thus shows less sedimentation and nutrient run-off, and higher annual rainfall regions will experience high sedimentation and nutrient run-off.⁸² It was found that in urbanized coasts, elevated sedimentation and nutrient benefits, small and more opportunistic species of algae leads to the shifts from the canopy to algal-dominated blooms.⁸³

Plant communities have been transformed by climate change. It includes migration of host and root symbiont, alterations in plant and fungal species, and their contribution to the global carbon cycle.⁸⁴ A study by Giam *et al.* (2010) explained that the various anthropogenic activities form new variables that affect the capability of tree species along with their fungal associates to scatter in response to climate change.⁶⁸ Besides this, it was also observed that climate change is competent in disrupting phenology, flowering, and fruiting by negatively influencing the efficient pollinators.⁸⁵ For the effective prioritization of conservation efforts, it is important to estimate their impacts on biodiversity.⁸⁶ Based on climate change, several kinds of research have been conducted on the extinction patterns of plant species.^{68,81} Measures are adapted to reduce the effect of climate change by recognizing and quantifying effects of climate change on biodiversity.⁶⁶ Conservation planning for climate change using a variety of conservation tools is initiated in some countries.⁸⁷

1.2.5 Pollution

Global environmental pollution is regarded as one of the significant drivers of biodiversity loss by disrupting the earth's ecosystem causing the extinction of species and their habitat.⁸⁸ In developing countries, pollution is damaging due to overpopulation and uncontrolled urbanization along with the development of industrialization resulting in loss of biodiversity or species extinction.⁸⁹ Amongst all pollution, air pollution is the most damaging one in terms of biodiversity loss, as it influences the quality of water and soil. This affects the overall soil quality and properties, resulting in an adverse effect on crop and food productivity.^{90,91} However, the research on the effect of different pollutants in ecosystem alteration is poorly studied.⁹² The various pollutants such as sulphur dioxide, ozone, heavy metals, inorganic nutrients, detergents, herbicides, pesticides, and nitrogen compounds (NO_x, NH_y, and HNO₃) are competent of altering the various biochemical and ecological processes in soil, air, and water. Plants species such as *Hylocomium splendens*, *Corchorus oltorius*, *Medicago sativa*, *Nicotiana tabacum*, *Calluna vulgaris*, *Impatiens* spp., *Phaseolus*



vulgaris, *Lotus corniculatus*, and *Campanula rotundifolia* have been mainly affected due to the presence of an excessive amount of nitrogenous compound and ozone.⁹³⁻⁹⁶

Lichens are environmental indicators or biomonitors of atmospheric pollution. These plants absorb atmospheric gases and dissolved substances through their surface as waxy cuticle and stomata are absent.⁹⁷ There is a direct relationship between high concentrations of sulphur and nitrogen oxides in the air and a decrease in the lichen population.^{98,99} Due to increased concentration of nutrients (majorly nitrogen) in water magnifies the growth of algae lead to *Eutrophication* which can cause disequilibrium in the aquatic ecosystem. The addition of these inorganic nutrients in coastal water stimulates the production of phytoplankton also. This favors several opportunistic species in water which increases turbidity and resulted in the structural change of littoral communities and species composition.¹⁰⁰ increased heavy metal contamination and the addition of a large number of pollutants have resulted in the disappearance of numerous habitat-forming macroalgae.^{101,102} Other consequences of increased metal contamination can be the accumulation of heavy metals by algae and their transfer to other trophic levels and eventually to humans. Pollution resulted in severe decline in *Cystoseira* sp of Mediterranean regions.¹⁰³

1.2.6 Other causes

Out of several protected areas surveyed in major parts of the world, overexploitation in the form of timber felling, extraction of firewood, fodder, livestock, and grazing was found to be the most proximate threats to biodiversity.¹⁰⁴ Ten major factors affecting biodiversity loss apart from climate change are, poverty, overexploitation, human use of net primary productivity, human appropriation of available freshwater and GMOs, and indifference to nature (biophobia), and population growth of farm animals. Besides this, developmental pressures on land resources, deforestation, and natural disasters are major causes for habitat loss and destruction of the crops and their wild relatives.¹⁰⁵⁻¹⁰⁷ Unsustainable resource consumption and persistent poverty is a major cause of environmental degradation and needs certain policies to solve environmental problems.^{108,109}

The forest loss is one of the principal concerns for the countries which have low-income and food-deficit as the government does not invest in agriculture and forestry. Poor or developing countries require governance and management to develop policies to secure land tenure and effective law enforcement. Integrated land-use planning is important for creating a strategic framework.^{36,110}

1.3 Need for Conservation

Keeping the consequences of biodiversity loss in mind, there is an imperative need for us to conserve it. The biodiversity is essential because of its commercial utility, productivity, social services, ethical values, aesthetic

values, and option values. In 1992, the significance of biological diversity was recognized at the World Summit held in Rio de Janeiro, Brazil. This resulted in the establishment of the Convention on Biological Diversity (CBD), its role is associated with ecosystem services and are strictly linked to human well-being.^{111,112} The three main objectives of the CBD are sustainable usage of its components, fair and equitable sharing of the benefits from the use of genetic resources. This treaty was approved by various nations at the United Nations Conference, on Environment and Development. Based on National Forest Policy, forests should be managed prime as an ecological necessity, other as a source of goods for local populations, and third as wood for industries.¹¹³ Species loss can be decreased by developing new bio reserves and improve management practices for existing protected areas.

The biodiversity forms a support system for the growth and development of living beings and plays an important role in providing food, health, and industrial goods. The plants, trees, and forests are significantly crucial for improving the urban environment quality. A healthy forest is of great ecological significance as it reduces stormwater runoff, maintains the earth temperature, sequesters CO₂ from the atmosphere, and reduces air pollution either directly or indirectly.^{114,115} The trees can dissolve water-soluble pollutants available in the atmosphere by directly absorbing pollutants (SO₂, NO₂, and O₃) through leaf stomata and leaf surfaces.¹¹⁶ The trees can reduce the atmospheric temperature through evapotranspiration and reduces the emission of air pollutants by generating energy.¹¹⁷

The current decade (2011-2020) was declared as Biodiversity Decade by UN (2011; the EU Biodiversity Strategy to 2020), with the objectives to reduce the loss of biodiversity, ecosystem restoration and degradation.^{1,118,119} In recent years, increased public awareness has resulted in the realization of the fact that biological diversity is of great importance for the stability and sustainability of the earth's ecosystem.¹²⁰ The Conference of Parties of CBD, adopted certain global strategies for plant conservation (GSPC) in 2002 with five major aims: (a) to understand and document plant diversity; (b) to conserve plant diversity; (c) to use plant diversity sustainably; (d) to promote, education and awareness about plant diversity; and (e) to build capacity for plant diversity conservation. The GSPC helps in giving the current status of plant conservation to support, monitor, and check the biodiversity loss at different levels and also helps in the sustainable use of diversity.¹²¹

The conservation strategies largely depend on the material to be conserved.¹²² The role of these recommended strategies is highlighted separately in the available literature. In this review paper, we are focusing on all the aspects of the initiative required for the conservation of plant diversity. The conservation strategies discussed in this paper include the use of keystone species, germplasm



conservation, reproductive biology, NPAs, taxonomy, and educational awareness.

1.4 Strategies for Conservation

1.4.1. Keystone species

Keystone species has been determined as a species that plays a central role in sustaining community structure, biodiversity conservation, nutrient conservation and ecosystem functioning by maintaining the stability of the ecosystem.¹²³ The research on keystone species can provide important evidence for habitat management, conservation biology, ecosystem stability, species richness, and biodiversity.¹²⁴ The importance of Keystone species in improvement and manipulation of ecosystem functions have not been explored in detail so far, as variation in the keystone species possess great impacts on entire community.¹²⁵ The removal or addition of keystone species is a more straightforward way of managing biodiversity in the ecosystem.

This thought came from the study by Paine on rocky intertidal communities, wherein if the sea star (*Pisaster ochraceus*) eliminated from a stretch of shoreline in Makah Bay, Washington, in the United States, the ecosystem lost almost half its resident diversity.¹²⁶ The loss of keystone species showed a disproportionate effect on community structure, loss of biological interactions, and restructuring of the system.^{127,128} Several species of *Artemisia tridentata*, *Diospyros montana*, and *Emblca officinalis*, *Castor spp.*, *Ficus benghalensis*, *Bison bison*, *Ficus religiosa*, *Ficus glomerata*, *Plantago albicans* and *Sphagnum warnstorffii* are now considered as keystone species because of the role they play in the conservation of a wide variety of insects, birds, and mammals.^{129,130} The dominant tree species in the forest of Cherrapunji in Meghalaya, India namely, *Englehardtia spicata*, *Syzygium cuminii*, *Alnul nepalensis* and Bamboo (*Bambusa tulba*) contain a high level of N, P, K in the leaf tissue even though that these tree species grown in highly infertile soils, which is required for neighboring species to grow.¹³¹ The palms tree acts as a keystone species located in the Atlantic rainforest of Anchieta Island, Sao Paulo, Brazil, and develop as alternative food support in terms of moderate fruit availability in disorganized environments.

In both natural and artificially managed ecosystems, the keystone species plays an important role in maintaining the ecosystems through conceived rehabilitation strategies.¹³² The removal of keystone species naturally or artificially results in various effects.¹³³ In an anthropogenic ecosystem, there is a need to conserve the population of keystone species by translocation methods. The scientists have used keystone species as a tool for conservation.^{130,134,135} Conservation of trees is critical if the goal is to conserve the variety of other species that are dependent on them in some way or other. These species are of value in re-establishing the ecosystem following succession, and handling these is the easiest way of maintaining the entire ecosystem.

1.4.2 Reproductive biology

The study of sexual and asexual reproduction processes in plants is known as reproductive biology. The process of flowering phenology, inflorescence, floral biology, pollination biology, seed quantity, quality, dispersal, and germination, gamete development, endosperm formation, and embryo development are reproductive characteristics to be studied in natural populations.¹³⁶ These features provide information for understanding the reproductive limitations of the plants that need conservation.¹³⁷ Reproductive failures are considered as one of the main reason for the extinction of most species. If this process continues it can ultimately lead to elimination or extinction of species. The various studies carried on the reproductive biology of plants clearly indicated that the data obtained from such studies are useful in understanding the status of RET species.^{47,138} The studies can provide information for preserving seedling longevity, pollen viability, and prolonging dormancy in seed banks and pollen banks. The collective information obtained can be used as an effective tool for conservation and sustainable development. The management of some RET species has been carried out by previous studies using reproductive biology.^{139,140} However, there are very few plants that have been studied for conservation due to their large size, insufficient knowledge, unawareness, and inaccessibility. Reproductive biology forms the basis of plant improvement programs through breeding, management, and conservation of biological resources.¹⁴¹ It also helps in developing strategies to conserve the germplasm of rare species requires for restoration and reintroduction of the plants in their native environment

Pollinators provide vital services to agriculture and ecosystems as they are the essential component required for the reproduction of ~ 90% of angiosperms. The economic value of pollination shows a direct correlation with global agricultural production as it affects reproductive success, species diversity, and fitness of flowering plants.¹⁴²⁻¹⁴⁵ The environmental and anthropogenic activities cause a global decline in pollinators. Reduction in the number of pollinator leads to high inbreeding, decreased fruit set, or seed production due to insufficient pollen transfer. The crops that are specific to a region, when experienced the loss of native pollinators, showed a great impact on economies. The floral biology will help in determining the pollination syndrome of species and help in the reproductive success of the species. The failure of the reproductive process to cope up with the environmental changes may be the ultimate reason for the species loss.¹⁴⁶ Various studies have shown there is a direct correlation between diverse pollinators with increased crop yield as compared to only one pollinator species.^{119,147} The fruit or seed dispersal is another major factor that helps plants to improve their population size.

The reproductive biology studies will help in developing new conservation strategies to preserve the genetic



material of RET plant species, which are crucial for restoration and reintroduction.

1.4.3 Natural protected area

Conservation of ecologically and economically important site (NPAs) are considered as the most effective measures of site conservation for reducing global biodiversity loss¹⁴⁸⁻¹⁵⁰ By adopting several policies large numbers of critically endangered species of plants and animals are conserved. The importance of NPAs was felt in the year 1992 at the CBD where it performs the functions of biodiversity protection and ecosystem functioning.¹⁵¹ The NPA through its research, educational activities, ecotourism, and supporting traditional activities contribute to local and regional economies of the world. NPAs serve as a foundation for the large numbers of indigenous peoples and as the only environment in which their traditional culture survives. Biodiversity conservation by NPA is effected by uncertain disputed values and long-term consequences.¹⁵² Even though it is a matter of dispute that how effective is the NPA in protecting the biodiversity loss. NPA has now become “a new way of thinking, viewing, and acting of the world effectively and innovatively”.¹⁵³ The protected areas are considered as an important ingredient due to their social and ecological values.^{154,155}

1.4.4 Taxonomical studies

Taxonomy helps in giving essential information for the conservation of genetic resources. The taxonomic evidence performs a significant role in characteristics and evaluating cultivated plants that is an important characteristic for identification and documentation of genebank collection. ¹⁵⁶ Taxonomy assists in identifying variations in the genome between different organisms to be recognized as different taxa. Genetic diversity, adaptation, and fixation of genes are the basis of speciation. The classical taxonomic is based on a comparison of morphological characters and modern taxonomy utilizes molecular techniques to generate data for phylogeny and classification of plant groups. The species lists provided using taxonomic evidence can be applied for conservation planning and to determine which species should be the focus of conservation actions. Taxonomical there are two alternatives for the conservation; i) use of practical values for standardizing the species units available in the list ii) Involves the use of the method of recovery planning which includes the study of the natural system of each unit and differences from the units in the process.¹⁵⁷ There is an urgent need to collect the data of species rich arrears and make them available to get the advantage of biodiversity informatics on plant conservation.¹⁵⁸

The taxonomical evidence also plays an important role in studying evolutionary sciences. The data obtained can contribute important perspectives on plant origin, distribution of species. The taxonomic branch helps in providing the data for taxonomic studies, eco-geographic surveys, the management of genetic resources and

breeding system. The knowledge obtained from this is also useful for the international recognition of approved targets for plant diversity conservation. Taxonomical studies can also be managed to describe the value of genetic diversity in deciding which species needs conservation and ensures that the resources are well maintained by assessing the availability of genetic diversity within and between populations of any species.²²

1.4.5. Germplasm Conservation

Germplasm (genes of a species) acts as a reservoir of raw materials or genes that are used by breeders to develop commercial crop varieties. The scientists are working on germplasm conservation due to rapid erosion of genetic diversity, as the conservation technique has become the major strategies to protect the world's germplasm diversity.²² It performs a significant role in monitoring genetic erosion, genetic diversity of horticultural crops, broadening of their genetic basis to adapt to varying climatic conditions, and also in developing resistance to various pests and diseases.¹⁵⁹ Germplasm is considered an imperative element for collection and evaluation of breeding programs. The Food and Agricultural Organization (FAO) adopted an international material transfer agreement in 2001 to promote the conservation of genetic resources with CBD. Due to the variation in nature, population size, life cycle, and mode of reproduction which, conservation strategies are useful for the plant species are still a question for scientists.¹⁶⁰ In-situ or ex-situ are the two important methods of germplasm conservation. In in-situ, the wild species is preserved along with its complete natural ecosystems. The preservation of germplasm in artificial conditions such as gene banks, seed banks, plant banks, shoot tip banks, cell banks, and DNA banks refers to *ex-situ* methods of conservation.

Additional approaches for germplasm conservation include cryopreservation, slow growth cultures, desiccated somatic embryos, artificial seeds, and DNA clones. In cryopreservation, the plant materials are preserved by terminating all cellular divisions and metabolic activities at low temperatures. This method provides a long-term storage of genetic resources.¹⁶¹ *In vitro* techniques for germplasm conservation, storage holds great promise for clonally propagated and recalcitrant or short-lived seed crops. Pollen and seed preservation is acknowledged as the easiest method to conserve their germplasm, as it requires minimal efforts, space, and resources. Besides this, the materials modified by genetic engineering may sometimes be unstable and need to be preserved for future use. These methods show an advantage over the other conventional process as it takes less space, stores germplasm free from diseases, insects, pathogens, and weeds for longer periods, along with a reduced risk of somaclonal variation.¹⁶² There are certain limitations for germplasm conservations such as weather change or diseases, which can ruin the entire preservation of germplasm.¹⁵⁹ However, this method requires sophisticated facilities, great skill in handling and



maintenance, and even damage to cells and tissues. There are various national and international institutes which perform a significant role in germplasm conservation, IRRI (International Rice Research Institute, Los Banos, Philippines), International Livestock Research Institute (ILRI), CIMMYT (International Maize and Wheat Improvement Center, Mexico), CIAT (International Center for Tropical Agriculture, Columbia), IITA (International Institute of Tropical Agriculture, Ibadan, Nigeria), Global Forum for Agriculture Research (GFAR), CIP (International Potato Center, Peru), ICRISAT (International Crops Research Institute for the Semi-Arid-Tropics, India), International Center for Agricultural Research in Dry Areas (ICARDA), WARDA (West Africa Rice Development Association, Liberia), IPGRI (International Plant Genetic Resources Institute, Rome Italy) and AVRDC (The Asian Vegetable Research and Development Centre, Taiwan).¹⁶³

In India, NBPGR (National Bureau of Plant Genetic Resources) is one of the premier research organizations established in 1976 that serves in the conservation of germplasm. These organizations help in planning, collecting, conducting promoting, exchange, evaluation, documentation, and sustainable management of germplasm. NBPGR maintained the gene bank of various crop species such as wheat, rice, maize, potato, onion, cotton, tobacco, and groundnut. The tissue culture and cryopreservation techniques have been carried out in several fruit crops, bulbs, and tuber crops for their germplasm conservation, and a total of 5,131 accessions of orthodox seeds were added to the base collection establishing the total germplasm holding to 3,88,985 accessions in the National Gene bank by this organization.¹⁶³

1.4.6 Environmental pedagogy and civic awareness

Environmental education and civic awareness play a significant role in making a healthy environment as it helps individuals to recognize the difference between the essential requirements and limited natural resources. The ultimate goal of environmental education is to improve the behaviour of individuals towards the environment.^{164,165}

Promotion of education and awareness about plant diversity is one the major objectives of the GSPC (Global Strategy for Plant Conservation). To achieve this goal, many organizations and stakeholders need to act together and have to concentrate on conservation efforts. The various strategies for the conservation of biodiversity and sustainable living have highlighted the importance of education in preventing biodiversity loss.

Numerous organizations in India such as the Centre for Environmental Education (CEE), Ahmedabad, Bombay Natural History Society (BNHS) Mumbai, The Andaman and Nicobar Islands Environmental Team (ANET), World Wide Fund for Nature-India (WWF) Delhi, and Centre for Science and Environment (CSE), New Delhi are managing towards conservation of biodiversity through their environmental education program. CEE is committed to ensuring that due credit should be provided in the advancement of

sustainable use. It promotes programs, projects, seminars, and conferences to improve the capacity of individuals in education. It helps in improving strategies and environmentally sustainable technologies. The CSE organization works on environmental related issues in India and publishes an environmental education magazine, Gobar Times.

The awareness and training programs should be conducted at various levels such as national and international levels for youth and children. This will help by changing the people to think positively about the environment and protect their natural resources by sustainable use. Awareness can be achieved with the cooperation of TV, Radio, newspapers, posters, and social media. Exhibitions can be conducted for local people residing in the vicinity to make them aware of flora and fauna in that area. There are instances where public awareness has resulted in the conservation of biodiversity. One such case is the Chipko movement or Chipko Andolan, which practiced Gandhian ways of non-violence by hugging medicinally and economically important trees. This milestone event occurred in March 1974, under the leadership of Sunderlal Bahuguna where a group of women living in Reni Village, Hemwalghati, in Chamoli district, India, Raise the voice against cutting of trees by their king to reclaim their traditional rights.¹⁶⁶ The initiative took by these women's motivated several other such movements taken from time to time at various parts of India. As a result various people sensitive policies were made to stop cutting trees in regions of Vindhya and the Western Ghats. Thus, change in perception of the individual to more sustainable utilization of resources more efficiently can help in conserving biodiversity.

CONCLUSIONS

Biodiversity, its types, importance, and threats have been acknowledged worldwide. However, there is unawareness regarding diverse conservation strategies. Inadequate governance and poverty also played a substantial role in the effective conservation of species. There is a need to prioritize various conservation strategies in countries where an economic and political part is more dominating. The nations abundant in biodiversity are mostly developing countries. However, the developed countries are still exploring biodiversity and are now showing their interest in making biodiversity a universal resource for all nations. India, being wealthy in biodiversity is making excellent use by using genetic engineering and biotechnology. In this review paper, various major threats have been discussed such as habitat loss, invasive alien species, pollution, population, overexploitation, overharvesting, global warming, ozone layer depletion, climate change, lack of efficient pollinators, and reproductive isolation. The process of conservation is still new and needs to be further improved and analyzed. More than half of the world's biological diversity is still unexplored. There is a constant need for us to always look for new alternative conservation strategies that are



effective enough for the existing and unexplored genera. Several techniques and strategies have been proposed and implemented for the conservation of plant genetic resources. These methods are in use for decades, however there is a need for us to improve environmental education, awareness, environmental laws, fines, punishment, and penalties.

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