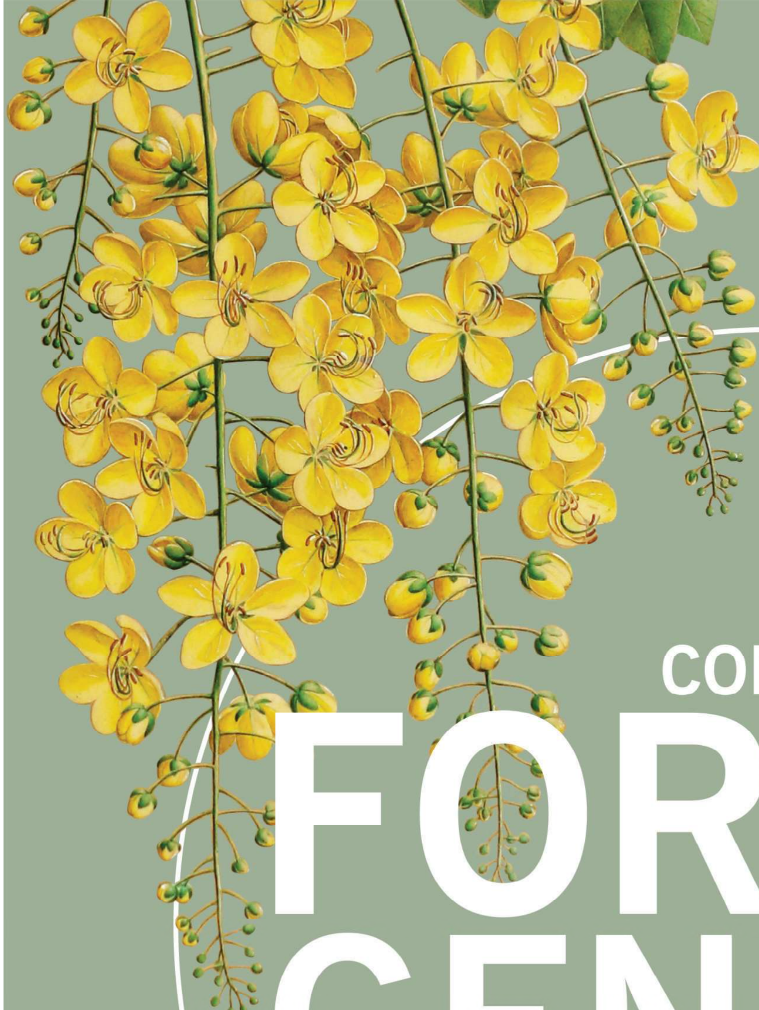

CONSERVATION OF FOREST GENETIC RESOURCES

STATE REPORT UTTARAKHAND 2022

CONSERVATION OF FOREST GENETIC RESOURCES

National Program for Conservation and Development of Forest Genetic Resources
&
Establishment of Center of Excellence on Forest Genetic Resources (CoE-FGR)

Pilot Project
Implementation of Strategy and Action Plan
(2016-2022)

Funded under
National CAMPA Fund
Government of India
Ministry of Environment, Forest and Climate Change

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(Indian Council of Forestry Research and Education)
New Forest, Dehra Dun – 248006
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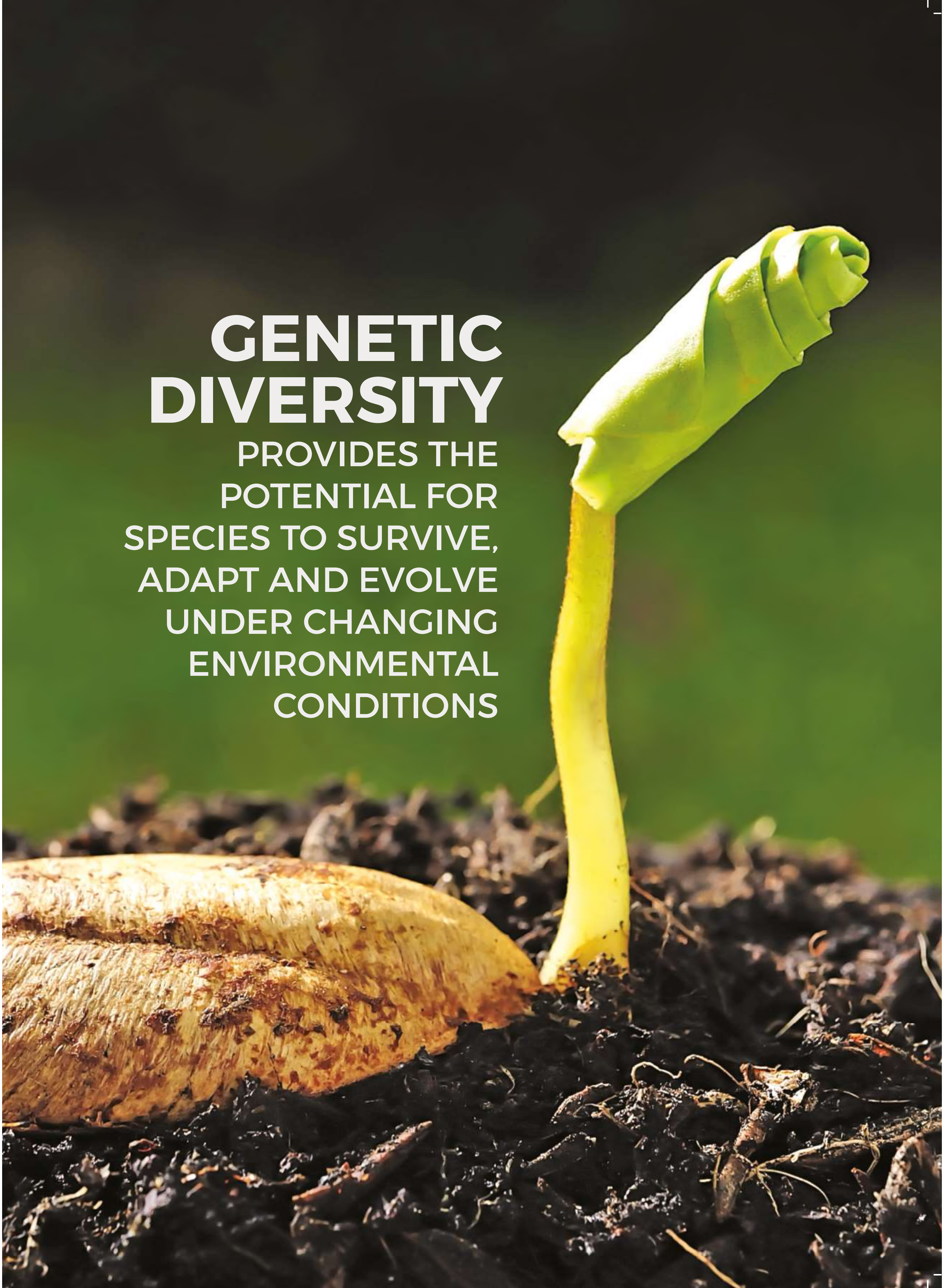

GENETIC DIVERSITY

PROVIDES THE POTENTIAL FOR SPECIES TO SURVIVE, ADAPT AND EVOLVE UNDER CHANGING ENVIRONMENTAL CONDITIONS

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Thanks are also due to Dr. Kuldeep Singh, former Director and Dr. Veena Gupta, Principal Scientist, National Bureau of Plant Genetic Resources, New Delhi for their great support for conservation of FGR at National Gene Bank, NBPGR, New Delhi and signing MOU between ICAR and FRI.

The guidance and help received from Dr. G.S. Rawat, former Director, Wildlife Institute of India (WII), and Dr. S.K. Srivastava, the then In-charge, Northern Region, Botanical Survey of India (BSI), in taxonomic consultations, species prioritization; and Dr. Raman Nautiyal, Scientist (Retd.), ICFRE in sampling design is gratefully acknowledged. Thanks are also due to Shri S.T.S. Lepcha, IFS (Retd.); Shri Manoj Chandran, IFS; Dr S.K. Singh, BSI; Dr. Kumar Ambrish, BSI; Dr. K. Chandra Sekar, G.B. Pant Institute of Himalayan Environment and Sustainable Development; Dr. Vijay Prasad Bhatt, Herbal Research and Development Institute; Dr. Gajendra Singh, Uttarakhand Space Application Centre; Dr. Ishwari Datt Rai, Indian Institute of Remote Sensing; Dr Amit Kumar, WII; and Dr. Navendu Page, WII for their help and valuable inputs in threat assessment consultation on FGR. Thanks are also due to Dr. Hitendra Padalia, IIRS for providing information on vegetation types of Uttarakhand.

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Last but not the least, gratitude goes to all my colleagues, scholars and students who directly or indirectly helped me to complete this book as an outcome of the Pilot Project on FGR.

Dr. H.S. Ginwal
(Project Coordinator)

Ministry of Environment, Forest and Climate Change

सत्यमेव जयते

चन्द्र प्रकाश गोयल, भा.व.से.
वन महानिदेशक एवं विशेष सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय

Chandra Prakash Goyal, IFS
Director General of Forest & Special Secretary
Ministry of Environment, Forest and Climate Change
Government of India

FOREWORD

Forest Genetic Resources (FGR), an intergenerational heritable resource within and among trees and other woody plants are of utmost importance not just for the resilience of diverse forests, but also have enormous actual and potential values of social, economic, and ecological significance.

I am delighted to know that the Forest Research Institute (FRI), Dehra Dun has successfully completed the MoEFCC sponsored and CAMPA funded pilot project entitled the 'National Program on Conservation and Development of Forest Genetic Resources : Centre of Excellence on Forest Genetic Resources' in the context of Himalayan State of Uttarakhand. The multidisciplinary studies undertaken during the pilot project (2016-2022) focused on improving the availability of, and access to, information and documentation on prioritized FGR; germplasm storage; characterization; and *in situ* and *ex situ* conservation besides made notable contribution towards the establishment of a Centre of Excellence on Forest Genetic Resources (CoE-FGR) at FRI. I am overwhelmed by the final output of the pilot project that has been prepared in the form of an impressive book providing overall synthesis of knowledge generated on FGR relevant to Uttarakhand for the wider use by varied stakeholders, especially the policy and decision makers, field practitioners, entrepreneurs, scientists, researchers, and students. I understand that this pilot state-specific valuable report provides foundation for similar efforts in other States/ UTs of the country and offer much desired direction in the emerging field of FGR conservation.

I congratulate the Director General, ICFRE, Director, FRI and the entire project team for their untiring field work in the rugged terrain and harsh climatic conditions prevalent across different forest sub-types, and forest/ wildlife divisions in the Himalayan State; laboratory-based species characterization (chemical, genetic, and pathogenic); and other notable works relevant to the forest botany, floristics, taxonomy, ecogeographic distribution of prioritized species, germplasm storage, vegetative propagation, establishment of field gene banks, modernization and digitization of Dehra Dun Herbarium, and creation of FGR database.

I am confident that the Uttarakhand Forest Department will be keen to optimally utilize the information and knowledge generated through the pilot project and immensely help the resource managers in effective planning and conservation of FGR in the State.

Chandra Prakash Goyal
Date: 01st August, 2022
Place: New Delhi

अरूण सिंह रावत, भा.व.से.
महानिदेशक
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MESSAGE

Genetic resources, are key elements of all biodiversity, essential for humanity. Forest Genetic Resources (FGR) in particular, includes the genetic diversity inherent in seeds, pollens, standing trees, and entire forests, within and between species and populations. FGR are important for the survival and continuance of trees and other woody species, and withstanding the ever-increasing biotic pressure and implications of climate change besides varied ecological, economic and societal purposes. For adaptation and evolution, forests and associated species need sufficient genetic diversity. Forest fragmentation, habitat degradation, population loss, unsustainable harvest, invasive species and increasing extreme climatic events contribute towards the decline of genetic diversity, causing enhanced risk of species extinction.

I am glad to know that FRI, Dehra Dun has successfully completed the major project on the conservation of FGR, as a pilot endeavour in the State of Uttarakhand harbouring rich and unique forest diversity and published the final report in the form of a demonstrative and informative book incorporating a wide array of themes and topics based on multidiscipline. This notable output offers valuable insight to the field practitioners in terms of documentation, germplasm storage, characterization and conservation of prioritized FGR species for formulation of appropriate management strategies. This timely achievement by FRI project team, despite constraints on account of pandemic and resultant lockdown for a considerable time is laudable. Dr. H.S. Ginwal, Senior Scientist and Project Coordinator, FRI deserves special appreciation for coordinating the overall effort involving a large number of scientists, researchers, forest professionals and experts.

I wish that recommendations of the pilot project would be optimally utilized by the project demonstration State so as to ensure effective conservation of FGR species, and the report would serve as a pathfinder to sister institutions under the umbrella of ICFRE to follow the suit for similar efforts in other States/ UTs.

Arun Singh Rawat

Date: 25th July, 2022
Place: Dehra Dun

रेनू सिंह, भा.व.से., पी.एच.डी
निदेशक, वन अनुसंधान संस्थान
एवं
कुलपति, व.अ.सं सम् विश्वविद्यालय

Renu Singh, IFS, Ph.D.
Director, FRI and Vice-Chancellor,
FRI (Deemed to be University)

Forest Research Institute
(Indian Council of Forestry Research & Education)
Dehra Dun – 248 006

MESSAGE

Forest Genetic Resources (FGR) underpin the diversity, stability, productivity and resilience of diverse forests and forest species. Improving the availability of, and access to, information on FGR besides their germplasm storage, characterization and conservation not only allows effective management of the precious 'natural capital' of forests but also ensures sustained flow of ecosystem services for human well-being, and maintenance of adaptative capacity and evolutionary potential of forests. Although, FGR are central to protection of forest ecosystems, landscapes, and production systems, they are subjected to irrational use and enhanced biotic pressure, and even face implications on account of climate change. Sustainable use and management of FGR is the global conservation priority. India being signatory to the UN Convention on Biological Diversity and other Conventions/ Treaties relevant to forest, biodiversity, environment, climate change, and sustainable development, is alive to global obligations and national level commitments, particularly implementation of the Global Plan of Action prepared by the FAO's Commission on Genetic Resources. Keeping in view the strategic priorities for action, country initiated the 'National Program on Conservation and Management of FGR' and FRI was entrusted the task to execute the Pilot Project on FGR in the State of Uttarakhand.

I am extremely happy that FRI has successfully completed the priority conservation project adopting Uttarakhand as the demonstration state and bringing out a comprehensive document on conservation of prioritized FGR involving multidisciplinary field and laboratory-based researches. I appreciate the efforts made by the scientific team based at the Institute and compliment each involved member for his/ her valuable contribution.

I also take this opportunity to thank the senior officials of the Ministry of Environment, Forest and Climate Change, Government of India and ICFRE for reposing confidence in us by entrusting an important task of the pilot project. Project of such magnitude would have not been possible without the assured finances by the National CAMPA Fund. The Uttarakhand Forest Department (UKFD) and several professionals/ experts were our active partners and collaborators in this major endeavour. I am sure that the set of research findings, recommendations and priority actions flagged in the document will provide desired direction to the UKFD in dealing with matters related to FGR.

Renu Singh

Date: 12th July, 2022
Place: Dehra Dun

PREFACE

The world's forests provide humanity a wide range of benefits from improving human health and well being, to supporting wildlife, sequestering and storing carbon, delivering timber, and other products and services. Forest Genetic Resources (FGR) comprising tree, shrub and other woody species contain valuable and unique genetic diversity, the foundation of adaptation in a changing environment. Genetic diversity among individuals and populations of FGR species influences the stability of forest ecosystems. Sustainable forest management depends on conserving genetic diversity and ensuring that it is passed on from one generation to the next. Genetic diversity also permits artificial selection and breeding for the optimization of forest products and ecosystem services.

As a part of the global endeavour towards conservation of forests and its associated biodiversity, the *Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources* in 2013 identified 27 strategic priorities grouped into four areas: (i) improving the availability of, and access to, information on FGR; (ii) conservation of FGR (*in situ* and *ex situ*); (iii) sustainable use, development and management of FGR; and (iv) policy, institutions and capacity building. In response to this, India initiated an ambitious countrywide'National Program on Conservation and Management of Forest Genetic Resources', and as a part of this, launched the pilot project in Uttarakhand in 2016. The pilot project assigned to FRI, supported by the National CAMPA funds was implemented by the institute during 2016-2022.

The project adopted multipronged approach involving multidiscipline, multiscale and professionals and experts, especially senior forest officials and frontline staff of Uttarakhand Forest Department. As envisaged, the project created four Cells pertaining to documentation, germplasm storage, characterization and conservation of FGR involving six prominent Divisions of FRI and a large number of scientists besides varied field and lab-based tools and techniques. The extensive consultative process allowed prioritization of 250 FGR species for various investigations based on broad criteria adopted keeping in view the ecological and socioeconomic significance of different FGR species. Five Components of the pilot project included 23 planned tasks/ activities spread over the project duration. Prominent outputs of the pilot project were in the form of: (a) modernization and digitization of DD Herbarium; (b) documentation of 250 prioritized FGR species highlighting population structure, regeneration status, threats and uses; (c) potential ecogeographic mapping of 50 species; (d) study on seed biology and storage behaviour of 100 species and storage of seed germplasm at the National Bureau of Plant Genetic Resources; (e) *in vitro* storage of germplasm through tissue culture, and pollen germination and medium term storage of ten species; (f) biochemical, molecular and pathological characterization of five prioritized species viz., *Betula utilis*, *Myrica esculenta*, *Quercus semecarpifolia*, *Rhododendron arboreum*, and *Taxus wallichiana*; (g) standardization of propagation techniques of five economically important species of high conservation concern; (h) establishment of *in situ* forest genebanks, and *ex situ* field genebanks in case of four and six prioritized species, respectively; (i) development of FGR digital database; and (j) establishment of the Centre of Excellence on FGR in FRI.

The pilot project has not only made notable contribution towards conservation of 250 prioritized FGR species in the context of Himalayan State of Uttarakhand, but also allowed to optimally use the various concepts, strategies, approaches, and standardized protocols to replicate similar efforts in other States/ UTs being covered under the Phase I program supported by the CAMPA Fund. The lessons learnt and technical and field-based experience gained have facilitated the improved execution of varied activities planned during the Phase I. The project has provided a valuable baseline information on FGR that will be helping in understanding and monitoring the impact of changes in land use, developmental activities and climatic perturbations on the account.

I am sure that an elucidate account on FGR in the form of a comprehensive and demonstrative book will catalyse efforts on conservation of FGR in the country.

Harish Singh Ginwal, Ph.D.
National Coordinator, FGR Project

Forest Research Institute
(Indian Council of Forestry Research & Education)

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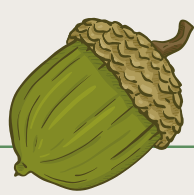
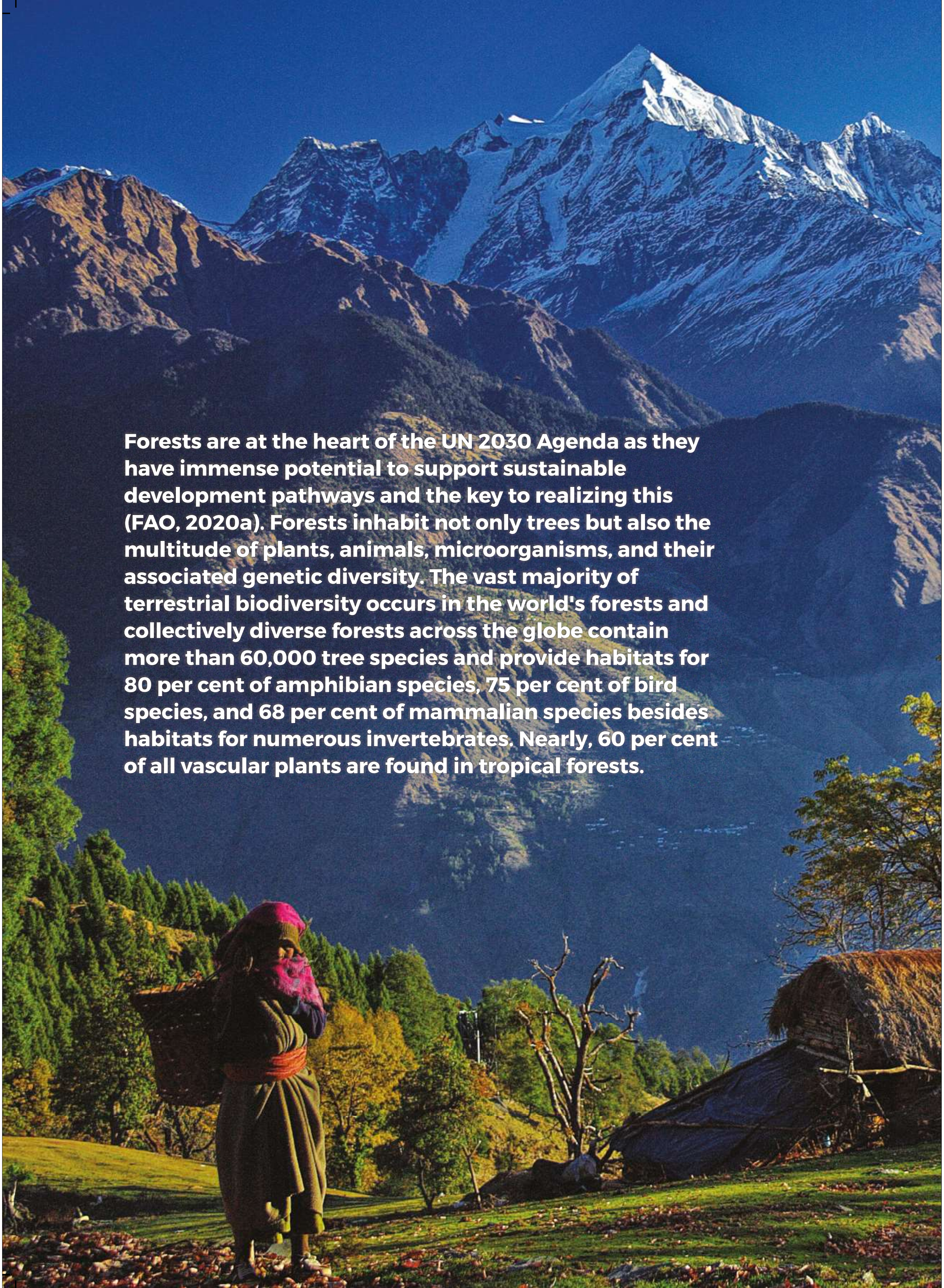
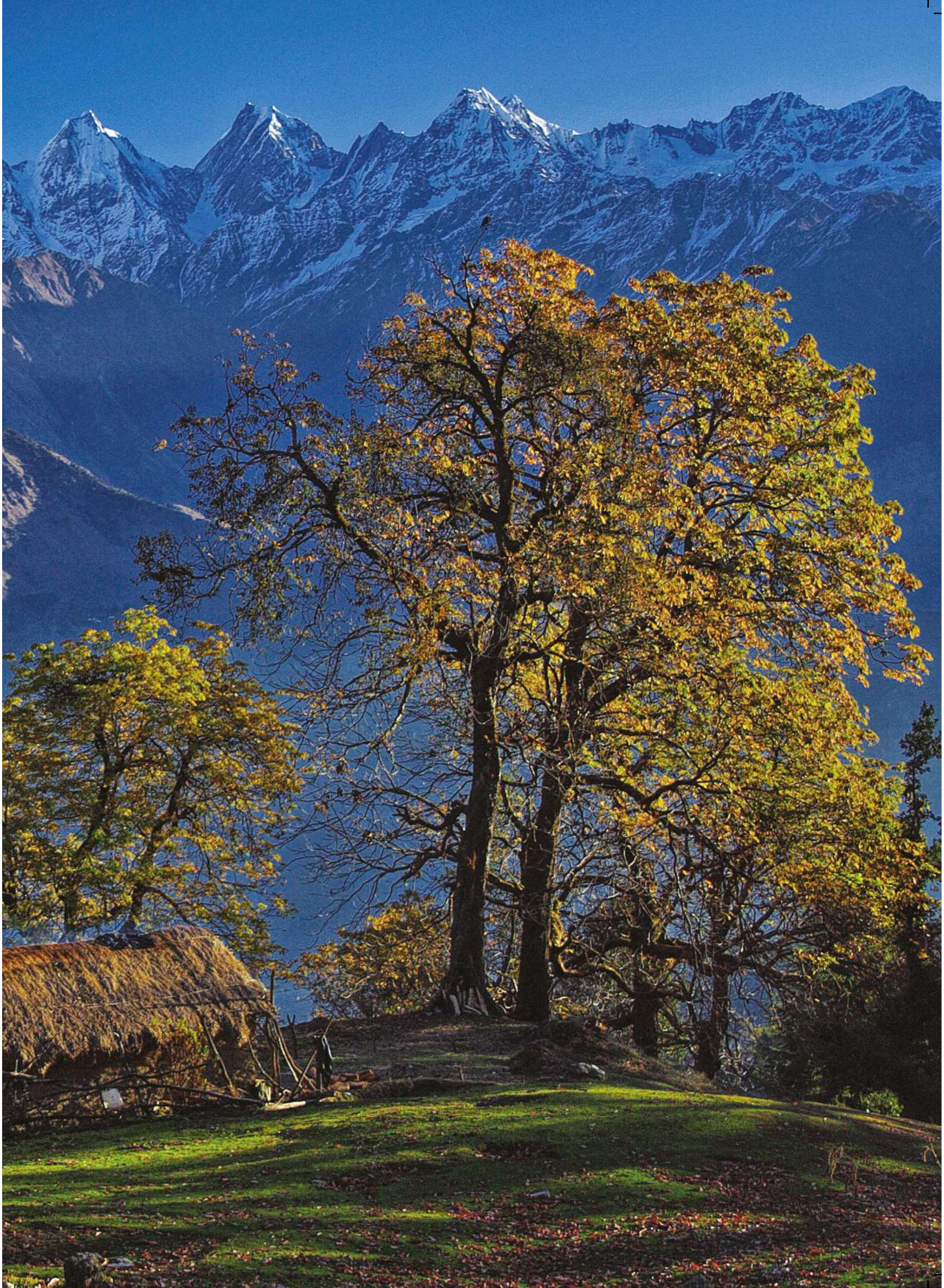
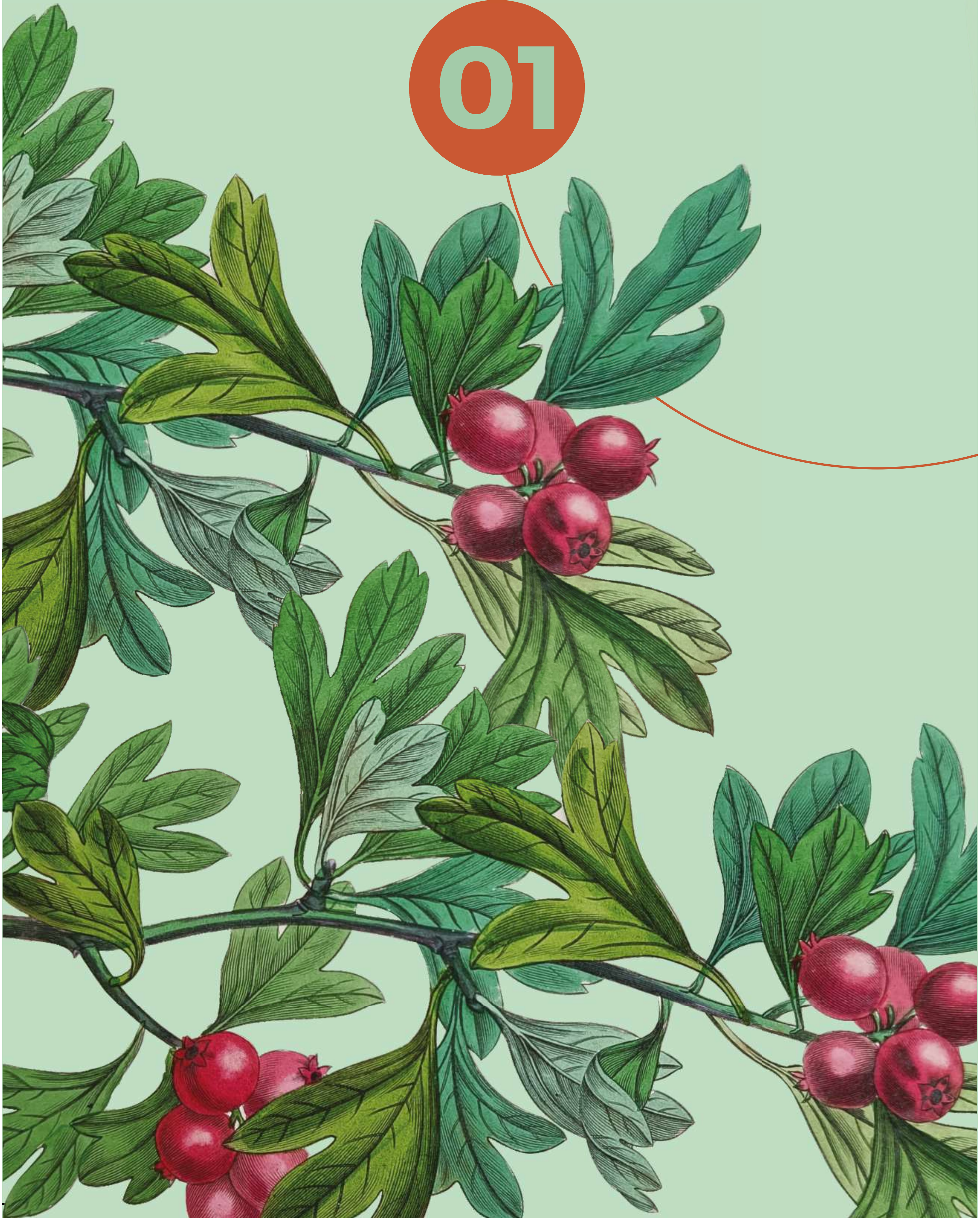




Forests are at the heart of the UN 2030 Agenda as they have immense potential to support sustainable development pathways and the key to realizing this (FAO, 2020a). Forests inhabit not only trees but also the multitude of plants, animals, microorganisms, and their associated genetic diversity. The vast majority of terrestrial biodiversity occurs in the world's forests and collectively diverse forests across the globe contain more than 60,000 tree species and provide habitats for 80 per cent of amphibian species, 75 per cent of bird species, and 68 per cent of mammalian species besides habitats for numerous invertebrates. Nearly, 60 per cent of all vascular plants are found in tropical forests.



PART 01



FOREST GENETIC RESOURCES AND PILOT DEMONSTRATION STATE

Tropical forests are the repository of biological diversity and offer a wide array of ecosystem services, essential for the healthy planet and healthy people. They have immense potential to support sustainable development pathways and the key to realizing this. Forest Genetic Resources (FGR) means genetic material of actual and potential value, while genetic material means material of plant containing functional units of heredity, vital for adaptation and evolutionary processes. Enhanced human activities have adversely impacted not only the diverse forests but also the FGR. Part I deals with the concepts, approaches and strategies relevant to conservation of FGR and highlights basic characteristics of the Demonstration State of Pilot Project.

Chapter 1
Introduction

Chapter 2
Uttarakhand - Project Demonstration State

INTRODUCTION

01

Ginwal, H.S., Rawat, A., Singh, S. and Mathur, P. K.

The UN Convention on Biological Diversity (CBD) recognizes that biological diversity encompassing ecosystems, species, and genes has an intrinsic value and sustains all living systems. Biodiversity, and the multiple benefits it provides, is pivotal for human well-being and a healthy planet. Forests are the single most important repositories of terrestrial biological diversity and they offer a wide range of ecosystem services to people throughout the world. Forest trees and other woody plants in particular support a variety of organisms, and have developed a complex mechanism to maintain high level of genetic diversity, evolved over 3.5 billion years. Forest Genetic Resources (FGR), a subset of biodiversity like other components of biological diversity are declining worldwide at an unprecedented rate and this decline is projected to continue or worsen under business-as-usual scenario despite concerted efforts at all levels. The newer approaches emerging towards conservation of biological diversity emphasize on conservation of vital FGR for the maintenance of ecological integrity, livelihoods, climate change mitigation and adaptation, and also achieving Vision 2050 of the CBD and UN 2030 Agenda on Sustainable Development.

1.1

Forest, Biodiversity and People

Forests are at the heart of the UN 2030 Agenda as they have immense potential to support sustainable development pathways and the key to realizing this (FAO, 2020a). Forests inhabit not only trees but also the multitude of plants, animals, microorganisms, and their associated genetic diversity. The vast majority of terrestrial biodiversity occurs in the world's forests and collectively diverse forests across the globe contain more than 60,000 tree species and provide habitats for 80 per cent of amphibian species, 75 per cent of bird species, and 68 per cent of mammalian species besides habitats for numerous invertebrates. Nearly, 60 per cent of all vascular plants are found in tropical forests. More than 28,000 plant species are currently recorded as being of medicinal use and many of them are found in forest ecosystems. Forests, particularly trees enhance and protect landscapes, ecosystems, and production systems (FAO, 2020a). Since time immemorial, much of the human society has at least some interaction with forests and the biodiversity they contain and all people living both in low–and high–income countries and in all climatic zones, particularly human communities that live within forest or in fringe areas rely the most directly on forest biodiversity for their sustenance and livelihoods, using a wide range of products obtained from varied forest resources for food, shelter, fodder, energy, medicine, and income generation (Fig. 1.1). In addition to the consumptive uses, the non-consumptive uses of forest biodiversity, such as recreation and tourism are growing as a part of cash economies at a fast pace. Further, forests play pivotal role in enriching soil fertility and control of soil erosion, nutrient cycling, maintenance of catchments of rivers and hydrological functions, water purification, capturing and storing carbon and mitigating climate change.

Fig. 1.1
Human and Forest Biodiversity

1.2

Forest Genetic Resources

Biological diversity embraces the diversity of all life on Earth and the CBD commonly distinguishes it at three hierarchical levels and values of biodiversity are generally associated and attributed to these levels (Fig. 1.2). Typically, environmental and life support values are provided at ecosystem level, material goods at species level, and the improvement of production depends on the availability of genetic variation (FAO, 1989; Graudal *et al.*, 2014). According to the Article 2 of CBD 'Genetic resources' means genetic material of actual or potential value while 'Genetic material' means any material of plant, animal, microbial or other origin containing functional units of heredity. In other words, genetic resources are a subset of biological resources. The wording of these definitions emphasizes on two qualifying elements (functionality and value). The functionality relates to 'units of heredity' which pertains to essential and dynamic elements of biology, knowledge and technology, the biological and biotechnological functions for its understanding. The definition of genetic resources also seeks to capture the value- actual and potential- of the genetic material. These values are not restricted solely to economic value but they could be 'social, economic, cultural, and spiritual in nature' (Schei and Tvedt, 2010).

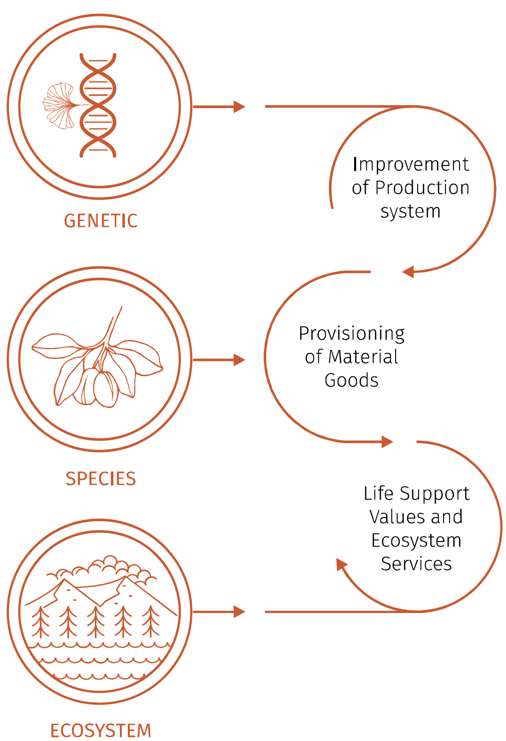


Fig. 1.2
Three Hierarchical Levels of Biodiversity

The global report on the 'State of the World's Forest Genetic Resources' by the Food and Agriculture Organization (FAO) defines Forest Genetic Resources (FGR) as 'the heritable materials maintained within and among trees and other woody plant species' which are essential for the adaptation and the evolutionary processes of forests and trees as well as for improving their resilience and productivity (FAO, 2014a). FGR consist of entities such as seeds, standing trees, entire forest, etc. that contain valuable and unique genetic diversity that is important for ecological, economic, and societal purposes, now and in the future (EUFORGEN, 2021). It is difficult to predict what resources human societies will need from their forests in the future and what forests themselves will need to survive, adapt and evolve. Hence, FGR have been recognized as key resources of possible benefit to society and the environment as the genetic diversity in FGR influences the development of forest ecosystems and provide foundation for adaptation.

1.3

State of World's Forests

Two important entities of the United Nations namely, FAO and the United Nations Environment Programme (UNEP) have jointly published *The State of the World's Forests 2020 (SOFO)* and provided valuable insight on the state of forest ecosystems across the globe while highlighting trends and causes of forest degradation, species diversity, genetic resources, multiple benefits provided to people by forests and biodiversity, restoration, forest in protected areas, and conservation efforts by world's countries. Based on this global report, the following section attempts to summarize key highlights and messages:

1.3.1

Status and Trends in Forest Area

Diverse forests across the globe harbour most of the Earth's terrestrial biodiversity and the conservation of world's biodiversity is primarily dependent on the way in which human interact with and use these varied forests. Forests represent 31 per cent of the global land area and cover 4.06 billion ha. Forests are not equally distributed around the globe and among the world's people. Presently, 0.52 ha per person forest is available (FAO, 2020a). Nearly, half of the world's forest area is relatively intact, and more than one-third is primary forest (i.e., naturally regenerated forest of native species, where there are no visible indications of human activities and the ecological processes are not significantly disturbed). Among five major climatic and ecological domains (boreal, polar, temperate, sub-tropical, and tropical), the largest part of the world's forests being 45 per cent has been reported from the tropics. Ninety-three per cent (3.75 billion ha) of the forest area worldwide is composed of naturally regenerating forest while an extent of 290 million ha of forests or just 7 per cent of the world's forests are planted. These planted forests are of indigenous, native as well as exotic species. The plantation forests predominantly of exotics or cash crops (teak, rubber, cashew, palm, wattle, eucalyptus, etc.) grown as monocultures cover about 131 million ha and represent 45 per cent of the total area of planted forests or 3 per cent of the global forest area (FAO, 2020b). About two-thirds (66 per cent) of forests are found in 10 countries *viz.*, Russian Federation (33.9%), Brazil (20.1%), Canada (12.2%), USA (8.5%), China (7.6%), Australia (5.4%), Congo (3.3%), Indonesia (3.1%), Peru (2.3%), and India (1.8%) (Fig. 1.3). Accordingly, as per the FAO's Global Forest Resource Assessment Report 2020, India ranked tenth amongst the world's forests.

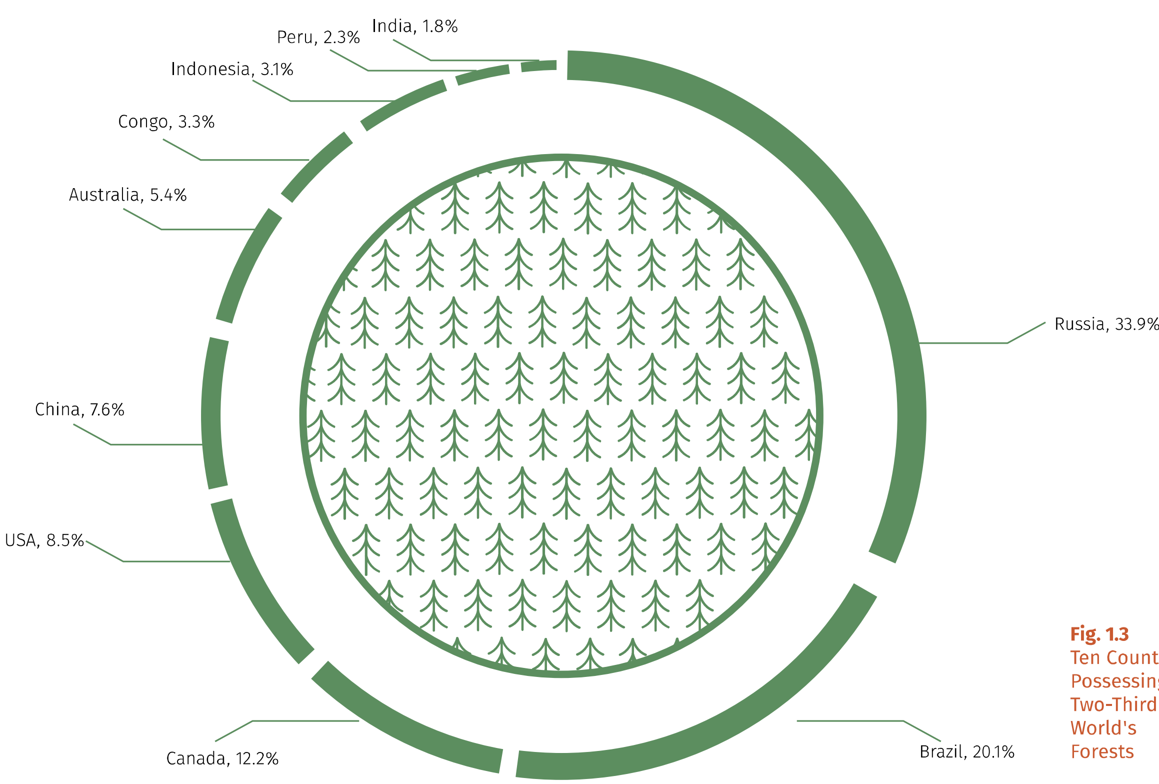


Fig. 1.3
Ten Countries Possessing Two-Third of World's Forests

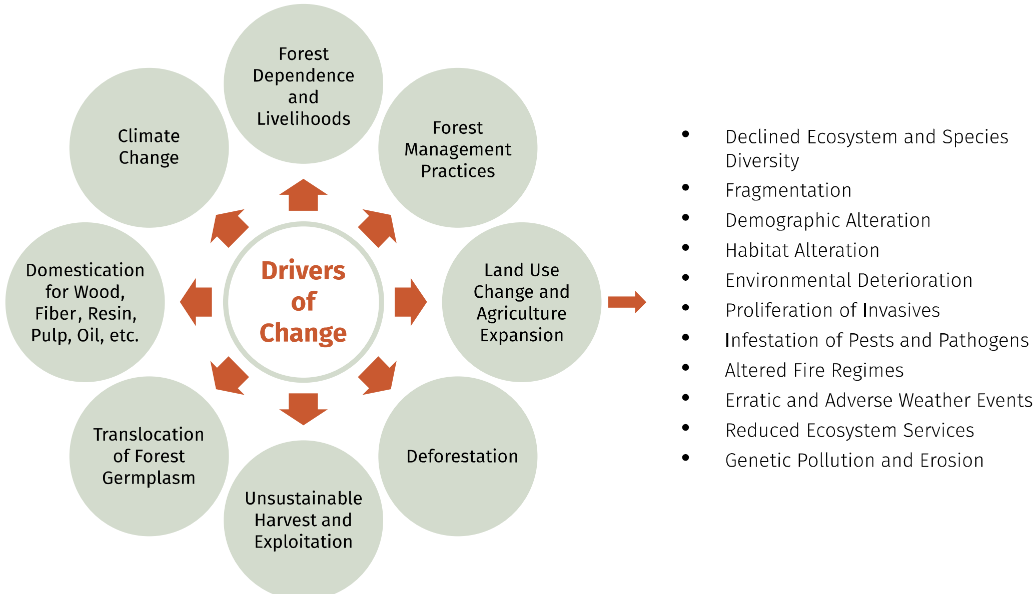
1.3.2

Human Impacts and Drivers of Change Affecting Forest Genetic Resources

Human impacts on forests date back to antiquity and even to prehistory as human societies have displaced and exploited forests for millennia (Behre, 1988). Most stresses to forests are not new. Although, their effects are widespread and intensive than ever before. Ledig (1992) has elaborated human impacts on genetic diversity of forest ecosystems. Since time immemorial, humans have converted forests to agricultural and urban uses, exploited species, fragmented wild lands, change the demographic structure of forests, altered habitat, degraded the environment with atmospheric and soil pollutants, introduced exotic pests and competitors, and domesticated favored species (Fig. 1.4). Stresses caused by atmospheric pollutants and climate change are relatively new.

The prominent drivers of change and threats to FGR in recent times are almost exclusively of human origin and they mainly include traditional forest dependence, forest management practices, land use change and agriculture expansion, deforestation, unsustainable harvest and exploitation, energy production, translocation of forest germplasm, and domestication. External drivers like demographic, economic, technological, and climate changes all shape forest development. These human activities have resulted into declined ecosystem and species diversity, forest fragmentation and degradation, altered population structure of trees, environmental pollution, proliferation of invasives, infestation of pests and pathogens, altered fire regimes, reduced ecosystem services, and genetic erosion. Deforestation and forest degradation continue to take place at alarming rates and significantly contribute to the ongoing loss of forest resources and biodiversity. Although, the rate of deforestation has decreased over the past three decades or so, yet nearly 420 million ha of forest have been lost through conversion to other land uses since 1990. Worldwide, since 1990 the area of primary forest has decreased by 80 million ha. A considerable extent (more than 100 million ha) of forests is adversely impacted by forest fires, livestock grazing, pests, diseases, invasive species, drought, and other adverse weather events. Undoubtedly, the agriculture expansion world over continues to be the main driver of deforestation, forest fragmentation, and the associated loss of forest biodiversity. In a decadal period, from 2000 to 2010, large scale commercial agriculture accounted for 40 per cent of tropical deforestation while agricultural activities for local subsistence contributed for another 33 per cent. Ironically, water and food security and human capacity to adapt to climate change predominantly depends on that very biodiversity. Trees with extensive root systems, especially in mountain ecosystems prevent soil erosion. Forest dwelling insects, birds, squirrels, bats, and monkeys have mutual interdependence as they immensely help in pollination, seed dispersal and germination of forest species while forests provide key habitats for such faunal diversity. The mangrove forests provide resilience against storms and flooding in coastal areas. Dryland-adapted shrub and tree species help in combating desertification. In recent times, threats to FGR have aggravated and continue to increase in the future owing to reduction in forest cover and degradation, modified structure and composition of forests, spread of invasive and ecosystem-transforming species and interactions of different threat factors (FAO, 2014a). Climate change is emerging as the major threat to FGR as stressed trees are more susceptible to insect pest and diseases. The changing climate is expected to alter the frequency and intensity of forest disturbances *viz.*, wildfires, insect outbreaks, pathogens, invasives besides incidences of severe cyclones and droughts, land slides and flooding, ultimately affecting forest cover and composition, timing and intensity of flowering and seeding events, physiological processes, and chemical defense mechanism. Migration of keystone ecosystems at the upland and lowland tree line, particularly in the mountainous regions and temperate forests is evident as range of several species is being altered. The endemic species in key biodiversity hotspots are predicted to decline. Altered hydrological conditions associated with climate change are likely to result in enhanced severity and duration of flooding, which can kill whole stands of trees or result into successional changes.

Fig. 1.4
Human Impacts on Forest Genetic Resources



1.4 Evolving Concepts of Genetic Resources and Key Terms

With the growing experience in the field of Conservation of Biodiversity; advancement of disciplines like Cellular and Molecular Biology, Biotechnology, Bioinformatics, Synthetic Biology, Bioprospecting, and Bioeconomy; and development of modern tools and techniques relevant to DNA technology, genomics, proteomics, genetic markers, *in vivo* and *in vitro* conservation of germplasm in past four decades or so, especially since the inception of CBD, the substantial knowledge, concepts, and terms pertaining to genetic resources or genetic material have emerged and keeps evolving – particularly in light of new insight and understanding being developed. Schei and Tvedt (2010) in their paper, '*Genetic Resources' in the CBD: the Wording, the Past, the Present and the Future* provide an insight that how the concepts of genetic resources in CBD have evolved and how they relate to a functional international regime on 'Access and Benefit Sharing (ABS) of genetic resources in fair and equitable manner'. They looked at multifarious examples of different ways in which the term 'genetic resources' is being used in varied international arenas other than the CBD. All these developments have laid the foundations for new ways of understanding and realizing the actual and potential values of 'functional units of heredity'. This may have implications for the formulation of scope and other articles under the ABS regime. Knowledge about and techniques using genetic material are evolving rapidly. Thus, the concepts of genetic resources cannot be understood only narrowly, in senses related to the original and current state of knowledge. The ABS system may not be able to capture the future potential value of genetic material, especially when it is used in or as a basis for synthetic biology or other new bioeconomic technologies (Schei and Tvedt, 2010). It is pertinent in view of the premise of CBD which is based on a perspective wherein conservation must be seen in the context of sustainable use and benefit sharing. Schei and Tvedt (2010) stated that the concept of genetic resources is not used with any one single, consistent meaning. Instead, they noted a range of differences, from a focus on accession for breeding, through DNA, to the informational dimension, pure digitalized information, and to the generalized concept of biological diversity at the gene level. Obviously, much has happened in the knowledge and technological fields since the entry into force of the CBD. Hence, it is interesting to develop understanding: firstly, how genetic material is being used today and have potential in the future; secondly, how newer and emerging insights on genetic material will have implications for *in situ* and *ex situ* conservation.

The CBD adopted a 'Strategic Plan for Conservation of Biodiversity 2011-2020' that included 20 targets to be achieved by 2020 and were referred as the 'Aichi Biodiversity Targets (ABTs)' (CBD, 2010). The Global Biodiversity Outlook 5 (GBO 5) by CBD and UNEP reported that at the global level, none of the 20 ABTs were fully achieved by the end of 2020, although, six ABTs (Targets 9, 11, 16, 17, 19, and 20) have been partially achieved. The CBD released 'Post-2020 Global Biodiversity Framework (GBF)' as a strategy so as to realize the Vision 2050 for biodiversity and accomplish milestones by 2030 coinciding with the period of the UN-2030 Agenda on Sustainable Development (UN, 2015; CBD, 2021). The GBF

calls for ambitious and transformative change to halt and reverse the process of biodiversity loss by providing enabling environment and tools. The GBF suggests five Goals focusing on maintaining the three levels of biodiversity recognized in the CBD: (a) ecosystems, (b) species, (c) genetic diversity, and on ensuring (d) sustainable benefits to people, and (e) equitable sharing of benefits from use of biodiversity and traditional knowledge. Hoban *et al*. (2020) commented that the inclusion of genetic diversity as a primary Goal (a higher level than the Action Targets) hopefully reflects enhanced recognition of the role of genetic biodiversity for ecological and economic resilience. They also observed that the draft genetic diversity Goal in the GBF does not focus specifically on domesticated and socio-economically or culturally important species, as the previous 2010 and 2020 CBD targets did and they considered this as an important and positive development. Further, they highlighted that the genetic erosion occurs via similar processes in wild and domesticated species (e.g., inbreeding, genetically small effective population size – *N*e, and loss of distinct variants, breeds, or populations) and provided a glossary and clarified key genetic terms relevant to biodiversity policies and strategies at the global, national, and sub-national levels. Availing the benefit of glossaries and clarifications on emerging concepts and terms provided by Hubert and Cottrell (2007), FAO (2014a), and Hoban *et al.* (2020), the present document has made an effort to list the key genetic terms (Table 1.1) and elaborate them below.

As already stated, the term FGR has been defined as the heritable materials maintained within and among trees and other woody plant species. The heritable material is essential for the adaptation and evolutionary processes of forests and trees as well as for improving their resilience and productivity. The Commission on Genetic Resources for Food and Agriculture, FAO (FAO-CGR) responsible for the wider theme of genetic resources since its inception in 1983 emphasized on the genetic material of plant, animal, microbial or other origin containing functional units of heredity and having actual and potential value. The term emphasizes on two qualifying elements (functionality and value). The functionality relates to 'units of heredity' which pertains to essential and dynamic elements of biology, knowledge and technology, the biological and biotechnological functions for its understanding. The term also seeks to capture the value- actual and potential- of the genetic material. The total genetic material of an organism has been termed as the genome. Plants contain three types of genomes *viz.*, nuclear, chloroplast, and mitochondrial. Plant genome consists of long deoxy ribonucleic acid DNA molecules referred as chromosomes. A chromosome may contain part or all of the genetic material of an organism, found in the nucleus of most living cells, carrying genetic information in the form of genes. Genes are DNA sequences assigned with specific functions while variant in DNA sequence at a given gene is termed as allele. These variants (alleles) on genes provide a common way to measure genetic diversity within a species.

The 'genetic diversity' is the total number of genetic characteristics in the genetic makeup of a species. In other words, it denotes the total amount of genetic differences within a species, also referred to as intra-specific variation (Graudal *et.al.*, 2014). Since a species may include multiple populations, intra-specific variation could be either inter or intra-population variations (among and within population genetic diversity). The differences in DNA sequences of a genome make an individual unique and such differences have been termed as the genetic variation. In case of trees, individual uniqueness could be in form of tree height, leaf or seed size, and number of seeds produced by a fruit. The genetic variation between two or more populations, demes, or sub-populations due to restricted gene flow between them has been referred as the genetic differentiation.

The term 'genetic diversity' was not explicitly defined in definitions incorporated in the CBD, particularly in case of trees. Genetic diversity is an essential foundation for evolutionary change and is critical for species to adapt to changing climate, habitats, and biotic interaction including novel diseases.

The transfer of genetic material from one population of a species to another also takes place and results into interbreeding. This is more prevalent in case of plants as seeds, pollens, and propagules are often displaced from one area to the other by wind, water, pollinators, and seed dispersers. The transfer of genetic material from one population of a species to another is called as gene flow or gene migration. Mating among close relatives or siblings results into inbreeding. Loss of fitness owing to inbreeding and accumulation of recessive deleterious alleles causes inbreeding depression.

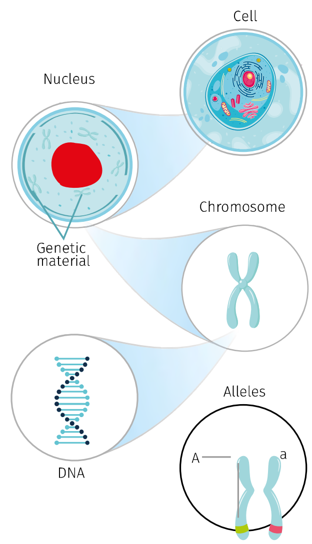
The condition of having two different alleles at a locus is referred as heterozygosity and it is fundamental to the study of genetic variation in populations and a common way to measure genetic diversity. In contrast, the presence of two identical alleles leads to a condition of homozygosity. The random reduction in heterozygosity or genetic variation in a population from one generation to the next enhanced by small population size denotes genetic drift. Genetic erosion occurs due to one or more of: (a) loss of alleles (gene variants), (b) decrease in heterozygosity, (c) loss of distinct populations or significant conservation units, and (d) altered gene flow (Hoban *et al.*, 2014 and 2020). According to Hoban *et al.* (2020), the genetic erosion is the:

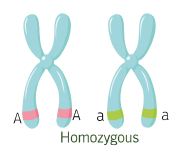
- *Loss of genetic diversity (e.g., evolutionary potential), lineages, traits, populations, meta populations; and/ or*
- *the disruption of processes maintaining genetic resilience such as genetic connectivity; and/ or*
- *high levels of hybridization; and/ or*
- *other threats to genetic diversity such as high inbreeding.*

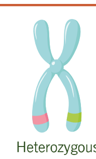
Hoban *et al.*(2020) also stated that 'prevention of genetic erosion' is approximately synonymous with 'genetic diversity is maintained'. Safeguarding genetic diversity would require *in situ* conservation (protection of well managed protected areas) or *ex situ* conservation (seed, pollen, tissue, or living individual taken from the wild and kept in large, well-documented, managed populations) of a sufficient representative amount of genetic diversity from a species' geographic range including genetically distinct populations and the full range of environmental heterogeneity. Safeguarding may also include assessment of genetic diversity, supporting genetic exchange among populations, breeding programs, research, etc. In other words, safeguarding genetic diversity pertains to actions performed *in situ* or *ex situ* which aim to characterize, slow, arrest, or reverse genetic erosion, and promote the processes ensuring adaptive potential.

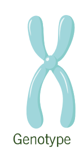
Table 1.1 Key Terms Relevant to Forest Genetic Resources and Genetic Diversity

Forest Genetic Resources	The heritable materials maintained within and among trees and other woody plant species' which are essential for the adaptation and the evolutionary processes of forests and trees as well as for improving their resilience and productivity. In other words, FGR are a subset of biological resources.
Genetic Material	Any material of plant, animal, microbial or other origin containing 'functional units of heredity'. It carries all the information specific to an organism and is passed from one generation to the next. It can be DNA or RNA.
Genome	An organism's genome represents its total genetic material, and plants comprise of three separate genomes: nuclear (about 50,000 - 1,00,000 genes), chloroplast (about 100 -120 genes), and mitochondria (about 40 -50 genes).
Chromosome	A chromosome is a long DNA molecule with part or all of the genetic material of an organism, found in the nucleus of most living cells, carrying genetic information in the form of genes.
Genes	They are nuclear deoxy ribonucleic acid (DNA) sequences to which specific functions can be assigned.
Alleles	A variant in DNA sequence at a given gene; a common way to measure 'genetic diversity'.
Homozygosity	It is the state of possessing two identical alleles at a locus. It describes the genetic condition where an individual has inherited the same DNA sequence for a particular gene from both the biological parents.
Heterozygosity	It denotes the condition of having two different alleles at a locus. It is fundamental to the study of genetic variation in populations and a common way to measure genetic diversity.
Genotype	The term refers to the hereditary material, or DNA, contained within genes and passed from one generation to the next. The genotype of an individual is the sum total of the genetic information contained on the chromosomes.
Phenotype	The term refers to the observable physical properties (structural and functional) of an individual; these include the organism's morphology, development, and behavior. Unlike the genotype, it is not inherited from its parents. Instead, phenotype is determined by its genotype, which is the set of genes the individual carries, as well as by environmental influences upon these genes. Alleles contribute to the individual's phenotype, which is the outward appearance of the organism.

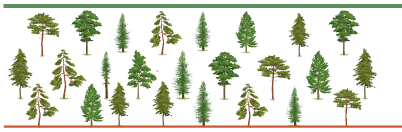
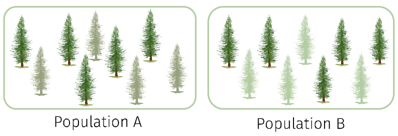
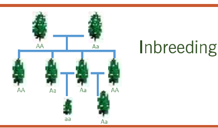
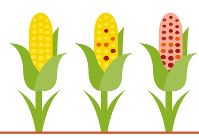
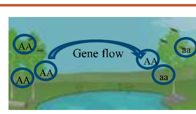
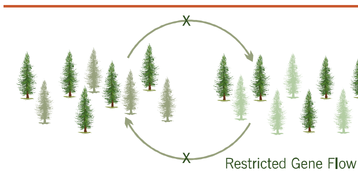
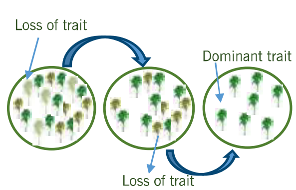








Source Adopted and Modified from Hubert and Cottrell (2007); Leroy *et al.* (2017); Hoban *et al.* (2020)

	The number of different species present in an ecosystem and the relative abundance of each of those species.	**Species Diversity**
	A group of similar organisms which can interbreed in nature and produce fertile offspring. It is the fundamental taxonomic unit of biological classification.	**Species**
	A group of interbreeding individuals in a defined area genetically distinct from other such groups. Most species have multiple populations.	**Population**
	Mating among relatives, e.g., siblings.	**Inbreeding**
	Loss of fitness (growth rate, lifespan, reproductive output) due to inbreeding and accumulation of genetic load, primarily recessive deleterious alleles.	**Inbreeding Depression**
	Evolution via natural selection as environmental conditions change.	**Adaptation**
	A change in DNA sequence which can result from copying errors during replication, exposure to ionizing radiations or chemicals called mutagens and infection by viruses.	**Mutation**
	The term refers to diversity in gene frequencies between individuals or populations. Mutation is the ultimate source of genetic variation, but mechanisms such as sexual reproduction and genetic drift contribute to it as well. It enables natural selection, one of the primary forces driving the evolution of life.	**Genetic Variation**
	It denotes the transfer of genetic material (by interbreeding) from one population of a species to another. It is also referred as 'gene migration.'	**Gene Flow**
	It is a measure of genetic variation between two or more populations, demes or subpopulations which are isolated or partially isolated. It occurs because of accumulation of differences in gene frequencies due to restricted gene flow between them.	**Genetic Differentiation**
	The term refers to the random reduction in heterozygosity or genetic variation in a population from one generation to the next enhanced by small population size. The loss of diversity is greater as isolated population reduce in size. It is a mechanism of evolution. It occurs due to random loss of alleles due to chance events. Genetic drift can cause traits to be dominant or disappear from a population.	**Genetic Drift**
	Refers to one or more of: loss of alleles (gene variants); decrease in heterozygosity; loss of distinct populations or significant conservation units; or altered gene flow, usually measured with genetic data.	**Genetic Erosion**

1.5

Importance of Forest Genetic Resources and Genetic Diversity

Forest genetic resources constitute a unique and irreplaceable resource for the future, including for sustainable economic growth and progress and environmental adaptation. FGR, particularly the genetic diversity within tree and woody species is at the root of ecosystem-based management of forests aiming at the provision of multiple goods and sustained flow of ecosystem services (Mendoza and Prabhu, 2000; Ratnam *et al*., 2014). Forest tree species are generally long lived and extremely diverse as one species can naturally occur in a broad range of ecological conditions. Moreover, most forest species have evolved under several periods of major climatic change. Accordingly, tree species have been recognized as the most genetically diverse organisms on Earth. Surely, genetic diversity of tree species and other FGR is a key component of forest ecosystem functioning. The importance of genetic diversity within all species cannot be overemphasized in view of the significant contribution of forests and trees towards meeting the present and future challenges of food and water security, poverty alleviation, and sustainable development. It has been well recognized that in order to realize varied interconnected goals of sustainable development including climate change mitigation and adaptation, the availability of rich diversity between and within tree species and other plant resources of forests is vital besides the maintenance of healthy forest ecosystems.

Genetic resources have been recognized as one of the key pillars of Sustainable Forest Management (SFM). The SFM depends on conserving genetic diversity and ensuring that it is passed from one generation to the next. The capacity of trees and other FGR to develop resistance and tolerance to biotic and abiotic stresses depends upon genetic diversity. Genetic diversity also permits artificial selection and breeding for the optimizing of forest products and ecosystem services.

Evolution is impossible without genetic diversity. FGR have provided the potential for adaptation in the past, and will continue to play this key role as human kind addresses the challenge of mitigating or adapting to future climate change. Keller and Waller (2002) stated that without adaptation, population size of FGR eventually declines, which can result in local extinction. The genetic diversity in FGR influences the development of forest ecosystems. The forest trees at a given location contain this genetic diversity in multiple combinations, and these combinations are extremely important as insurance for the future, because genetic diversity is the foundation of adaptation (EUFORGEN, 2021). At the ecosystem level, genetic diversity is important for maintaining fitness and adaptability of species. Genetic diversity of 'flagship species' (those who are responsible for the maintenance of architecture of specific forest ecosystem, e.g., teak – *Tectona grandis*, sal – *Shorea robusta*, Banj oak – *Quercus semecarpifolia*) and 'keystone species' (those whose effect is disproportionately large relative to their population size as they can influence the presence, distribution, and abundance of several prominent forest species, e.g., Banyan – *Ficus benghalensis*) can affect species diversity of associated communities and productivity. The genetic diversity of ecosystem engineers or keystone species (e.g., trees, pollinators, microbes, and pathogens) supports large number of species which facilitate ecosystem stability, or supports ecosystem functions including primary productivity, nutrients, and energy flows. Genetic diversity within species supports not only species persistence but also ecosystem integrity, adaptability, and risk reduction (Hoban *et al*., 2020). Thus, genetic diversity is an essential

component of long-term forest health as it provides a basis for stability, adaptation, and resilience to environmental stress and change (Schaberg *et al.*, 2008).

The need to conserve FGR and genetic diversity has emerged as the most important and urgent action with increasing evidence of global climate change and the associated risks that forest ecosystems face and in all likelihood that the species and populations will suffer or may become extinct as a result. The past few decades represent the beginning of an era of unprecedented change in selective pressures on almost all tree and other woody species, these altered selective forces include extreme climatic events, gradual increase in temperature and altered rainfall regimes, enhanced events of droughts, floods, and cyclones, changed fire regimes, increased air pollution, elevated atmospheric CO_2 levels, habitat loss and fragmentation, spurt in pest and disease outbreaks, appearance of new pest and disease species, competition with invasive exotic plant species including transformer species capable of changing the ecology of entire ecosystems, and the loss of or changes in pollinators and dispersal agents. Genetic diversity underpins the resilience in the context of climate change and related disturbances. Managing FGR and genetic diversity is of key importance in fostering resilience of forest ecosystems to climate change and human disturbances (Vinceti *et al.*, 2020) The need for urgent action to conserve genetic diversity is indisputable (EUFORGEN, 2021).

In short, FGR and the genetic diversity they possess are the mainstay of biodiversity and biological stability – it enables species to adapt to changing environment and to survive. No single individual possesses more than a fraction of the genetic variance of the species. The sum of gene differences among scattered and isolated populations of a given species constitutes the gene pool. As the number of individuals and populations that comprise a species are reduced and its gene pool is eroded, the species can be pushed towards extinction (NRC, 1991).

In view of the above stated significant contributions and pivotal roles, the FGR and genetic diversity are of utmost importance in order to ensure that forests, particularly trees and other woody elements can survive, adapt and evolve especially under changing environmental conditions owing to human disturbances and climate change (Fig. 1.5) (FAO, 2014a).

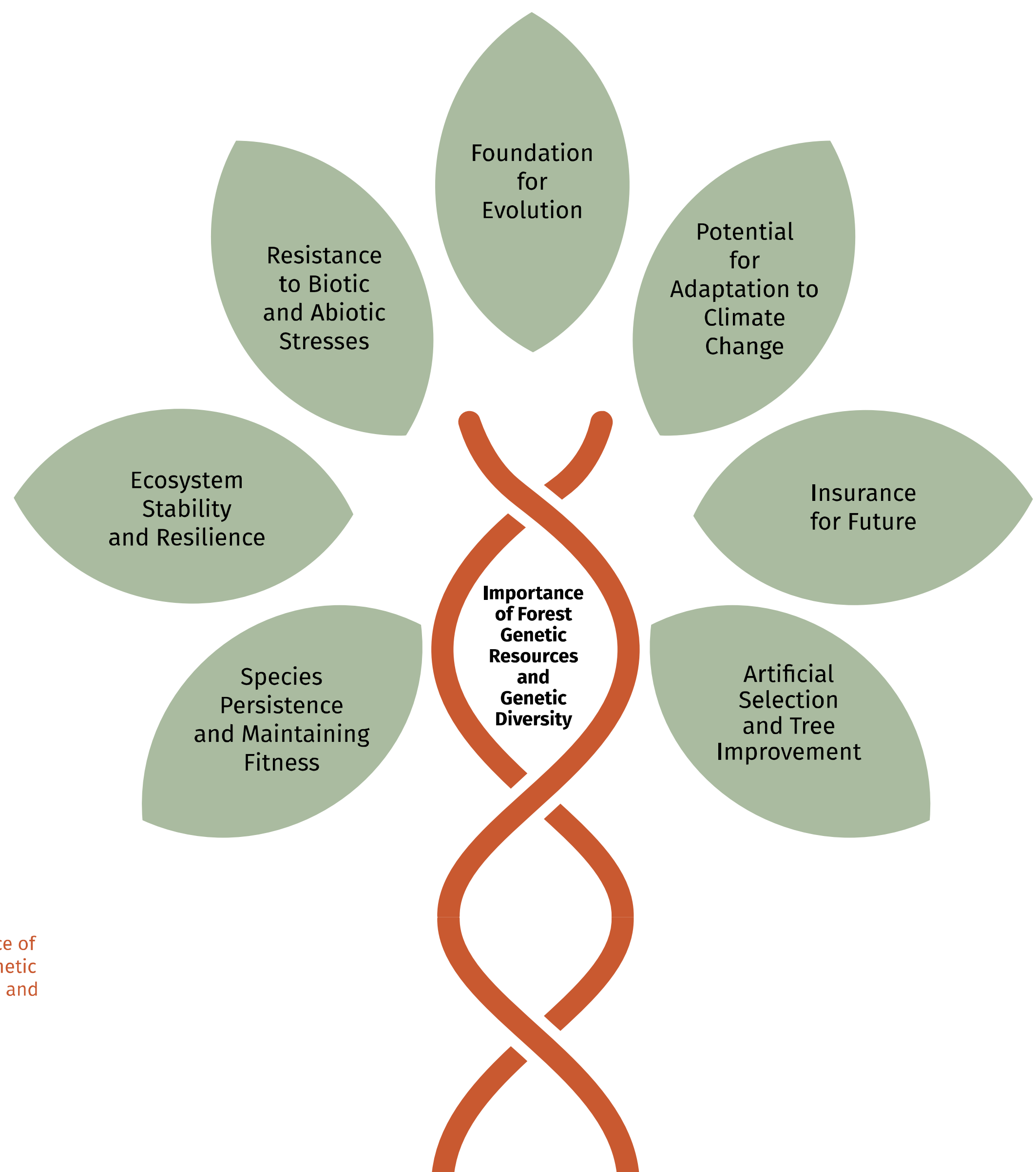


Fig. 1.5 Importance of Forest Genetic Resources and Genetic Diversity

1.6

Factors Influencing Genetic Diversity

Most forests across globe are now home to a range of native, non-native, and naturalized tree and shrub species that have adapted in various ways to their growing environments owing to natural processes and human induced activities. Much of this genetic diversity has evolved naturally over generations as species have adapted at a fine scale to local conditions. In other cases, diversity is the product of enhanced anthropogenic activities or deliberate efforts over recent decades to develop tree varieties that are productive as a part of tree improvement. The foregoing section 1.3.2 has already elaborated on human impacts and drivers of change influencing FGR. Certainly, genetic diversity within a species or intraspecific diversity is influenced by natural processes like: (a) natural colonization, (b) natural selection, (c) gene flow, and (d) mutation (Hubert and Cottrell, 2007).

In nature, natural colonization at a given site through pioneer stages of succession is a chance event and the genetic material (seed, pollen, propagule) that arrives at the particular location may not necessarily be the best adapted material that is present within the entire species. At a specific site, trees with a long period (in terms of generations) of occupancy are generally considered the most optimal, being the original colonizing material. After the first step of natural colonization, the second important process influencing the genetic material and genetic diversity is natural selection. Natural selection can only act on the material that is present at a particular location. Factors that prevent or reduce reproduction in certain individuals of a population represent a selection pressure and this process increase the frequency of those traits that contribute to adaptive potential of an individual in a population. The third important process relates to gene flow via natural dispersal of seed, pollen or vegetative propagules through natural connectivity (corridors, slope, streams or rivers) or by way of natural (wind, water) and biological (pollinators, seed dispersers, humans) agents. Connectivity and ensured gene flow enhances the capacity of a forest to respond to changing selection pressures by providing a regular input of genetic material from trees adapted to different ecological conditions. Finally, a random event of mutation (either neutral or adaptive genetic variation) may also add to the genetic variation within a species. In short, the genetic locality of a given species is largely the product of original colonizing material, natural selection, gene flow, and mutation (Hubert and Cottrell, 2007).

Over and above the natural processes, anthropogenic activities by way of change in land use, forest management practices, agriculture expansion and intensification, enhanced biotic activities (forest fires, livestock grazing, lopping, unsustainable harvest, introduction of invasive exotics, and developmental activities), and pollution have pervasive and sometimes dramatic changes in the environment of forest ecosystem (Schaberg *et al.*, 2008). Although, many natural and human influences may work to reduce the genetic diversity within forest stands, the prominent factor that could alter the gene pools of forest ecosystems is forest management practices.

Forest management practices modify forest composition, tree density, age class structure, at different stages during a forest stand rotation, and can have strong effects on genetic diversity, connectivity and effective population size (Ledig, 1992). Since trees are long-lived, detecting which environmental factors affect most of their genetic diversity is not straightforward. Regeneration is the basic process that maintains forest ecosystem dynamics and, as such, is a key aspect of sustainable forest management system (Ackzell, 1993). Distinction between natural regeneration based on seeds and seedlings or vegetative propagules, and artificial regeneration by direct seeding or planting is important for FGR. Artificial regeneration disrupts the continuous evolution of tree populations at a given site but at the same time opens up opportunities for enhanced genetic diversity and increasing productivity through the selection of superior provenances. On the contrary, natural regeneration allows the transmission of genetic information to the next generation, and also adaptive and non-adaptive changes of genetic structures. Enrichment planting may also have impact on genetic diversity. Regeneration, from fecundation to seed dispersal and seedling recruitment, is a key stage affecting genetic diversity in natural forest tree populations. In managed forests, silvicultural practices can modify the natural processes *viz.*, demographic factors such as pollen and female flower quantity, flowering synchronicity, number, aggression, and density of congeners and their spatial distribution and these processes can modify the genetic diversity and structure of a forest population (Oddou-Muratorio *et al.*, 2011; Sagnard *et al.*, 2011; Ratnam *et al.*, 2014). Variable results have been documented for genetic impacts of clearcut harvestings of forests in the pasts as well as natural and artificial regeneration systems adopted in diverse forests (Ratnam *et al.*, 2014). Some of the commercially important timber species have been exploited for economic development or extensive as well as monoculture plantations of such species have been undertaken after clear felling. In several instances, extensive plantations of cash crops (rubber, palm, coconut, etc.) have also been undertaken. Genetic impacts of selective harvesting, patch cut, shelterwood cut, and retention of green trees have been varied in nature and long impacting. In tropics, rapid socio-economic development, particularly in agricultural and industrial infrastructure and traditional practice of shifting cultivation has affected the level of timber production, forest ecosystem services and the precious wealth of genetic diversity. The impact of logging on the population structure of tree species depends strongly on the degree of disturbance and intensity of logging (Ho *et al.*, 2004). Increasingly, areas of the world's forests are being planted as opposed to native forest. Plantation forestry is often associated with the use of seed sources not native to the planting site. Gene flow between plantation and natural forest has been recognized as an important threat to genetic material of native populations but yet overlooked owing to ignorance and lack of understanding of likely impacts like increased introgression and genetic drift (Ratnam *et al.*, 2014; Leroy *et al.*, 2017). Positive impacts of plantation forests on the adjacent native forest have been described by different authors as the planted forest provides corridors allowing the movement of biota between forest fragments, habitats for birds, insects and other species that experience difficulty in habiting small forest fragments, and enhance genetic diversity through either seed or pollen dispersal into inbred remnant populations (Bennett, 2003; Neuschulz *et al.*, 2011; Mazzoli, 2010; Byrne and Macdonald, 2000). Adverse impacts of plantation forests also could be in the form of changing the abiotic environment (e.g., lowering the water table) changing fire frequency, damage to native forest remnants during harvesting, altering the biotic environment (e.g., increasing the pest-mammal, invertebrate, fungal, bacterial load), and changing native gene pools through the invasion of native forest by introduced seeds (Kagawa *et al.*, 2009; do Nascimento *et al.*, 2010; Jairus *et al.*, 2011; Potts *et al.*, 2003).

In addition to aforementioned four natural processes and anthropogenic activities influencing the genetic diversity, human aggravated climate change is having wider implications in form of population bottleneck, fragmentation and isolation, reduced regeneration and population size, altered distribution range of the tree species and phenology, asynchrony of pollinating and seed dispersing agents, modified seed biology and germination behaviour, and introduction of pathogens and pest infestation, ultimately affecting the fundamental processes of colonization, selection, gene flow, mutation, etc. Yet another natural process that may influence the genetic diversity is the genetic drift i.e., a random reduction in genetic variation in a population from one generation to the next enhanced by small population size and/or isolation of populations.

Leroy *et al.* (2017) in a review and synthesis article highlighted that for population management, assessing genetic erosion *per se* is essential for monitoring evolutionary potential and elaborated on the proximate causes and drivers of change while narrating the underlying genetic processes and mechanisms leading to consequences of genetic erosion. They also depicted the relationship amongst proximate causes/ drivers, genetic mechanisms, and consequences of genetic erosion diagrammatically. This has been appropriately modified and presented in Fig. 1.6.

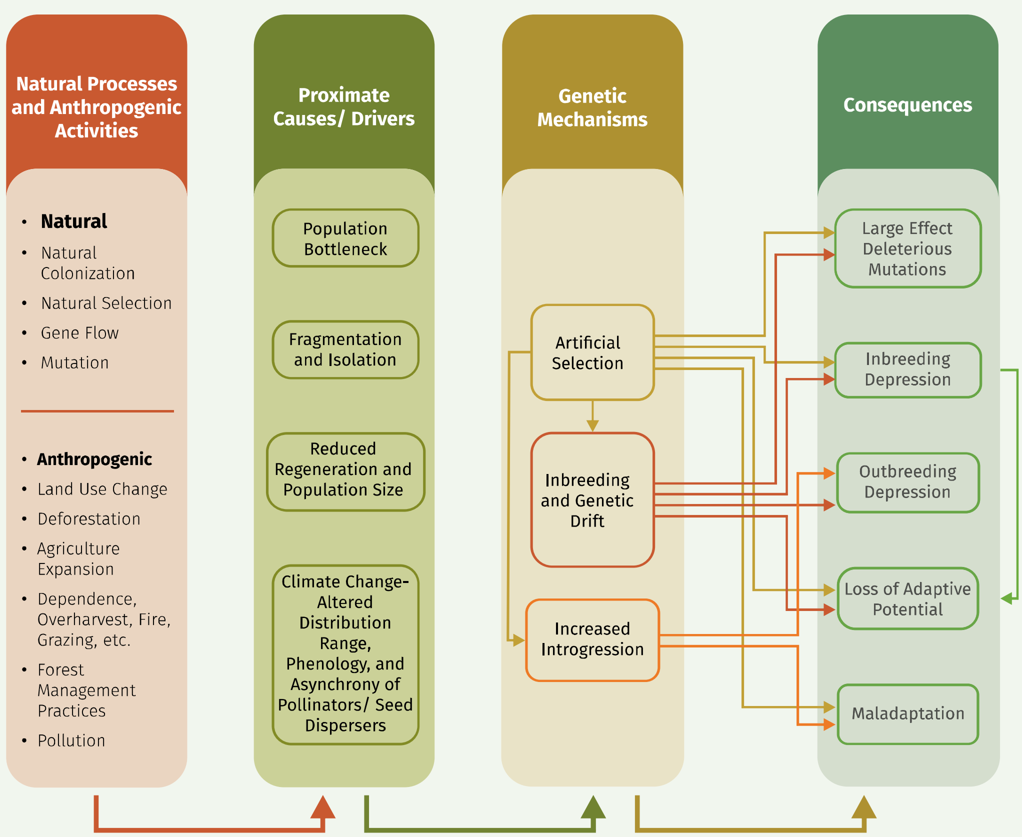


Fig. 1.6
Linkages Amongst Natural Processes, Anthropogenic Activities, Proximate Causes/ Drivers, Genetic Mechanisms and Consequences of Genetic Erosion

Source
Adopted and Modified from Leroy *et al.* (2017)

1.7

Global Developments and Initiatives for Conservation of Forest Genetic Resources

The foregoing sections have aptly narrated that genetic diversity in all living organisms on the earth is a reflection of biological evolution that has accumulated during some three thousand million years. This diversity constitutes the vital genetic resource of the planet essential for maintaining the stability and functioning of ecosystems, and provides a buffer against climatic and other environmental changes (Palmberg and Esquinas-Alcazar, 1990). The above sections also highlighted that the human species is a part of nature as well as the dynamic process of evolution. However, an unprecedented increase in human population, increased movement of people, goods, services, information and know-how across the globe, and development of powerful new technologies have made notable and constant change in demands on forests, wood and non-wood products and environmental services, ultimately shifting the boundaries and priorities of the forest genetic resource sector (FAO, 2004).

The global instruments of direct relevance to FGR fall under the purview of environmental, agricultural or forestry sectors. A number of instruments (policies, conventions, treaties, bilateral and multilateral agreements, etc.) relevant to forests, forestry, forest genetic resources, and allied wider disciplines like biodiversity conservation, climate change, and sustainable development organizations and associated frameworks have come into existence and greatly increased at both international and national level in response to enhanced environmental awareness and related national agenda and international obligations and programs.

In the past seven decades or so, international priorities in genetic resources gradually moved from initial focus on plants, agricultural crops in particular to domesticated animals, fisheries, human genomics, microorganisms, and finally to forest trees and woody plants as these different sectors form a part of wider biodiversity, have strong cross-sectoral interconnections, and evident sharing of common technological tools. In the context of FGR, the early focus in 1960s and early 1970s was on genealogical studies and seed collection underpinning species and provenance research that too on a few commercially important timber species and has progressively shifted to the wider management of genetic resources of a range of trees and shrubs for multifarious purposes and end uses relevant to a variety of national and local needs (FAO, 2004).

The principles of protecting genetic diversity are not new and not only confined to the present or past century, but *in situ* conservation of animal and forest resources was mandated by official decrees in parts of India and China as early as 700 B.C. (Swaminathan, 1983; Palmberg and Esquinas-Alcazar, 1990). However, the present concepts of systematic exploration, conservation, and sustainable utilization of plant genetic resources for agricultural and forestry development are relatively of recent origin, having been pioneered by scientists such as de Candolle in the late 1800s, and Vavilov and Meyer in the early 1900s (Palmberg and Esquinas-Alcazar, 1990).

1.7.1

Chronology of Development Towards the Recognition and Use of FGR

Prominent international efforts towards the recognition and use of FGR originated in the late 1960s, with the guidance and support of the UN Food and Agriculture Organization (FAO) and several national institutions, mostly from developed countries. Since then, not only the institutional interest has been stimulated due to the fact that tree improvement programs have successfully demonstrated realization of economic benefits using genetic resources to improve forest production but in past decades, environmental awareness, advancement of tools and techniques, understanding the factors responsible for diminishing genetic diversity, and voluminous literature on different aspects of FGR have also grown substantially.

Palmberg and Esquinas-Alcazar (1990) have provided a detailed account on the role of United Nations agencies and other international organizations in the conservation of plant genetic resources and highlighted the notable contributions made by the FAO in the wider field of genetic resource conservation relevant to agriculture, animal husbandry, fishery, and forestry. The FAO was established in 1945 with initial mandate to support agricultural and nutrition research and providing technical assistance to member countries to boost production in agriculture, fishery, and forestry. Within FAO, deliberations on plant genetic resources first began in 1948 and a meeting convened in 1961 led to the establishment of a 'Panel of Experts on Plant Exploration and Introduction' in 1962. The panel was mandated to advice FAO on the issues relevant to the involvement and development of international guidelines for collection, conservation and exchange of crop germplasm. In 1967, the FAO Conference recognized that forest genetic diversity was increasingly being lost, and requested the establishment of yet another Panel of Experts specific to FGR (Panel on Forest Gene Resources or the Forest Gene Panel). Accordingly, the new Panel on FGR was established in 1968. The FAO formed a 'Plant Genetic Resources and Crop Ecology Unit' to organize and promote activities in the conservation and utilization of plant genetic resources and convened sequential international conferences in plant genetic resources during 1967-1981. Concurrently, as a consequence of FAO's catalytic action, several national, regional, and international organizations or agencies were either established or have strengthened their programs relevant to the sustainable utilization of plant genetic resources. FAO's activities on FGR are an integral part of FAO forestry program and contribute to other program components *viz*., Global Forest Resources Assessment, national forest programs, sustainable forest management, tree breeding and plantation development, and protected area management. The FAO has acknowledged the importance of FGR since its inception and for several decades, the Forest Gene Panel has continued to guide FAO's work on FGR. The FAO jointly with the World Bank and UNDP in 1971 founded an independent, international consortium named as the Consultative Group on International Agriculture Research (CGIAR). Under the aegis of the CGIAR, 13 autonomous international agricultural research centers (IARCS) and the International Board for Plant Genetic Resources (IBPGR) were set up. The mandate of IBPGR was to 'further the study, collection, preservation, documentation, and evaluation and utilization of genetic diversity for the benefit of the people throughout the world' (Palmberg and Esquinas-Alcazar,1990). In October 1993, IBPGR became the 'International Plant Genetic Resources Institute (IPGRI)' and in 1994, IPGRI began independent operation as one of the centers of the CGIAR.

The FAO in its 22nd Conference held in 1983 took two important actions on the need to guarantee the free exchange of germplasm between all nations of the world and to provide an international forum for discussion on the vast subject of genetic resources. As a result, firstly, an international undertaking was developed on plant genetic resources so as to ensure that they will be explored, conserved, evaluated, and made available, without restriction for breeding and scientific purposes. Secondly, FAO established a 'Commission on Plant Genetic Resources (FAO-CGR)' in 1983, open to all member nations and associated members with the intention to provide an international forum to discuss matters related to plant genetic resources. Though the importance of genetic resources was well recognized in 1950s itself, but two important international instruments *viz*., (i) Convention on Biological Diversity (CBD), and (ii) International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) came into existence in 1992 and 2001, respectively and reinforced the importance of genetic resources and genetic diversity. Subsequent to the CBD, FAO-CGR broadened the mandate to cover all components of biodiversity to food and agriculture. Thereby, forest biodiversity, FGR in particular not only got the further recognition but the scope of the FAO-CGR was enlarged several folds and the FAO initiated the development of REFORGEN, a database on forest tree species and the management of their genetic resources in 1993. The system has data on more than 1,600 forest tree species in 146 different countries and offers information based on species with related activities in a given country and data on institutions dealing with FGR in participating countries. The technical development of REFORGEN has been possible with the support of USDA Forest Service (USFS). Willan (1995), has described history and ongoing activities of FAO's Program on FGR, with special reference to conservation as they evolved from its initial work in afforestation. One of the prerequisites for successful forest plantations was recognized on the provision of propagating material (usually seed) that is genetically suitable for both the ecological conditions and the end uses. The importance of exotics in afforestation in several countries introduce an international element to seed procurement and thus an essential role for an international agency such as FAO. The Panel of Experts on FGR also recognized the important differences which exist between the genetic resources of forest trees and of agricultural crops; in particular, the forester has to deal with wild and variable populations of species which may take decades to reach sexual maturity, while the agronomist commonly handles annual crops, domesticated over thousands of generations and frequently depleted in respect of genetic variability.

The FAO-CGR in its 11th Session held in June, 2007 emphasized on the urgent need to conserve and sustainably use FGR, and included a report on *The State of the World's Forest Genetic Resources* (SOW-FGR) in its Multi-Year Programme of Work. It took almost three years to finalize the process for preparation of the SOW-FGR and to mobilize resources. Once the process was established and approved by the FAO-CGR, FAO invited countries to nominate National Focal Points and to prepare and submit country reports, which have been the main source of information for the preparation of global report on FGR following a country driven process. FAO provided guidelines for the preparation of country reports including the methodology besides organized regional and sub-regional training workshops and encouraged to adopt a participatory approach while engaging a wide range of stakeholders. In response, all together 86 countries submitted reports, accounting for 76 per cent of the world's land area and 85 per cent of the global forest area, with adequate latitudinal and ecoregional representation. The draft report prepared by the Commission was reviewed by the Intergovernmental Technical Working Group on Forest Genetic Resources (ITWG-FGR) at its second session in January, 2013 and presented to the Commission in April, 2013. Countries were invited to provide comments on the final draft, which were taken into consideration in the finalization of the report (FAO, 2014a). The chronology of global developments and initiatives towards the recognition, conservation and sustainable use of FGR is summarized in Fig. 1.7. The final report (SOW-FGR) was published in 2014 and the summary and key findings of this world's report are highlighted in Box 1.1.

1.7.2

Global Plan of Action for the Conservation, Sustainable Use and Development of FGR

The global synthesis on The State of World's Forest Genetic Resources by FAO provided valuable information and knowledge on FGR and also allowed the Commission to develop *The Global Plan of Action for the Conservation, Sustainable Use, and Development of Forest Genetic Resources* based on its key findings and recommendations. This global strategic framework was agreed by the FAO-CGR in January 2013, and subsequently adopted by the FAO Conference in June, 2013. The Commission of Forestry, the highest FAO Forestry statutory body, recommended the implementation of the Global Plan of Action on FGR in its 22nd Session in June, 2013. This comprehensive global plan of work on FGR identified 27 strategic priorities, grouped into four priority areas: (i) improving the availability of, and access to, information on FGR; (ii) conservation of FGR (*in situ* and *ex situ*); (iii) sustainable use, development and management of FGR; and (iv) policies, institutions and capacity building (FAO, 2014b) (Fig. 1.8). Implementation of the Global Plan of Action was expected to strengthen management and sustainability of FGR while assisting countries in integrating FGR conservation and management needs into wider policies, programs and frameworks of action from local to national, regional, and global levels besides developing sound technical and scientific programs for the successful management of FGR and contributing towards the global goals of biodiversity conservation and sustainable development (FAO, 2014b; EUFORGEN, 2021).

1.7.2.1

Rationale, Nature, and Aims of the Global Plan of Action

The Global Plan of Action on FGR became essential in view of key features of genetic resources in the context of diverse forests across globe. Primarily, it was necessary in view of the fact that most forest tree species are wild, managed in extensive natural ecosystems, and are at a very primitive stage of selection and domestication compared to agricultural crops. Unlike agricultural crops, forest tree species are characteristically long lived, highly heterozygous organisms that have developed natural mechanisms to maintain high levels of intra-specific variation owing to high rates of out crossing, and dispersal of pollen and seeds over wide areas. These natural mechanisms, combined with surrounding environments are often variable, both in time and space, and have contributed to evolution. Further, forest tree and woody species provide multifarious goods and services, and nearly 80 per cent of people in developing countries use non timber forest products for subsistence (food, nutrition, and health) and economic reasons. Economic valuation of FGR is often difficult for the fact that most forest products including timber, small timber, fuelwood, fodder, fruits, spices, herbal and aromatic plants, etc. are harvested for local consumption or even commercialized without proper national monitoring and documentation. Also, their present or potential contribution and values towards sustainable livelihoods and development are underutilized and undervalued. Moreover, current knowledge of FGR is widely scattered and possessed by varied level institutions that too in unpublished reports, meaning that in several countries, access to vital information is restricted and limited. Generally, the baseline information on species diversity, distribution, and status; threats; seed biology and behaviour; chemical and molecular characterization; and forest reproductive material catalogues are grossly lacking or obsolete in absence of periodic monitoring and updated information. Furthermore, the current efforts by world's countries towards test and improve forest species focus on approximately 450 species, a minuscule proportion of the overall known and documented forest tree species exceeding ca. 80,000 (FAO, 2014b).

The nature of Global Plan of Action prepared by the FAO-CGR provides a country wide flexibility as it is voluntary and non-binding. The Plan envisages that it should not be interpreted or implemented in contradiction with existing national legislation and international agreements. It is a rolling document as it can be updated in line with any follow-up that the Commission may decide upon (FAO, 2014b). The relative importance of each strategic priority and associated actions may vary considerably as per the requirement of country and the region, and would depend on the genetic resources themselves, the natural environment or production systems involved, current management capacities, and financial resources or policies already underway for the management of FGR.

The main aims of the Global Plan of Action relate to: (a) improving and strengthening knowledge of FGR, assessment of traditional knowledge and practices, access and sharing of information, and enhancing institutional capacity for research, education, and training; (b) promoting the sustainable use and management of FGR by assisting countries to integrate FGR conservation needs into wider national policies and programs at different levels, by providing adequate access to, and use of, quality forest reproductive material to support research and development, and also by promoting ecosystem and ecoregional approaches as efficient means of sustainable use and management of FGR; (c) developing and strengthening *in situ* and *ex situ* conservation programs for FGR; and (d) promoting national policies, programs, and framework emphasizing on inventory, characterization, conservation, development, sustainable use, capacity development, and monitoring relevant to FGR (Fig. 1.8).

Fig. 1.7
Establishment of FAO and Chronology of Global Developments and Initiatives Towards Recognition, Conservation and Sustainable Use of FGR

- **1945** – The United Nation's Food and Agriculture Organization (FAO) was established
- **1962** – Panel of Experts on Plant Exploration and Introduction was established
- **1967** – Panel of Experts on Forest Genetic Resources was established
- **1971** – Consultative Group on International Agriculture Research (CGIAR) was founded
- **1971** – International Board of Plant Gene Resources (IBPGR) was set up
- **1983** – FAO's Commission on Genetic Resources (FAO-CGR) was established
- **1992** – UN Convention on Biological Diversity (CBD) came into existence
- **1993** – Data base on forest tree species – REFORGEN was developed
- **1993** – IBPGR became International Plant Genetic Resources Institute (IPGRI)
- **1995** – FAO-CGR broadened the mandate to cover all components of biodiversity of relevance to food and agriculture
- **2001** – International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) was signed
- **2007** – FAO-CGR Emphasized for an urgent need to conserve and sustainably use FGR and included a report on 'The State of the World's Forest Genetic Resources
- **2013** – FAO-CGR Developed 'Global Plan of Action for the Conservation, Sustainable Use, and Development of FGR'
- **2013** – FAO's The State of the World's FGR (SOW-FGR) Report based on reports by 86 countries representing 86% of the global forest cover was approved

Box 1.1 Summary of the State of The World's Forest Genetic Resources Report

The global synthesis report on FGR based on information provided by 86 countries offers:

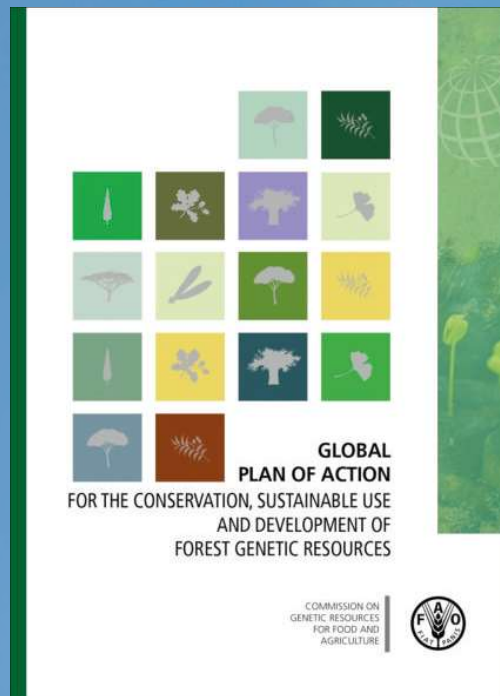
An overview of definitions and concepts related to FGR and a review of their value

A description of the main drivers of change

The presentation of key emerging technologies

An analysis of the current status of FGR conservation, use and related developments

Recommendations addressing the challenges and needs.



The report summarized that:

- Knowledge of FGR is inadequate for well-informed policy and decision making or management in most countries.
- The number of studies and the number of species studied have enhanced significantly but so far studies have described genetic parameters for less than 1 per cent of tree species.
- Despite most recent studies have focused on the molecular level, the accumulating knowledge has little direct application in management, improvement or conservation in absence of whole organism information.
- A few species (mainly comprising temperate conifers, eucalypts, acacias, teaks, and other broadly adapted, widely planted and rapidly growing species) have been well researched-through both molecular and quantitative studies and genetically characterized. Emergence of valuable quantitative genetic knowledge has led to notable productivity gains in a few selected high valued planted timber species.
- In comparison to herbaceous crop species, the genomic knowledge of forest trees has lagged behind. However, for several tree species, the entire genome has been or is in the process of being sequenced, and markers have been linked to important traits.
- Several species identified as priorities for local use have received little or no research attention.

Fig. 1.8 Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources Showing Four Priority Areas and 27 Strategic Priorities

Priority Area	Strategic Priorities
Improving the availability of, and access to, information on FGR	• Establish and strengthen national FGR assessment, characterization and monitoring systems • Develop national and subnational systems for assessment and management of traditional knowledge on FGR • Develop standards and protocols for inventories, characterization and monitoring of trends and risks • Promote and establish FGR databases on uses, distribution, habitats, biology and genetic variation of species
***In situ* and *Ex situ* conservation of FGR**	• Strengthen the contribution of primary forests and protected areas to *in situ* conservation of FGR • Promote, establish and develop *ex situ* conservation systems, including *in vivo* collections and gene banks • Support assessment, management and conservation of marginal and/or range limits forest species • Support and develop sustainable management and conservation of FGR on farmland • Support and strengthen the role of forests managed by local communities in conservation of FGR • Identify priority species for action • Develop and implement regional in situ conservation strategies and promote networking and collaboration
Sustainable use, development and management of FGR	• Develop and reinforce national seed programs for genetically suitable seeds for national plantation programs • Promote restoration and rehabilitation of ecosystems using genetically appropriate material • Support climate change adaptation and mitigation through proper management and use of FGR • Promote use of emerging technology to support the conservation, development and sustainable use of FGR • Develop research programs on tree breeding, domestication and bioprospection to unlock potential of FGR • Develop and promote networking and collaboration to combat invasives, diseases and pests affecting FGR
Policies, institutions and capacity building	• Develop national strategies for *in situ* and *ex situ* conservation of FGR and their sustainable use • Integrate conservation and management needs into wider policies, programs and frameworks of action • Develop collaboration and promote coordination of national institutions and programs related to FGR • Establish and strengthen educational and research capacities on FGR • Promote participation of local communities in FGR management in the context of decentralization • Promote and apply mechanisms for germplasm exchange to support research and development • Reinforce regional and international cooperation to support education, knowledge share and research • Establish, develop and support international networking and information sharing on FGR conservation • Promote public and international awareness of the roles and values of FGR • Strengthen efforts to mobilize resources, including financing for conservation, use and development of FGR

1.8

Regional Programs and Initiatives on FGR

The foregoing description has amply narrated that the major international efforts towards the concepts and use of FGR originated in the 1960s, with the guidance and support of the FAO and several national institutions, mostly from developed countries. Since then, institutional interest has not only been stimulated because on one hand, the tree improvement programs have demonstrated that economic benefits can be realized from using genetic resources to improve forest production, while on the other hand enhanced recognition of deforestation, species loss, environmental concerns, and need to preserve gene resources and maintain genetic diversity, but also led to the establishment or launch of a large number of policy-level international or regional initiatives, programs, projects, networks, and framework instruments dealing with the wider subject of conservation of FGR (NRC, 1991).

When national-level programs are in place, they provide the much-required framework for action towards conservation of FGR. However, in the context of FGR, often national-level programs have a number of technical limitations. Firstly, the natural distribution of several forest tree species transcends political borders. Secondly, some tree species or populations that are of little current importance in their countries of origin have become socially or economically important outside their natural ranges (e.g., *Eucalyptus* spp., *Prosopis* spp., *Acacia* spp., *Leuceana* spp., *Populus* spp., *Tectona grandis*, *Casuarina* spp.). Such situations raise question regarding responsibility for conservation, especially *in situ* conservation. Thirdly, a number forest tree introduction, often of undocumented origin, have evolved into landraces which are well adapted to environmental conditions in the species' new habitat. These landraces may play vital role in genetic conservation activities, and collaboration between two or more countries so as to ensure a comprehensive and complimentary *in situ* and *ex situ* activities. At the same time, such introductions of new germplasm (intentional and unintentional) resulted in a number of biological risks including proliferation as invasives. Fourthly, formal inclusion of forest genetic diversity in the work program of the CBD, and enhanced understanding of genetic diversity in recent decades owing to documentation, characterization, and management provides an important vehicle for nations to further justify, augment, and strengthen programs relevant to conservation of FGR. Finally, national activities are increasingly guided or supported by commitments made at the international level (e.g., International Treaty on Plant Genetic Resources for Food and Agriculture - ITGRFA) and usually rely on funds from international agencies or private donors (FAO, 2004). Further, these activities were obviously promoted as the FGR have strong linkages with the enforcement of international conventions/ treaties on biodiversity, climate change, and sustainable development and as a result they got a boost. The CBD affirmed that nations have sovereign rights over their biological and genetic resources, and that they are responsible for conserving and using their biological resources in a sustainable manner. Thus, in recent decades, several national level initiatives by different countries covered a wide range of activities including inventories, assessments, and conservation measures to protect rare, endangered, and threatened (RET) species and populations, regulations governing seed collection and transfer, and comprehensive approaches to the management of landscapes, and the restoration of native ecosystems including forests that have an impact on FGR and genetic diversity (FAO, 2004).

Prominent regional, sub-regional or ecoregional collaborative programs or networks established are: Africa – SAFORGEN; Asia-Pacific and Oceania – APAFRI, APFORGEN, and SPRIG; Europe – EUFORGEN; the Near East - Silva Mediterranea; and North, Central, and South America – NAFC, CONFORGEN, CAMCORE, LAFORGEN. Mostly, they aim at addressing the issue of FGR in entirety from a holistic and intersectoral approach. In recent years, regional approaches have been complimented by ecoregional approaches and by action focused on common priority species or group of species. Some of the well-known species specific FGR networks are: *Acacia* spp. and *Prosopis* spp. in arid and semi-arid zones; LEUCNET – *Leucaena* spp.; TEAKNET – *Tectona grandis*; INBAR – bamboo and rattan; COGENT – coconut; International Neem Network (INN) – *Azadirachta indica*; etc. (FAO, 2004 and 2014a). In addition, several international, regional, and national organizations and institutions have established complimentary databases and information systems on forest and tree genetic resources with different focus and objectives (e.g., REFORGEN by FAO, MAPFORGEN by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - IPBES, EUFGIS by EUFORGEN). Certainly, in past four to five decades or so, the number of instruments and associated programs, networks, initiatives, and databases related to forests, forestry, and FGR have greatly increased in response to international agreements, emerging requirements, and enhanced environmental awareness. Thus, the need of the hour is to ensure close collaboration between such initiatives so as to avoid duplications and to encourage synergy among them.

1.9

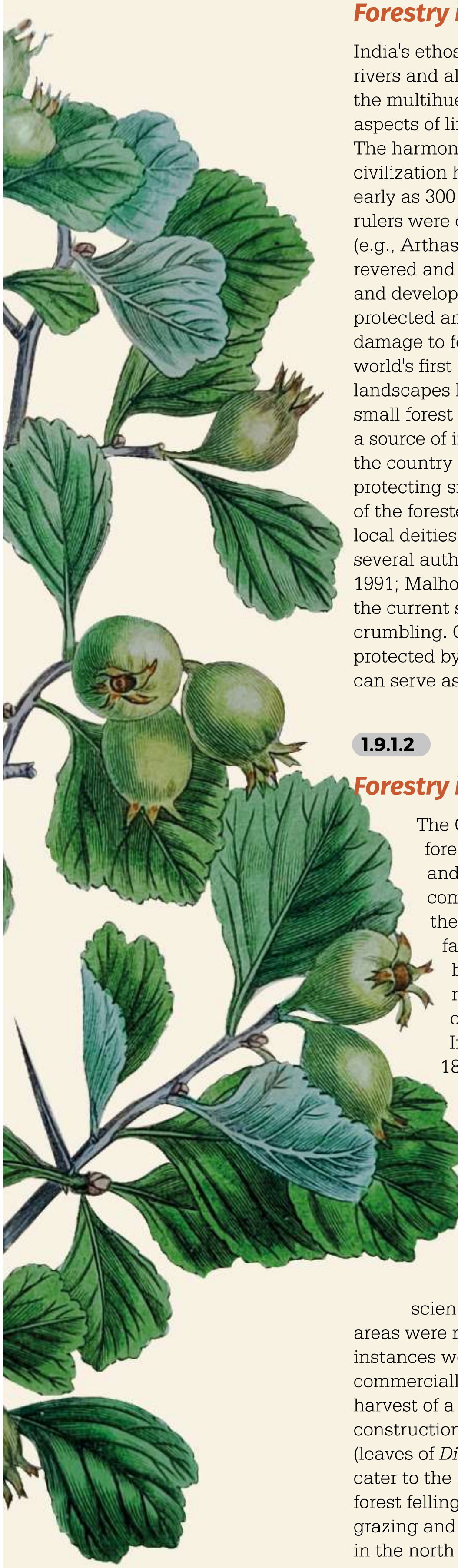
India's Initiatives on Conservation of FGR

The Republic of India is a distinct geographical entity in the South Asian region, located between latitude N 8°4' to 37°6' and longitude E 68°7' to 92°25'. The country covering the geographical extent of 32,87,263 km^2, represents just 2.4 per cent land area of the world and is the seventh largest nation. According to the Worldometer, India has crossed the 1.4 billion mark of population in March, 2022 with human density of 464 persons per km^2 and thus, is the second most populated country in the world. Despite small geographical extent, populous and one of the developing countries in the tropics, its contribution to the world's biodiversity is about 8 per cent and has been designated as one of the seventeen megadiverse countries of the world (Mittermeier *et al.*, 1997) and ranks eighth in the world. Owing to country's strategic location at the confluence of three biogeographic realms (Palearctic, Indo-Malayan, and Afrotropical), it harbors varied landforms, experiences extremities of climate and vast altitudinal variation and as a result possesses enormous diversity of natural ecosystems including thorny to evergreen forests along with associated wild floral and faunal diversity favorably comparable with that of many countries in the world. India is one of the eight Vavilov Centers of the world where most of the living plants have evolved and harbors a wealth of domesticated animal breeds and cultivated plants.

1.9.1

Forest Management in India

Forests in India or the Indian Forestry has a long history of management. Broadly, it has been described in four broad categories: (a) Forestry in ancient and medieval India, (b) Forestry in Colonial system, (c) Forestry in India from 1947 to 1990, and (d) Post 1990 forestry in India.



1.9.1.1

Forestry in Ancient and Medieval India

India's ethos and culture promotes conservation of nature, particularly forests, mountains, lakes, and rivers and all life forms since time immemorial. Concerns for nature conservation is deeply embedded in the multihued Indian society. The human being is a part of a well ordered, complex system in which all aspects of life and nature have their place, and are not in opposition, but in harmony with each other. The harmony between humans and nature is integral to the Indian traditions and ethos. The Indian civilization has been known as an 'ecofriendly civilization' (Badola *et al.*, 2022). The emperor Asoka as early as 300 B.C. vowed to protect all living creatures. Generally, the state administration and all the rulers were directed to preserve and promote environmental welfare. Numerous ancient Indian texts (e.g., Arthasastra, Vedas, Manusmriti, Ramayana, Mahabharata, etc.) reflect that in India, forests are revered and trees worshiped. Kautilya in the Arthasastra documented the need for the establishment and development of abhyàranya, forest and animal sanctuaries, where trees and animals were protected and saved from hacking and slaughter. Kautilya prescribed penalties for poaching and damage to forests, particularly the productive ones. Hence, India was the pioneer in enacting the world's first documented conservation measures. Conservation of sacred species, groves, forests and landscapes has been an important traditional aspect of ethics of the Indian culture. The sacred groves, small forest patches devoted to local deities are important repositories of floral and faunal diversity, and a source of inspiration, cultural and spiritual values. Traditionally, local communities in different parts of the country have been following an ancient practice of an *in-situ* nature conservation by way of protecting small undisturbed patches of vegetation in the outskirts of the villages and towns or as a part of the forested areas that are inextricably linked with the culture, traditional rituals and dedicated to local deities. These traditional sites have been named differently in different parts of the country and several authors have provided valuable information on varied aspects of sacred groves (Joshi and Gadgil 1991; Malhotra, 1998; Krishna and Amrithalingam, 2014; Amrithalingam, 2016). In several instances, the current situation of existing sacred groves owing to ignorance and enhanced biotic disturbances is crumbling. Certainly, from the perspective of conservation of FGR, sacred groves established and protected by local communities are the best examples of long-term *in situ* conservation efforts and they can serve as useful reference sites.

1.9.1.2

Forestry in Colonial System

The Colonial regime played a pivotal role in the history of Indian forest by way of enactment of forest laws; reservation of forests; establishment of forestry infrastructure (survey, demarcation and delineation of management units-forest divisions, ranges, blocks, beats and compartments, buildings, fire lines, road network, timber depots, etc.) in the country including the hierarchical State Forest Department for management of forests; research and training facilities; and formulation of forest policies, strategies and working plans for silviculture based forestry. In 1840, the British Colonial administration promulgated an ordinance named as the Crown Land (Encroachment) Ordinance targeting forests in Britain's Asian colonies, and vested all forests, wastes, unoccupied and uncultivated lands to the crown. In India, the Imperial Forest Department was established in 1864 and the Indian Forest Act, 1865 was enacted so as to assert the British State monopoly over Indian forests. This law established the government's claims over forests. Later in 1878, the colonial administration enacted a further far-reaching Forest Act, thereby acquiring the sovereignty of all wastelands including all forests and demarcated reserved and protected forests. All local rights were abolished in the former while in the latter the existing rights were accepted as a privilege offered by the British regime to the local people which can be taken away, if necessary. The British laws brought the forests under the centralized sovereignty of the state. Sir Dietrich Brandis, a British-German botanist and forest administrator was appointed the Inspector General of Forests in India and he served for a period of 20 years (1864-1883) and laid the much-desired foundation for the scientific forestry in the country. He has been regarded as the 'Father of Tropical Forestry'. Forest areas were recognized as a national resource and soon became a source of revenue as forests in several instances were clear felled, mechanized logging was operationalized, extensive plantations of commercially important timber species (*Tectona grandis, Shorea robusta,* Pine spp.) were raised besides harvest of a wide range of non- timber forest products (NTFPs). Teak forests were exploited for ship construction while sal and pine forests for railway sleepers. The prominent NTFPs i.e., 'Bidi patta' (leaves of *Diospyros melanoxylon*) and bamboos were exploited in vast extent of forest lands so as to cater to the growing requirements of markets of cigarette, and paper and pulp. Extensive and heavy forest fellings by the SFDs along with traditional resource dependence for timber, fuel wood, livestock grazing and a variety of NTFPs by the forest dwellers and massive rural population, shifting cultivation in the north eastern region and developmental works resulted in shrinkage of forests and degradation.

1.9.1.3

Forestry in India from 1947 to 1990

The period between 1947 i.e., the post-independence of the country and end of the Colonial regime and 1990 has been very important for the Indian forestry from two perspectives. Firstly, the country required expansion and intensification of agriculture so as to bring 'self-sufficiency' and diversion of forest lands for non-forest or developmental works (highways, harness of hydropower, industries, increase in irrigation potential, gradual urbanization, etc.,). Additionally, new carved out provinces (States) required sustained revenue sources. This led to exploitation of forests, shrinkage and degradation. Post-independence, the country brought the National Forest Policy, 1952. As a result, forests which were earlier with the *zamindars* (land-lords) and also most of the industries related to forest wood and non-wood forest products were nationalized. The new policy aimed at bringing one-third of the total land area with 65% in hilly and 25% in plains under the forest cover. Secondly, this period post-independence was important from the perspective of gradual initiation and support for conservation of forests as it is evident by the enactment of Wildlife (Protection) Act, 1972 facilitating establishment of National Parks and Sanctuaries, protection of wildlife habitat and wild fauna from 'hunting'; launch of 'Project Tiger' in 1973 and initiation of programs related to conservation of iconic or flagship species Tiger; enactment of Forest (Conservation) Act, 1980, a milestone in the Indian forestry so as to curb the rampant diversion of forest land for non-forest purposes. Owing to the WPA and conservation initiatives, the State Governments gradually not only set aside the protected areas but also started forego vital revenue generated from forest. The time between 1947-1990 was important in the history of Indian Forestry, as it promoted countrywide social forestry program aiming for extensive plantations including introduction of exotics and monocultures. India launched its revised National Forest Policy in 1988 after a gap of almost four decades advocating conservation measures (protection of forests-soil and moisture conservation, forest fire, catchment maintenance and setting aside Protected Areas besides promoting community participation in forest management by way of initiation of popular 'Joint Forest Management (JFM)' program. Certainly, on one hand the enhanced human induced activities continue to decline the extent of forests and allowed the degradation of remaining forests while on the other hand, some of the pioneer conservation efforts and paradigm shift in forest management started showing initial signs of recovery of ecosystems, habitats and floral and faunal species.

1.9.1.4

Post 1990 Forestry in India

Interconnected environmental challenges (land and soil degradation, water crisis, food insecurity, loss of biodiversity and reduced ecosystem services, and climate change) besides cross cutting social issues (human rights, gender, inequality, social justice and peace) are widespread and have emerged as global concerns. Human dominated country like India is no exception. Growing global challenges and concerns have led to the launch of several international conventions, treaties, agreements and national level policies, strategies, frameworks, and action plans towards conservation of not only diverse forests but the entire array of biological diversity, sustainable livelihoods, climate change mitigation and adaptation, and sustainable development. The UN Convention on Biological Diversity opened in 1992 and came into force in 1993 was a hallmark for most nations including India as one of the signatories leading to conservation of biological diversity or biodiversity at three hierarchical levels (ecosystem, species and gene) including forest ecosystems and forest genetic diversity. Additionally, two other concurrent Conventions (UNCCD-United Nations Convention to Combat Desertification, and UNFCC-United Nations Framework on Climate Change) are also significantly contributing towards the protection and conservation of 'natural capital' including complex and dynamic forest ecosystems and associated diversity. Gradual enforcement of moratorium on green felling by States in 1990s and amendment to WPA in 1991 drastically reduced fellings of forests in managed forests and sanctuaries.

In 1996, the country's Apex Court in its historical judgement in the case of W. P. (C) No. 202/1995 between T.N. Godavarman Thirumulpad and Union of India & Ors) issued detailed directions for the sustainable use of forests and created its own monitoring and implementation system through regional and state level Committees, regulating the felling, use and movement of timber across the country in the hope of preserving the nation's forest. As a part of this judgement, the Court examined in detail all the aspects of the National Forest Policy, 1988 and the Forest (Conservation) Act, 1980, which were formulated/ enacted with a view to promote sustainable management of forest in the country and check further deforestation, respectively. The Court elaborated on the new broader definition of 'forest' and emphasized that any forest be defined, regardless of ownership, and would be subject to section 2 of the FCA. Section 2 of the Act specifies that no State Government or other authority may allow the use of any forest land for any non-forestry purpose without prior approval from the Central Government. Under the new interpretation of forest land under section 2 of the FCA, States could no longer de-reserve protected forests for commercial or industrial (non-forestry) use without permission. Further, the Court directed the State Governments to cease all forest activities throughout the country, without the specific approval of the Central Government. Accordingly, running of saw mills, plywood mills and mining were recognized as non-forest purposes and they cannot be carried out without the approval of the Central government. The Court also directed that felling of all trees in all forests should remain suspended, except in accordance with the approved Working Plan by the Central Government. The Court imposed a complete ban on the movement of cut trees and timber from any of the north eastern States of the country. Railways were asked to shift immediate to concrete sleepers while defense establishments were asked to find alternatives to consumption of wood-based products. The Court directed the Central Government to constitute a high-power Committee to oversee the implementation of the judgment and to guide the Court in making further orders, especially in the context of North Eastern India. Additionally, the Apex Court provided directions for disposal of timber lying in forest depots, suspend permits to wood-based industries, and prepare action plan for protection and monitoring of vulnerable forests.

1.9.2

State of Forests in India

India ranks 10th amongst the ten most forested countries of the world (FAO, 2020b). The Forest Survey of India (FSI), an organization of the Ministry of Environment, Forest and Climate Change (MoEFCC), GoI has been monitoring India's forest and tree resources through periodic assessments and presenting the findings in its biennial publication being referred as the 'India State of Forest Report' (ISFR) since 1987. The most recent report (ISFR 2021), 17th in the series provided the comprehensive and comparative picture of India's forest and tree resources over time in the country as well as in each of the State/UT and district.

1.9.2.1

Forest Cover and Trees Outside Forests (TOF)

As per the ISFR 2021, the Recorded Forest Area (RFA) under the control of State Forest Department in different States/ Union Territories (UTs) extends over 7,75,288 km^2 and it represents 23.58 per cent of the total geographical area (Table 1.2). The ISFR 2021 presents the latest status of the 'Forest Cover' and 'Tree Cover' of the country, estimates of growing stock, extent of 'Trees Outside Forests (TOFs), mangrove cover, bamboo resources and assessment of forest carbon stock (FSI, 2021).

The Forest Cover includes all lands more than 1 hectare in extent with tree canopy density of more than 10 per cent, irrespective of the origin of the tree crops/ tree species (whether natural or man-made), ownership, land use, and legal status. Tree cover means forest patches less than 0.1 hectare in extent irrespective whether natural or man-made, or of ownership, land use and legal status. TOF refers to all trees growing outside recorded forest area (RFA), irrespective of the patch size. Thus, the patches of 1 ha and above outside the RFA and Tree Cover, both constitute the TOF. As per the ISFR 2021, India has total Forest Cover of 7,13,789 km^2, representing 21.71 per cent of the total geographical area of the country (Table 1.2). In terms of canopy density classes, area covered by Very Dense Forest-VDF ($\geq$70 per cent) was 99,779 km^2 (3.04 per cent), Moderately Dense Forest-MDF ($\geq$40 to $<$70 per cent) 3,06,890 km^2 (9.33 per cent), and Open Forest-OF ($\geq$10 to $<$40 per cent) 3,07,120 km^2 (9.34 per cent). The VDF and MDF together constituted 57 per cent of the overall Forest Cover of the country. The recent report by FSI documented a net increase of 1,540 km^2 or net change of 0.22 per cent in the Forest Cover at the national level in comparison to the previous biennial assessment (ISFR 2019). Some States and UTs registered gain or increase in the Forest Cover while others showed loss or decrease.

In addition to the Forest Cover, the extent of Tree Cover (patches less than 0.1 ha) within RFA as well as outside forest registered by the ISFR 2021 was 95,748 km^2, representing 2.91 per cent geographical area of the country. The net increase in Tree Cover in comparison to the previous biennial assessment was of the tune of 0.02 per cent. Thus, the total area combined of Forest Cover and Tree Cover was 8,09,537 km^2, representing 24.62 per cent or about one-fourth of the total geographical area of the country (Table 1.2). The TOF i.e., Tree Cover ($<$0.1 ha in RFA and outside) and patches of 1 ha and above exclusively outside RFA covered an area of 2,92,907 km^2, and represented 8.91 per cent of the total geographical area. The TOF in the previous assessment was 2,93,840 km^2. Hence, a net decrease of 933 km^2 in TOF was recorded in the recent assessment. In short, Forest Cover and TOF together constituted 30.62 per cent geographical area of the country (FSI, 2021).

1.9.2.2

Forest Diversity in India

The foregoing description has highlighted that India is one of the seventeen megadiverse countries of the world and stands 8th in the world ranking as it harbours parts of four global biodiversity hotspots besides the country ranks 10th among the ten most forested countries of the world. The diversity of Indian forests ranges from thorn forests predominantly in driest arid region of Rajasthan and Gujarat to wet evergreen forests in wettest moist sub-humid region of the North Eastern India. Between these two extremes, intermediate categories of dry and moist deciduous and semi evergreen forests besides littoral and swamp, pine, broadleaved hill, dry evergreen, temperate, and sub-alpine forests also occur. In addition, alpine pastures and varied grasslands in different forests contribute significantly to the forest diversity in the country.

(a) Forest Types

Forests of undivided India (India and Burma) were first enunciated in 1935 as a classification system based on preliminary survey by H. G. Champion (Champion, 1936). Subsequently, S. K. Seth joined Champion in refining the initial work by bringing out a seminal document 'A Revised Survey of the Forest Types of India' in 1968 that provided a standard forest type classification for the independent India (Champion and Seth, 1968). They defined Forest Types as 'a unit of vegetation which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units'. The revised classification was based on the premise that a forest type unit could be treated as a distinct ecosystem, and placed greater emphasis on the main tree layers keeping in view the practical utility from the perspective of forest management instead of the earlier efforts on classification(s) based on climate, soil or vegetation alone. The three-tier revised system of classification included climate based six major Groups (I- Moist Tropical Forests, II- Dry Tropical Forests, III- Montane Sub-Tropical Forests, IV- Montane Temperate Forests, V- Sub-Alpine Forests, VI- Alpine Scrub). These six major Groups were further divided into 16 precipitation and temperature range- based Forest Type Groups (climatic types). Sixteen type groups were further divided into Southern and Northern forms, and finally subdivided into 200 Sub-group Types based on floristic, edaphic, and physiographic factors (Champion and Seth 1968; ISFR 2019). Diverse forests across different biogeographic zones of the country representing 6 Groups, 16 Type Groups, and 200 Sub-group types are repository of a wide array of plant and animal species (MoEF, 2012). The revised classification on Forest Types has immensely helped in providing a scientific basis for diverse applications of forest management *viz*., forest resource assessment, silviculture research, preparation of working plan, biodiversity studies, wildlife management, conservation of FGR, etc.

(b) Mapping of Forest Types

The classification of forest types of India published by Champion and Seth in 1968 included description of 200 Sub-group Types and their higher hierarchical levels and a broad-based diagrammatic representation on distribution of 16 forest types in the country. The remote sensing data, GIS facilities, and gradual advancement in forest cover mapping owing to improved satellite data facilitated FSI to generate distribution maps of forest sub-group types in the country as well as in each State/ UT. The FSI has made first attempt to create an insight on the distribution and mapping of 16 forest types using low resolution (IRS LISS II; 36.25 meters) satellite data and visual interpretation technique and provided area details on different forest types in the ISFR, 1995 (FSI, 1995). With the availability of high-resolution data (IRS LISS IV; 5.8 meters resolution) under the National Natural Resources Management System (NNRMS) Program, the long-standing information requirement on the distribution of forest types and sub-types was undertaken by FSI as the nation-wide exercise during 2005-2010 and the final outcome was released as the 'Forest Type Atlas of India' on 1:50,000 scale in the digital and hard copy forms in the year 2011. This first country-wide exercise using high resolution data could map only 178 forest types with an accuracy of 88.5 per cent at the 16 forest types level, and 77.5 per cent at the 200 sub-types, and extent figures under each category were generated. Twenty-two forest types could not be mapped either owing to limitations of the data, definitions adopted in the study, deficient ground truthing or even non-discernibility of sub-types under various stages of degradation. The subsequent exercise of mapping was undertaken after a gap of ten years to refine and update forest type maps of the country using latest baseline layer of forest cover map pertaining to ISFR 2017 so as to identify the remaining 22 forest types which could not be mapped in the previous forest type mapping of 2011 and also to check the existence of remnant 27 forest types (those types whose total area is less than 50 km^2) based on the outcome of the earlier exercise (FSI, 2019). The revised mapping also aimed to identify and map varied plantations (fruit orchards, cash crops, and agroforestry), delineate and assign nomenclature for grasslands besides aligning the forest types of India with the prevailing international classification systems. As a result of revised mapping after a gap of 10 years, 188 forest types could be identified and mapped besides the distribution and extent of grasslands and plantations were also mapped. Based on this revised mapping, FSI also brought out an updated 'Atlas on Forest Types of India' in 2020.

(c) *Extent of Different Forest Types*

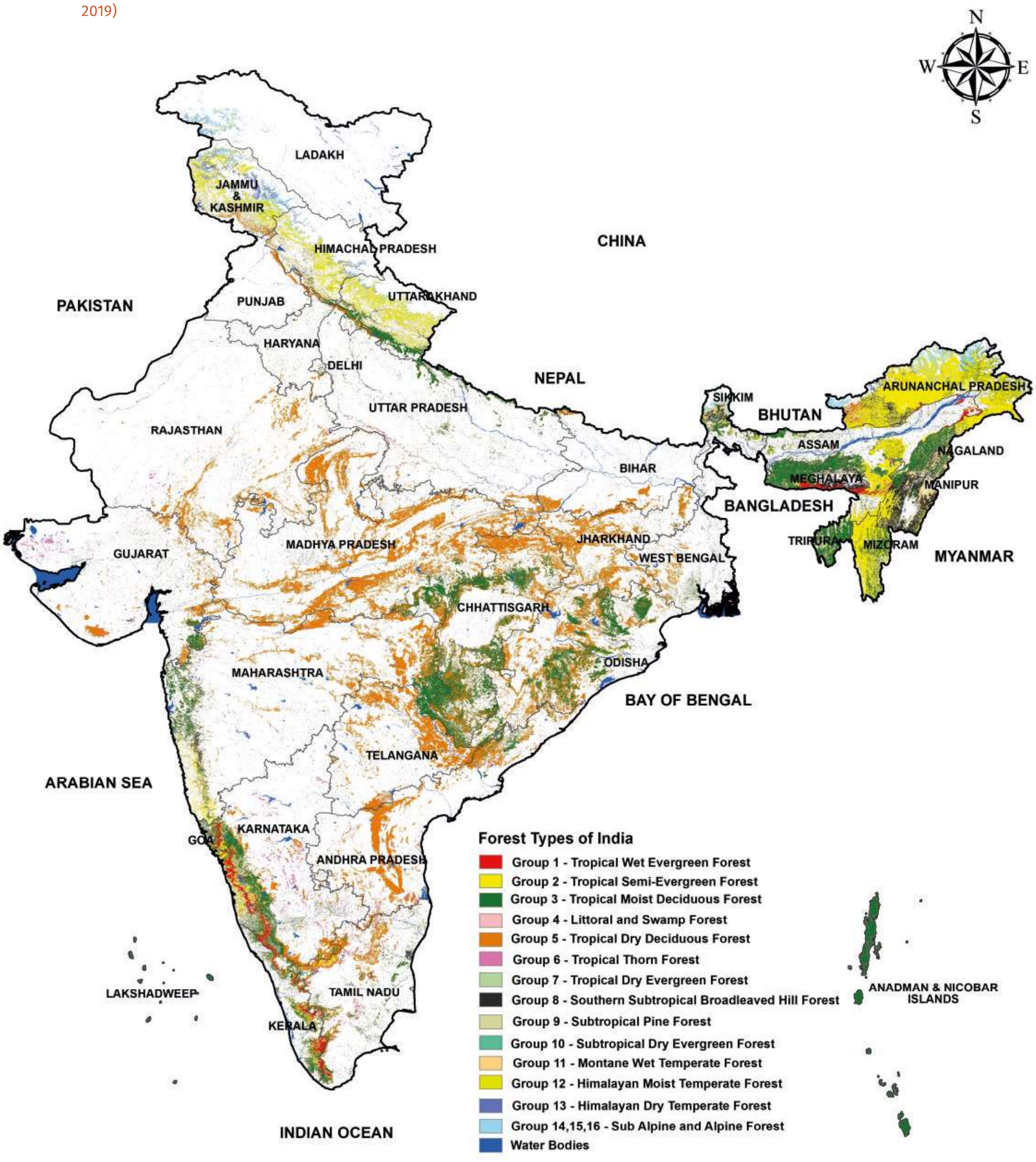
The FSI in its ISFR 2011 could delineate and describe the extent of forest types under 14 categories as Group 14-Sub-Alpine Forest, Group 15-Moist Alpine Scrub, and Group 16-Dry Alpine Scrub were clubbed as one category. In addition, the ISFR 2011 also mapped and provided extent for Plantation/ TOF (Fig. 1.9). The ISFR 2019 based on high resolution data could delineate and provided extent of 16 mapped Forest Types besides Plantation/ TOF and their values are also presented in Table 1.5. Further, this Table includes values on the extent for each forest type as the per cent of Forest Cover in RFA and TOF, and also temporal change in the extent of forest type during 2011-2019. According to the ISFR 2019, amongst 16 forest types, the maximum extent of 3,13,617 km^2, representing 40.86 per cent of total Forest Cover was registered by Group 5-Tropical Dry Deciduous Forests, followed by Group 3-Tropical Moist Deciduous Forests covering 1,35,492 km^2 or 17.65 per cent of total Forest Cover and TOF. The Group 2-Tropical Semi-Evergreen Forests covered an extent of 71,171 km^2 and represented 9.27 per cent of total Forest Cover and TOF. Remaining 13 forest types registered values of extent below 5 per cent. Tropical Dry Evergreen Forests and Sub-Tropical Dry Evergreen Forests covered small extent of 937 km^2 and 180 km^2, representing just 0.12 per cent and 0.02 per cent of total Forest Cover and TOF, respectively. Certainly, these two forest types have highly limited distribution and require special attention as most FGR species in these forests are under severe threat. The category of Plantation / TOF represented 8.45 per cent and covered extent of 64,839 km^2. Grasslands in different Forest Type Groups covered as much as 13,329 km^2 and represented just 1.74 per cent of total Forest Cover and TOF.

(d) *Decadal Change in the Extent of Forest Types*

The assessment of decadal change in the extent of different forest types based on ISFR 2011 and 2019 revealed that the major Group I-Moist Tropical Forests represented by three prominent forest types (Tropical Wet Evergreen, Tropical Semi-Evergreen, and Tropical Moist Deciduous) collectively showed a decline of 25,458 km^2 in the total extent (FSI, 2011 and 2019). This is alarming in view of the fact that these three forest types are not only important for FGR, and floral and faunal diversity but also center of endemism, part of biodiversity hotspots, source of ecosystem services, and have huge adaptive and evolutionary potential. Certainly, these three forest types in past three to four decades in the Himalayas, Western Ghats, and North- East India biogeographic zones have been extensively and intensively impacted adversely by growth in hydropower projects, expansion of road networks, and varied other developmental activities. These three forest types harbour disproportionately higher percentage of RET species. Two forest types (Tropical Pine Forests and Tropical Dry Evergreen Forests) belonging to the major Group III-Montane Sub-Tropical Forests, and two forest types *viz*., Himalayan Moist Temperate Forests and Himalayan Dry Temperate Forests as a part of the major Group IV-Montane Temperate Forests registered decline of 98 km^2, 28 km^2, 2,769 km^2 and 186 km^2, respectively during the decadal period. These forests harbour several important FGR including RET species *viz.*, *Abies pindrow, Acer caesium, Cedrus deodara, Pinus wallichiana, Pinus gerardiana, Quercus semecarpifolia, Quercus ilex, Taxus baccata, Tsuga dumosa*, etc. In contrast, Group 5-Tropical Dry Deciduous Forests, Group 6-Tropical Thorn forests, Group 8-Tropical Broad-Leaved Hill Forests, and Group 11-Montane Wet Temperate Forests registered an increase in their extent by 23,865 km^2, 5,306 km^2, 14,090 km^2 and 15,660 km^2, respectively. Gain in these four forest types could be attributed to the gradual retrogressive succession from Tropical Moist Deciduous Forests and Himalayan Moist Temperate Forests on account of enhanced biotic pressure and developmental activities. Further, the extent of Sub-Alpine Forests, and Moist and Dry Alpine Scrubs showed an increase in the extent by 2.5 per cent in the decadal period. Generally, these three forest types have lowest proportion of FGR as much of the vegetation is predominantly scrub or short lived herbaceous flowering plants, except a few small trees, and shrubs *viz*., *Betula utilis, Juniperus* spp., *Rhododendron* spp., etc.

Fig. 1.9
Forest Types of India Based on ISFR 2019

Source
ISFR 2019 (FSI, 2019)



(e) Vegetation Types of India

The above description on the distribution of forest types in India based on the revised classification by Champion and Seth (1968) relying on broad climatic, physiographic, edaphic, and local conditions, and the decadal change in their extent has provided valuable insight from the perspective of planning and developing future conservation strategies for FGR. Further, a comprehensive high quality vegetation type map of India has been constructed on the basis of IRS LISS-III images, supported with adequate ground observation by Roy *et al*. (2015). The vegetation type map developed through a collaborative effort involving multiple institutes and scientists provides spatial information on 100 vegetation types in the country consisting of natural, semi-natural, and managed formations clubbed under 10 broad categories. The three dominant systems included mixed, gregarious, locale-specific, degraded formations, plantations, and woodlands, followed by scrublands, grasslands, and managed ecosystems. Roy *et al.* (2015) classified eleven evergreen and nine deciduous forests including semi-evergreen classes under mixed natural and semi natural formations from tropical to sub-alpine ranges. The three temperate forest classes and one sub-alpine forest class were found to be present in the Himalayas. In mangrove formations, five dominant genera (*Avicennia, Lumnizera, Pheonix, Rhizophora,* and *Xylocarpus*) could be classified and delineated as a separate class, whereas others were retained under the broad 'mangrove' class. Likewise, five genera forming three dominant associations (*Lasiurus-Panicum, Cenchrus-Dactyloctenium,* and *Sehima-Dichanthium*) could be identified and delineated as separate classes, whereas other were retained under the broad 'grassland' class. The riverine class was categorized under 'locale-specific' or 'grassland' on the basis of the distribution of trees or herbs, respectively. Further, they documented that the tropical evergreen forests are distributed mainly in the Western Ghats, north east regions and Andaman and Nicobar Islands, whereas tropical semi-evergreen forests occur as a transition zone between evergreen and moist deciduous forests, tropical moist deciduous forests are distributed in strips along the foothills of the Himalayas along the eastern side of the Western Ghats and in Chhota Nagpur Plateau and the northwestern hills. Tropical dry deciduous forests concentrated on both sides of the Tropic of Cancer, predominantly consists of teak (*Tectona grandis*) and sal (*Shorea robusta*). Tropical thorn forests found in western India are often composed of short trees, generally belonging to thorny leguminous species. Sub-tropical forests include both broad-leaved hill forest and dry evergreen forests and could be mapped in both the Western and Eastern Himalayas. Temperate broad-leaved forests are found between 1500 m and 3000 m elevation in the Eastern Himalayas and the upper reaches of the Western Ghats. Temperate mixed forests comprising coniferous and broad-leaved species are distributed primarily in the Western and Eastern Himalayas. Sub-alpine forests extend up to tree line throughout the Himalayas and are succeeded by alpine meadows (moist and dry). Mangroves as primarily evergreen vegetation are distributed in the river deltas along the coasts. Scrub/ shrub areas constituting less than 10 per cent of the forest cover and small sapling and trees are found in northern India, the central highlands and areas of southern India. Grasslands are found as both primary and secondary formations in the plains along the coasts of western India, along the slopes in the Himalayas and in the abundant shifting cultivation lands.

Roy *et al.* (2015) described altogether 100 vegetation types in terms of their occurrence and distribution, area occupancy, percentage of protected area covered by each vegetation type, range of elevation, mean annual temperature and precipitation over the past hundred years. Out of this, 15 vegetation types *viz*., Southern hilltop tropical evergreen, Montane wet temperate, Red sanders, *Anogeissus pendula, Rhododendron* spp., Mangrove, *Avicennia* spp., *Lumnitzera* spp. Mangrove scrub, *Phoenix* spp., *Rhizophora* spp., Lowland swamp, Sholas, Swampy grassland, and Coastal swampy grassland covered more than 30 per cent extent in the protected area. In contrast, predominant varied evergreen, semi-evergreen, moist deciduous, dry deciduous, and thorn forests besides Sal (*Shorea* spp.), Teak (*Tectona* spp.), *Dipterocarpus* spp., Bamboo, Pine (*Pinus* spp.), Fir (*Abies* spp.), Oak (*Quercus* spp.), Deodar (*Cedrus* spp.), *Acacia catechu*, etc. were inadequately covered (<30 per cent) under the legal status of protected area. Vegetation types dominated by exotics *viz.*, *Prosopis juliflora* and *Lantana* scrub covered extent of 5,435.2 km^2 and 4,985.24 km^2, representing coverage of 18 per cent and 11 per cent in PAs, respectively (Roy *et al.,* 2015).

1.9.2.3

Bamboo Bearing Area

The total bamboo bearing area of the country has been estimated to be 1,49,443 km^2 and it represents 19.27 per cent of the RFA (Table 1.2). As compared to the estimates of ISFR, 2019, the total bamboo bearing area in the country has decreased by 10,594 km^2. The total green weight of bamboo culms at national level was estimated at 402 million tonnes of which green sound bamboos contributed about 66 per cent and dry sound bamboos contributed remaining 34 per cent. As compared to the estimate of ISFR 2019, an increase of about 124 million tonnes equivalent green weight of bamboo was observed in the recent assessment.

1.9.2.4

Mangrove Cover

The ISFR 2021 revealed that the mangrove cover in the country collectively under three canopy categories (VDF, MDF, and OF) amounted to 4,992 km^2, which represented 0.15 per cent of the total geographical area (Table 1.2). Out of total mangrove cover, the VDF occupied 1,475 km^2 (29.55 per cent) while MDF and OF covered extents of 1,481 km^2 (29.67 per cent) and 2,036 km^2 (40.78 per cent), respectively. There has been a net increase of 17 km^2 in the mangrove cover of the country as compared to the previous assessment of 2019.

1.9.2.5

Growing Stock and Carbon Pool

The total volume of growing stock at the national level was estimated at 6,167.50 m cum or 56.60 cum per ha (Table 1.2). The cumulative forest carbon stock in different pools-above ground biomass, below ground biomass, dead wood, litter, and soil for the country was estimated as 7,203.84 million tonnes while the carbon stock per hectare was computed to be 100.92 tonnes/ ha.

Table 1.2
Comparison of the State of Forests in India as per ISFR 2019 and ISFR 2021

Sr. No.	Forest Attributes	Value as Per ISFR, 2019 (km²)	Per cent of GA (2019)	Value as Per ISFR, 2021 (km²)	Per cent of GA (2021)	Change (km²)	Per cent of GA
1.	Geographical Area of the Country	32,87,263	-	32,87,263	-	-	-
A.	**Legal Status of Forests**						
2.	Recorded Forest Area (RFA)	7,67,419	23.34	7,75,288	23.58	7,869	0.24
3.	Reserved Forests (RFs)	4,34,853	13.22	4,42,276	13.45	7,423	0.23
4.	Protected Forests (PFs)	2,18,924	6.65	2,12,259	6.45	-6,665	-0.2
5.	Unclassed Forests (UFs)	1,13,642	3.45	1,20,753	3.67	7,111	0.22
B.	**Forest Cover**						
6.	Forest Cover (patches > 1 ha in RFA or outside)	7,12,249	21.67	7,13,789	21.71	1,540	0.04
7.	Very Dense Forest (VDF) (Canopy Density≥70)	99,278	3.02	99,779	3.03	501	0.01
8.	Moderately Dense Forest (MDF) (Canopy Density ≥40 to <70)	3,08,472	9.38	3,06,890	9.33	1,582	-0.05
9.	Open Forest (OF) (Canopy Density ≥10 to <40)	3,04,499	9.26	3,07,120	9.34	2,621	0.08
10.	Scrub (Canopy Density <10)	46,297	1.40	46,539	1.41	242	0.01
C.	**Tree Cover and Trees Outside Forests**						
11.	Tree Cover (patches <0.1 ha in RFA and Outside)	95,027	2.89	95,748	2.91	721	0.02
12.	Trees Outside Forests (TOF) (Tree Cover and patches of ≥1 ha outside RFA)	2,93,840	8.94	2,92,907	8.91	-933	-0.03
D.	**Bamboo Resources**						
13.	Bamboo Bearing Area (out of RFA)	1,60,037*	20.85	1,49,443*	19.27	-10,594*	-1.58
14.	Equivalent Green Weight of Green Culms (million tonnes)	181.6	65.44@	263.5	65.54@	81.9	0.10
15.	Equivalent Green Weight of Dry Culms (million tonnes)	95.9	34.55@	138.4	34.42@	42.5	-0.13
16.	Total Weight of Bamboo Culms (million tonnes)	277.5#	-	402.0#	-	124.5#	-
E.	**Mangrove Forests**						
17.	Total Mangrove Cover	4,975	0.15	4,992	0.15	17	0
F.	**Growing Stock and Carbon Pool**						
18.	Estimated Volume of Growing Stock in Forest and TOF (m cum)	5,915.76	-	6,167.50	-	251.74	-
19.	Estimated Growing Stock in Forest (cum/ ha)	55.69	-	56.60	-	0.91	-
20.	Estimated Growing Stock in TOF (cum/ ha)	7.87	-	8.40	-	0.53	-
21.	Cumulative Carbon Stock in different pools (million tonnes)	7,124.67	-	7,203.84	-	79.17	-
22.	Carbon Stock in different pools (tonnes/ ha)	100.03	-	100.92	-	0.89	-

*- Values of Bamboo Bearing Area are in RFA

- Total Weight of Bamboo Culms in million tonnes

@ - Per cent Equivalent Green Weight of Green Culms/ Dry Culms in proportion of Total Weight of Bamboo Culms

Source - Compiled from ISFR 2019 and ISFR 2021 (FSI, 2019 and 2021)

1.9.2.6

Abundance and Growing Stock of Prominent Tree Species

FSI in its biennial ISFRs in past decade or so has been providing valuable insight on the estimated number of trees and volume by species and diameter class. In addition, important information on growing stock of tree species in forests and TOF is also being provided. The ISFR 2021 listed assessed number of 40 prominent tree species in three diameter classes (10-30 cm, 30-60 cm, and 60+ cm) along with estimated volume in different forests. Accordingly, altogether 1,400.79 million trees represented by different species were estimated in country's forests, excluding TOF. Out of this, 84.92 per cent trees (1,189.51 million trees) were estimated under the diameter class of 10-30 cm, followed by 13.38 per cent or 187.36 million trees were estimated under the next higher diameter class (30-60 cm). A small proportion of just 1.70 per cent or 23.92 million trees represented the diameter class of 60+ cm (FSI, 2021). Based on cumulative estimated number of trees, *Shorea robusta* had the highest share of trees, being 121.87 million or 8.70 per cent trees; followed by *Tectona grandis* (92.03 million or 6.57 per cent trees), *Anogeissus latifolia* (51.36 million or 3.67 per cent trees), *Terminalia tomentosa* (49.51 million or 3.53 per cent trees), and *Lannea coromandelica* (40.9 million or 2.92 per cent trees). Collectively, these top five species contributed 355.67 million or 25.39 per cent of total number of trees estimated in the country. Other prominent species in contribution of estimated number of trees arranged in a descending order were: *Lagerstroemia parviflora* (2.22 per cent), *Pinus roxburghii* (2.18 per cent), *Cleistanthus collinus* (1.85 per cent), *Quercus leucotrichophora* (1.94 per cent), and *Buchanania latifolia* (1.81 per cent). Perusal of valuable data on number of trees based on diameter classes amply revealed that majority tree species occurred in the category of 10-30 cm, indicating that bulk of diverse forests in the country are relatively younger or trees with higher girth classes have been harvested. Notably, tree species with higher girth classes or 'old growth' are conspicuously missing. Further, information on estimated volume by species and diameter classes in forests at the country level revealed that varied forests collectively had a growing stock of 43.88 million m^3. Out of this, the maximum contribution to growing stock of 18.31 million m^3 or 41.73 per cent was by trees in the diameter class of 30-60 cm. The diameter classes of 10-30 cm and 60+ cm contributed growing stock to the extent of 14.06 million m3 (32.04 per cent) and 11.51 million m^3 (26.23 per cent), respectively. The pattern of contribution to estimated volume by species in forests was by and large on the lines of estimated number of trees in forests. Accordingly, *Shorea robusta, Tectona grandis, Terminalia tomentosa, Pinus roxburghii,* and *Anogeissus latifolia* remained top five tree species based on their contribution to cumulative estimated volume. *Cedrus deodara, Abies pindrow, Lannea coromandelica, Abies smithiana,* and *Quercus leucotrichophora* remained next five top species in the descending order. Similar information for estimated number of trees and volume by species has also been provided in case of TOF. Prominent tree species contributing to the cumulative estimated number of trees.

As stated above, FSI has been generating valuable information on the growing stock contributed by prominent/ top ten tree species for past three decades or so. On behest of India, FSI has been contributing this information to the database of FRA maintained by FAO. The trends in growing stock of top ten tree species as of 2015 have been incorporated in the database and presented in Table 1.3. Accordingly, the total growing stock of native tree species has grown from 4,363 million m^3 in 1990 to 5,142 million m^3 in 2020. In general, an increase in growing stock in prominent tree species has been documented in past three decades. *Shorea robusta* is the main contributor to the overall growing stock, followed by *Tectona grandis, Pinus roxburghii, Terminalia tomentosa, Anogeissus latifolia, Quercus semecarpifolia, Lanea coromandelica, Pinus excelsa, Quercus leucotrichophora,* and *Boswellia serrata*. These ten prominent species contribute nearly 25-30 per cent of the total growing stock of native species.

Table 1.3 Growing Stock in Prominent Tree Species in Forest

Sr. No.	Species	Common Name	Growing Stock in Forest (million m^3 over bark)				
			1990	2000	2010	2015	2020
1.	*Shorea robusta*	Sal	321.00	345.00	545.00	506.00	508.00
2.	*Tectona grandis*	Teak	162.00	173.00	224.00	222.00	223.00
3.	*Pinus roxburghii*	Chir Pine	124.00	133.00	142.00	168.00	169.00
4.	*Terminalia tomentosa*	Saja	108.00	114.00	140.00	168.00	169.00
5.	*Anogeissus latifolia*	Dhauda	94.00	102.00	130.00	131.00	132.00
6.	*Quercus semecarpifolia*	Kharsu oak	82.00	88.00	75.00	86.00	86.00
7.	*Lannea coromandelica*	Jhingan	54.00	60.00	77.00	84.00	84.00
8.	*Pinus excelsa*	Kail	51.00	57.00	78.00	81.00	81.00
9.	*Quercus leucotrichophora*	Bluejack oak	57.00	64.00	62.00	74.00	74.00
10.	*Boswellia serrata*	Salai	55.00	61.00	71.00	68.00	68.00
	Remaining Native Trees		**3,255.00**	**3,622.00**	**3,558.00**	**3,534.00**	**3,548.00**
	Total Growing Stock		**4,363.00**	**4,819.00**	**5,102.00**	**5,122.00**	**5,142.00**

1.9.2.7

Trends in Change of Forest Cover and Forest Transition

Wide range of direct and underlying causes and factors have been responsible for changes in Forest Cover leading to either enhanced deforestation and degradation or forest recovery as a result of declined deforestation and degradation. In India, primary causes for deforestation and degradation in past 150 years or so were prolonged phase of 'production forestry' and forest exploitation, growth of forest-based industries, agriculture expansion, diversion of forest lands for non-forest uses and traditional resource dependance of tribals, forest dwellers and rural population (Dangwal, 2005). In contrast, causes and factors attributed to reduced deforestation, increased Forest Cover and forest recovery are 'conservation forestry', improved land use planning, supporting forestry policies and conservation laws, international agreements and global obligations, rehabilitation and afforestation, private tree/ forest production and agroforestry, Open General License (OGL) transactions for import of wood and forest products, substitution of wood by steel and plastic, intensification of agriculture and higher yields, economic development, emergence of secondary and tertiary sectors in economy, rural-urban migration and growth in urban population, globalization, growing environmental consciousness, change in attitude and perspective, and realization of multiple values of forests (Singh *et al.*, 2015; Bhojvaid *et al.*, 2016).

The shift in continuous decline of forest cover that persisted for several decades until it reached a lowest point and halted, to gradual recovery towards increasing forest cover associated with economic development has been referred as forest transition. Mather (1992) first described and defined 'Forest Transition (FT) as a process in which, in a given territory and over a period of time, the area of forest cover declines until it reaches a lowest point, after which the forest area gradually recovers' in the context of Europe. Subsequently, the process was also described for North America and countries outside the Europe and North America (Walker, 1993; Mather and Needle 1998; Rudel *et al.*, 2005).

Dangwal (2005) has described the process of commercialization of forest, timber extraction and deforestation in the Himalayan State of Uttaranchal (presently, Uttarakhand) during the nineteenth century and the first half of the twentieth century (1815-1947) and highlighted the declining vegetation cover owing to extraction of more wood than the regenerative capacity of forests. He stated that unsustainable extraction of forest resources does not directly lead to denudation but to a slow degradation not likely to be apparent until a long time. He analyzed growth of wood extraction and timber trade in three phases and attempted to study the changing nature of demand for forest produce. Certainly, Asia is one region where forest transition has taken place in several countries as the net loss of forests persisted for several decades before it was halted and replaced by a net increase in forest cover (Mather, 2007; Southworth *et al.*, 2010). Richards and Flint (1994) estimated Forest Cover in India in 1880 to the tune of 102.7 million ha, representing 32.12 per cent geographical area. Probably, it is the oldest available figure on the extent of Forest Cover in context of the independent India. Subsequently, available literature documents continuous decline in Forest Cover upto 1970s (Singh *et al.*, 2014, 2015; and Bhojvaid *et al.*, 2016).

In case of India, forest transition was studied and detailed account was provided by Bhojvaid *et al.*, 2013. Singh *et al.* (2014 and 2015) reported that India experienced a sustained forest cover decline to the tune of 14.1 million ha during 1900-1950, and 12.7 million ha during the period of 1950-1970 (Table 1.4). These estimates do not include the area under the slash and burn or shifting cultivation being practiced in approximately 7 million ha extent in north-eastern states. India's forest area began to increase in 1980s, when the country had a forest cover of 19.5 per cent. Table 1.5 summarizes Forest Cover under three different forest canopy classes from 2001-2021 based on biennial ISFRs by FSI.

Perusal of Table 1.4 and 1.5 amply shows forest transition as they reveal that decline of Forest Cover in the country persisted for almost a century (1880s – 1970s), bringing a halt in 1970s and notable increase for the first time in 1980. Singh *et al.* (2015) described three different phases of development illustrating forest transition in India: (a) deforestation, (b) afforestation, and (c) conservation domination and narrated the direct and underlying causes and factors favoring forest transition (Fig. 1.10).

Firstly, the highlighted causes and factors for forest transition included continued expansion in notified forests from 40.48 million ha in 1950-51 to 69.53 million ha in 2008-09, and progressive increase in Forest Cover from 63.4 million ha in 1980 to 71.37 million ha in 2021. Increase in Forest Cover after a century long persisted decline was attributed to agricultural transformation during 1950-1980 by way of agriculture expansion and intensification (118.75 million ha in 1950-51 to 141.36 million ha in 2008-09) post-independence of India, especially during the phase of 'Green Revolution'. Agriculture land expanded by 22 million ha during 1950-70 and agro-technological developments (enhanced irrigation, improved seed, use of fertilizers, insecticides and weedicides, use of modern agricultural implements and tools, etc.) led to increase of wheat productivity from 663 kg/ ha (1950) to 1,307 kg/ ha (1970) and further to 2,708 kg/ ha (2000) and 2,938 kg/ ha in 2010. Despite the continued development of agriculture sector during 1950-1980, the relative contribution of agriculture towards GDP gradually declined from 53.10 per cent in 1950-51 to 36.10 per cent in 1981-82, finally to 14.50 per cent in 2010-11 (Singh *et al.*, 2015). Independence of the country also saw the beginning of large-scale developmental activities, leading to rapid industrialization, expansion of linear infrastructure (rail, highways, roads, canals and pipelines- water and petroleum products), a boom in construction activities, multipurpose hydro projects, and industrialization impacting forests and FGR. About two decades after independence, the country began its transformation to industrialization and the era post 1980 was marked by stabilization of the forest estate and forest recovery. India's economy beyond 1980 became dominated by the service sector as its contribution to GDP increased from 38 per cent in 1981-82 to 57.70 per cent in 2010-11. The country registered tremendous increase in human population from 361 million in 1950-51 to 1,210 million in 2010-11 while the literacy rate increased from 18.35 per cent in 1950-51 to 74.4 per cent in 2010-11.

The 'conservation forestry' influenced by the Wildlife (Protection) Act, 1972; Forest (Conservation) Act, 1980; National Forest Policy, 1988; Convention on Biological Diversity, 1992; and the new frontiers of social forestry triggered forest rehabilitation, ecorestoration, afforestation, and forest recovery. Large-scale afforestation, social forestry and agro-forestry programs on one hand significantly contributed to the expansion of forests in India but on the other hand facilitated unchecked introduction of exotics and planting material of unknown origin without realizing the long-term implications on FGR, particularly the genetic diversity. Following the FCA 1980, the annual diversion of forests to other land uses was reduced from 0.16 million ha/ year to 0.036 million ha/ year. Environmental jurisprudence through judicial activism promoted important legal judgements helping in forest and biodiversity conservation, and environmental management. The enhanced focus on conservation of forests in the country was evident by way of liberal government policy in 1996 facilitating import of wood and wood products. Since OGL for import of wood and wood products, the volume of wood import steadily increased. In addition to policy support, law enforcement, social forestry programs, a public-private partnership and private sector initiatives linked to new market opportunities laid the foundation for agroforestry projects. Promising agroforestry projects encouraged farmers replacing agriculture on low productivity land with tree planting, agroforestry and farm forestry. First two decades of the twenty first century have also witnessed intensive conservation efforts of India's forests by way of ambitious programs like the Green India Mission targeting creating additional five-million-hectare plantations outside forests, massive afforestation along major Indian rivers and their tributaries.

Despite forest transition in 1980s, reduced deforestation, forest expansion, and concerted efforts towards conservation forestry supplemented by above stated policies, laws, ambitious programs and initiatives of afforestation and forest rehabilitation, persistence of pre-forest transition factors (fuelwood collection, livestock grazing, forest fires, and exploitation of other NTFPs) lead to proliferation of invasive species, soil erosion, reduced ecosystem services, fragmentation of forests, genetic erosion, and overall poor health of forests. Hence, a wide range of drivers continue to operate and pose challenges for the maintenance of diverse and productive forests in the country. The process of forest transition in a human dominated country like India is different and complex on account of climatic, ecological, social and cultural situations. In short, forest transition is a complex interplay of multifarious direct and underlying causes of deforestation and degradation or forest recovery (Singh *et al.*, 2015). Thus, maintenance of diversity of FGR and their adaptive and evolutionary potential, being a part of the larger and complex forest ecosystem influenced by a wide variety of forest transition pathways is a challenging task.

Year	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Forest Cover (Million ha)	89.9	87.1	87.0	83.3	79.4	75.8	69.1	62.9	63.4	66.2	66.8	69.2
Forest Cover of Geographical Area (%)	27.4	26.5	26.5	25.3	24.2	23.1	21.0	19.1	19.5	20.2	20.3	21.1

Table 1.4
Trend in Forest Cover in India During 1900-2010

Source
Singh *et al.* (2014)

Year	2001	2003	2005	2009	2011	2013	2015	2017	2019	2021
Forest Attributes										
Very Dense Forest	41.68*	5.13	5.46	8.35	8.35	8.35	8.86	9.82	9.93	9.98
Moderately Dense Forest	-	33.93	33.26	31.9	32.07	31.87	31.27	30.83	30.84	30.68
Open Forest	25.87	28.77	28.98	28.83	28.78	29.56	30.01	30.17	30.45	30.71
Forest Cover	67.55	67.83	67.70	69.08	69.20	69.78	70.14	70.82	71.22	71.37
Forest Cover of Geographical Area (%)	20.55	20.64	20.6	21.02	21.05	21.23	21.34	21.54	21.67	21.71

* - includes extent of Moderately Dense Forest

Table 1.5
Trend in Forest Cover in India During 1900-2010

Source
Compiled from FSI's ISFR 2001, 2003, 2005, 2009, 2011, 2013, 2015, 2017, 2019, and 2021.

Period	Extent of Tree Plantations Raised (million ha)	Approximate Investment (million USD)
1950-1980	3.54	40
1980-1985	4.64	155
1985-1990	8.86	430

Table 1.6
Extent of Tree Plantations in India Under the Social Forestry and Agroforestry Programs

Source
Compiled from ICFRE (2010) and Singh et al. (2015)

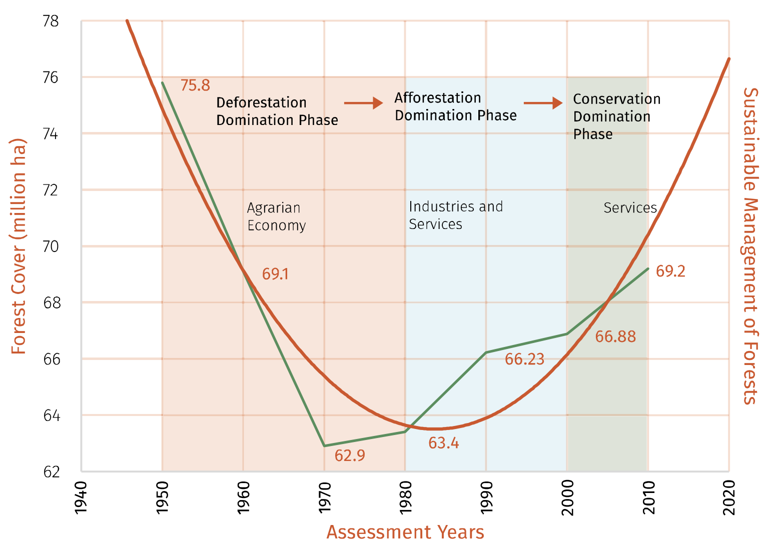
Conservation of Forest Genetic Resources

National Program for Conservation and Development of Forest Genetic Resources

1.9.2.8

Trends in Naturally Regenerating and Planted Forests

The FAO has been monitoring the world's forest resources and undertaking periodic assessments in cooperation with its member countries since 1946. The information provided by the FAO's Global Forest Resources Assessment (FRA) presents a comprehensive view of the world's forests and the trends in resource change and factors responsible. The global picture supports the development of sound policies, practices and investments affecting forests and forestry. In past seven decades or so, the public interest in the state of the world's forest resources has gradually enhanced. Hence, the scope and framework of the FRA has evolved in view of emerging global information needs. Presently, FRA embraced a more holistic perspective so as to address varied aspects of sustainable forest management (SFM). Since 1990, FAO publishes Global FRA every five years and generates country reports for its member nations as well (www.fao.org/forest-resources-assessment/fra-2020/country-reports/en/). In the context of India, the FSI has been the primary source agency in providing required information for the preparation of FRA and generation of India's country report. Besides valuable biennial information on Forest Cover and other relevant aspects incorporated in the ISFR, FSI also uses vital forest statistics generated by ICFRE on the basis of data provided by SFDs and other concerned national/ state level agencies. Contents and nature of forest information in 17 sequential ISFRs has evolved in view of the advancement of RS and GIS based technologies and country specific newer requirements. Likewise, FRA has also evolved in past seven decades and ensures to fulfill the global expectations on forest resources. Certainly, there is some difference in terms, concepts, and attributes adopted by two agencies (FAO and FSI) as well as mismatch in figures. Nevertheless, information and databases created year after year by both agencies are of utmost importance for understanding the issues related to conservation of FGR. For example, FRA incorporates country specific information on the extent of naturally regenerating forests vis-a-vis planted forests, distribution of forests under different ownerships and management rights, management objective, production of NTFPs and their economic value, and volume of prominent timber producing tree species, while such national level perspective in ISFR is not available. Hence, vital insight on some pertinent attributes having everlasting influence on FGR is being extracted from FRA and presented below.



Deforestation Domination Matrix	Afforestation Domination Matrix	Conservation Domination Matrix
Deforestation & Degradation Afforestation/Rehabilitation Conservation	Afforestation/Rehabilitation Deforestation & Degradation Conservation	Conservation Afforestation/ Rehabilitation Deforestation & Degradation

Fig. 1.10
Forest Transition Phases of India in Different Stages of Development

Source
adopted from Singh *et al.* (2015)

The FRA identifies two broad categories of forest: (a) Naturally Regenerating Forest, and (b) Planted Forest. There is an ongoing debate on the functions of naturally regenerating forests and planted forests. The former category of 'naturally regenerating forests or natural forests' perform multiple functions and offer a wide range of ecosystem services compared to planted forests. The FAO has elaborated the definition of 'Planted Forest' and accordingly it has been defined as 'forest predominantly composed of trees established through planting and/ or deliberate seeding'. Sustainably managed planted forests can immensely help in reducing pressure on natural regenerating forests and can offer some valuable services. FRA also collects information on two subcategories of planted forests *viz.*, (a) Plantation Forest, and (b) Other Planted Forest. The 'Plantation Forest' is intensively managed forest which fulfills all the criteria (one or two species, even age class, and regular spacing) at the maturity stand. Generally, plantation forests are raised for addressing demands of timber, fiber, energy, and NTFPs, and mainly composed of introduced exotic species. The introduced exotic species represents one subcategory of the plantation forests (FAO, 2020b). The second category of planted forest i.e., the 'Other Planted Forest' does not meet the criteria of plantation forests and even may resemble with natural forests at the maturity stand level. Other planted forests are generally planted for ecorestoration, soil and moisture conservation, and catchment treatment so as to restore degraded forests or river ecosystems. Globally, in most world countries, the extent of planted forests has notably enhanced in past two decades or so and it has happened at the cost of depletion of naturally regenerating forests. Thus, planted forests have several implications and cascading effect on the maintenance of diversity of FGR. Firstly, diverse native forests and associated FGR are depleted and fragmented. Secondly, native forest biodiversity including soil biota and soil condition are severely impacted. Finally, planted forests result into introduction of non-indigenous and exotic species or planting material of inferior quality ultimately leading to genetic erosion.

(a) Naturally Regenerating and Planted Forests

Availing information from FRA 2020 – India Report, trends in naturally regenerating forest, planted forest, and its two subcategories (plantation forest and other planted forest) during 1990-2020 are summarized in Table 1.7 (FAO, 2020b). Vital information on the extent of introduced exotic species in plantation forests is also provided in Table 1.7. The perusal of the trend revealed that the extent of natural regenerating forest from 2000 to 2010 decreased from 5,82,230 km^2 to 5,67,173 km^2. Subsequently, it showed gradual increase to 5,88,910 km^2 in 2020 (FAO, 2020b) (Table 1.7). The naturally regenerating forests represented 81.61 per cent of the total forest area in the country. The planted forest increased from 57,150 km^2 in 1990 to 93,680 km^2 in 2000, and 1,27,780 km^2 in 2010. Later, the extent of planted forests showed slow increase or gradually almost stabilized, and attained the extent of 1,32,690 km^2 in 2020. The planted forests in 2020 represented 18.39 per cent of the total forest area (Fig. 1.11). This notable and increasing proportion of planted forests in the country has several implications for the native floral and faunal forest diversity and FGR in particular. This may be one of the reasons in all likelihood for decline in native habitat and species, and increase in RET species. In 2020, the plantation forest represented 75.66 per cent of the planted forest. Plantations of introduced species covered 9.91 per cent of planted forests, and it represented 1.82 per cent of total forest area. Coverage of nearly one-tenth extent by introduced species in planted forests and about two per cent of total forest area in a short span of time is alarming and worrisome from the perspective of long-term conservation of FGR as current actions may have irreversible impact owing to either ignorance of likely implications or lack of data.

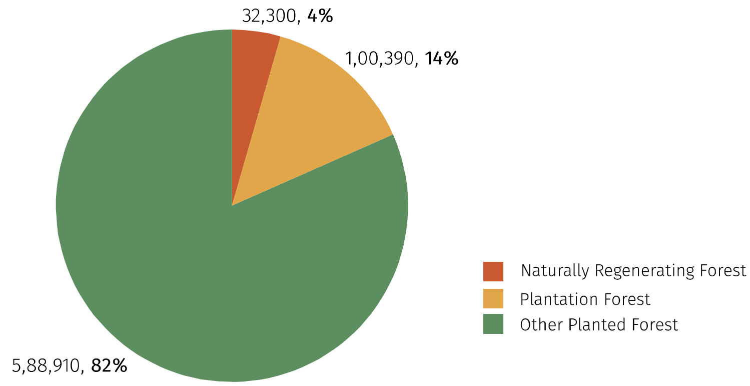
FRA Categories	Forest Area (km^2)								
	1990	2000	2010	2015	2016	2017	2018	2019	2020
Naturally Regenerating Forest (a)	5,82,230	5,82,230	5,67,173	5,78,040	5,80,220	5,82,392	5,84,566	5,86,740	5,88,910
Planted Forest (b)	57,150	93,680	1,27,787	1,30,240	1,30,720	1,31,216	1,31,706	1,32,196	1,32,690
Plantation Forest	35,140	71,670	96,680	98,540	98,900	99,275	99,646	1,00,020	1,00,390
... of which introduced species	4,600	9,390	12,660	12,910	12,960	13,000	13,050	13,100	13,150
Other Planted Forest	22,010	22,010	31,106	31,700	31,820	31,941	32,060	32,176	32,300
Total (a+b)	6,39,380	6,75,910	6,94,960	7,08,280	7,10,940	7,13,608	7,16,272	7,18,936	7,21,600
Total Forest Area	6,39,380	6,75,910	6,94,960	7,08,280	7,10,940	7,13,608	7,16,272	7,18,936	7,21,600

Table 1.7 Trends in Naturally Regenerating and Planted Forests in India During 1990-2020

Source Compiled from Global Forest Resources Assessment-India Report 2020 (FAO, 2020b)

Fig. 1.11
Natural Regenerating and Planted Forests in India in 2020

Source
FAO (2020b)



(b) Primary Forest

The FRA, 2020 also provided valuable insight on the extent of 'Primary Forest', distribution of forests based on ownership and management right, and management objective. Primary forest are naturally regenerating forests of native tree species, where there are no clearly visible indications of human activity and ecological processes are not significantly disturbed. As such the human presence in a densely populated country like India is widespread. However, some near pristine areas or large chunk of forests falling in the purview of strictly protected national parks, core or inviolate space of tiger reserves, sparsely populated forested tracts in the Himalayas, Western Ghats, North-East India, and Islands biogeographic zones continue to harbour considerable extent of primary forests as repository of FGR. In India, the estimated extent of primary forest in 2020 was 1,57,010 km^2 (FAO, 2020b).

(c) Forest Ownership and Management Rights

FRA 2020 by FAO offers valuable insight on ownership and management rights of forests in the country. Accordingly, India has an extent of 5,77,470 km^2 or 82 per cent of total forest area as the 'Public Forest' either the control and ownership of the government i.e., the public administration (RFs, PFs, and UDFs) under SFDs, Defense/ cantonments, Revenue Department (Civil Soyam), Municipal bodies, National/ State level organizations, etc. or local tribal and indigenous management (e.g., Van Panchayat, Autonomous Tribal Councils, etc.) (Table 1.8). These varied ownership and management rights have direct and indirect implications on conservation of forests and FGR as they are governed by different laws and management regimes (active to passive management), reflecting diverse conditions of forests. In addition to public forest, country also has an extent of 1,30,810 km^2 of 'Private Forest', representing 18 per cent of total forest area (Table 1.8; Fig. 1.12). Private forests are forest parcels of varied extent either under the control of larger corporates dealing with cash crops (soft wood-WIMCO, tea and coffee estates, cashew, rubber, mango, banana, spices, etc.) or individual entities (farmers/ villagers) growing orchards or agroforestry plantations (*Tectona* sp., *Eucalyptus* spp., *Populus*, Bamboo spp., *Azadirachta* sp., *Dalbergia*, *Leucaena*, *Ailanthus* spp., etc.)

Table 1.8
Extent of Forests in India in Different Ownership and Management Rights

Source
Compiled from Global Forest Resources Assessment- India Report 2020 (FAO, 2020b)

Sr. No.	Forest Ownership and Management Rights	2010 (km^2)	2015 (km^2)
1.	Public Forest	5,74,850	5,77,470
	Public Administration	3,28,380	3,29,880
	Local Tribal and Indigenous Management	2,46,470	2,47,590
2.	Private Forest	1,20,110	1,30,810
	Total Forest Area (1+2)	**6,94,960**	**7,08,280**

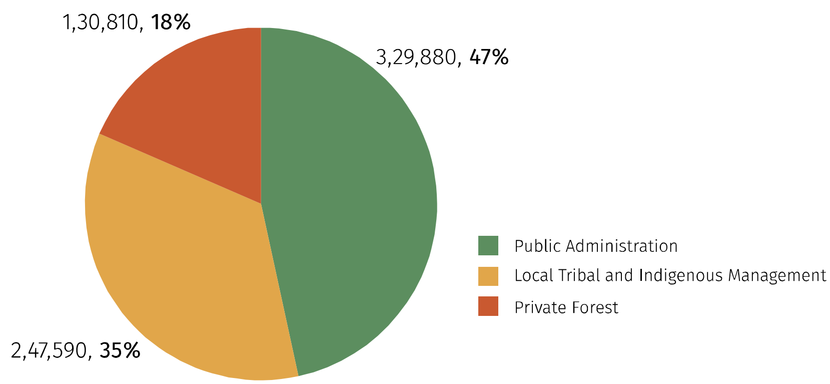


Fig 1.12 Distribution of Forests in India Under Different Ownership and Management Regimes

Source FAO (2020b)

(d) Distribution of Forests as per the Management Objectives

Forests in the country are being managed for varied management objectives since the commencement of Indian forestry. In general, prior to 1960s, the focus of forest management was on production of commercially important tree species including NTFPs irrespective of ownership. Subsequently, forests are being managed for specific objectives *viz.*, soil and water conservation, maintenance of catchment, conservation of biodiversity, wildlife habitat, and multiple objectives. Increasingly, SFDs are managing diverse forests across the country for multiple values including production, protection of soil and water, riparian habitats, protected areas, conservation of biodiversity, recreation, wildlife tourism, etc. Forests under the control of state level Forest Development Corporations for production of timber or other forest-based resources. The autonomous tribal councils in the northeastern region traditionally manage forests for the purpose of shifting cultivation, production of bamboo, and collection of NTFPs for self-consumption or local requirements. Corporates dealing with tea/ coffee estates manage forests in their estates for the purpose of maintenance of desired shade, pollinators, nitrogen fixation, soil and water conservation, and meeting needs of fuelwood and NTFPs of the laborers and workers of the estate. The traditional dependence of mountain people in the Uttarakhand Himalayas for timber, fuelwood, livestock grazing, fodder, water, medicinal plants, other NTFPs besides spiritual and cultural values solely relies on the small forest parcels entrusted to each of the Van Panchayats (VPs). The forests under >12,000 VPs in the State of Uttarakhand are being managed for such multiple values and benefits since 1920s. The FRA, 2020 provided an insight on the distribution of forests in India under different management objectives. Accordingly, the highest extent of forest amounting to 2,63,050 km^2 or 36 per cent of the total forest area is being managed for the objective of multiple uses, followed by 1,83,510 km^2 (25%), 1,62,180 km^2 (22%), and 1,12,860 km^2 (16%) for the objective of production, conservation of biodiversity, and protection of soil and water, respectively (Fig. 1.13). Certainly, forest management practices under different management objectives and regimes (ownership, legal status, management goals) will have substantially varying impact from active to passive, extensive to limited, and adverse to positive on forest biodiversity, ecosystem services, FGR, and adaptive and evolutionary processes of the forest. Forest management practices based on the past practices of clear felling, selection system, coppice with reserve, etc. will have an indelible mark on the genetic diversity of FGR and their adaptive capacity in the changing climate scenario. In contrast, forest working falling under the protection and conservation felling system or protected area system (strict protection and no human use as in national parks or core of tiger reserves) will have positive effect on the diversity of FGR and their long-term sustainability. Adoption of Ecosystem Based Forest Management (EBFM) involving large forested landscapes, range of management regimes, multistakeholder, multidiscipline, and multiscale activities will definitely help to maintain diversity of FGR besides forest biodiversity, productivity, and vital ecological processes.

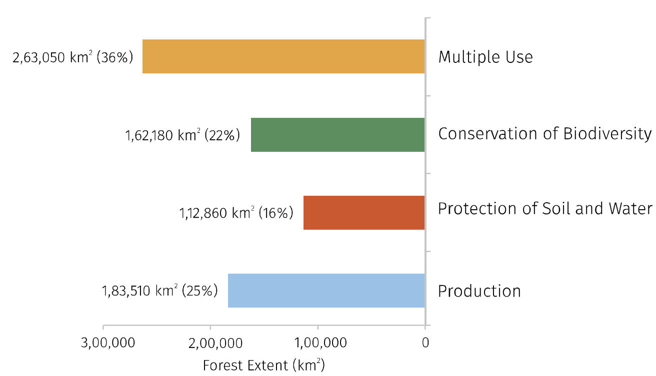


Fig 1.13 Distribution of Forests Under Different Management Objectives

Source FAO (2020b)

1.10

Biodiversity Governance Models in India

The conservation of FGR in India is strongly linked with two types of concurrent conservation approaches evolved over a long period of time towards protection of nature and biodiversity governance. These are: (a) community-driven conservation, and (b) state-driven conservation. Krishnan *et al.* (2012) have described five biodiversity governance models as a continuum that operate and focus on conservation, sustainable use, fair and equitable sharing of biological resources across landscapes (Fig. 1.14). Two governance models namely, Protected Areas (PAs) and Managed Forests (MFs)/ Territorial Forests represent the state driven conservation system of biodiversity governance while three models- Autonomous Community Efforts, Co-management of Forests, and Decentralized Governance of Biodiversity align more closely with community driven conservation efforts.

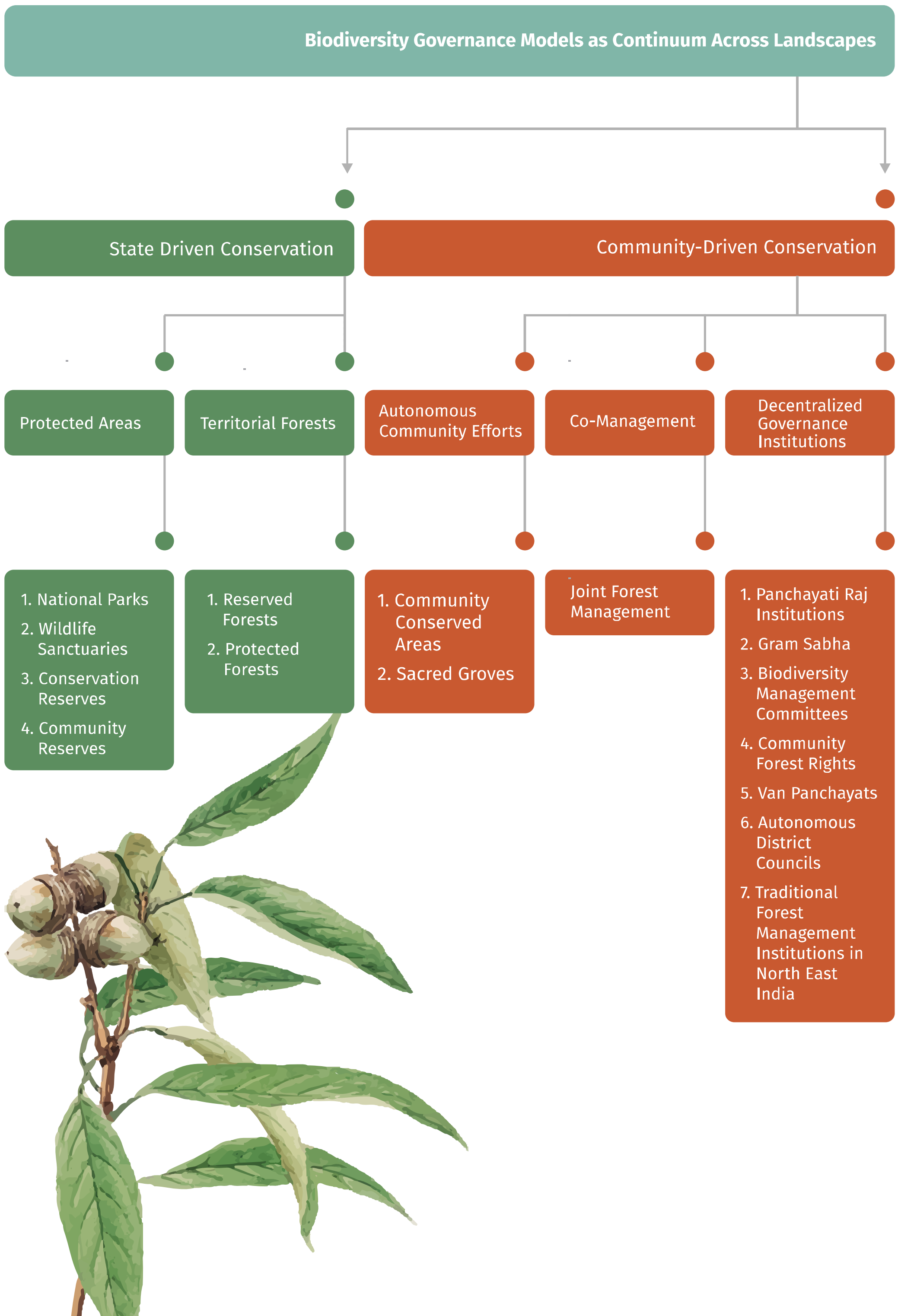


Fig 1.14 Biodiversity Governance Model in India

Source Adopted from Krishnan *et al.* (2012)

1.10.1

State Driven Conservation

The state driven conservation includes two broad categories of biodiversity governance models. These are: (a) Protected Areas, (b) Managed Forests.

Protected Areas

Presently, India has four legally designated categories of PAs including the National Parks, Wildlife Sanctuaries, Conservation Reserves, and Community Reserves established as per the provisions of the Wildlife (Protection) Act, 1972 (WPA). World over, the PAs have been recognized as the building blocks for protection and safeguarding of forest biodiversity so as to allow in situ conservation for facilitating ecological and evolutionary processes to unfold alongside the maintenance of ecological, species, and genetic diversity. PAs in India are being managed by the State/Union Territory (UT) Forest Department under the overall supervision of State/ UT's Chief Wildlife Warden. No human use is permitted in the National Park (NP), except wildlife tourism and thus, receives highest and stricter protection. After the amendment to the WPA in 1991, the finally notified Wildlife Sanctuary (WLS) also enjoys stricter protection but law has provisioned for regulated livestock grazing and tourism activities. In 2003, yet another amendment to the WPA provisioned for two additional categories of PAs namely, the Conservation Reserve, and the Community Reserve. The former can be created on the government land while the latter category can be established on private lands with due consent of local communities. The Government of India (GoI) in recognition of dwindling populations of the 'iconic' or a 'flagship' species i.e., tiger (*Panthera tigris tigris*) brought another amendment to the wildlife law of the country in 2006 and introduced a separate chapter on the 'National Tiger Conservation Authority' (NTCA) and provisioned for creation of legally notified 'Core' (inviolate space or *sanctum sanctorum*) comprising of NP and WLS, and 'buffer' comprising managed/territorial forests forming a 'Tiger Reserve' (TR). The core area has stricter protection and allows only regulated tourism activities in a smaller designated area as the tourism zone. The concept of buffer area allows the agenda of 'co-existence' of humans with wildlife and thereby, permits regulated production activities by different sectors while promoting mainstreaming biodiversity concerns in varied production sectors. Rodgers and Panwar (1988) provided the biogeographical basis for assessing the conservation status of country's spectacular biodiversity and divided the whole country in 10 biogeographic zones and 27 biotic provenances, and also made recommendations for the creation of a protected area network. At the time of comprehensive review of PAs in 1988 and gap analysis revealed that the country had 63 PAs including 4 National Parks and 59 Wildlife Sanctuaries upto 1970 and the PA network increased to 54 National Parks and 372 Sanctuaries collectively representing 3.34 per cent geographical area of the country (Table 1.9). Based on review. they proposed 870 PAs including 160 national Parks and 707 sanctuaries representing 5.74 per cent country's geographical area. Against this, as on 1st January, 2022, India has 987 PAs covering 1,73,053.69 km^2 and representing 5.26 per cent geographical area of the country (National Wildlife Database). The present PA network includes 106 National Parks, 564 Wildlife Sanctuaries, 99 Conservation Reserves, and 218 Community Reserves. These 987 PAs including the core areas of legally notified 51 TRs constitute priority *in situ* conservation areas in different States/ UTs. The Environmental (Protection) Act, 1986 and the National Wildlife Action Plan (2002-2016) envisaged that areas outside PA network are often vital ecological corridor links and must be protected to prevent isolation of fragments of biological diversity which will not survive in the long run. The Government of India is obliged as per the EPA, NWAP and the directives of the Supreme Court to delineate and notify 'Eco-sensitive Zone (ESZ)' around each National Park and Wildlife Sanctuary so as to serve some kind of 'shock absorber' for the PAs and they would serve as the transition zone from areas of high protection to areas of lesser protection. The existing law requires delineation and final notification of ESZ around a National Park or Sanctuary, preparation of Master Zonal Plan within 2 years of final notification of ESZ, and constitution of the Monitoring Committee. The notification of ESZ incorporates details of activities which are prohibited, regulated and permitted. PAs immensely help in maintenance of diverse ecosystems, floral and faunal species and genetic diversity among them besides vital FGR and associated evolutionary processes.

Protected Area Category/ Year	1970[#]		1988[*]		2022[#]	
	Number	Area (km^2)	Number	Area (km^2)	Number	Area (km^2)
National Park	4	2,403.24	54	21,003	106	44,372.42
Wildlife Sanctuary	59	9,796.53	372	88,649	564	1,22,509.33
Conservation Reserve	-	-	-	-	99	4,726.24
Community Reserve	-	-	-	-	218	1,445.71
Total PAs	63	12,199.77	426	1,09,652	987	1,73,053.69
Representation of Country's Geographical Area (%)	-	-	-	3.34	-	5.26

Table 1.9
Growth in Protected Areas in India

Source
*Rodgers and Panwar (1988); #National Wildlife Database, WII.

Managed Forests

In addition to the legally designated PAs as the state-driven in situ conservation areas, the country has yet other and much older legal categories of 'Reserved Forests (RFs), Protected Forests (PFs), and Un Demarcated Forests (UDFs) or Un Classified Forests, falling under the purview of state-driven managed/territorial forests (Fig. 1.14). The process of forest reservation and establishment of legally designated RFs/PFs began in the country in 1860s with the commencement of forestry under the British regime. Managed Forests notified under the Indian Forest Act, 1927 under the custody and management of State Forest Department (SFD) make notable contributions towards the maintenance of forest diversity and FGR in particular in different parts of the country. These territorial forests differ primarily on the extent of rights and concessions accorded to forest dwellers and other local people and have long history of management of nearly past 150 years or so based on silviculture practices incorporated in approved Forest Working Plan of the respective Forest Division (FD). Considerably large (ca. 500-1,000 km^2) FD comprises of multiple management categories *viz.*, forest Ranges, Blocks, Beats, and Compartments in a descending order based on areal extent. Usually, a FD is being managed by the forest officer of the rank of Divisional Forest Officer (DFO)/ Deputy Conservator of Forest (DCF). Two or more FDs form the 'Forest Circle' and being supervised by the Conservator of Forests (CF). The higher hierarchical levels are Chief Conservator of Forests (CCF), Additional Principal Chief Conservator of Forests (APCCF), Principal Chief Conservator of Forests (PCCF), and the Head of the Forest Force (HoFF). Generally, officers at the level of DCF and above are responsible for planning and decision making. The Range Forest Officer (RFO) and his/ her subordinates (Deputy Ranger, Forester, and Beat Guard) are the implementing officials at the ground level. The lowest category of Beat Guard is in-charge of 3-5 compartments usually of 2-5 km^2 each. The Beat Guard is responsible for protection of forest area in his jurisdiction and ensures implementation of approved management interventions.

1.10.2

Community Driven Conservation

Broadly, three types of biodiversity governance models fall under the category of community-driven conservation.

Autonomous Community Efforts

The autonomous community efforts including Community Conserved Areas (CCAs), and Sacred Groves (SGs) are the oldest community-driven initiatives for conservation and management of biological resources in the country (Fig. 1.14). However, they differ in government institutions, management objectives, resource use, and ecological impact (Krishnan *et al.*, 2012). CCAs have been defined as natural and modified ecosystems with significant biodiversity, ecological and related cultural values, voluntarily conserved by indigenous peoples and local communities through customary laws or other effective means (Kothari, 2006; Pathak and Kothari, 2009; Pathak, 2009). In addition to CCAs, as stated earlier, traditionally, local communities in different parts of the country have been following an ancient practice of *in situ* nature conservation by way of protecting small undisturbed patches of vegetation in the outskirts of the villages and towns or as a part of the forested areas that are inextricably linked with the culture, traditional rituals and dedicated to local deities. Conservation of sacred groves has been an important traditional aspect of ethics of the Indian culture. Sacred groves have been named differently in different parts of the country and several authors have provided valuable information on varied aspects of sacred groves (Joshi and Gadgil 1991; Malhotra, 1998; Krishna and Amrithalingam, 2014; Amrithalingam, 2016). In addition to sacred sites, several plant species have been recognized as sacred plants in Hindu mythology. Kandari *et al.* (2014) have documented state-wise distribution of 13,720 sacred groves in the country and a list of 31 sacred plants (e.g., *Aegle marmelos, Azadirachta indica, Betula utilis, Cedrus deodara, Embilica officinalis, Ficus benghalensis, F. religiosa, Pinus roxburghii, Santalum album, Terminalia arjuna, Quercus leucotrichophora,* etc.). Although, no specific policy or legal framework for autonomous community efforts exists but a number of existing laws and policies relevant to forests, wildlife, biodiversity and environment have a bearing on them. CCAs and SGs are important forest areas not only conserving some of the RET species but also sparsely distributed FGR.

Co-management

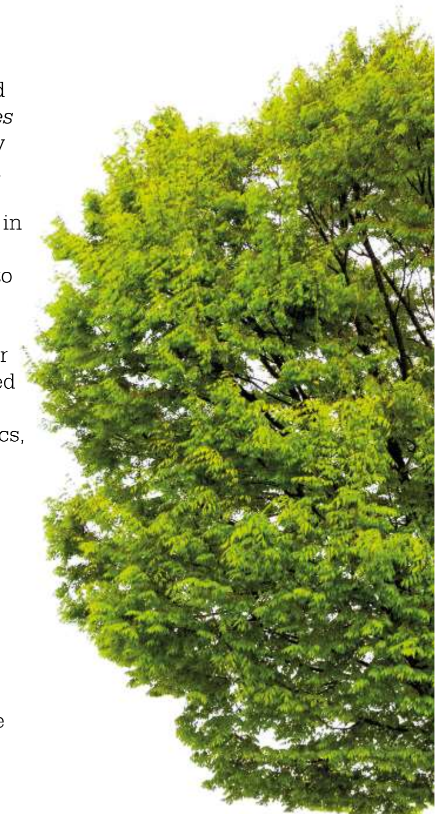
Although, forest dwellers, tribals or local communities inhabiting forest settlement villages in the interiors of the forest and local people living in forest fringe areas have been involved in the management of state-driven managed forests for a long since the establishment of territorial forests and these people have been helping the SFD in regular works related to forest management, particularly prevention, detection and control of forest fires (Fig. 1.14). The formal experiment on the concept of co-management of state-owned natural resources including forests wherein the SFD had entered into an agreement with the local community which allowed greater access to the forest resources as well as a share in revenue in return for protection of forests against illegal activities is popularly known as Joint Forest Management (JFM) was initiated in the 1980s and the innovative idea was ultimately crystallized and translated as a major policy endeavor in 1988. The NFP, 1988 advocated for the creation of massive people movement and accordingly, the countrywide program of JFM was designed, institutionalized and supported in 1990 by the Union Ministry of Environment and Forests with the aim to accomplish national goals of afforestation/ reforestation, production of NTFPs, and protection of forests. In past three decades or so, the JFM program has grown and it is now one of the largest community-driven forest management programs in the world (Krishnan *et al.*, 2012).

Decentralized Governance Institutions: Yet another community-driven biodiversity governance model relates to decentralized village/ community level institutions working at the grassroots level (Fig. 1.14). Presently, a wide range of decentralized institutions *viz*., Autonomous District Councils, Van Panchayats, Gram Sabha, Panchayati Raj Institutions (PRIs), Biodiversity Management Committees (BMCs), etc. are working in different parts of the country and helping in the process of adopting bottom up and decentralized approaches towards conservation of forests and other natural resources (Krishnan *et al.*, 2012). Much of the forests in the north eastern region are under the control of autonomous District Tribal Councils instead of the usual SFD like in most States/ UTs of the country. The District Councils have their own Acts and Regulations for the management and use of forest resources. The well-known and probably the oldest successful initiative of decentralized governance is 'Van Panchayats (Forest Councils) or VPs' in the Himalayan State of Uttarakhand initiated a century ago in the colonial period under the provisions of the Van Panchayat Act, 1921. A large number of VPs entrusted with small forest parcels in the State have been protecting, managing, and sustainably using assigned forest lands for past 100 years or so. 73rd Amendment to the Constitution of India in 1992 facilitated the three-tier governance system in the country by constituting the PRIs- Gram Panchayats and Gram Sabhas as the basic units at the lowest hierarchical level in the village. The Amendment also listed 29 Subjects devolved to PRIs including minor forest produce, social forestry, farm forestry, etc. The PRIs also play a pivotal role in the implementation of the Biological Diversity Act, 2002 (BD Act) at the grassroots level by way of legally defined Biodiversity Management Committees (BMCs). Presently, the country has nearly 2,70,000 BMCs across the country under the control of State Department of Panchayati Raj while the SFD and State Biodiversity Boards provide technical backstopping and help in capacity development so as to implement programs related to biodiversity conservation, access and benefit sharing of genetic resources. BMCs are also responsible for the preparation of People's Biodiversity Registers (PBRs) facilitating documentation of comprehensive information on availability and use of local biological resources including FGR besides any traditional knowledge associated with them.

1.11

Status of FGR in India

Accurate knowledge and information on diversity, distribution, extent/ abundance and status of ecosystems and species is the prerequisite for effective planning, management, and conservation of FGR at the national, sub-national, regional, and local levels. Taxonomic information on plant species across the globe including India is being constantly updated based on explorations, descriptions, and acceptance of species since the pioneer published work on botanical binomial nomenclature - *Species Plantarum* by Linnaeus in 1753 (Linnaeus, 1753). The number of plant species is increasing every day and as a result numbers of species of given families fluctuate as the systematic research is not static, and new species and genera are continually being explored, identified, described, and accepted. Moreover, in several instances, species names are being synonymized and even often disagreements in taxonomy with differing opinions on species circumscriptions in some taxonomic groups exist (Pimm and Joppa, 2015; Christenhusz *et al.*, 2016). Obviously, reliable accounts at a given time are difficult to find as by the time the number of species is published, the number becomes outdated. As per Christenhusz *et al.* (2016), the age of large general botanical explorations appears to be over, even though several new species are continually being discovered and described. Fundamental research or taxonomic research, essentially needed to build upon applied studies, which are generally well funded either receive lesser recognition and finances or the charm for the discipline has been gradually declining at the cost of newer disciplines *viz*., physiology, ecology, biochemistry, microbiology, genetics, bioinformatics, and molecular biology.



1.11.1

Global Plant Diversity

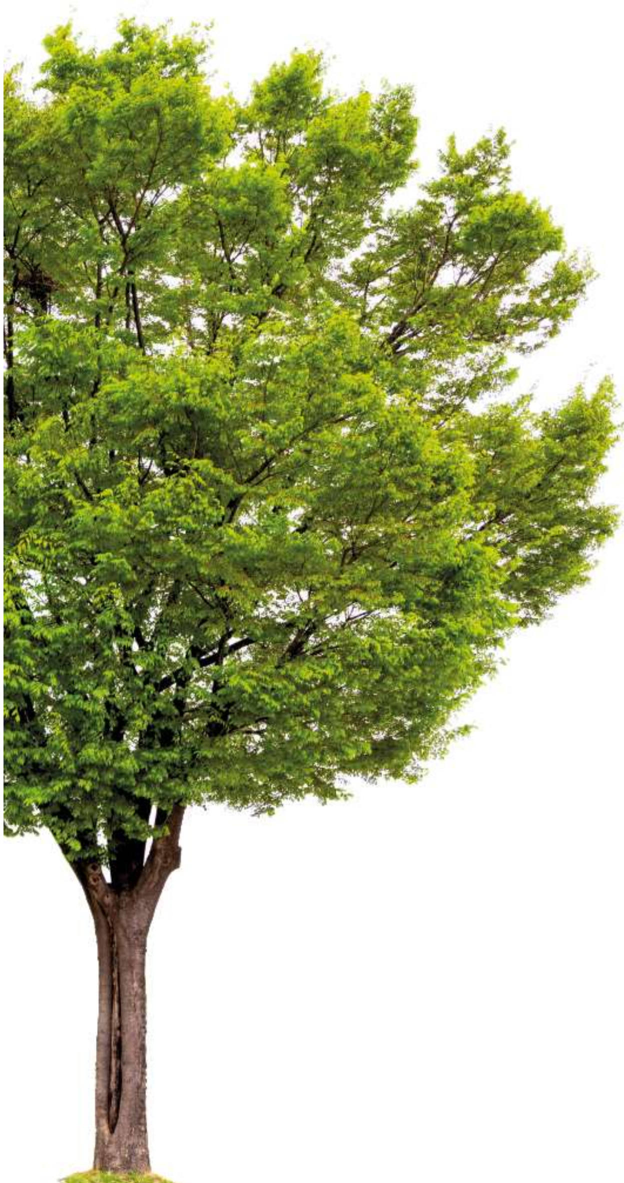
In view of the above, varying account on global number of plant species exist. As per the MoEFCC (2019), altogether 4,02,750 plant species representing varied taxonomic groups *viz*., angiosperms (2,50,000), gymnosperms (650), pteridophytes (10,000), bryophytes (16,600), algae (40,000), fungi (72,000), and lichens (13,500) have been documented from different parts of the world (Table 1.10). Phytotaxa, currently the largest journal in the field of systematic botany in the world has counted the presently known, described and accepted number of plant species as ca. 3,74,000 based on the *Kew Checklist of Selected Plant Families* (Zhang *et al*., 2014; Christenhusz *et al.*, 2016). Out of this, approximately 3,08,312 are vascular plants, with 2,95,383 flowering plants (angiosperms: monocots- 74,273; and eudicots- 2,10,008). Global number of smaller plant groups described by Christenhusz et al. (2016) include: algae ca. 44,000, liverworts ca. 9,000, hornworts ca. 225, mosses 12,700, lycopods 1,290, ferns 10,560, and gymnosperms 1,079. Christenhusz *et al*. (2016) further stated that the list provided by them is also out of date as every year nearly on an average 2,000 new plant species are being described, added, and published and nearly six-year period have elapsed since their publication. Pimm and Joppa (2015) have provided a higher estimate of 4,50,000 plant species. Christenhusz *et al.* (2016) stressed that their counts are more accurate and reliable as they are actual counts of accepted, published species, rather than informed estimates from group specialists or hypothetical number of possible species by using statistical models. Estimation of the number of known species is of utmost importance as the planet is facing with an unprecedented rate of extinction of species. From the time of seminal work by Linnaeus in 1753, 165 described plant species are known to have become extinct or only occur in cultivation (IUCN's categories EX-extinct and EW-extinct in the wild (IUCN, 2021). The IUCN has assessed the status of 58,343 plant species upto 2021 and listed them against different threat categories *viz*., Critically Endangered (CR) - 4,976; Endangered (E) - 9,400; Vulnerable (VU) - 8,959; Lower Risk/ Conservation (LR/ CD) Dependent - 147; Near Threatened (NT) - 3,500; Least Concerned (LC) - 26,511; and Data Deficient (DD) - 4,686 (IUCN, 2021).

Table 1.10
Plant Diversity in the World and in India

Source
Compiled from Christenhusz *et al*. (2016); Implementation of India's National Biodiversity Action Plan – An Overview 2019 (MoEFCC, 2019); Plant Discoveries 2020 (BSI, 2021)

Taxonomic Groups of Plant Kingdom	Global Plant Species		Number of Plant Species in India			
	Christenhusz *et al.* (2016)	MoEFCC (2019)	BSI (2021)	Per Cent Species of the World based on MoEFCC (2019)	Endemic Species	Threatened Species
Angiosperms	2,95,383	2,50,000	21,849	8.73	4,303	1,242
Gymnosperms	1,079	650	82	12.61	12	07
Pteridophytes	11,850*	10,000	1,310	13.10	66	414
Bryophytes	21,925**	16,600	2,791	16.81	629	80
Algae	44,000	40,000	8,979	22.44	1,924	Not Known
Fungi	-	72,000	15,504	21.53	4,100	580
Lichens	-	13,500	2,961	21.93	520	Not Known
Total	**3,74,237**	**4,02,750**	**53,476**	**13.27**	**11,554**	**-**

*- includes lycopods; ** - includes liverworts, hornworts, and mosses



1.11.2

Plant Diversity in India

The Botanical Survey of India (BSI) since it was founded in 1890 has been exploring and describing the plant species in the country and it is responsible for providing the updated account on floral diversity. In terms of plant diversity, India ranks 10th in the world and 4th in Asia (MoEF, 2012). BSI (2021) described altogether 53,476 plant species in India representing 13.27 per cent species of the world (Table 1.10). Out of this, different taxonomic groups include number of species and worlds representation as: angiosperms (21,849; 8.73%); gymnosperms (82; 12.61%); pteridophytes (1,310; 13.10%); bryophytes (2,791; 16.81%); algae (8,979; 22.44%); fungi (15,504; 21.53%); and lichens (2,961; 21.93%) (MoEFCC, 2019; BSI, 2021). Thus, the diversity of flowering plants in the country account for 21,849 species.

Trees are most conspicuous habits of the complex and dynamic forests, which broadly define structure and function of these ecosystems. Hence, database of trees from global to local level has immense value in planning any conservation strategy. Deplorably, precise, updated, authentic, and published information on the distribution of flowering plants as per their habits (tree, shrub, herb, climber, grass, etc.) at all levels is often devoid in the literature including publications by BSI for the country. However, recently the Botanical Gardens Conservation International (BGCI), based on a comprehensive analysis of published data sources and expert input, came up with the number of known tree species in the world as 60,065 while the different estimates were ranging from 45,000 to 1,00,000 species (Bhatt *et al*., 2020). Based on database by BGCI and other floras, an authentic list of 1,466 tree species found in the Indian Himalayan Region (IHR) covering 11 Indian States and 2 UTs. Bhatt *et al*. (2020) based on detailed analysis described distribution of wild and cultivated tree (angiosperms and gymnosperms) diversity in IHR and its constituents States and UTs across altitudinal range along with patterns of evergreen and deciduous trees and phenological events of trees. Earlier, MoEF (2012) documented 2,863 trees out of previously listed 17,527 flowering plants that included some of the highly valued timbers of the world. FSI (2019) has described diversity of tree, shrub, and herb species in different States/ UTs of the country based on the rapid assessment of biodiversity. Accordingly, the number of tree species in different States/ UTs ranged from 16 species in Delhi to 325 species in Karnataka. States harbouring tree species richness >150 species were Andhra Pradesh (242), Karnataka (325), Kerala (238), Maharashtra (170), Odisha (192), Tamil Nadu (252), and Telangana (167). Certainly, these figures on tree species richness in context of different states are under estimation keeping in view insight provided by state/ region/ area specific available floras. Efforts are needed by the survey organization like BSI to provide authentic information on vital components of flowering plants.

1.11.3

Endemic and Threatened Plant Species

IUCN has assessed the threat status of 58,343 species in the world, out of which 23,335 species or ca. 40 per cent are threatened (CR, E, and VU). Among threatened plants (23,335), 22,477 or 96.32 per cent species are angiosperms; 403 gymnosperms; 281 pteridophytes; and 165 bryophytes (IUCN, 2021). BSI has listed altogether 1,663 threatened plant species in the country, out of which 1,242 species are angiosperms (74.68 per cent), followed by 414 species of pteridophytes, and 07 species of gymnosperms (Table 1.10). High degree of endemism in plant species in India has been reported. As per the available information, altogether 11,554 species are endemic, of which 4,303 are flowering plants (Table 1.10). High endemism has been reported in the Western Ghats, North East India, and Himalayas.

1.11.4

Species Diversity in Bamboo and Rattans

Bamboos, the most diverse group of plants in the grass family belong to the sub-family Bambusoidae of the family Poaceae (Gramineae) and are very important forest resources found in the forests as well as the non-forest area in the country. Bamboo bearing areas represent 19.27 per cent of RFA and 4.54 per cent of the geographical area of the country (FSI, 2021). Nearly, 1,200 species of bamboo belonging to 90 genera have been described across the world (FAO, 2007). India has about 125 indigenous and 11 exotic species of bamboo belonging to 23 genera, and represents about 11 per cent global diversity of bamboos (FSI, 2021). Bamboos occur widely in different forest types, ranging from tropical to sub-alpine zones, and are found in abundance in the deciduous and semi-evergreen forests of the North-Eastern region of the country and the tropical moist deciduous forests of Northern and Southern India. Endemism in Indian bamboos is of a very high order (Tewari *et al.*, 2019). The North-Eastern hilly states harbour nearly 90 species of bamboos and 41 out of them are endemic to the region. Three large genera are *Bambusa, Dendrocalamus,* and *Ochlandra* with more than ten species each. Thus, these three genera represent ca. 45% of total bamboo species found in India. Some genera *viz*., *Ampelocalamus, Sarocalamus, Chimonobambusa, Pseudostachyum,* and *Stapletonia* are represented by only one species each (Tewari *et al*., 2019; FSI, 2021). Bamboos have been recognized as poor man's timber or 'green gold' and they significantly contribute towards the socio-economic, cultural, and ecological development in several regions of the country. Bamboo, contributes to livelihoods of about 2 million traditional artisans as they solely depend on harvesting, processing, value addition and selling of bamboo products, such as baskets, mats, handicrafts, etc. (FSI, 2021).

Bamboos were once extensively worked along with timber operations in managed forests, wildlife sanctuaries, and other public/ private forests. ISFR 2021 has revealed decline in bamboo bearing area and reduction in dense bamboo area. The extent of bamboo working has drastically reduced owing to the fact that a large chunk of RFs/ PFs have been converted as protected areas and the 1991 amendment to WPA curtailed bamboo working even in the wildlife sanctuaries. In general, bamboo resources for consumption from forest lands suffered on two accounts: firstly, substantial bamboo area under PAs was prohibited from felling, and secondly, the biotic pressure on bamboos particularly in PFs and UDFs enhanced due to growing human population and their demands, and illegal cutting and collection in different parts of the country.

From time to time, several national and state level programs and initiatives have been launched by the SFDs so as to restore and rehabilitate degraded forests including implementation of UNDP supported pilot project on the 'Rehabilitation of Degraded Bamboo Forest (RDBF)' in Madhya Pradesh as a part of the major project Sustainable Land and Ecosystem Management (SLEM). The pilot project had twin goals: (a) improvement and ecorestoration of degraded forests, and (b) promoting sustainable livelihoods of forest dwellers and tribal people. The project provided much desired direction for improving degraded forests including bamboo forests through engagement and participation of local communities (Laurie and Mathur, 2016). Further, in order to enhance the extent and productivity of bamboo resources, the government of India promulgated the Indian Forests (Amendment) Ordinance, 2017 to exempt to bamboo grown in non-forest areas from definition of tree, by amending the Section 2 (7) of the Indian Forest Act, 1927 and thereby doing away with the requirement of felling/ transit permit for its transport and economic use. The objective of the amendment was to promote cultivation of bamboo in non-forest areas to achieve the twin objectives of increasing the income of farmers and also increasing green cover of the country (FSI, 2021).

In addition to bamboos, rattans, members of the family Arecaceae (or Palmaeae) form a remarkable group of plants known for their lightness, strength, durability, and elasticity. In all 22 genera of rattans represented by more than 650 species have been reported from the world. Nearly, 61 species of rattans under 5 genera *viz*., *Calamus, Daemonorops, Korthalisa, Plectocomia,* and *Zalacca*. The rattans comprise more than 50 per cent of the total palm taxa found in the country and widely distributed from sea level to over an elevation of 3000 m and found in a wide range of habitats. Rattans, or canes are one of the most important NTFPs supporting the livelihoods of several forest dwelling communities in the country. There are a number of economically important species endemic to Western Ghats. Uma Shaanker *et al.* (2004) provided a detailed account on bamboo and rattans of the Western Ghats based on a study on population biology, socio-economics and conservation strategies. Ravikanth *et al.* (2001) mapped

genetic diversity of rattans in central Western Ghats for identification of hotspots of variability for *in situ* conservation.

Due to increasing demand for rattan products both locally and internationally, rattans have been heavily extracted from natural populations. Extensive harvesting, loss of habitat and poor regeneration has severely impacted populations of rattan and dwindled their extent and productivity. Rattans are dioecious and when they are prematurely harvested, they rarely flower and fruit, resulting in poor seed set, which in turn adversely affects the regeneration of the species. Pollination success is also hindered by habitat disturbance. Five of the 21 species of rattans are known from less than five localities and a couple of other species show patchy distribution. Three species *viz*., *Calamus neelgiricus, C. vattayila,* and *C. pseudofeanus* have narrow distribution. Eighteen of the 21 species of the endemic rattans of the Western Ghats occur only in evergreen forests and these forests in the region have undergone drastic reduction in the extent in past two centuries. Two important hotspots of rattan richness *viz.*, Coorg – Wayanad in central Western Ghats and Agastyamalai region in southern Western Ghats. The conservation of rattan species is of high priority as they are not only economically important, but several species are endemic with a narrow distributional range. Urgent actions are required for conservation of FGR associated with rattans (Ravikanth *et al*., 2001; Joshi *et al*., 2017). Domestication of rattans has been suggested as they contribute significantly to national economies and in maintaining some sort of forest cover. Cultivation may also help to increase recognition of the importance of wild species and encourage preservation and restoration of wild populations in their natural habitats (Joshi *et al*., 2017).

1.11.5 Species Diversity in Mangroves

Mangroves have been recognized as important refuges of coastal biodiversity and serve as bio-shields against extreme climatic and other natural events (FSI, 2021). Mangroves also help in stabilizing the shoreline. Mangrove plants have been categorized into two categories: true mangroves (mangroves limited to the mangrove habitat) and the mangrove associates (mainly distributed in a terrestrial or aquatic habitat but also occur in the mangrove ecosystem) (FAO, 2007). Further, true mangroves have been classified into two: major mangroves (mangroves that can form dense pure stands) and minor mangroves (denoted by their inability to form a conspicuous element of the mangrove vegetation) (Tomlinson, 1986; Polidoro *et al*., 2010). Mangroves of South and Southeast Asia form the world's most extensive and diverse mangrove systems comprising 41.4 per cent of global mangroves. Indian mangroves make little over three per cent of the total global cover and about 8 per cent of Asian mangroves. In India, mangrove forests covering an area of about 5,000 km^2 are distributed along all the maritime states and 7,500 km long Indian coastline, except the Union Territory of Lakshadweep. Nearly 60% of the mangroves occur on the east coast along the Bay of Bengal, 27% on the west coast bordering the Arabian Sea, and 13% on Andaman & Nicobar Islands (Singh *et al*., 2012). A review of the mangrove floristics of India by Ragavan *et al*. (2016) documented that Indian mangrove consist of 46 true mangrove species belonging to 14 families and 22 genera, which includes 42 species and 4 natural hybrids. In other words, about 57% of the world's mangrove species are represented in India. The East coast has 40 mangrove species belonging to 14 families and 22 genera. The West coast has 27 species belonging to 11 families and 16 genera and the Andaman and Nicobar Islands (ANI) have 38 species belonging to 13 families and 19 genera. Sundarbans mangrove forests in the Bay of Bengal is a large chunk of mangroves across India and Bangladesh and a substantially large extent is being conserved under the categories of protected areas. Sundarbans Tiger Reserve, India is an important reserve from the perspective of mangrove forest diversity, tiger conservation, and ecosystem services it offers to a considerable human population in a large number of villages located in the area.

The substantial population, primarily rural in coastal areas depend on mangrove ecosystems for the requirements of biomass and livelihoods. Hence, many stretches of mangrove forests are under tremendous biotic pressure and they are being over exploited. In addition, varied developmental activities in the coastal and marine environments all along the Indian coastline is also causing adverse impact on mangrove forests and their diversity. Considering the ecological, social, cultural, and economic importance of mangroves and also the threat perception, the MoEFCC has initiated a country wide program for conservation and management of mangroves. Mangroves definitely deserve special attention from the perspective of conservation of FGR.

1.11.6

Medicinal Plants

In recent decades, there has been a global resurgence in the traditional and alternative healthcare systems (Ayurveda, Unani, Siddha, and Homeopathy) which date back to more than 3,000 years and have deep-rooted wider social acceptance. Major proportion of vast diversity of herbal ingredients used in traditional health systems is being derived from wild plants that too mostly forested tracts in different parts of the country. Nearly 7,500 plant species are known to be used in the Indian systems of traditional medicine (Kala *et al*., 2006; Ved and Goraya, 2007). As many as 1,748 species have been recognized as medicinal plants from the Indian Himalayan Region (Samant *et al*., 1998). The maximum medicinal plants (1,717) species have been reported around the 1,800 m elevation range. On the regional scale, the maximum species of medicinal plants were reported from Uttarakhand, followed by Sikkim, and North Bengal (Samant *et al*., 1998; Kala *et al*., 2006) The growing commercial demand for herbal drugs has led to a wide range of plant resources under great stress owing to unsustainable harvests. In majority instances, reliable information and estimates of demand, supply, source forest areas of collection of plant material, and proportion of legal and illegal harvests are not available. The assessment of demand and supply of medicinal plants is a complicated affair due to relative opacity of the medicinal plant trade at the level of gatherers, traders, and the industry. However, in past three decades or so, literature on varied aspects of medicinal plants in the country has grown substantially as several national and state level scientific institutions, industries involved in herbal products, cosmetics, and pharmaceuticals, and individual botanists/ foresters, etc. have been contributing on the subject. The National Medicinal Plant Board (NMPB) under the Department of Ayush, Ministry of Health and Family Welfare, Government of India has the primary mandate of supporting programs relating to conservation and development of medicinal plants. The NMPB sponsored and supported a study to the Foundation of Revitalization of Local Health Traditions (FRLHT) so as to assess the quantum of domestic supply and demand and unravel the trade dynamics. The study also paid attention to the non-commercial demand of medicinal plant resources by the rural households. The research findings revealed that 178 plant species out of about 960 species in trade require focus as they are being traded in high volumes in quantities exceeding 100 MT per year. Ved and Goraya (2007) have segregated 178 plant species based on source of collection from different forests and other places including plant material obtained through import. Out of 178 plant species, 91 species are being collected from forests *viz*., 21 species (12 per cent) from temperate forests and 70 species (40 per cent) from tropical forests. Remaining 87 species (48 per cent) being collected from cultivation/ plantation areas, road sides and other degraded lands, and imported from other countries. As many as 127 species or 71.34 per cent species out of 178 priority plant species are FGR. Among them, 58 are tree, 51 shrub, and 18 woody climber species constituting FGR.

The wider subject of medicinal plants those are in trade require proper scientific assessment on methods of collection, extent covered, and people involved besides regeneration status in the wild and effective enforcement of existing forest/ wildlife/ biodiversity laws of the country.

1.11.7

Diversity of Forest Genetic Resources

Accurate knowledge and information on FGR across the globe and India in particular are deficient in view of the aforementioned description stating devoid of exact information on species richness of trees, shrubs, and woody climbers. Globally, a range of 80,000 to 1,00,000 number of tree species is the most widely used estimate. The range of published estimates is much wider, from 50,000 to 1,00,000. As stated earlier, the BGCI has estimated the tree species richness of 60,065. Presently, as per the most recent described diversity of higher plant species, India has 21,931 species (21,849 angiosperms and 82 gymnosperms), of which more than 80 per cent is envisaged to inhabit the forest habitats. It is assumed that nearly half of the higher plant diversity comprises of trees and other woody species, the remaining half is formed by the herbaceous plants, including soft climbers, twiners, herbs, and grasses. Hence, currently India harbours about 10,966 tree and other woody species. Considering that about 80 per cent plant diversity inhabits the forests, nearly 8,773 tree and other woody species (10,966 x 0.8) constitute the known and documented Forest Genetic Resources (FGR). This number will definitely increase as the botanical exploration, identification, description, and acceptance of newer plant discoveries progresses. The known and documented FGR predominantly occur in diverse natural public forests across different biogeographic zones of the country as highlighted above. A large proportion of India's FGR is known to be used by the local communities to meet their day to day needs of fuelwood, fodder, fiber, food, small timber, medicinal plants, and other NTFPs. Additionally, a small proportion of FGR is distributed in planted forests (plantations and other planted forests). Broadly, prioritization of FGR for conservation can be achieved by considering ecological values and functions performed by tree and woody species, conservation values (biodiversity, threatened species, and endemic species), scientific and cultural values, threat perception, and socio-economic benefits besides at the finer level, elements of eco-distribution, intra-specific variation, pest and pathogen resistance, chemical and genetic characterization need to be taken into account. MoEF (2012) has prioritized and listed 272 species which are actively managed for productive aims in India. In addition, a list of 195 tree and other woody forest species providing environmental services or having social values has also been provided. Further, a list of 261 tree and other woody forest species considered to be threatened in all or part of their range from genetic conservation point of view has also been provided. Furthermore, a list of forest species for which genetic variability has been evaluated incorporating 104 species has also been documented (MoEF, 2012).

1.11.8

Dependence on Forests and Use of Forest Genetic Resources

Forest resources, particularly FGR are being globally used for timber and NTFPs and their demands are generally on an increase. FRA periodically assess country-wise quantity of NTFPs and their economic value (FAO, 2020b).

1.11.8.1

Timber Supply and Demand

The International Tropical Timber Organization (ITTO) also collects information on country-wise timber supply and demand. India's timber supply and demand during 2010-2030 have been summarized by Kant and Nautiyal (2021). Accordingly, despite India's forest and tree cover has been steadily increasing during past two decades or so, the country still remains deficient in timber production and a larger proportion of its surging demand is being met from imports. This trend began in the 1980s when the country was passing through the 'forest transition' and roundwood production was in the range of 10 to15 million m^3 per year. The gradual decline in production was recorded owing to adoption of conservation forestry after the enunciation of the National Forest Policy, 1988. The Compounded Annual Growth Rate (CAGR) declined continuously during the decadal period of 1991 to 2000, by 0.70 for industrial coniferous roundwood, 1.15 for industrial non-coniferous roundwood, 8.72 for coniferous sawnwood, 8.39 for non-coniferous sawnwood, and 5.09 for veneer. The sharper decline was registered in the following decade due to stricter restrictions imposed by the Apex Court on harvesting from forests (Kant and Nautiyal, 2021). The overall demand estimates of roundwood by wood-based sectors (paper and pulp, furniture, panels and plywood, and construction) has grown from 58.79 million m^3 round wood equivalent (RWE) in 2016 to the projected value of 97.81 million m^3 RWE in 2030. Against this, the total production of roundwood in the country is around 47 million m^3 per annum of which a meagre quantity of about 2 million m^3 comes from the state-owned forests where harvesting has been severely curtailed, while the remainder larger portion of 45 million m^3 is met from TOF. The gap in the timber demand is met by imports which were facilitated in 1996 by bringing wood under the Open General License (OGL) by the GOI with the intention of easing the wood shortage and reducing demand for timber from natural forests. Thus, the GOI and State Governments made conscious efforts to conserve forests, forego revenue, and protect the domestic wood processing industry. India's wood imports are mostly in the form of roundwood (logs) and its imports for wood and wood products increased from USD 1,331 million to about USD 1,950 million during 2009-2019. Likewise, imports for pulp rose from about USD 240 million to USD 510 million in the same period. The estimated CAGR of the sector is expected to grow around 13 per cent during 2020-2024.

1.11.8.2

Status of Non-Timber Forest Products

The foregoing sections have offered a valuable insight on the 'production forestry' relying on silviculture-based forest management in the country for a period of almost one century, initiated in the colonial period and continued upto 1960s, and its sole emphasis on production of commercially important timber species so as to meet the varied requirements of timber and timber products. This long history of forest management and information on forest transition provided desired appreciation and understanding on the impact on the country's forests, trends in forest cover and production of timber, and adoption of varied governance models by the government and communities. The period of 1970s-1980s witnessed a general recognition and upsurge in global interest in Non-Timber Forest Products (NTFPs) due to varied reasons: (a) paradigm shift from production forestry to conservation forestry, (b) realizing that NTFPs as a group of forest resources are economically important natural resource, (c) belief that promotion of sustainable use of NTFPs could lead to a win-win situation for poverty alleviation and biodiversity conservation, (d) easy accessibility to the poor, (e) mostly short annual harvest/ rotation period, (f) collected, used and sold by women so it has a strong linkage with women's financial empowerment, (g) potential harvest with relatively little impact on the forest environment, and (h) notable contribution of the export in the forestry sector and forest exchange earnings (FAO, 1995 and 2008; Myers, 1988; Neuman and Hirsch, 2000; Van Andel, 2000; Shiva and Verma, 2002; Saxena, 2003; Rasul *et al.*, 2008; Ahenkan and Boon, 2011; Patil, 2022).

(a) Definitions and Policy Issues relevant to NTFPs

According to Ahenkan and Boon (2011), a lot of confusion has persisted with semantics and terminologies relevant to NTFPs despite a significant volume of information on the importance, potential and utilization of NTFPs and its impact on poverty reduction, livelihood improvement and environmental sustainability has been documented. It has been difficult to clearly define NTFPs because of the blurred boundaries between timber and non-timber products, and the underlying difficulty in defining a forest. Owing to the overabundance of definitions/ terminologies (non-timber forest products, non-wood forest products-NWFPs, minor forest products-MFPs, forest biological resources, special forest products, etc.) relating to a single term having a range of interpretations and none of them is universally recognized has not only caused confusion but also blowed up the debate on the definition of NTFPs since the term was coined by de Beer and McDermott in 1989 (Ahenkan and Boon, 2011).

Globally, NTFPs/ NWFPs have been defined as 'forest products consisting of goods of biological origin other than wood, derived from forests, other woodlands and trees outside forests. The UN FAO preferred to use the term NWFP and defined it as a product of biological origin other than wood derived from forests, other wooded lands and trees outside forests that may be gathered from the wild or produced from forest plantations, agroforestry schemes and from trees outside forests. Shiva (1998) termed NTFPs or NWFPs or MFPs as all usufructs/ utility products of plants, animal and mineral origins except timber obtainable form forests or afforested/ domesticated land areas. The center of debate is also about the question of whether the product or service is produced in a forest environment; what exactly is a forest; and the more problematic question of whether NTFP is really an NTFP if it is cultivated. Thus, the terms 'forest' and 'product' are also debatable. Policy issues relating to definition of NTFPs also debated around the expected contribution to poverty reduction, nutrition and health, current and potential benefits to poor/ tribal communities vs their further impoverishment. It is very difficult to distinguish NTFPs from natural forests and those from human influence systems as they have been dealt by people from varied fields and professional backgrounds (e.g., forestry, ethnobotany, economic botany, conservation biology, protected area management, agroforestry, and marketing). In short, the debate over the concept of NTFPs arouses primarily due to varied definitions reflecting interest and priorities of the proponents and they are usually centered on five key issues *viz.*, (a) nature of the product - inclusion/ exclusion of non-industrial timber; (b) source of the product - inclusion/ exclusion of forest/ tree plantations or managed agroforestry systems on private agricultural lands; (c) nature of production of the product - wild or domesticated (e.g., rubber, oil palm, cocoa, etc.); (d) scale of production - capital intensive at industrial scale vs small scale; and (e) ownership - forest department or commercial agency or private entity and distribution of benefits (Ahenkan and Boon, 2011; Patil, 2022).

Unfortunately, there is still no universally accepted definition, particularly a legally accepted definition of NTFP in the country. However, the term MFP has been used in the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 or the Forest Rights Act, 2006 and has defined MFP as the minor forest produce that includes all non-timber forest produce of plant origin including bamboo, brushwood, stumps, cane, tussar, cocoons, honey, wax, lac, tendu or kendu leaves, medicinal plants or herbs, root tubers and the like. A closer scrutiny of this definition allows several pertinent revelations. On one hand, it states the condition of plant origin but includes tussar, cocoons, honey, wax and lac which are essentially animal products while on the other hand, it includes 'stumps' which essentially are woody and might have timber value (Ahenkan and Boon, 2011; Patil, 2022). Moreover, various definitions proposed in literature makes the dichotomization of forest resources into 'timber' and 'non-timber' overly simplistic. Likewise, varied concepts and definitions of FGR are being used across the globe and as of now there is no legally defined and accepted term of FGR in the context of India. It is possible that in all likelihood the rampant and unchecked exploitation of FGR might be already occurring on the lines of NTFPs owing to the ambiguity in its existing definition as well as absence of legally defined term. Moreover, currently the subject is developing and evolving.

(b) Status of NTFPs in India

There is a growing realization that NTFPs in a vast rural population of the country dependent on forest resources play an important role in their livelihoods as a source of food, fodder, medicines, construction materials, and income. Hence, a wide range of produces *viz*., flowers, fruits, nuts, seeds, roots, leaves, bark, gums, resins, honey, wax, cocoons, lac, orchids, ferns, bamboo, rattan, fibers, etc. are being collected in huge quantities from different forests throughout the year besides fuelwood, small timber, and minerals. Prominent NTFPs are also important FGR *viz*., leaves of tendu (*Diospyros melanoxylon*), seeds of sal (Shorea robusta), katha- heartwood powder (*Acacia catechu*), gum (*Acacia nilotica*), Indian gooseberry-amla (*Phyllanthus emblica*), myrobelan fruits of baheda (*Terminalia bellirica*), harrad (*T. chebula*), bark of arjuna (*T. arjuna*), chironji seeds (*Buchanania cochinchinensis*), daal cheeni-bark (*Cinnamomum zeylanicum* and *C. glanduliferum*), tejpatta-bay leaf (*C. tamala*), mahua flowers and seeds (*Madhuca longifolia*), flowers of burans (*Rhododendron arboreum*), kaphal-fruit (*Myrica esculenta*), leaves-fodder (*Quercus semecarpifolia; Bauhinia racemose; Butea monosperma*), leaves and bark of thuner (*Taxus wallichiana*), nuts- chilgoza (*Pinus gerardiana*), kali mirch-fruit (*Piper nigrum*) gum of salai (*Boswellia serrata*), cane furniture – stem (*Calamus tenuis, Ochlandra travancorica*), paper and pulp, handicrafts and furniture - culm (*Bamboo* spp.), gum karaya (*Sterculia urens*), resin – heartwood (*Pinus roxburghii*) etc. (Fig. 1.15). Relevance of NTFPs in the Indian context is highlighted in Box 1.2.

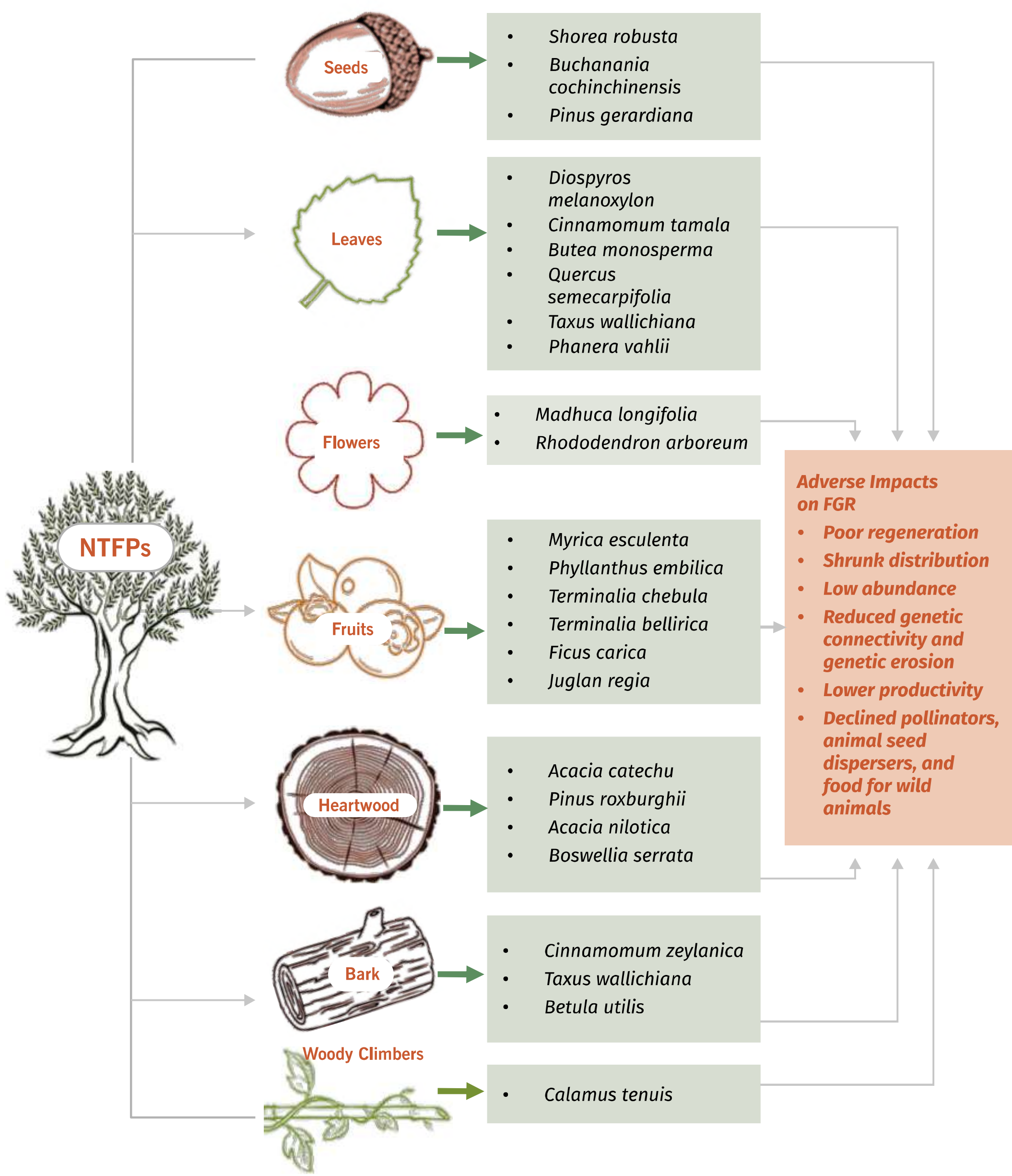


Fig. 1.15
Major NTFPs Adversely Impacting Distribution and Status of FGR

Box 1.2
Significance of NTFPs in the Indian Context

Source
Patil (2022)

- A substantial human population (ca. 30 per cent) particularly a larger proportion of the rural population living in forest fringe areas depend upon NTFPs for their subsistence and cash livelihoods. The dependence is specifically intense for half of India's 89 million tribal people, the deprived section of the society who live in forest fringe areas.
- The NTFP sector alone is able to generate nearly 10 million workdays annually in the country and it is one of the largest unorganized sectors of India with a business turnover of Rs. 60,000 million per annum.
- NTFPs account for nearly 68 per cent of the export in the forestry sector.
- NTFPs contribute to about 20-40 per cent of the annual income of forest dwellers, particularly tribals, economically backward, deprived and landless.
- NTFPs provide opportunities for vital subsistence during the lean seasons.
- A large section of rural women is engaged in collection of NTFPs and they either use for domestic consumption or sell them. Hence, it has a strong linkage to women's financial empowerment.
- A large number of NTFPs significantly contribute towards the Indian share of global medicinal plants trade which is increasing at an annual growth rate of 20 per cent. India ranked third amongst the biggest exporters of medicinal plants.

(c) Dependence of Forest Fringe Villages on NTFPs

Traditionally, a large segment of nearly 68 per cent rural population of the country depend on the adjacent forests to meet the requirements of timber, small timber, fuelwood, fodder, livestock grazing and a wide range of NTFPs. As a result, fringe forests and adjoining lands, which cover vast area in the country bear onslaught of the exploitation though they stand guard to the more valuable forest inside. Once, fringe forests are excessively used and degraded and they are unable to offer adequate yield enough to meet the local needs, then drivers of degradation will crossover to the interior precious forest and effect the potential ecosystem services they provide. FRI (2017) as a part of the country wide major project on 'Forest Resource Dependence and Ecological Assessment of Forest Fringes in Rainfed Districts of India' has defined 'Forest Fringe' as one kilometer distance outside the forest from outer periphery of the forest while 'Forest Fringe Villages' as the villages lying within the one-kilometer distance along the outer periphery of the forest boundary. On the other hand, one kilometer distance inside the forest from outer periphery of the forest has been defined as the 'Fringe Forest'. Effective protection and management of fringe forest areas is critical to safeguard the forest interiors or 'core' areas and associated biodiversity. Hence, in-depth understanding of the forest fringe areas and the extent of dependence of local communities inhabiting forest fringe villages to meet their day-to-day requirements are pivotal for efficient decision making and meaningful management interventions. In addition to the forest fringe villages, several managed forests and even some protected areas also have 'forest settlement villages (FSVs)' and 'revenue villages' enclaved within the limits of forest area. Certainly, enclaved villages are solely dependent on forest resources for their daily requirements and livelihoods. As per the Census 2011, country has about 6,50,000 villages in different districts and out of this nearly, 1,70,000 villages are located in the proximity of forest areas (FSI, 2019).

As a part of the above-mentioned major project, FRI carried out the study in 275 rainfed districts in 27 States and one UT of the country and identified 1,39,342 forest fringe villages out of total 3,10,416 villages in these districts. Thus, nearly 45 per cent villages in 275 rainfed districts were located within one kilometer distance from the outer boundary of the forest and predominantly were dependent on forest resources. The detailed assessment by FRI provided the State/ District level insight on land holdings, dependence on forest, energy consumption, fodder and fuelwood consumption, and extraction of wood and NTFPs for self-consumption and/ or sale. In addition, FSI also undertook a country wide assessment on forest dependence (small timber, fuelwood, fodder and bamboo) adopting a stratified sampling and assessed annual collection of fuelwood, fodder, small timber, and bamboo by forest fringe villages to the tune of 85.29 million tonnes, 1,053.03 million tonnes, 5.84 million m^3, and 1.83 million tonnes, respectively (FSI, 2019). An insight on State/ UT wise per capita removal of these four NTFPs has also been provided. The values of average removal (per capita/ annum) of these NTFPs among different States/ UTs ranged *viz.*, fuelwood- 0.090 t (Manipur) to 0.830 t (Nagaland); fodder- 3.601 t (Kerala) to 7.972 t (Mizoram); small timber- 0.0001 m^3 (Telangana) to 0.074 m^3 (Dadra and Nagar Haveli), and bamboo- 0.003 t (Maharashtra) to 0.074 t (Andaman & Nicobar Islands) (FSI, 2019). The values of cumulative annual collection and average per capita removal of four NTFPs in different States/ UTs amply indicate the enormous biotic pressure of forest fringe villages on limited extent of diverse forests across the country, impacting the diversity and productivity not only of forests but also of FGR.

Table 1.11 Estimated Quantities and Economic Values of Prominent NTFPs

Sr. No.	NTFP Product	Key Species	Quantity	Value (million INR)	NTFP Category
1.	Tendu leaves	*Diospyros melanoxylon*	6,52,677 MT	839.15	8 other plant products
2.	Resins	*Pinus* spp.	1,057 MT	89.36	3 Raw Material for medicine and aromatic products
3.	Honey	-	32,852 Qlt	35.45	11 wild honey and bee wax
4.	Sal Seed	*Shorea robusta*	1,28,998 Qlt	15.16	1 Food
5.	Grass	-	4,196 MT	10.86	2 Fodder
6.	Lac	-	3,849 Qlt	7.66	8 other plant products
7.	Gum	-	12,063 Qlt	7.24	8 other plant products
8.	Mahua	*Madhuca longifolia*	20,942 Qlt	3.33	1 Food
9.	Amla	*Emblica officinalis*	784 Qlt	0.35	11 wild honey and bee wax
10.	Wax	-	11 Qlt	0.01	
	Total			**1,008.57**	

MT-Metric tonnes; Qlt- Quintal (100 kg)

Source Compiled from FRA, 2020 (FAO, 2020)

(d) Economic Value

The FRA maintains country-wise database on the quantity and economic value of prominent NTFPs. Accordingly, the quantities collected/ harvested/ extracted of prominent NTFPs along with their economic values for 2015 are presented in Table 1.11.

(e) Issues Relevant to Management and Conservation of NTFPs

The elemental role played by FGR (trees, shrubs and woody climbers) towards contribution to major NTFPs *viz.*, fuelwood, fodder, food, fiber, medicines, bidi making, gums, resins, wax, handicrafts, in construction, etc. and rural livelihoods through their many uses is significant on account of area coverage, high volume, employment generation, economic turnover, foreign currency earning, women financial empowerment, vital subsistence and cultural values. Obviously, from collection/ harvest or extraction to end users through storage, supply chain management, processing, value addition, marketing, and even export, the NTFP sector involves varied stakeholders (primary collectors, collection/ facilitating/ regulating agencies, growers, entrepreneurs and traders) and huge investment of manpower.

Legal and Institutional Support for NTFPs:

In case of public forests, Forest Department of States/ UTs are the custodian of forest lands and associated forest resources, and responsible for implementation of National Forest Policy and enforcement of varied national/ state level laws pertaining to forest, wildlife, biodiversity, and environment. In addition, forests are also under control and management of Van Panchayats, Autonomous Tribal Councils, Civil Soyam, and Municipal Bodies. The revised National Forest Policy of 1988 after a gap of 36 years aimed to affect the paradigm shift from production forestry to conservation forestry. On one hand, the policy emphasized for the need to conserve natural heritage of the country by preserving the natural forests and associated flora and fauna, representing the remarkable biological diversity and genetic resources while on the other hand stressed on meeting the requirements of fuelwood, fodder, MFP, and small timber of the rural and tribal populations besides enhancing the productivity of the forest and creating a massive people's movement including women so as to achieve objectives of the policy and to minimize pressure on country's forests. The policy emphatically mentioned that MFP should be protected, improved and their production enhanced with due regard to generation of employment and income. The policy clearly outlined the need to recognize special rights and concessions for special groups or communities (tribals, scheduled casts, other deprived section of the society and forest dwellers) and envisaged their (tribals') domestic requirements of fuelwood, fodder, MFP, and construction timber as the first charge on forest produce. In order to implement the new policy, the Government of India issued a guideline on Joint Forest Management (JFM) in 1990 so as to develop and manage degraded forestland under the custody of SFDs with the help of the local community and voluntary organizations. As a result, a large number of Joint Forest Management Committees (JFMCs) came into existence across the country. The guidelines on JFMs clearly retreated the mandate of MFP and stated that the tribals and other communities living around forests have first right over forest produce. Further, as stated earlier, in order to promote decentralized, bottom-up approaches for program implementation of various sectors, the Constitution of India through the Constitution (Seventy-Third Amendment) Act, 1993 introduced the concept of three-tier (national, state, and local) governance including the Panchayats and Gram Sabhas at the grassroots/ local level. As a part of this Constitutional Amendment, the country for the first time recognized and mentioned MFP through the Article-243G and the Eleventh Schedule of the Constitution. The Article-243G provisioned that the Legislature of a State may, by law, endow the Panchayats as institutions of self-government, and also devolve powers and responsibilities for the preparation and implementation of plans/ schemes for economic development and social justice in matters listed in the Eleventh Schedule. The mention of MFP in the Eleventh Schedule appeared at serial no. 7. The Panchayats (Extension to the Scheduled Areas) Act, 1996 (PESA) enforced to apply the provisions of the Seventy-Third Constitutional Amendment to the Schedule Areas. This provided for the ownership of MFP to Panchayats and the Gram Sabha in the Scheduled Areas with appropriate powers and authority. Subsequent to this notable milestone in the history of the country, the world community started deliberating on the wider subject of biodiversity and India became a member country to the CBD in 1992. As a follow up and implementation of the CBD, India has launched several programs in support of conservation of biological diversity and enacted the BD Act, 2002. The BD Act addressed varied aspects of NTFPs under the term 'Biological Resources', and provided for their conservation, sustainable use, and fair and equitable sharing of the benefits. In one way, the BD Act has not only covered the NTFPs at three hierarchical levels (ecosystem, species, and gene) but also the entire array and varied aspects of FGR. Later, the Forest Rights Act, 2006 has defined the term MFP and recognized rights related to MFP/ NTFP under the Community Rights such as *nistar*. Concurrently, State Governments also enacted state level legislations/ guidelines/ rules dealing with NTFPs and some States created MFP Federations or Forest Development Corporations with the objectives of exploiting vast forest resources including NTFPs and translating the National/ State Policy of protecting economic interest of tribes, deprived people, and forest dwellers , and vested the Gram Panchayat the authority to regulate the purchase, procurement and trade so that the primary collectors get a fair price for the NTFPs collected by them. Some States have unique feature regarding the benefit sharing as they are not claiming any profit earned from the trade of a small number of monopolized NTFPs. The State Governments in such cases allow 60 to 70 per cent of the profit earned in a financial year to be distributed among the primary collectors as dividend while the remaining part of the profit is divided into two halves and spent on the development of the forests and community development in the villages of the primary collectors.

In short, it is noticeable from the foregoing description that different mechanisms and bodies for collection, procurement, and trade of NTFPs have been created in States/ UTs and they themselves behave as the forest department. Though, the mandate of NMPB is limited to medicinal plants only, but they constitute a large portion and huge volume of the NTFP pie.

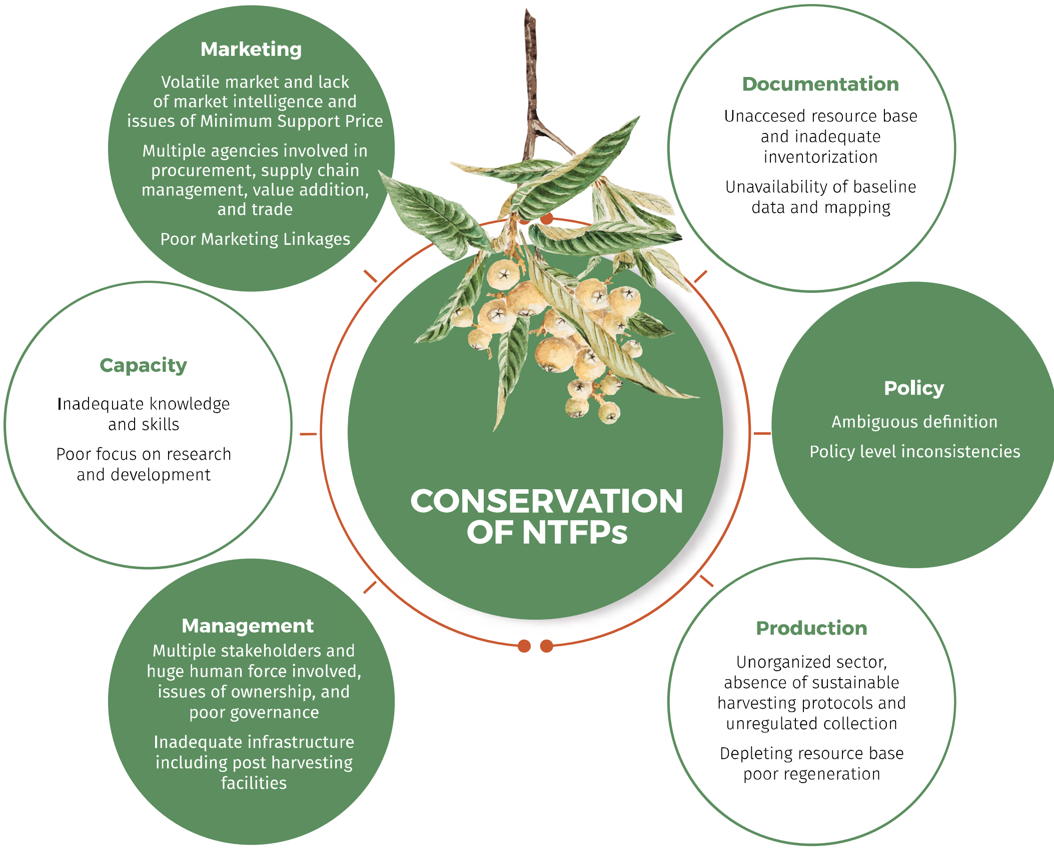
Issues and Challenges for Conservation of NTFPs:

Some of the pertinent issues and challenges regarding conservation of NTFPs can be grouped in six categories *viz*., (a) availability of information and documentation; (b) inconsistencies in policy; (c) production-high volumes, unsustainable harvesting, depleting resources, and absence of sustainable harvest protocols; (d) management; (e) marketing; and (f) capacity (Fig. 1.16). The fundamental issue is that the SFDs and other concerned agencies dealing with the management of NTFPs know little about the distribution and status of NTFPs and have meager understanding about their impact on regeneration of NTFP species and overall ecological integrity of forest ecosystems. The dilemma persists about the role of SFDs in conservation and management of NTFPs as a number of overlapping agencies have been mandated the task on collection, procurement, processing, and trade. Despite overlapping jurisdictions, the SFDs cannot be discharged from its responsibility mandated in NFP and different laws of forest/ wildlife/ biodiversity seeking for the maintenance of environmental stability, conservation of natural heritage, enhancing substantially the forest/ tree cover, increasing productivity, meeting people's requirement, sustainable utilization, etc. It is noteworthy to mention here that the SFDs are not the primary stakeholders in the management of NTFPs, instead a large number of governmental and non-governmental organizations and communities are involved in large scale operations. Thus, it is of paramount importance that SFDs adopt an inclusive approach in efficient management of NTFPs. The Forestry Commission, 2006 and the Twelfth Five Year Plan (2012-2017) have carefully examined varied aspects of NTFPs and made valuable recommendations. The recommendations predominantly pertain to address issues and challenges summarized in Fig. 1.16.

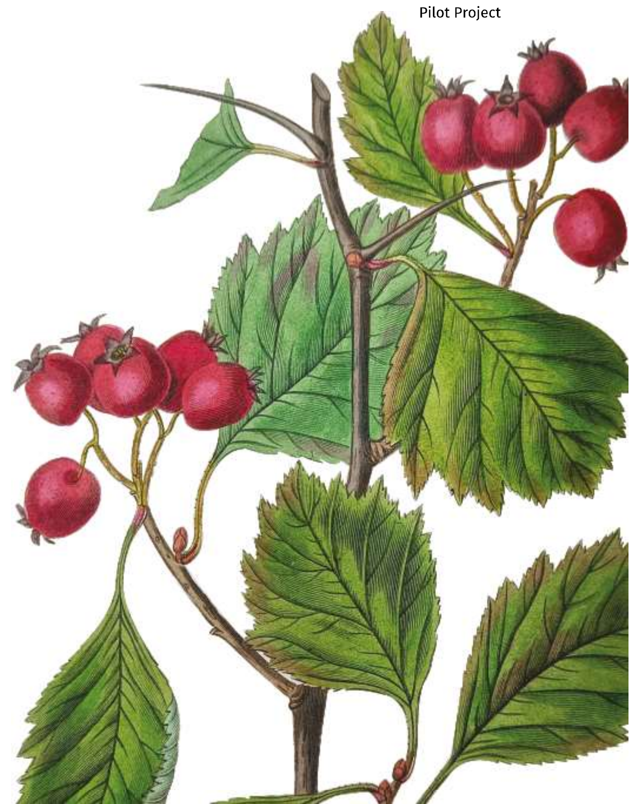
Traditionally, as well as now, predominantly the collection/ harvest or extraction of NTFPs continues to take place on natural forest lands, mainly under the control of SFDs, Van Panchayats and Tribal Councils. However, in past three to four decades, smallholder agroforestry practices involving the integration of trees with annual cultivation, livestock production and other farm activities widely adopted globally and nationally on private lands and some of the large-scale commercial plantations of cash crops by corporates have also expanded. Tree products grown and collected on farms are often described as 'Agroforestry Tree Products (AFTPs)' to differentiate them from NTFPs and timber harvested from forests (Simons and Leakey, 2004; Dawson *et al*., 2014). Gradations between natural forests, anthropogenic secondary forests and agroforests, however, mean that there is often no clear boundary between NTFPs and AFTPs, a complicating factor in the estimation of relative contributions to livelihoods, and devising management options tailored for different settings (Byron and Arnold, 1997).

Fig. 1.16
Issues and Challenges Relevant to Conservation of NTFPs

Source
Compiled from ISFR 2011 and 2019 (FSI 2011 and 2019); MoEF (2012)



Commercializing the wild harvest of NTFPs has been widely promoted as a conservation measure based on the assumption that an increase in resource value is an incentive for collectors to manage forest and woodland more sustainably (FAO, 2010; Dawson *et al.*, 2014). However, the worldwide experience illustrates that the concept of commercialization and conservation proceeding in tandem is often illusory as more beneficial livelihood outcomes are generally associated with more detrimental environmental outcomes (Belcher and Schreckenberg, 2007; Kusters *et al.*, 2006; Dawson *et al.*, 2014). Moreover, in most cases of collection of NTFPs, the significance of important factors such as the breeding system and the effective population of the plant species involved – in supporting regeneration, the persistence of stands and the sustainability of harvesting – has not been taken into account (Ticktin, 2004; Dawson *et al.*, 2014). The sustainable management of NTFPs also need to take into account activities of timber felling as timber and NTFPs are sometimes harvested from the same species, indicating competition or compounded effect on the tree species itself. A number of timber species and NTFP species may undergo dysgenic selection based on only inferior characteristics, which thereby contribute to the seed crop for the establishment of subsequent generations. In simple terms, the 'dysgenic selection' is an action or a process wherein knowingly or inadvertently undesirable genetic qualities or characteristics are selected and passed out to the subsequent generations exerting a detrimental effect on populations through the inheritance. The dysgenic selection could be by way of domestication and movement of germplasm from one area to the other areas for plantation activities. Reductions in genetic diversity and changes in tree stand structure and composition may change mating patterns leading to inbreeding depression. The excessive and unregulated harvest of seeds, leaves, flowers, and fruits could on one hand can lead to the poor regeneration of the species and shrinkage in its distributional range, while on the other hand this may result into reduction in productivity, biomass, pollinators, and number of animal seed dispersers, declining genetic connectivity in populations and



increasing the prospects for threatening the status of the species (Vasquez and Gentry, 1989; Lowe *et al.*, 2005; Dawson *et al.*, 2014).

Definitely forests, particularly trees and other FGR have been providing enormous multiple values including NTFPs. Hence, tree-based production systems have been often promoted because of their biological, economic, and social resilience in the context of anthropogenic needs, climate change, and other production challenges. However, the extra resilience provided by trees to humanity cannot be taken for granted or overestimated. The improved management of tree genetic resources for livelihood and sustainability requires a number of steps which involves a greater understanding of ecological and genetic aspects of production (e.g., ecological- autecology and synecology, past and current distribution, regeneration status; genetic- population size and variability, gene flow and genetic connectivity, selection and movement of germplasm, and domestication). Despite a long history of managing NTFPs by local communities and government agencies, a definition and scope of the concept still remain a major challenge to research and development, and promotion of NTFPs owing to conflicting interests and objectives. Most of the products that are being marketed as NTFPs originate both from natural forests, managed vegetations and domestication. Thus, in practice, the distinction between 'wild, semi or cultivated products will continue to be difficult and challenging. Moreover, NTFPs cannot be harvested indefinitely without proper management and domestication practices to sustain their yields as they are being depleted at an alarming rate and forest dependent communities continue to lose them, either through overexploitation or habitat degradation. The sole primary purpose of NTFPs is to conserve precious forest resources through improved livelihoods, a process of gradual domestication in human modified systems would be desirable (Ahenkan and Boon, 2011). Urgent measures are needed to reverse the current trend of excessive and unchecked harvesting of NTFPs from the wild as several of these products and concerned species will disappear before they are documented. Also, there is a priority need to appreciate the posited links amongst conservation, commercialization, and cultivation of tree resources/ NTFPs so as to overcome the challenges to 'conventional wisdom' about their use, value, and management.

1.11.9 Strategies, Approaches and Initiatives for Conservation of FGR

The conservation movement seeks to manage and protect natural resources, also known as 'nature conservation'. The movement is deep rooted to the time when it was evolved out of necessity to maintain vital natural resources such as forests, fisheries, wildlife, water, etc. as they were plundered to meet enhanced human and developmental demands during the industrial era. The foregoing section on the history of forest management in the country has already highlighted that India's ethos and culture promotes conservation of nature which is deeply embedded in the multihued Indian society. Accordingly, the country has implemented a continuum of five biodiversity governance models (see section 1.10) across landscapes for conservation of state and community driven forests. Broadly, two basic approaches to conservation, namely, in situ and ex situ conservation have evolved worldwide over a period of time. Like select world countries, India has not only taken a lead but also from time-to-time launched varied programs and adopted innovative approaches towards *in situ* as well as *ex situ* conservation of forests and other natural resources.

1.11.9.1 *In situ Conservation*

In situ conservation of forests has been recognized as the core activity of FGR conservation and management, where the trees and woody species are allowed to grow, adapt and evolve while remaining in their natural environment and constantly interact with sympatric plant and animal species. *In situ* conservation not only helps in maintenance of species but allows to maintain the existing natural pool of genetic variability, permitting their ecological functions to perform, and occurrence of adaptive and evolutionary processes to operate. Additionally, *in situ* conservation facilitates maintenance of the typically wide range of variation required for effective selection for breeding and genetic improvement of FGR with high commercial or service value (FAO, 2014a). On one hand, the *in situ* conservation has notable advantages and superiority as it allows the maintenance of ecological, aesthetic, ethical, and cultural values besides providing large quantities of a wide range of FGR through simultaneous conservation of the entire array of species. Over and above, *in situ* conservation in a reasonably large natural area ensures that in the absence of catastrophe and genetic bottlenecks, the vigour and the genetic variability contained in the target species is maintained at a high level and serves as the foundation on which selection pressures can direct adaptation to new conditions arising due to human disturbances and climate change. In view of this, the *in situ* conservation has been referred as the dynamic process, as it allows the genetic variation contained in a species or a population to change over time. Predominantly, *in situ* conservation is the foremost key step towards conservation of forests, FGR, and other forms of biodiversity. Table 1.12 elaborates varied *in situ* conservation approaches adopted from time to time by communities and the Central/ State Governments in the country.

Table 1.12 Approaches to *In situ* Conservation of FGR

Description

1. Sacred Groves (SGs)

Sacred Groves are one of the finest examples of ancient *in situ* conservation practice initiated by local communities. Generally, sacred groves are small land parcels predominantly of forests or other vegetation and in most cases, these sites are linked to local deities, and they harbour representative undisturbed forests and most sites are still well protected and human use is restricted/ regulated. Sacred groves (SGs) in India are still being documented. Malhotra (1998) stated that the number of SGs in the country may be in the range of 1,00,000 to 1,50,000. Gokhale *et al.* (1998) reported that actual area of SGs across the country could be high as 420 km^2. Amrithalingam (2016) documented and authenticated altogether 10,377 SGs. Roy *et al.* (2015) estimated the extent of SGs in the country based on RS and GIS and documented 277.13 km^2, representing 9.8 per cent of the protected areas. Being community driven initiative, SGs can be designated as the Community Reserves under the WPA, 1972. However, SGs get legal support under the Biological Diversity Act, 2002.

2. Protected Areas (PAs)

Four different legal categories of PAs have been provisioned in the WPA, 1972. PAs represent State driven biodiversity governance model as elaborated in the section 1.10.1.1. The NPs receive highest level of protection and as far as possible, natural ecological and evolutionary processes are being allowed/ promoted with least human disturbance, except the tourism zone or any other zone designated for specific purposes *viz.*, ecorestoration, management of threatened habitat or a species, etc. The sanctuaries as per WPA can now permit only regulated grazing. Many NPs and WLSs constitute legally designated 'core' areas or 'inviolate space' or 'sanctum sanctorum' of Tiger Reserves (TRs), Elephant Reserves (ERs), UNESCO's Biosphere Reserves (BRs) and World Heritage Sites (WHSs). Presently, the cumulative core area of existing 51 TRs covers an extent of 40,541.07 km^2 constituted by NPs and WLSs. By this way, 24.29 per cent of these two important categories of PAs get over and above supplemental conservation support under the directives of the National Tiger Conservation Authority (NTCA). Hence, a larger proportion of NPs and WLSs are extended additional protection and conservation support under the country's highest priority conservation programs dealing with the iconic/ flagship species or the global initiatives on BRs and WHSs. Certainly, PAs with adequate support of country's multiple laws on wildlife, forest, biodiversity and environment are rightfully considered the first course of action towards *in situ* conservation, both for FGR and other forms of biodiversity. Mandatorily, each PA requires approved Wildlife Management Plan by the State's Chief Wildlife Warden while the Tiger Conservation Plan (TCP) for the constituent 'core', 'buffer', and 'corridors'/ connecting areas with adjacent TRs/ PAs of TRs are being prepared adopting the landscape approach to conservation and approved by the NTCA. Most PAs, particularly NPs and larger sanctuaries have greater conservation significance. All TRs and WHSs also receive considerable management attention and inputs towards research on flora and fauna, especially threatened species as well as monitoring. As stated earlier, each NP and WLS is required to have legally designated Eco Sensitive Zone (ESZ) as per the provisions of the Environmental (Protection) Act, (EPA, 1986). BRs and WHSs are being monitored at the international level. Protection and management of PAs is, thus, the core activity of conservation of biodiversity including FGR.

3. Managed Forests (MFs)

Managed Forests under the three legal categories (RFs, PFs, and UCFs) as per the provisions of Indian Forest Act, 1927 cover the largest extent of *in situ* conservation measures for diverse forests in the country. Out of total RFA (7,75,288 km^2) in the country, 6,02,234.31 km^2 or 77.68 per cent constitutes MFs while remaining 1,73,053.69 km^2 or 22.32 per cent extent is represented by legally covered PAs (FSI, 2021). As per ISFR, 2021, the country had 57.04 per cent extent under RFs, followed by 27.38 per cent PFs, and 15.58 per cent UCFs of RFA. Managed forests have long history of scientific forest management based on silvicultural practices prescribed in the duly approved Forest Working Plan (FWP) of the concerned Forest Division. The country has revised the FWP from time to time. The Code for FWP, 2014 emphasizes on conservation of biodiversity, soil and water conservation, sustainable use of forest resources, and mitigation and adaptation for climate change. Hence, increasingly, MFs are contributing significantly towards conservation of FGR, other elements of biodiversity, enhanced productivity and sustainable forest management.

4. Tiger Reserves (TRs)

The prestigious *in situ* conservation program known as the 'Project Tiger' launched in 1973 aimed to conserve the dwindling population of tiger and initially established nine TRs. Since then, this countrywide program has been legally supported by the amendment to WPA, 1972 in 2006 and provisioned for the establishment of NTCA, and establishment of TRs constituted by 'core', 'buffer', and 'corridors'. In past five decades, number of TRs has increased from nine to 51. These TRs fall in 18 states of the country, categorized into five landscapes, covering an area of 73,972.50 km^2 comprising 40,541.07 km^2 as core and 33,431.43 km^2 as buffer areas. The cumulative extent of 51 TRs represents nearly 2.25 per cent of the geographical area of the

Description

country. As stated above, core areas are legally designated by inclusion of existing NPs and/or WLSs. Buffer areas of TRs promote the agenda of co-existence. Hence, they don't include any PA but constituted by incorporating areas of MFs (RFs, PFs, and UCFs), revenue and private lands. Efficiently and effectively managed TRs strongly backed up by appropriate policies and legislations, comprehensive protection strategy, rigorous scientific research, evidence based extensive and intensive monitoring, community engagement, awareness, capacity development, etc. despite prevailing insurgency in some pockets, human pressure in buffer and corridor areas, and other constraints, India's tiger population has increased from 1,411 tigers in 2006 to 2,967 in 2020. Presently, tigers in India account for 70 per cent of the world's total estimated tiger population of 3,890 (Jhala *et al.*, 2018; FSI, 2021). As per ISFR, 2021, TRs occupy about 2.27 per cent country's geographical area and represents 55,666.27 km^2 or 7.80 per cent of the country's total forest cover. Nearly 75 per cent area of TRs is represented by forest cover. Decadal change in forest cover in TRs between 2011 and 2021 assessments recorded a slight decrease of 22.62 km^2 area or 0.04 per cent. Nearly, 40 per cent TRs registered an overall gain in forest cover during the past decade whereas 60 per cent TRs recorded an overall loss of forest cover (FSI, 2021). Nevertheless, TRs with effective protection, management and conservation strategy evolved over past five decades are undisputedly are important repository of diverse forests, FGR, other elements of biodiversity, and source of enormous ecosystem services. From the perspective of conservation of FGR, TRs, particularly their core areas are of immense significance.

5. **Elephant Reserves (ERs)**

After the success of Project Tiger, India initiated yet another important country wide priority program for conservation of endangered Asian Elephant (Elephas maximus) in 1992. Presently, India has 32 ERs across 16 range States and these reserves cover an extent of 69,582.80 km^2, representing 2.12 per cent geographical area of the country (Menon and Tiwari, 2019). Out of total cumulative extent of 32 ERs, 18,732.06 km^2 or 26.92 per cent is constituted by PAs. The total extent under 32 ERs represents nearly 59 er cent of the total elephant range in the country (Rangrajan *et al.*, 2010) As per the Elephant Census 2021, country has about 28,000 elephants. Certainly, extensive area under ERs with adequate legal coverage of the WPA, 1972; Indian Forest Act, 1927; Forest (Conservation) Act, 1980; and the Environmental (Protection) Act, 1986, and focusing on the wild megaherbivore like elephant immensely helps in conservation of diverse forests and FGR.

6. **Biosphere Reserves (BRs)**

Since 1986, country has been implementing the UNESCO's Man and the Biosphere Program by way of designating Biosphere Reserves (BRs) across the country so as to deal with one of the questions of reconciling the conservation of biodiversity, quest for social and economic development and maintenance of associated cultural values. Presently, 18 BRs in different biogeographic zones focusing on some priority biodiversity conservation areas cover a total extent of 89,163.96 km^2, representing 2.71 per cent geographical area of the country. A substantial portion of BRs forms their 'core' areas which have legal coverage of WPA while 'buffer' areas are covered under the Indian Forest Act, FCA, EPA, and BD Act.

7. **World Heritage Sites (WHSs)**

India being the signatory to the UNESCO's World Heritage Conservation, 1972, has nominated several natural, cultural and mixed sites to be designated as the World Heritage Sites (WHSs). Presently, country has seven Natural and one Mixed WHSs. Natural features- physical and biological, geological, and physiographical formations, including habitats of threatened species of animals and plants, and natural sites which are important from the point of view of science, conservation or natural beauty, are defined as natural heritage. One of the natural sites of Western Ghats covering an extent of 7,953.15 km^2 is actually a 'serial site' represented by 39 prominent PAs across the length and breadth of the Western Ghats, an older mountain range than the Himalayas, and also one of the globally recognized biodiversity hotspots. Western Ghats have reported diversity of over 7,402 species of flowering plants and at least 325 globally threatened species of plants and vertebrates. In addition, other prominent WHSs include: Great Himalayan National Park, Nanda Devi and Valley of Flowers National Parks, and Khangchendzonga National Park in the Himalayas; Kaziranga National Park in Brahmaputra floodplains and Manas in north-east India; and Sundarbans National Park in Bay of Bengal, predominantly a mangrove forest and inter-tidal ecosystem besides Keoladeo National Park (a complex of wetland, grassland and woodland).

In addition to various broad-based approaches to *in situ* conservation, indigenous and forest dwelling communities in different parts long ago recognized merits in protection of nature (trees, birds, other living organisms). Such initiatives have been well documented (e.g., protection of green trees of 'Khejri' *Prosopis cineraria* by Bishnoi community in 1730 in the Indian Great Desert or Thar Desert and some members going to death in protest against cutting trees; Chipko movement - 'hugging' of trees by women in the Indian Himalayas in order to prevent their felling by the contractors and 'Appiko' movement in Western Ghats in 1980s). Further, some of the prominent small-scale *in situ* conservation measures include the following:

(a) Preservation Plots

These are small sized patches of natural forests earmarked within different forest types across the country. The idea of delineation and establishment of preservation plots was provided by the Fifth All India Silvicultural Conference in 1929 and it offered detailed instructions regarding layout, maintenance, and record-keeping. The Conference recommended eight hectares as the minimum area for such plots. The purpose was to study forest structure, composition, growth and successional changes over a period of time besides assessment of the annual increment. The common feature of all these plots has been the diameter measurement of individual trees at periodic intervals. The network of plot has potential to play a useful role in research, as ecological reference centers and as benchmark reserves for the maintenance of biodiversity. According to Tewari (2016), there were 309 preservation plots in the country, of which 187 were located in natural forests, and 122 in plantations covering a total area of ca. 8,500 ha. Rodgers (1986) highlighted that in general, the management status of plots is poor, several have disappeared, rarely are prescriptions for maintenance or monitoring given in working plans, and actual research use is very rare. He suggested that greater investment should be made in the preservation plot network so as to achieve their full potential. Tewari *et al.* (2014) stressed that there is a need to stimulate proper maintenance and upkeep of these sites which are invaluable for forestry research. Tripathi *et al.*, (2009) and Singh *et al.*, (2021) assessed the phytosociology and regenerates status in different preservation plots within Madhya Pradesh and provided an insight on the current status.

(b) Plus Trees

Plus tree selection is one of the methods to conserve diversity at the species level. Plus tree has high vigour and a phenotypically superior tree. In forestry, it is easy to see that trees of a particular species vary in growth, form and wood character. In some cases, much of the variation may be genetic and in others environmental. Selection is normally the first step in a tree improvement program and will determine how much gain will be obtained, both in first and succeeding generations. It is when the conserved genes are used that individual selection and breeding within locally adapted provenances will provide additional improvement in selected characteristics. Thus, as a first step 'Candidate tree' is selected for grading because of its desirable phenotypic qualities but has not been graded or tested. A tree that has been recommended for production or breeding following grading is being referred as the Plus tree. It is of superior phenotype for growth, form, wood quality or other desired characteristics and appears to be adaptable. It is yet to be tested for its genetic superiority, although the chance of it having a good genotype is high with a reasonable heritability. The SFDs in country have made efforts to identify Candidate Plus Trees (CPTs) of select species and Plus Trees once they have been selected after grading. Rawat and Ginwal (2009) provided a list of superior phenotypes of species selected in different states. During the past two decades or so, the ICFRE has developed comprehensive strategies for tree improvement program for various species of commercially importance like *Tectona, Azadirachta, Acacia, Pinus, Eucalyptus, Populus, Dalbergia Casuarina, Cedrus, Jatropha, Albizia,* and *Gmelina* spp. The approach involves the development of seed production areas, clonal and seed orchards to select germplasm for progenitors and clonal accessions of high value. Several hundred trees have been identified as candidate plus trees, which are propagated vegetatively and established as a germplasm bank.

The foregoing description amply reveals that community and state driven wide range approaches and initiatives towards *in situ* conservation have immensely helped in conservation of vital forest resources, FGR and other elements of biodiversity in diverse forests that too under different legal, management, and ownership regimes, and certainly these efforts are laudable, especially in human dominated country like India. However, in general, these efforts have ignored the much-desired focus on identification of priority FGR in each of the forest types and biogeographic zones and implementation of species-specific interventions. Further, some of the forest types and sub-types, and biogeographic zones and provinces have either been ignored and received lower attention or they have inadequate legal coverage under the prominent categories of *in situ* conservation. Thus, urgent efforts are needed to identify and prioritize FGR for each forest type, State/ UT, and also on the biogeographic basis so a comprehensive strategy for their conservation can be planned and executed.

1.11.9.2

Ex situ Conservation

In contrast to the above described dynamic in situ conservation, alternative measures principally static in nature are being referred as *ex situ* conservation. *Ex situ* conservation refers to the conservation of genetic material or biological diversity outside of the natural habitats of the species (Rawat and Ginwal, 2009). This type of conservation is usually considered only when it has been realized that *in situ* conservation is not feasible, or when a species is at serious risk of extinction in the wild. The *ex situ* conservation efforts, thus, help in preserving a 'snapshot' of the variability at the time of conservation of the germplasm (FAO, 2014a). Generally, the conservation takes place in facilities which support either storage or the continuity of the conditions suited to maintain the viability and genetic constitution of the genetic material or diversity. *Ex situ* conservation virtually safeguards and provides a required supply of germplasm for research and breeding. In a broader sense, the *ex situ* form of conservation includes the botanical gardens and storage of seed, germplasm or vegetative material in gene banks. The field gene banks where clonal materials are maintained as living collections in a field/ orchard or plantation also represent *ex situ* form of conservation. Generally, the field gene banks have the potential risk of germplasm being lost due to disease, stress or disaster, and large amount of space and labor are required to maintain a small proportion of diversity. Long term cryogenic preservation of seed/ germplasm or vegetative material is yet another measure of *ex situ* conservation and it holds promise, especially for base collections (Khanna and Singh, 1991). In past four decades or so, efforts to conserve genetic resources ex situ in seed gene banks have accelerated in the country (Rawat and Ginwal, 2009). The National Bureau of Plant Genetic Resources (NBPGR) under the Indian Council of Agricultural Research (ICAR) is the sole national level agency to deal with storage of seed/ plant germplasm in the gene bank. The facility aims to provide ideal storage conditions so that the mean viability period of the seeds is greatly extended by reducing the life processes to a low level. Successful seed storage depends on effective control of multiple factors like temperature, seed moisture content, storage atmosphere etc. in response to storage conditions. Generally, seeds with heterogenous germplasm accessions frequently get deteriorated at different rates thereby causing selection within the samples to favor genotypes more amenable to storage conditions. Thus, the selection within the germplasm accessions during seed conservation and subsequent regeneration as a strong influence on the genetic composition of an accession (Khanna and Singh, 1991). The various possible approaches in *ex situ* conservation of FGR as described by Rawat and Ginwal (2009) are listed below (Fig. 1.17):

(a) Botanical Gardens

World over, most Botanical Gardens (BGs) were set aside and established in past 2-3 centuries with the main aim to maintain documented collections of living plants for the purposes of scientific research, conservation, display, and education, and typically labelled with their botanical names. Generally, these BGs are run by the scientific research organizations or universities and have associated herbaria and research programs in plant taxonomy or some other aspect of botanical science.

Fig. 1.17 *Ex situ* Measures for Conservation of FGR

Most BGs are also being used for recreational purpose. Presently, India has more than 138 BGs under different management systems and ownership and located in different biogeographic zones of the country (BGCI, 2022). Surprisingly, updated inventory and consolidated authentic information on BGs in the country is grossly lacking and much desired details like size, plant diversity in overall collection, extent of FGR, and RET species are difficult to find. The oldest and largest BG is the Acharya Jagadish Chandra Bose Indian Botanical Garden, Shibpur, Kolkata. However, as per the MoEF (1998), the Central and State Governments managed 33 BGs that maintained the diversity in the form of plants or plant populations. Further, a study of 61 BGs revealed that 14 were purely botanical, 21 have a mixture of botanical, horticultural and agricultural species, and 26 were purely horticultural gardens (MoEF,1998; Rawat and Ginwal, 2009). The efforts to acquire and conserve rare native species and their genetic diversity are rather inadequate. Nevertheless, BGCI as a plant charity based at Kew, Surrey, England has over 3,755 BGs across ca. 150 countries and has the mission to mobilize member BGs in securing plant diversity for the well-being of people and the planet (BGCI, 2022).

The Botanic Garden of Indian Republic (BGIR) has been set up on ca. 78 hectares of prime land in Gautam Buddha Nagar, Uttar Pradesh by the Botanical Survey of India (BSI) under the MoEFCC, Government of India (Mandal, 2008). The BGIR has been identified as a 'Green Channel' Project under the National 'Jai Vigyan' Science and Technology Mission of the Ministry of Science and Technology and with full support from the Planning Commission (NITI Aayog) and other relevant ministries and departments. It aspires to attain an international stature and serve as a nodal center for networking of BGs in the South East Region. The BGIR would *inter alia* facilitate *ex situ* conservation and propagation of threatened/ endangered plants of the country, serve as a center of excellence for research and training, and thereby cater to the conservation needs of endangered species in the region. The BG is mandated for conservation of rare and threatened plants of the country and would serve as a national center of excellence for conservation, research and environmental education, thus, providing a window for interface between science and society. By developing special innovative features, it is expected to become a major attraction for ecotourism as it develops into one of the most uniquely landscaped BGs of modern times.

(b) Arboreta

An arboretum refers to an area established for the conservation of tree species. FRI, Dehra Dun has established an arboretum with 130 forest tree species and a bambusetum of 53 species. Similarly, the Regional Plant Resources Centre of the National Bureau of Plant Genetic Resources (NBPGR) at Bhubaneswar has established an arboretum with 1,430 species of trees, a palmatum of 100 different types of palms, a bambusetum with 61 collections of bamboo, and an orchidarium housing 220 species of orchids. Some prominent arboreta of the country are at Kolkata, Bengaluru, Lucknow, Peechi belonging to different organizations. The review and web search revealed that, at the national level the interest in establishing arboreta is very weak, probably because of the costs involved and the larger extent of suitable land required for the purpose. Nevertheless, there is a need for additional arboreta for tropical tree species whose behaviour for seed storage is in most cases either unknown or poorly known. Establishment of arboreta for such species may be the first step towards their conservation (Singh *et al.*, 2004; Rawat and Ginwal, 2009).

(c) Clonal Repositories

Most institutions under the ICAR and ICFRE dealing with perennial or vegetatively propagated domesticated plants have field repositories for the conservation of FGR (Rawat and Ginwal, 2009). Therefore, most of the institutes dealing with horticultural crops, agroforestry species and medicinal and aromatic plants have field repositories. ICFRE has established field repositories in the form of Vegetative Multiplication Gardens (VMGs), clonal banks and germplasm banks at its regional institutes in Dehra Dun, Shimla, Jorhat, Jodhpur, Jabalpur, Ranchi, Hyderabad, Bengaluru, and Coimbatore. Such repositories have also been established in the jurisdiction of the state forest departments for their use. Likewise, the NBPGR has established field repositories of certain perennial and tree species at various regional stations at Shimla, Bhowali, Jodhpur, Thrissur, Akola, Amravati and Hyderabad (Rawat and Ginwal, 2009).

(d) Herbal Gardens

Herbal gardens predominantly conserve herbs and shrubs that are of medicinal and aromatic value (Singh *et al.*, 2004; Rawat and Ginwal, 2009). Post 1980s, the concept of herbal gardens was suddenly picked up by several NGOs in the country with the popularity and advancement in alternate medicines (Ayurvedic, Unani and Siddhi) and growing national/ international markets in aromatic plants for the purpose of perfumery, etc. Several NGOs in different parts of the country, particularly in tribal areas in Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Chhattisgarh and Uttarakhand, have established herbal gardens with the objective of conserving local biodiversity of medicinal and aromatic plants and other economically important species (Singh *et al.*, 2004).

(e) Herbaria

Practice to preserve plant diversity in herbaria is quite old. An herbarium specimen consists of dried plant parts with labelled information on scientific name and collection data. It has immense use in plant identification, systematics studies and ecological studies. The Botanical Survey of India (BSI) and its different regional centers across the country collectively have more than 30,00,000 herbarium specimens persevered (BSI, 2022). Out of this, the BSI, Kolkata has the largest holding of 20,00,000 specimens. The FRI, Dehra Dun has a collection of more than 3,50,000 specimens. There are many more herbaria, such as the National Botanical Research Institute (NBRI), Lucknow (2,60,000) and Blatter Herbarium at St. Xavier's College, Mumbai (2,00,000).

(f) Provenance Trials

In comparison to global average, productivity of Indian forests is very low owing to lack of long-term concerted efforts on tree improvement. Tree improvement program was perceived in view of the: (i) requirement of a reliable supply of seed, (ii) improvement in the productivity, (ii) protection against the adverse conditions, and (iii) development of disease/ insect resistance tree species. India has initiated tree improvement program on Pine and Teak way back in 1930. The first provenance trials for two important native species, *Tectona grandis* (teak) and *Pinus roxburghii* (Chir pine) were initiated by Professor M.L. Laurie and Sir Harry Champion, respectively, during the time when they were silviculturists at the FRI, Dehra Dun. Provenance trials of teak were established between 1928 and 1930 in a number of locations in India. The tests on teak and Chir pine have yielded useful information (Emmanuel, 2000; Rawat and Ginwal, 2009). International provenance trials of *Tectona grandis* and *Gmelina arborea* have been established in different states in collaboration with the Danida Forest Seed Centre (DFSC). ICFRE has initiated national level provenance experiments on *Tectona grandis*, *Pinus roxburghii* and *Bombax ceiba*. ICFRE has also collaborated in international provenance testing of eucalypts, particularly *Eucalyptus tereticornis*, *E. camaldulensis* and *E. grandis*. Trials have also been laid for acacias and tropical pines, such as *Pinus oocarpa, P. caribaea* and *P. kesiya*. Technical inputs have been extended to SFDs for provenance tests for species of interest such as *Eucalyptus grandis* and *E. globulus*. The provenance trials have been further systematized by ICFRE. Several institutes have conducted both national and international provenance trials in collaboration with the SFDs and international agencies. Species wise details on provenance trials established by ICFRE have been provided by Katwal *et al*. (2004). Thus, in past seven to eight decades a large number of tree species have been covered under this endeavor, but the results obtained so far are not so encouraging (Kedharnath, 1984; Tomar, 2018). Tomar (2018) summarized the essence of genetic improvement, methodologies employed for genetic trials *viz*., provenance, progeny and clonal trials as well as establishment of Seed Production Areas (SPAs), Seedling Seed Orchards (SSOs) and Clonal Seed Orchards (CSOs) including evaluation of such trials. He also elaborated on the establishment of Vegetative Multiplication Garden (VMG) and development of various clonal techniques for different tree species and achievements therein.

According to Aitken (2004), the traditional provenance trials involve five steps: (i) collection of seed; (ii) growing of seedlings; (iii) planting of a replicated experiment on multiple field sites; (iv) measurement of traits; and (v) analysis and interpretation of results. Seed is typically collected from 10 to 25 trees per location, to ensure a representative sample of the natural population from each provenance. Parent trees sampled are usually 50-100 m (or more) apart, to minimize sampling of closely related individuals. Seeds are sometimes kept separate by seed parent (called a provenance–progeny trial), to allow for the estimation of within-provenance genetic variation and trait heritability as well as to facilitate some initial selection for selective breeding; however, bulk seed lots are often used, with seed pooled across parents within provenances. Seed is collected from accessible locations scattered throughout the zone of interest within the species' range, with anywhere from just a few to over 100 locations sampled, depending on the size of the area and the resources available. Provenance trials help in the exploration of gene resources called genecological exploration. Through genecological exploration, patterns of ecological and phenotypic variation within the natural range of species are studied, which then lead to and can be applied for provenance seed collection and provenance evaluation (FAO, 1975). Knowledge of the breeding system and biology of the species, and methodology for growing them in plantation condition or storing their seeds are pre-requisites of *ex situ* conservation. More than 90 species provenance trials have been laid out in different parts of India to screen out the best provenances for raising new plantations with increased productivity. Since these provenances are collected from different geographical, ecological and environmental conditions, such traits play an important role in gene conservation. (Emmanuel *et al*., 1990).

(g) Seed Orchards

Seed orchards contribute greatly to the production of quality planting stock of the desired species. These are plantations established primarily for the production of seed of proven genetic quality. Seed orchards are of two types: clonal seed orchards and seedling seed orchards. These orchards can be categorized under selective conservation, as one of the objectives in *ex situ* conservation. Establishment of seed orchards is part of a long-term conservation management program and also a long-term breeding program. Seed orchards for different priority tree species were established in different states. ICFRE (2003) provides a list of seed orchards developed in different states for varied species.

(h) Seed and Germplasm Storage

Efforts for storage of seed germplasm of priority trees for long term conservation at -18°C have been made by FRI at the National Bureau of Plant Genetic Resources (NBPGR). As an alternative complementary method, attempts are also being made to cryopreserve pollen of forest tree species (Rawat and Ginwal, 2009).

Notably, as in the case of *in situ* conservation, India also initiated concurrent efforts towards *ex situ* conservation of FGR (botanical gardens, herbaria, arboreta) as early as nearly two centuries ago, and other priority interventions such as, provenance trials way back in 1930s for Teak and Pine species besides other approaches (identification and conservation of Plus trees, clonal repositories, seed and germplasm storage, herbal gardens, seed orchards, etc.) in past five decades or so. The advantages of such timely initiatives are that country is well established national/state level organizations engaged in botanical exploration, field surveys and assessments, systematic or taxonomical floral and faunal studies, maintenance of botanical gardens, herbaria, arboreta, herbal gardens, storage of plant genetic resources, etc. As a result, country is not only known for documentation of floristic and faunal diversity, especially forest types and associated diversity of flora and fauna, but has been recognized as the 17 megadiverse countries. Efforts are being made to explore for floral and faunal diversity biogeographic regions, forest types, and State/ UTs either least explored or inadequately surveyed so far, and also to modernize and digitize herbaria. Although, the NBPGR, National Bureau of Animal Genetic Resources (NBAGR), and National Fish Genetic Resources (NBFGR) under the control of ICAR have been taking care of storage of seed and germplasm in the context of plants relevant to agriculture/ horticulture crops, animal resources, and fish resources, respectively but country is still devoid of such dedicated facility for FGR despite the country's has vast extent and enormous diversity of forests. Conspicuously, owing to paradigm shift from the production forestry to conservation forestry, discipline of silviculture has been gradually ignored and requires new thrust in the changed scenario. Moreover, as a result of long history of past management of forests, enhanced human induced activities, a large number of tree, shrubs and woody climbers have reduced extent of habitats and face problems relevant to habitat fragmentation, poor regeneration, declining natural range of distribution, small populations, and genetic erosion. Further, most *ex situ* conservation measures so far specifically focused on a limited number of ca. 150 timber and other commercially important tree species including several exotic species. The need of the hour is to pay required attention to tree and other FGR which have multiple conservation significance from the perspective of ecosystem functions and services, ecological integrity, ecosystem services, wildlife habitat, maintenance of catchment and hydrological regimes, social and cultural values.

1.11.9.3

Comparison of In situ and Ex situ Conservation

Both, *in situ* and *ex situ* conservation have their own set of advantages and disadvantages or risks and difficulties and often, the choice between them is seen in terms of exclusive alternate strategies, but these two contrasting measures or approaches should be viewed more constructively as they are mutually complementary, and each can play an important role in safeguarding precious FGR species or populations (Table 1.13).

Table 1.13
Comparison of *In situ* and *Ex situ* Conservation

Sr. No.	*In situ* Conservation	*Ex situ* Conservation
1.	It is the 'on-site' and the most effective strategy of conservation of all the living species including FGR, as it seeks to conserve the existing pool of inter and intra-specific genetic variability in their natural ecosystems, habitats and environment while permitting persistence of natural selection, and ecological and evolutionary processes to operate besides the maintenance of aesthetic, ethical and cultural values. Notably, when the whole habitat or ecosystems are protected, entire array of forest genetic resources also enjoy the protection and benefit of natural processes.	It is the 'off-site' conservation of genetic material of a rare and threatened species as it seeks to conserve such species in the habitats outside their natural environment that reflect their natural living habitats and equipped for their protection and preservation. Thus, it involves the relocation from their natural habitats to protected sites/ areas. Primarily, strategy is specific to a species and devoid of extending benefit of natural selection and other processes.
2.	It is often considered the first course in conservation of FGR and other forms of biodiversity. This approach allows large amounts of FGR are efficiently conserved through simultaneous conservation of multiple species.	It is considered only when it has been established that a species is at a serious risk of extinction in the wild, and *in situ* measures are no longer feasible. Mostly, in this approach, efforts made are specific to the species of concern.
3.	It is being referred as the 'dynamic' approach as it not only ensures that the genetic variation contained in a population or target species is maintained at a high level and serves as the foundation on which selection pressures can direct adaptation to new conditions, but can also change over time in the absence of catastrophe and genetic bottlenecks.	In contrast, it is predominantly a 'static' approach that helps in preserving a 'snapshot' of the variability present at the time of conservation of the germplasm.
4.	In this approach, varied measures taken and associated processes have evolved over a long period of time. In India, the approach has been relatively better backed up by relevant policies, legislations, and desired institutional framework.	Predominantly, various measures tried so far are relatively new, at formative stage, trial phase, and small scale. Moreover, it is yet to receive desired attention and support of relevant policies, laws and institutional frameworks.
5.	In majority instances, *in situ* conservation initiatives were not designated or selected for the conservation of priority FGR and did not have management plan/ strategy specific to their particular needs.	Generally, *ex situ* initiatives are specific to priority FGR and have explicit strategy/ plan to relevant needs.
6.	Examples of *in situ* conservation of plant diversity including FGR are: state-driven protected areas and managed forests, and community driven sacred groves, van panchayats, forest areas under the autonomous tribal councils, JFMs, etc.	Examples of *ex situ* conservation of plant diversity including FGR are: botanical gardens, arboreta, herbaria, seed orchards, clonal repositories, provenance trials, cryopreservation, DNA banks, etc.

1.11.10

Policy, Law and Institutional Framework and Hierarchical Governance

The foregoing description has evidently illustrated that the complex and dynamic nature of conservation of FGR essentially requires adequate support of policy, legislations, institutions, and governance besides an apt mechanism for program implementation at multiple hierarchical levels (global, regional, national, state, and local), active engagement of varied stakeholders (policy and decision makers, custodians and field practitioners,, enforcement/ regulating agencies, professionals, scientists, academia, user agencies, and beneficiaries - communities), and finances. Thus, it is imperative to review, assess and appreciate the existing situation in this regard. In past decade or so, the UNDP has emphasized on the Biodiversity Finance Initiative (BIOFIN) and provided detailed framework/ workbook so as to assess the status of (a) Biodiversity Policy and Institutional Review (PIR), (b) Biodiversity Expenditure Review (BER), (c) Biodiversity Finance Needs Assessment (FNA), and (d) Biodiversity Finance Plan (BFP) (UNDP, 2018). FGR being an important subset of biodiversity, it was considered appropriate to appreciate existing international conventions, national/ state level policies and laws, institutional framework, and governance mechanism which are directly influencing varied aspects of conservation of FGR. The following sections attempt to briefly summarize various conventions, policies, laws, institutions, and hierarchical governance architecture.

1.11.10.1

International Conventions and Treaties

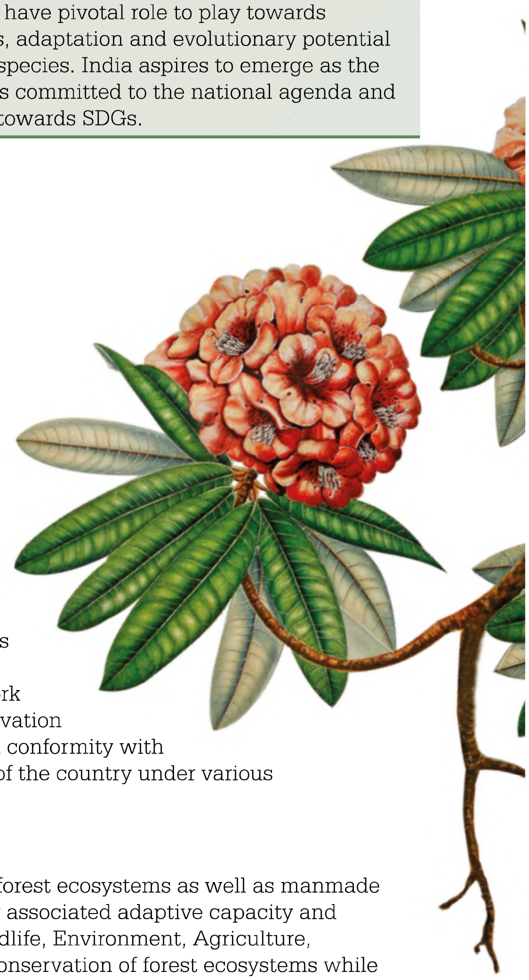
In the past five decades or so, a large number of international conventions, treaties and multilateral agreements relevant to wider disciplines of biodiversity and environment have been ratified by India in compliance to her international obligations and agreements, and national agenda, and the country has initiated a wide range of activities and actions (Table 1.14; Fig. 1.18). Majority of them are of immense significance and applicable for conservation of FGR.

Sr. No.	Convention/Treaties/Agenda	Objectives
1.	The UN Convention on Biological Diversity - 1992	India is signatory to the UNCBD and it addresses three hierarchical (ecosystem, species and genetic) levels of biodiversity and covers all aspects of wild and domestic biodiversity. The CBD focuses on three goals relevant to conservation, sustainable use of resources, and access and benefit sharing of biological resources. In order to contribute meaningfully for the goals of CBD, the country enacted the Biological Diversity Act, 2002; established the National Biodiversity Authority (NBA) in 2003; and State Biodiversity Boards (SBBs). India also prepared the National Biodiversity Action Plan (NBAP) and periodic submits National Reports to the Secretariat of CBD.
2.	Convention on International Trade in Endangered Species of Wild Fauna and Flora - 1973	India's 24 States collectively have 15,106 km of international land borders, shared with seven countries - China, Pakistan, Bhutan, Myanmar, Afghanistan, Nepal and Bangladesh and a coastline of about 7,516 km. The aim of CITES is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild, and it accords varying degrees of protection to more than 35,000 species of animals and plants.
3.	UNESCO's World Heritage Convention - 1972	The World Heritage Convention (WHC) deals with protection and conservation of World Heritage Sites (natural and cultural). Presently, India has altogether 40 World Heritage Sites. Out of these, 32 are cultural, 7 are natural, and 1 is mixed (meeting both cultural and natural criteria).
4.	United Nations Framework Convention on Climate Change - 1992	Treaty addresses issues arising on account of climate change which arestrongly linked with biodiversity objectives and SDGs. It seeks actions oriented towards mitigation and adaptation.

Table 1.14 Prominent International Conventions, Treaties, and Agenda Relevant to Conservation of Biodiversity and FGR

Source Compiled from MoEFCC (2019), FRI (2016) and Badola *et al.* (2022)

Sr. No.	Convention/Treaties/Agenda	Objectives
5.	United Nations Convention to Combat Desertification (UNCCD) - 1994	The Convention aims to combat desertification and mitigate the effects of drought through national action programmes. Considerable extent, particularly arid and semi-arid regions in the country face threat of land and soil degradation and resultant loss of FGR and their habitats,
6.	International Treaty on Plant Genetic Resources for Food and Agriculture - 2001	This treaty deals with world's plant genetic resources for food and agriculture and is in harmony with the CBD, which aims at guaranteeing food security through the conservation, exchange and sustainable use, and the fair and equitable benefit sharing arising from use of plant genetic resources, as well as the recognition of farmers' rights. FGR are integral to this treaty, particularly in context of exchange of germplasm of species being used in agroforestry
7.	UN 2030 Agenda for Sustainable Development-2015	UN 2030 Agenda on 17 Sustainable Development Goals (SDGs) is intertwined with the objectives of CBD, UNFCCC and other above stated conventions aiming protection and conservation of 'natural capital'. FGR, their habitats and associated species have pivotal role to play towards ecosystem services, adaptation and evolutionary potential of tree and woody species. India aspires to emerge as the 'New India'. India is committed to the national agenda and global obligations towards SDGs.



1.11.10.2

Conservation - Policies and Legislations

India's conservation history dates back to the ancient time. However, in recognition of her national level commitments towards the conservation of natural resources, environmental management, and sustainable development besides global obligations relevant to the forest management, biodiversity, climate change and cross cutting social issues, India has developed a comprehensive set of policies and legislations that primarily evolved in past 5-6 decades so as to address varied aspects of forestry and biodiversity conservation. The Indian Constitution provides much desired foundation and support for conservation of biodiversity and protection of environment which creates an abiding responsibility of the State and the people of the country to take positive actions so as to ensure protection and conservation of natural resources. The following section describes the policy framework and legal instruments which contribute to the forestry, conservation of biodiversity, and especially effective conservation of FGR in conformity with the mandate of the Constitution, international commitments of the country under various environmental conventions, treaties and agreements.

(a) Policy Framework

Varied human uses and developmental needs impact natural forest ecosystems as well as manmade agroforestry, particularly forest biodiversity and FGR and their associated adaptive capacity and ecological and evolutionary processes. Sectors like Forest, Wildlife, Environment, Agriculture, Horticulture, and Water Resources directly contribute to the conservation of forest ecosystems while several other sectors either use or impact forest biodiversity and FGR. Thus, national policies and programs related to FGR cover a wide range of activities, from conservation measures to protection of rare and endangered species and populations, as well as regulations governing seed collection and transfer in socioeconomically important tree species to comprehensive approaches to the management of landscapes, ecosystems and FGR. With these complexities in mind, considerations related to FGR in India have been integrated within broad frameworks, such as national forest programs and biodiversity action plans.

The management of an appropriate combination of genetic resources in various locations under diverse environmental and silvicultural practices, such as provenance trails and progeny trials, is considered to be the most efficient way to conserve various levels of genetic variation to increase the productivity.

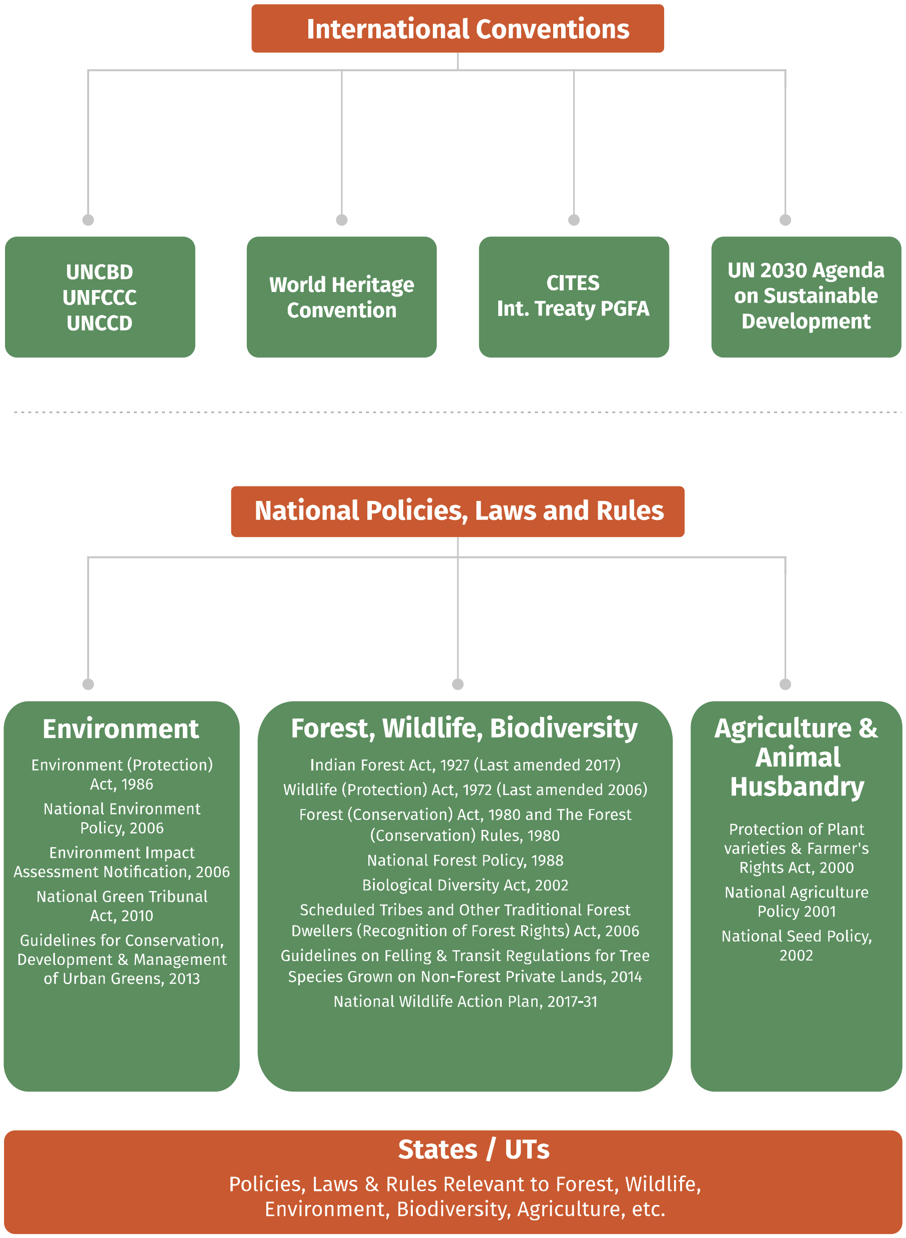


Fig. 1.18 International Conventions, Policies and Laws Relevant to Conservation

Source Adopted and Modified from Badola *et al.* (2022)

However, it takes relatively long time to evaluate and identify the provenances suitable for conservation. However, most often genetic conservation has to be carried out without a real understanding of the genetic background of the populations and depends on population genetic models. In case of Indian forest ecosystems, some economically important forest tree species have been conserved in gene banks, *in situ* and *ex situ* conservation sites with wide networking between the SFDs. Managed forests, protected areas – National Park, Wildlife Sanctuaries, Conservation Reserves, Community Reserves, Tiger Reserves, Elephant Reserves, Biosphere Reserves have been regarded as *in situ* conservation and management of FGR at the ecosystem, species and genetic levels. Thus, sectoral policies at the national and state level have a bearing on the conservation and sustainable use of forest resources. Prominent policies are described and presented in Table 1.15. In addition, from time to time, GoI as well as state government have prepared guidelines/ rules/ action plans relevant to forest management, biodiversity or the overall environment (Fig. 1.18).

Table 1.15
Prominent National/ State Level Policies, Guidelines, Rules, and Action Plan Pertaining to Forest Management, Biodiversity, Environment and Forest Genetic Resources

Source
Compiled from MoEFCC (2019, FRI (2016) and Badola *et al.* (2022)

Sr. No.	Policies/ Guidelines/ Rules/ Action Plans	Objectives/ Purpose
1.	**National Forest Policy, 1952**	The Independent India revised its earlier forest policy formulated during the colonial period in 1952 and articulated to cover one-third, or 33%, of the total land area under forests. It suggested the extension of tree lands on river/ canal banks, roads, railways, cultivable waste and degraded lands besides advising forest dwellers and tribal people for weaning from the practice of shifting agriculture.
2.	**National Forest Policy, 1988**	The Union Ministry of Environment and Forests (MoEF) revised the NFP of 1952 with aims to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which are vital for sustenance of all life forms, human, animal and plant. The policy envisaged that derivation of direct economic benefit must be subordinate to this principal aim and emphasized on the involvement of local communities in the protection, conservation and management of forests through Joint Forest Management Programme so as to enhance the extent of forest cover in the country, restoration of degraded forests and greater emphasis on conservation (*in situ* and *ex situ* conservation). The policy envisaged meeting the requirement of fuelwood, fodder, minor forest produce and small timber of the rural and tribal populations besides significant contribution in maintenance of environment and ecological stability in the country.
3.	**National Agriculture Policy, 2000**	The Policy seeks to actualize the vast untapped potential of Indian agriculture and aims at achieving a growth rate in excess of 4 per cent per annum in the agriculture sector. It also seeks to achieve growth with equity, which is widespread across regions and farmers. It also emphasizes the need to cater to domestic markets and maximize benefits from exports of agricultural products. Various measures have been taken to operationalize the policy. In pursuance of the policy, national policies on sectors like cooperation, seeds and extension have been framed.
4.	**National Seeds Policy, 2002**	The NSP, 2002 aims to provide an appropriate climate for the development of new and improved varieties of plants, timely availability of quality seeds, compulsory registration of seeds, creation of infrastructure, quality assurance, promotion of seed industry, abolition of licensing for seed dealers, facility for import of best quality seeds, encouragement for export of seeds and creation of Seed Banks and National Seed Grid. The Policy also aims to safeguard interests of Indian farmers and the conservation of agro-biodiversity besides encourages initiatives for investment in research and development. Since farmers are increasingly going for agroforestry plantations, this policy is of much relevance in the context of FGR.
5.	**National Agroforestry Policy, 2014**	The NAP, 2014 aims to enhance sustainable agricultural production bycombining tree farming with agriculture. Since India is predominantly an agrarian country, NAP is of much relevance in the context of FGR.
6.	**Guidelines on Felling and Transit regulations for Tree Species Grown on Non-Forest PrivateLands, 2014**	The guidelines provide opportunity for States/ UTs to develop a simple anduniform regulatory procedure relevant to tree felling and transit pass, especially for trees grown on non-forest private lands. Villagers/ farmers arebeing encouraged under different national/ state level programs/ schemes forafforestation activities. Hence, these guidelines are of much relevance to conservation, sustainable use, and management of FGR on private lands.
7.	**Urban Greening Guidelines, 2014**	These Guidelines is the outcome of blatant concretization of pavements inIndian cities, resulting in destruction of trees by making them weak and reducing their lives. The Guidelines suggests steps for protection of trees and enhancing their lives while undertaking concretization of pavement.

8.	**National Wildlife Action Plan, 2017-31**	India prepared the first National Wildlife Action Plan (NWAP) in 1983. It was revised and documented as the second NWAP (2002-16) and was implemented. Third sequential NWAP (2017-31) came in existence so as to have a concerted approach to protection, conservation, and management of wildlife throughout the country. The NWAP aims to conserve in situ all taxa of flora and fauna along with the full range of ecosystems they inhabit. The ecological requirements for the survival of threatened, rare and endangered species, together with their community associations of flora and fauna, must be ensured. Varied action and targets in the NWAP are of much relevance as it not only promotes conservation of forests and other natural ecosystems but emphasize on inventory, documentation, research, management of threatened species, sustainable use of resources, community engagement, landscape approach to conservation, ecorestoration, and maintenance of genetic diversity, all relevant to FGR.
9.	**Environment Impact Assessment Notification, 2006**	The EIA notification by the MoEF outlines the process of EIA and obtaining environment clearance for a developmental project. Generally, the clearance granted prescribes a list of management and mitigation measures. EIA is of direct relevance to safeguard ecological process performed by diverse forest ecosystems and vital role played by FGR.

In addition to the above list, the country at the national level has formulated several policies, guidelines, rules, and action plan relevant to wetland conservation and management, water, river conservation, etc. They directly or indirectly provide support to conservation of forests and FGR in forested catchment, riparian areas, and lowland forests.

(b) Legislation:

Presently, there is no legal framework exclusively governing the forest genetic resources. However, wide range of legislations related to forest management and conservation, wildlife protection, biodiversity conservation, and environmental management provide legal support for in situ management and conservation of forest resources besides regulation for collection of forest genetic resources from wild and their transport, sustainable use and access and benefit sharing of genetic resources. Legislations relevant to the protection of farmers' rights and plant varieties have implications on forest genetic resources have been also enacted. A set of large number of legislations pertaining to forests, wildlife, environment, agriculture and other sectors have been enacted in the country during the British regime and post- independence of the country. The prominent and important national/ state level legislations are highlighted in Table 1.16 that directly deal with the elements and issues related to conservation of forests and FGR (Fig. 1.18).

Table 1.16
Prominent National/ State Level Legislations Pertaining to Conservation of Forest

Source
Adopted, Compiled from MoEFCC (2019, FRI (2016) and Badola *et al*. (2022) and modified

Sr. No.	Legislations	Objective/ Purpose
1.	**Indian Forest Act, 1927 (last amended in 2017)**	This Act provisioned a criteria and modalities for reserving and designating forests for conservation and legal protection besides management of forest produce, and issues pertaining to the transit of forest produce and the fees and duties payable. The Director General of Forests at the national level, SFDs and their lower administrative levels implement this Act
2.	**Wildlife (Protection) Act, 1972 (last amended in 2006)**	The WPA provides powers to the States/ UTs to declare areas of ecological, faunal, floral, geomorphological or zoological association or importance as PAs under four legal categories, essential for conservation of FGR. The Act provides necessary powers to the State/ UT's Chief Wildlife Warden to deal with protection, conservation and management of habitats, associated floral and faunal species besides support for *ex situ* conservation. The WPA is being enforced by the central/ state governments.
3.	**Forest (Conservation) Act, 1980**	The FCA, 1980 specifically governs matters pertaining to diversion of forest lands for any type of non-forestry purpose. This Act has immensely helped in reducing the extent of such diversions across the country. The diversion of forest lands is subjected to stringent scrutiny and recovery of Net Present Value (NPV) and cost for compensatory afforestation equal to the area diverted from the user agency besides necessary provisions/ actions not only for protection and conservation of wildlife/ biodiversity but also FGR.
4.	**Environment (Protection) Act, 1986**	This umbrella legislation enables the GoI to develop rules and policies for the protection of environment and covers all matters relating to the protection and importance of environment at a broad level and empowers the State/ UT to issue notifications. The GoI is required to issue notifications for Eco-Sensitive Zones (ESZs) around PAs and other key environmental sensitive sites along with a provision for preparation of Zonal Master Plan incorporating prohibited/ regulated/ permissible activities within ESZ and the constitution of Monitoring Committee. FGR in ESZ or other environmental sensitive sites get due protection under this Act.
5.	**The Constitution (73rd Amendment) Act, 1993**	The Seventy Third Amendment to the Constitution in 1993 introduced the provisions (Article 243-G) for three tier governance mechanism in the country by adding 'Panchayat' and 'Gram Sabha' at the grassroots level and incorporating the subject and powers on MFPs in the Eleventh Schedule.
6.	**The Panchayats (Extension to the Scheduled Areas) Act, 1996**	The PESA enforced to apply the provisions of the Seventy-Third Constitutional Amendment to the Schedule Areas. This provided for the ownership of MFP to Panchayats and the Gram Sabha in the Scheduled Areas with appropriate powers and authority.
7.	**Biological Diversity Act, 2002**	The BD Act recognizes country's enormous biodiversity in varied natural ecosystems - wild diversity and manmade agroecosystems and livestock - domestic biodiversity and its commitment to implement the UNCBD so as to extend legal support for conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of the benefits arising out of the use of biological resources. The BD Act also envisages the establishment of State Biodiversity Boards, framing of biodiversity rules, constitution of Biodiversity Monitoring Committees (BMCs) and preparation of Public Biodiversity Registers (PBRs) besides promoting in situ and ex situ conservation, development of national/ state strategies and action plans, monitoring, public awareness, research, and training. Hence, the BD Act is of direct relevance and supportive for conservation, sustainable use, and access and benefit sharing (ABS) of FGR.

8.	**Protection of Plant Varieties and Farmers Rights' Act (PPVFRA), 2000**	This Act provides for establishment of an effective system for protection of plant varieties, the rights of farmers and plant breeders and for encouraging the development of new varieties of plants. The plant varieties will be registered for plant breeder. This Act provide support for activities related to use of FGR in Agroforestry, food and food security.
9.	**The Scheduled Tribes and Other Traditional Forest Dwellers (Reorganisation of Forest Rights) Act,2006**	The FRA 2006 recognizes and vests the forest rights in forest lands in the forest dwelling STs and other traditional forest dwellers who had been living in such forests for generations besides the Act seeks to balance these rights with the responsibilities for conservation of biodiversity, sustainable use and maintenance of ecological balance.
10.	**The National Green Tribunal Act, 2010**	The NGT Act pertains to the establishment of the National Green Tribunal and its benches across the country for effective and expeditious disposal of legal cases related to environmental protection, conservation of forests and other natural resources. The NGT follows varied principles incorporated in the National Environment Policy (NEP), 2006 for decision making.
11.	**Model Nursery Regulation Act, 1954**	The GoI had constituted model nursery regulation act long back in 1954. On this analogy, different State governments have also enacted their own state nursery registration acts depending upon the available crops and local requirements for producing certified nursery stock and to ensure availability of genuine planting material to farmers., the fruit nurseries shall have to maintain a scion block, a seed block, and stock bed and shall have to use the propagation material only from these sources. Supply of poor-quality nursery plants is one of the major causes for low productivity of horticultural and agroforestry plantations and other crops in the country.

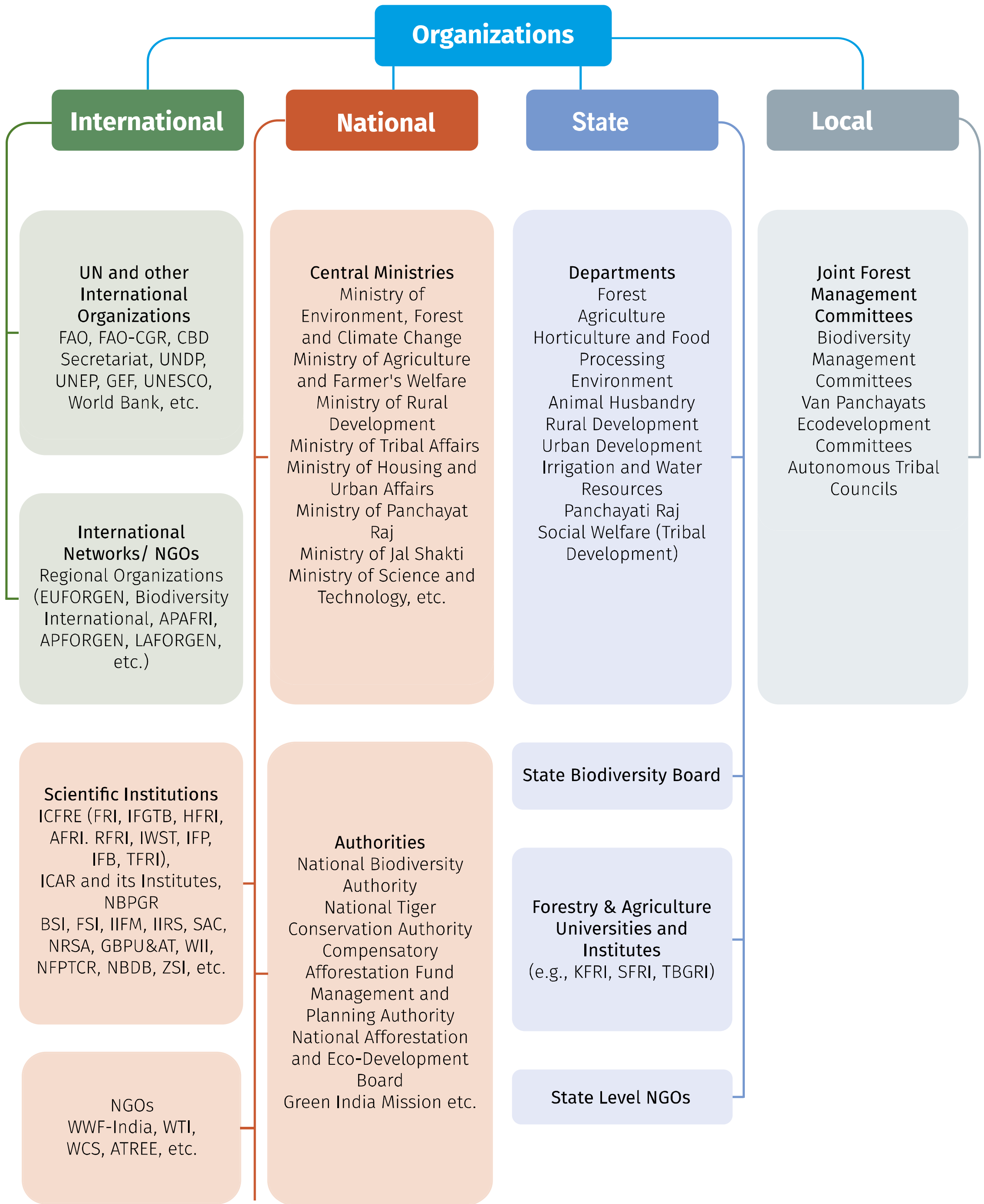
1.11.10.3

Institutional Framework

Sectors relevant to forest biodiversity and FGR in particular are prominently of three types: (i) custodians and supporting sectors responsible for protection, regulation, management and conservation; (ii) user agencies; and (iii) sectors impacting forests and FGR. Thus, conservation of FGR involves a wide range of stakeholders and envisages appropriate institutional framework at the global, national, state, and local levels responsible for framing policies and strategies; enacting legislations; developing guidelines, regulating mechanisms and rules; and field level protection, management, and conservation of forests (Fig. 1.19). In addition, several international and national/ state level professional agencies, multilateral partners of the government, NGOs, private organizations, NGOs and CBOs, and private entities are also involved. The institutional framework for conservation of FGR includes a variety of organizations operating at different spatial scales.

Institutions are a form of capital. Natural systems are complex, and important biological/ forestry processes take place on a variety of spatial and temporal scales. At the local level, although the term FGR means little to most rural communities, they often have extensive experience with a variety of sustainable manipulation and use systems that are compatible with forest conservation. The NFP 1988, BD Act, and the NWAP (2017-31) emphasize involvement of local communities and community-based organizations like JFMCs, BMCs, etc. The local institutional actors managing natural resources often depend on central/ state government for the legal recognition of their rights. At the national/ state level institutions, the sectoral government agencies have a significant impact on the conservation and management of forests, other natural ecosystems and even urban areas. Generally, the agriculture sector tends to be more influential than the relatively younger environment ministry and other related ministries dealing with the subjects of wetlands, rivers, water, etc. (Wells, 1998). The institutional issues pertaining to forest biodiversity and FGR are not limited to local management systems at the grassroots level and large state/ national government agencies, but it is also an international issue owing to an imbalance in the global costs and benefits from conservation. Forest biodiversity is concentrated in tropics, especially poor developing countries, and impoverished rural regions. Often, these developing countries face a range of crises arising on account of conflict between conservation and development agenda as well as due to limited public funds hindering mitigation measures. Thus, the international organizations not only have a role for creation of global policy directives but they need to provide technical know-how, and facilitate the international transfer of resources, from developed to developing countries so as to finance conservation activities. The institutional actors vary enormously in their size, location, purpose and type of activity. A large number of institutional actors are involved in conservation of forest biodiversity and FGR in the country.

Fig. 1.19
Organizations Concerning Conservation of FGR



1.11.10.4

Conservation Authorities

A small number of statutory conservation authorities at the national and state levels exist and they directly deal with the wider discipline of biodiversity conservation. Details on these central/ state level authorities are provided in Table 1.17.

Table 1.17 National and State Level Authorities Dealing with Conservation

Sr. No.	Authority	Objective/ Purpose and Role
1.	**National Biodiversity Authority (NBA), Chennai**	The NBA, a statutory body as provisioned by the BD Act, 2002 was established in 2003 and it is responsible for performing facilitative, regulatory and advisory functions for GoI on issues of conservation, sustainable use of biological resources and access and benefit sharing. The BD Act, 2002 mandates implementation of the provisions of the Act through decentralized system with the NBA focusing on advising the Central Government on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of the utilization of biological resources; advise the State Government in the selection of areas of biodiversity importance to be notified under Sub-Section (1) of Section 37 as Heritage Sites and measures for the management of such Heritage Site. The State Biodiversity Boards (SBBs) and BMC are responsible for access and benefit sharing of biological resources at the State and grassroots level, respectively.
2.	**National Tiger Conservation Authority (NTCA),**	Under the enabling provisions of the WPA, 1972 and subsequent to its amendment in 2006, the NTCA, as a statutory body was established for strengthening tiger conservation across the country. The 'Project Tiger', a Centrally Sponsored Scheme (CSS) of the MoEFCC provides funding support to tiger range States for *in situ* conservation of tigers in designated tiger reserves, and has put the endangered tiger on an assured path of recovery by saving it from extinction. Currently, NTCA advises and regulates management of 52 tiger reserves in the country, each having legally designated 'core or inviolate space' and 'buffer' zones. Diverse forests in 52 TRs are repositories of forest biodiversity and FGR.
3.	**Central Empowered Committee (CEC)**	The CEC was constituted under the EPA, 1986 pursuant to the order of Apex Court in 2002 for all matters relating to the application of the FCA, 1980.
4.	**Expert Appraisal Committee (EAC)**	The EAC constituted as per the EIA notification is responsible to appraise and grant clearance for developmental projects and thus, has pivotal role in safeguarding forest ecosystems.
5.	**State Biodiversity Boards (SBBs)**	States have established SBBs as per the provisions of the BD Act, 2002 and they deal with conservation, sustainable use and access and benefit sharing of biological resources. SBBs are also responsible for the constitution of the BMCs and their functioning including the preparation of PBRs.

Source Adopted and Modified from Badola *et al.* (2022)

1.11.11

Implementation Architecture for Conservation of FGR

FGR being a subset of biodiversity and an integral part of the diverse forest ecosystems across the country, it has remained a focus point of the Central Ministry dealing with the policy directives, enactment of laws, framing of rules and guidelines, and fund allocation relevant to the wider subjects of Forest, Wildlife and, Environment. Presently, the MoEFCC is the concerned Central Ministry dealing with the conservation of FGR. The GoI with the assistance from FAO prepared the National Forestry Action Program in 1999 which made specific action proposals for forestry research and technology, and included *in situ* and *ex situ* conservation of FGR. It also made specific recommendations on use of FGR to augment the supply of industrial wood. Since inception the SFDs in different States/ UTs are the prominent custodian of public forests as they have been responsible for reservation of forests, protection, management and conservation of forest resources including FGR. In addition, community owned and private forests under different ownership and management regimes also exist in different parts of the country. India has sovereign rights over its FGR.

The BSI, Kolkata with the major mandate to explore, survey, prepare inventories and document the plant resources of the country, and responsible for sorting out the nomenclature issues and providing the status of the threatened species has been a prominent and authentic source on floristics of forest vegetation including FGR. It also undertakes *ex situ* conservation of threatened plant species in the form of botanical gardens. The FRI, Dehra Dun being the oldest institution dealing with forestry research and education in the Indian sub-continent has been contributing in a significant way towards forest exploration, floristics, forest herbarium, arboreta, wood anatomy, NTFPs, forest ecology, plant physiology, hydrology, silviculture based forest management, survey and documentation of pests and pathogens, seed collection and storage, vegetative multiplication, tree improvement, seed orchards, chemical and genetic characterization, ecorestoration, climate change mitigation and adaptation, education, training, conservation, etc. These efforts by FRI were not only expanded but also gained considerable impetus once ICFRE with its nine institutions and varied centers came into existence in 1986. Forestry research in the country is attended by the ICFRE, its institutions, and also by State Forest Research Institutes and the research wing of the SFDs. It is largely in terms of the National Forestry Research Plan (NFRP) which has a national character and helps avoid duplication of research. ICFRE through FRI, IFGTB and other institutions has been collecting information on FGR and providing to FAO-CGR and regional networks like APAFRI and APFORGEN on behalf of the Government of India. Sister institutions of FRI/ ICFRE under the control of MoEFCC *viz*., FSI, Wildlife Institute of India (WII), Indian Institute of Forest Management (IIFM), G.B. Pant Institute of Himalayan Environment and Sustainable Development (GBPHESD), etc. have been making notable contributions towards biennial countrywide assessment of forest resources; planning and management for PAs, wildlife research and education, capacity development and biodiversity conservation; forest management; and Himalayan ecology and FGR conservation; respectively.

The ICAR and its countrywide specialized institutes deal with a wide range of aspects relevant to plant/ animal/ fish resources; agriculture/ horticulture crop varieties; agriculture diversification and production; genetic improvement; germplasm storage; agroforestry; animal husbandry and livestock production; dairying; pisciculture; education; extension; processing and value addition; and marketing. Thus, ICAR and its organizations make direct or indirect contribution towards conservation of FGR. Forestry/ Agriculture universities and institutes across the country contribute towards research, education, and extension relevant to forestry, agriculture, agroforestry, and FGR.

The NBPGR has been involved in conserving the plant germplasm with established facilities for long-term storage of seeds. The mandate of the organization is mainly related to acquisition and management of plant genetic resources for food and agriculture including their introduction for cultivation and conservation of wild relatives in the country. The National Facility for Plant Tissue Culture Repository (NFPTCR), created within the NBPGR, undertakes cryopreservation of seeds, pollen, embryos, as well as *in vitro* culture of plants of economic and scientific values, especially the clonally propagated material and the species having recalcitrant seeds. The National Bioresource Development Board (NBDB), set up by the GoI in 1999 under the aegis of DBT has been mandated to evolve effective strategies for *ex situ* conservation of bioresources of potential scientific and economic values. This Board has facilitated setting up of a few Centers to explore native bioresources in the country and undertake research on them. The primary mandate of NMPB is to develop an appropriate mechanism for coordination between various ministries/ departments/ organizations in India and implements support policies/ programs for overall conservation, cultivation, trade, export, and growth of medicinal plants sector both at the Central and State levels. A large variety of FGR is also medicinal plants which are being used in alternative medicines. The National Afforestation and Ecodevelopment Board (NAEB) is responsible for promoting afforestation, tree planting, ecological restoration and ecodevelopment activities in the country with special attention to the degraded forest areas and lands adjoining the forest areas, national parks, sanctuaries, and other PAs as well as the ecologically fragile areas like the Western Himalayas, Aravallis, Western Ghats, etc.

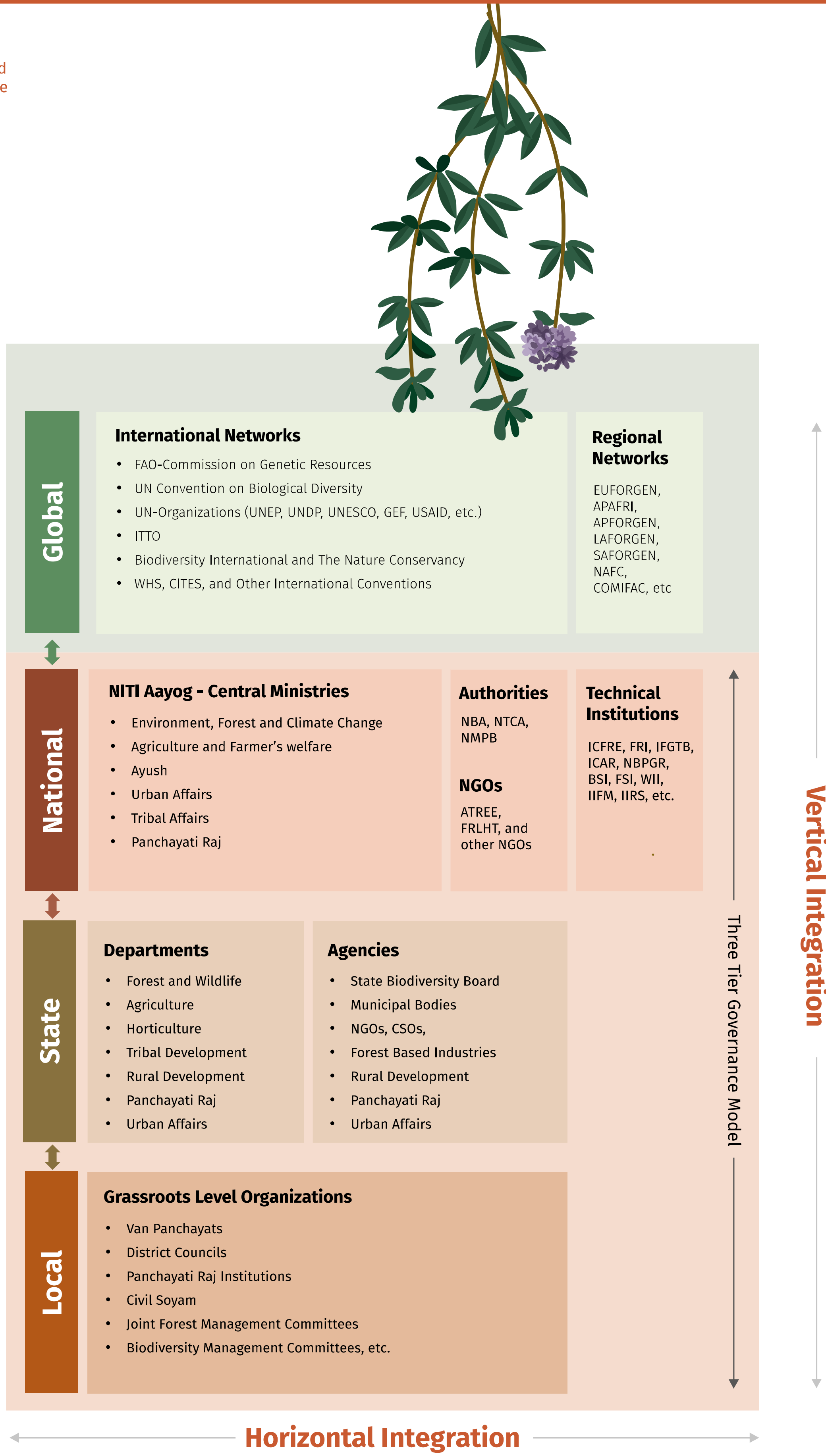
The NWAP (2017-2031) provides an insight on specific tasks, strategies, and actions relevant to the protection of flora and fauna in PA network, and that directly deals with the FGR. The National Biodiversity Action Plan (NBAP), 2008; addendum to NBAP 2008 in 2014; and the country's

'Implementation Plan on Biodiversity', 2019 also cover various aspects of conservation of biological resources including FGR and the genetic diversity at the national level. The Implementation Plan of NBAP envisages operationalization of country's biodiversity action plan at different levels of governance while adopting participatory, inclusionary and effective approach (MoEFCC, 2019). Accordingly, three levels of governance identified in the country included the national, state and local levels. The national level includes the MoEFCC, NBA, central line ministries (Agriculture, Horticulture, Ayush, Tribal Development, Panchayati Raj, Urban Affairs, etc.), professional organizations (ICFRE and ICAR and their institutions; FSI, WII, IIFM, etc.), and NGOs. Likewise, the state level implementation requires the protection and management by SFDs besides technical support and facilitation by the SBBs and state line departments, NGOs, CBOs, business houses/ corporates, and private entities. The local level implementation primarily includes Panchayati Raj Institutions, Gram Panchayats, Van Panchayats, JFMCs, BMCs besides local line agencies, and other institutions. The National Action Plan on Climate Change (NAPCC), 2008; Mangroves for the Future – National Strategy and Action Plan (MFF-NSAP), 2012; and the National Agenda on Sustainable Development cover vital aspects of conservation and use of forest and other biological resources.

From the foregoing description, it is evident that: (a) FGR is a subset of wild and domestic biodiversity; (b) varied aspects of conservation of FGR are embedded in the wider sectors of Forests, Agriculture, Horticulture, and Ayush; and (c) most existing programs, schemes, initiatives, strategies, and action/ implementation plans focus on either wild or domestic biodiversity. Thus, despite FGR involves vast extent in terms of their distribution, and deals with enormous diversity, high volumes of collection and harvest, manpower and institutions involved, and turnover, there is conspicuous absence of any national level designated agency and program to provide focus on the conservation and development of this very important and critically placed resource. It is only in the recent past that the MoEFCC through CAMPA funds has started financing a focused Pilot Project on conservation of FGR.

In view of the above, the existing implementation architecture for conservation of FGR across three levels of execution has been depicted diagrammatically (Fig. 1.20). The implementation architecture aims for horizontal and vertical integration at four levels for the inclusionary and effective approach. In addition, the global level agreements, directives, strategies, and innovative approaches arising as a part of the FAO's Commission on Genetic Resources, UNCBD and other international conventions supported by UN and other international agencies, and international NGOs are of paramount importance for effective implementation of conservation programs relevant to FGR (Fig. 1.20).

Fig 1.20
Hierarchical Governance and Implementation Architecture Showing Vertical and Horizontal Integration for Conservation of FGR



Conservation of Forest Genetic Resources

Establishment of Center of Excellence on Forest Genetic Resources (CoE-FGR)

Uttarakhand State

1.11.12

Research, Capacity Development, Extension and Monitoring for FGR

The effective conservation of FGR is not possible in the absence of requisite essential support of desired research, capacity development, monitoring, education and awareness. Despite its immense significance, explicit research, training, education, extension and monitoring programs focusing on FGR in India have been greatly lacking. However, varied priority aspects of conservation of FGR are being covered as a part of wider forestry research, education, capacity development, extension, and monitoring by the various forestry institutes and other allied organizations, primarily working under the MoEFCC. They have evolved over a long period of time. Brief details on these thematic activities are presented below:

1.11.12.1

Research on FGR

The foundation for Forestry research in the country was founded 158 years ago with establishment of the British Imperial Forest School in 1864 by Dietrich Brandis. The School was designated and renamed as the Imperial Forest Research Institute in 1906 under the British Imperial Forestry Service. It was moved to the present campus of FRI in 1929 and renamed after the country's independence. The forestry research in India evolved from an initial thrust on the production forestry focusing on select timber and other commercially important species. This phase based on silviculture continued for almost 90 years or so and during this phase, prominent disciplines of Forest Botany, Silviculture, Forest Entomology, Wood Science, Forest Pathology and Forest Products have developed. All these disciplines are not only the backbone for the wider subject of forestry but have also made notable contribution towards the description and documentation of forest diversity across the country, timber production, forest protection from pests and pathogens, and inventory of forest products including NTFPs and their management. In this phase, foundations for botanical garden, arboretum, bambusetum, and herbarium besides development of timber mechanics and engineering including wood preservation, seasoning and working; education; and extension were laid. Around 1960s, the emphasis of forestry research gradually shifted towards forest ecology, soil science, chemistry, physiology, biotechnology and genetics and a wide range of research studies were undertaken focusing on phytosociology, soil chemistry, biomass production, productivity, plant growth, seed biology, tissue culture, tree improvement, and sustainable management of forests. This second phase lasted for about 30 years prior to the enactment of WPA, 1972; FCA, 1980; and EPA, 1986; formulation of NFP, 1988; and signing of UNCBD in 1992. The thrust of researches in the second phase provided direction for conservation forestry. Nearly past four decades or the recent phase witnessed the emergence of newer disciplines/ themes of conservation of biodiversity, climate change, forest genetic resources, ecosystem services, and ecosystem-based forest management. All these disciplines/ themes have immensely contributed for enhanced understanding of FGR, and efforts towards in situ and *ex situ* conservation. Additionally, modern tools (Geographic Positioning System-GPS, portable biosensors, Unmanned Aerial Vehicle-UAV, DNA sequencer), technologies (IT, RS and GIS, DNA fingerprinting, bioinformatics) and techniques (prediction modelling for climate vulnerability, landscape genetics), concurrently developed during the recent phase and made notable contribution to the overall advancement of forestry research. Thus, the concerted multidisciplinary efforts towards forestry research over one and a half century have provided a strong foundation for the newer agenda on the conservation of FGR.

Specifically, the global recognition of FGR probably began for the first time around the second half of the nineteenth century with the advent of concepts of Mendelian inheritance, genes, genetic variation, and heredity in organisms leading to the emergence of 'genetics' as a new discipline. Prior to that, humanity believed that living things inherit traits from their parents and these observations were used to improve crop plants and animals through selective breeding. It was soon realized that natural selection will only cause evolution if there is enough genetic variation in a population, and by following the earlier common hypothesis of 'blending inheritance', genetic variance would be rapidly lost, making evolution by natural or sexual selection implausible. Since the development of an understanding of genetics and the nature of heritable materials, research on domestication of trees and tree improvement has evolved globally and nationally. As a result, the provenance trials for teak and pine were initiated at the Imperial Forest Research Institute (presently, FRI), Dehra Dun in 1920s. Subsequently, FRI, ICFRE and its institutes, ICAR, and other forestry/ agriculture universities and private entities have initiated relevant research and domestication of a large number of tree species in collaboration with SFDs. The improved reproductive material available in forestry were first classified in the country under the scheme for certification of Forest Reproductive Material in 1972 and later revised and issued in 1979 by the GoI as 'Certification of Forest Reproductive Material (FRM) in India' (MoEF, 2012). Initially, the tree improvement programs undertaken in the country mainly concentrated on increase in volume of timber. Subsequently, the breeding program has advanced to improve the pulping or wood quality, pest tolerance, disease resistance, etc. ICFRE has developed comprehensive strategies for improvement of several timber and other commercially important tree species. In the process, the ICFRE institutes have not only assembled germplasm of various species but also carried out provenance trials, created seed