# 1 Protecting Forest Structure and Functions for Resilience and Sustainability Concerns in the Changing World

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**Abstract**

Forest ecosystems are one of the most important ecosystems on earth, and sustainability of the planet heavily relies on diverse ecosystem services emerging from them. In order to maintain unrestricted flow of ecosystem services in the warming world, it is essential to conserve and sustainably manage them. This necessitates an understanding of past, present, and future structural and functional pattern of forests, their functioning as well as health status. There are substantial indications that unsustainable human activities have significantly affected the structure and functioning of natural forest ecosystems. To explain the distribution of forests, their functioning, and different drivers of loss to which forests are exposed, enormous methodological and socio-ecological and governance advancements have already taken place. In the opening chapter, we elaborate on the understanding of forest ecosystems from variations in definitions and conceptualizations of forests, emerging challenges, monitoring advancements, etc. Chapter broadly covers scientific advancements for monitoring various stressors, forest degradation, inventory using advanced tools to present the fate of forest structure, and functioning in the changing world. The volume highlights drivers of deforestation and forest degradation, provides insights to innovations, and also touches advanced institutional provisions and governance framework.

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The thematic and cross cutting chapters bring in scientific evidence-supported information and solutions to enhance the prospects for conserving forests in the fast changing world. Apart from providing a broader overview of the book, its growing relevance, the chapter also offers a brief outline of the chapters in different sections of the book.

**Keywords**

Forest monitoring · Forest management · Deforestation · Ecosystem services · Climate change

## 1.1 Introduction

Well-being of society and the human consumption of natural resources depend on available diverse biodiversity elements and ecosystem services. Structure and function of ecosystems interact in immensely complex spatial patterns from local to global levels to provide diverse nature's contributions for well-being (Mirtl et al. 2018). Our planet is covered with diverse ecosystems, and forest is one of the important ones. The Global Forest Resource Assessment (FRA) by the FAO at an interval of 5 years reveals that the total forest area in the world stands at 4.06 billion hectares, i.e., 31% of the land area (FAO 2020b). The spatial distribution patterns of forest ecosystems are determined by its relation with diverse environmental and climatic parameters that helps in determining the structure of the forest ecosystems in specific biogeographic zones. The diversity exhibited by the forests in terms of structure and function leads to the concept of forest types (Muys 2021). More than 850 million people across the world live close to natural forest ecosystems, whereas approximately 350 million are directly dependent on them for their livelihoods and other subsistence requirements (Runyan and Stehm 2020). Forests are home to rich floral, faunal, and organisms and by regulating global biogeochemical cycles, and supporting diverse subsistence demands and livelihoods, forests have been widely acknowledged for their role in securing human well-being (Kumar et al. 2019a; Haq et al. 2020). Forest biodiversity is key resource for many crucial ecosystem services, contributions, and impact of biodiversity on ecosystem functioning and processes (BEF) has central to ongoing ecosystem and biodiversity research (Pan et al. 2018). The inherent ability of the natural forests to recover after disturbances, i.e., their resilience, regulates their capacity to support its functions and process over time (Ibáñez et al. 2019). Ecosystem resilience as a vital component for sustainable human development and sustainable use of forest resources is relevant to uphold the sustainable consumption patterns by diverse socio-economic systems (Yan et al. 2011). Forests have been historically connected with human well-being for their diverse benefits, but it is relevant to acknowledge that the capacity to support human well-being is not unlimited and they are under significant stress because of much ongoing natural and human-induced pressure (Anonymous 2018). Forest structure and functioning have been significantly linked to the type and extent of human dependency (Haq et al. 2021). This is further influenced by the socio-economic and biophysical factors that lead to forest loss (Gardner et al. 2010). Forests have emerged as one of the most threatened ecosystems because of increasing deforestation and degradation trends because of the diverse direct and indirect drivers of forest loss (Li and Jiang 2021). Forest biodiversity that is affected by diverse range of drivers of loss that includes changes and human-induced land use land cover changes in various production systems is one of the relevant drivers worldwide (Díaz et al. 2019). The United Nations Framework Convention on Climate Change (UNFCCC) and independent nations in various scientific and international strategic alliances have stressed on the unforeseen and irreversible impacts of climate change on rich but fragile natural forest ecosystems. The structure and functions of forest ecosystems are rapidly changing due to forest fires (Joshi et al. 2021), deforestation (Runyan and Stehm 2020), urbanization (Olokeogun and Kumar 2020), climate change, and other relevant natural and anthropogenic drivers (Kumar et al. 2019b; Molina and Abadal 2021). In less than last 100 years, world has already lost forests equivalent to the loss in the last 9000 years. Global deforestation peaked around early 80s with a loss of around 150 million hectares during that decade (Ritchie and Roser 2021). However, the rate of loss has shown a considerable decline from 5.2 million ha/annum from 2000 to 2010 to 4.7 million ha/annum from 2010 to 2020. Furthermore, the rate of deforestation has also decreased from 12 million ha/annum from 2010 to 2015 to 10 million ha from 2015 to 2020 (FAO 2020b). Constant decline in forest cover in the past 50 year has reduced the ability of nature to ensure and support human well-being (Brauman et al. 2020). This decline, the way it is continued unrestricted, is expected to also affect the achievement and localization of the 2030 Agenda of UN SDGs and many other relevant global targets (Managi et al. 2019).

For centuries, forests have been considered climate stabilizers as they can significantly support cost-effective diverse nature-based climate solutions to more than 30% climate mitigation strategies to reduce vulnerability due to climate change and achieve globally projected UNFCCC targets (Brandon 2014; Griscom et al. 2017). There is growing demand to understand ecosystems as a critical components of the biological diversity of the planet in the changing world and as crucial natural capital that sustains human well-being (Ekins 2003). In a rapidly changing world where catastrophic climatic threats, land degradation, water depletion, industrialization, and pollution-related issues are frequent and prevalent, understanding the changing face of forest ecosystems is essential. For forest ecosystems to be considered biodiverse, it is necessary to evaluate soil, water, plant, and atmospheric intercontinuum systems in light of spatio-temporal variations. Comprehensive understanding of ecological processes is necessary to understand the changing patterns in the natural forest ecosystems (Kumar et al. 2020a; Muys 2021). For the preservation of natural forest ecosystems, a better understanding of critical socio-ecological interdependencies such as subsistence requirements of local communities, traditional agroforestry ecosystems, rapid land use, and land cover change dynamics, will be relevant (Dhyani and Dhyani 2020; Savita et al. 2018; Kumar et al. 2020b, 2021a). There is global evidence that forests develop differently under different production environments (Peng 2000; Kumar et al. 2018). There is necessity to address major changing dimension of forests through relevant forestry research to leverage upon the available data, knowledge, tools, approach to understand the fate of forests in the changing world and identify opportunities to improve the existing situations (Kalra and Kumar 2018; Rawat et al. 2020).

The pace of degradation of nature's contributions from forests makes their effective management crucial in present and future. Management of the forest ecosystem needs to be planned ahead of time and visionary in nature, as it takes years to replenish the supply of diverse ecosystems goods and services (FAO 2020b). Short- and long-term socio-ecological interactions with forests that aid in the provision of direct use values should be part of forest management strategies including socio-cultural, socio-ecological, and economic contributions (Dhyani et al. 2021). Depending on the amount of forest degradation, site-specific climate-adaptive restoration (Dhyani et al. 2020a) interventions are required to reduce dependency of local communities on forest resources to reinstate their necessary functions for long-term human well-being. There is growing need to re-examine our current approaches and discover customized metrics based on contemporary technologies, artificial intelligence, and big data that are well supported by indigenous and local knowledge systems enhance outcomes from conservation and restoration projects (Dhyani et al. 2020a).

Opening chapter for this volume presents overview about the present state of knowledge related to forests and sustainability of forests. Chapters in this book are authored by invited expert professionals, scientists, and practitioners who have decades of research experience on diverse research aspects of forest ecosystems. These experts have contributed innovative approaches to improve existing forest research to reduce deforestation and forest degradation, improve socio-ecological and economic benefits, and enhance climate adaptations for human well-being. The edited book volume is an effort to showcase the context, concept, issues, cases, relevance, and growing need to mainstream innovations in forestry research and governance in decision making. Despite forests across the world facing threat from extractions and climate variabilities, vulnerabilities importance of scientific and socio-ecological and economic innovations in forestry research are either ignored or have not received sufficient recognition so far. Under the different subheadings of this opening chapter of this book, we not only bring the diverse conceptualization of forest ecosystems but also showcase ongoing developments and novel approaches for enhancing mapping, scenario assessment, and sustainable management of natural forest ecosystems. Chapters in different sections of this book volume provide a broader overview on scientific advances in the field of forestry research followed by the key gaps and issues to be addressed. A dedicated last section of the book volume discusses about the opportunities and pathways to mainstream sustainable socio-ecological and economic approaches in forest policies planning.

## 1.2 Conceptualizing "Forest"

The definition of "forest" differs in diverse perspectives, management strategies, and assessment studies (Chazdon et al. 2016). Nearly 1600 distinct definitions of "forest" have been developed across the world, for a specific purpose in academia, research, or policies (Lund 2014). The multiple ways in which a forest has been defined show the humungous diversity which exists in forest definitions, conceptualizing forests, forest types, and other biogeographic zones around the world. A specific definition might leave out diverse forest types such as mangroves or alpines, a broader definition might lead to loopholes for misuse whereas, a definition that is only relevant to local environment might be rendered meaningless for global use (UNEP 2009). The Food and Agricultural Organization (FAO) regards forest as a land which is spread in more than 0.5 ha in size and is covered with trees of height greater than 5 m (FAO 2020a). The International Union for Conservation of Nature (IUCN) has considered forest as a "land having presence of continuous stand of trees" (IUCN 2012). Globally, international organizations and conventions have agreed on a few universal definitions, which are presented in Table 1.1.

Canopy cover and land use are the most commonly used criteria for defining a forest. The definitions by UNFCCC and FAO are based on parameters *viz.,* minimum area, minimum height, crown cover percentage, temporary and/or strip width (Trines 2002).

**Table 1.1** Diverse concepts and definition for forest ecosystems as proposed by different international organizations

| Proposed by | Definition of forest |
|---|---|
| UNFCCC (2001) | "Forest is a minimum area of land of 0.05–1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10–30 percent with trees with the potential to reach a minimum height of 2–5 meters at maturity in situ."<br>"A forest may consist either of closed forest formations where trees of various storey and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10–30 percent or tree height of 2–5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes, but which are expected to revert to forest." |
| UN FAO FRA 2020 (FAO 2020a) | "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use." |
| UN CBD | "Forest is a land area of more than 0.5 ha, with a tree canopy cover of more than 10%, which is not primarily under agricultural or other specific non-forest land use." |

### 1.2.1 Forest Types and Structure

A forest type is essentially a unit of vegetation which exhibits broad characteristics in terms of physiognomy and structure. The characteristics exhibited by a single unit of forest are adequately pronounced for its distinction from other such units. The vegetation characteristics of a particular region are largely dependent on the climatic conditions (temperature, precipitation, etc.) of the region which functions in isolation and in combination with the nature of the soil (Champion and Seth 1968). On a global scale, FAO classifies forests based on the climatic domain that the forest occupies namely Boreal, Temperate, Subtropical, and Tropical forests. With the purpose to maintain a standardized nomenclature for the understanding of forest types across the globe, IUCN has presented a habitat classification scheme classifying forests into nine broad types, according to their climatic zone and ecological characteristics viz., Boreal, Subarctic, Subantarctic, Temperate, Subtropical/tropical dry, Subtropical/tropical moist lowland, Subtropical/tropical mangrove vegetation above high tide level, Subtropical/tropical swamp, Subtropical/tropical moist montane, etc. (IUCN 2012). The classification of forests on a global scale is a direct function of the dynamism that all processes portray. Furthermore, these forests are already facing the impending risk of collapse (Sato and Lindenmayer 2018). IUCN has recently proposed a Global Ecosystem Typology which is a hierarchical classification system aimed at classifying ecosystems wherein the upper levels would define the ecosystem by their ecological functions, and the lower levels would distinguish the ecosystem based on their species assemblages (Capotorti et al. 2020). This classification system involves the classification of the globe into five realms, subsequently into 25 biomes, and into Ecosystem Functional Groups (EFG) in the first three levels. Through the EFGs, the presence of ten categories of forests that fall in the broader domains of tropical-subtropical forests and temperate-boreal forests and woodlands are identified. The innovativeness in this concept lies in its capability to represent the duality that is exhibited by an ecosystem in terms of composition and functionality that helps in identification of ecosystems that are in a precarious state and require immediate conservation and protection considerations (Keith et al. 2020). While forest types give us an idea about the diversity of forests spatially, it does not inform us about the density or the health of the forest. The density of the forest can be understood through the forest cover statistics. The term "forest cover" is associated with the terrestrial ecosystems which refer to the area of land covered by forests. Amongst forest types, proportionally, the tropical forests cover the largest area on the planet at 45% (FAO 2020b).

## 1.3 Forests Support in Diverse Nature's Contributions

Recently, natural capital has invited interest of researchers and policy planners to support and endorse sustainability (Kumagai et al. 2021). In his capability approach, Amartya Sen defines capabilities as the means of maintaining livelihood as well as intangible elements for achieving overall human well-being (Fritz-Vietta 2016).

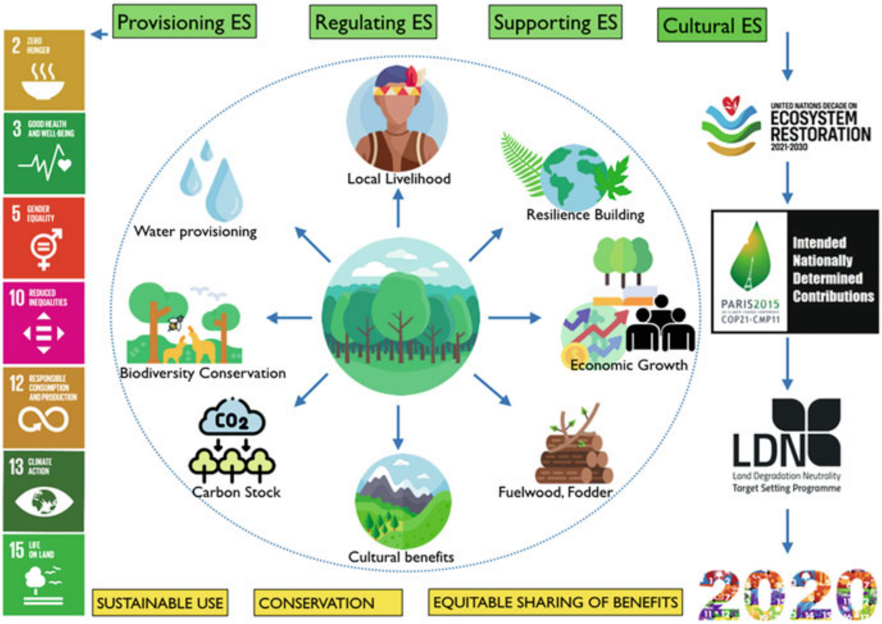


**Fig. 1.1** Diverse ecosystem services (NCPs) harnessed from natural forest ecosystems and their role in localizing and realizing diverse global goals and targets

Forest ecosystem is source of innumerous provisioning benefits, diverse regulating, supporting as well as cultural benefits (Dhyani and Dhyani 2016, 2020; Dasgupta et al. 2021; Kadaverugu et al. 2021) (Fig. 1.1). These benefits and functional roles have been represented as ecosystem services (ES) by Costanza and also highlighted in Millennium Ecosystem Assessment (MEA 2005; Costanza et al. 1997). Intergovernmental panel on biodiversity and ecosystem services (IPBES) has replaced the "ecosystem services" term with a more advanced "nature's contributions to people" (NCPs) (Kenter 2018). Origin of NCPs from the IPBES conceptual framework has a transdisciplinary approach that is action-oriented, and has inclusiveness to support and include pluralism. NCPs recognize diverse and emerging culturally mediated ideas about nature's contributions to people and what can be co-produce along with, nature (Hill et al. 2021). NCP is not very different from previously carried out ES research, but includes five relevant conceptual concepts about the NCP that include diverse worldviews about NCP, context-specific perspectives about NCPs, relational values of nature, diverse reporting categories, and inclusive language that provides novel conceptualization of nature-people relations and connections (Kadykalo et al. 2019). The differences between the instrumental and intrinsic values of nature and NCP indicate the broader array of the benefits people can harness from the natural forest ecosystems (Fritz-Vietta 2016). There was subsequently, emergence of a new concept known as ecosystem dis-services that reflect to the functions that harm or affect human well-being (Sandbrook and Burgess 2015; Costanza et al. 2017).

Spread of zoonotics, resulting in diseases and/or pandemics, is considered a significant disbenefit if the nature was degraded, and unsustainably used (Morand and Lajaunie 2021). The provision of diverse classes of ES or NCP largely depends on the process and functions of terrestrial biodiversity and complex biogeochemical cycling in the forest ecosystems. These relevant natural biogeochemical cycles operate at different spatio-temporal scales and rates. For millennia, humans have been harnessing the larger benefits of biogeochemical cycles for their well-being by living in harmony with the nature. In recent times, most of the ecosystems are been largely shaped by human interventions and interferences. Accidentally or by their interventions, they have a significant control over all kinds of ecosystems. This control has expanded and affected ES and NCPs that support human well-being, leading to global decline in the quality of NCPs (Kotiaho and Halme 2018).

### 1.3.1 Valuation and Mapping of NCPs from Forests

Valuation of NCPs can help decision-making process for sustainable management of natural resources. Economic valuations for NCPs include diverse factors viz., forest, as well as agricultural land, livestock rearing, fisheries, ores, and fossil fuels (Islam and Managi 2021). Valuation of NCPs helps to identify the critical ecosystem services from rich ecosystems and understanding the spatial distribution of these services by including them with endemism for emerging risks due to anthropogenic pressure for developing conservation policies in priority areas (Crossman et al. 2013). However, multifunctionality of ecosystems and their complex structure and functions are involved in diverse ecosystem services that pose a challenge for quantifying and valuation of ES that involves historical and spatial mapping, quantification, and simulations approaches (Birkhofer et al. 2015). In last few decades, valuation of ecosystem services has received considerable attention in ecosystem research and policy planning (Ninan and Inoue 2013). In 2011, forest sector contributed approximately 0.9% of the global GDP that was equal to USD 600 billion (Runyan and Stehm 2020). Forest ecosystems are considered important for their NCPs though, contribution of economically relevant and quantifiable values is scarce; hence, mapping these ecosystem values are pertinent for designing appropriate conservation strategies that can appropriately include forest conservation along with sustainable use of forest produce (Strand et al. 2018). Valuation of global forest changes has been lacking despite the relevance of forest ES and NCPs (Hansen et al. 2013). There is growing relevance need to acknowledge the role of valuation of forest ecosystem good and services (Zhang and Stenger 2015). Values of nature and NCPs can never be accurately assessed hence; an inaccurate approach should be largely avoided (Costanza et al. 2017). Ambiguity due to spatial heterogeneity and data insufficiency, uncertainty for assessing ES or NCPs can also arise due various drivers influencing ES especially governance and policies. Nonmarket valuation approaches that are demand-side-based provide only gross value of forest ecosystems and not an economic value. While, many nonmarketable and nonextractive ecosystem services of forests are mostly result of opportunity costs of resources. Hence, present total forest economic value of forest ES needs to be developed from an anthropocentric instrumental valuation, differentiate gross valuation, economic valuation, and market value (Zhang and Stenger 2015). Costanza et al. (1997) estimated the value of ES for diverse biomes across the world using any one of the three approaches that included the sum of consumer and producer surplus or net rent or price time quantity. Another method is the use of forest inventories, the collection of forest data in a systematic manner following a standard protocol helps in mapping the static supply of forest services. These inventories include the services provided by the forest, services extracted from the forest, etc. (Pereira et al. 2005). Along with these traditional methods, a wide range of modeling tools have been applied to estimate the ecosystem services and their response to change in environmental and societal conditions (Crossman et al. 2013). The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model uses an ecological production function to assess ecosystem goods and services. It shows how a change in ecosystem service potential (inputs) changes the flow of services (output). InVEST so far has been used to model, sediment retention, carbon sequestration, pollination, water purification, coastal vulnerability and protection, timber production, and marine ecosystem services (Nemec and Raudsepp-Hearne 2013). Artificial Intelligence for Ecosystem Services (ARIES) is another software application that works on the principle of demand and supply and simulates a stream of ecosystem service (Villa et al. 2009). Multiscale Integrated Models of Ecosystem Services (MIMES) uses SIMILE software that quantifies the impact of changing land use patterns on ecosystem services across various spatial scales (Boumans et al. 2015). Dynamic Vegetation Models have been designed to simulate vegetation structure and functions (Kumar et al. 2018, 2020a) in association with atmospheric processes and help in quantifying the ES such as nutrient flow, carbon flux, runoff generated, and also enumerate the proxies of ecosystem health such as primary productivity (Brown et al. 2014). Universal Soil Loss Equation (USLE) is widely used to estimate the soil loss due to runoff and establish ecosystem services value (Brown et al. 2014). Future forestry research requires focus on the high values but neglected ecosystem services like mountains, grasslands, and coastal areas, “disservices”, assessing the impact of dynamic factors and disaster risks on the provision of ES, to evaluate the advantages of keeping natural forests undisturbed versus changing them to alternate uses (Ninan and Inoue 2013).

## 1.4 Technological Advancements in Forest Inventory and Monitoring

There is mounting call for records on area under forests, growing tree stocks, sustainability concerns, biodiversity, and climate change. Forest resources methodologies are evolving with time as per need. Conventionally, the field plot-based system was typically used for assessing of characteristics viz., tree species, tree height, canopy cover, diameter at breast height, etc. (Mackey et al. 2021). The data from forest inventory can be grounded on two comprehensive methods viz.,

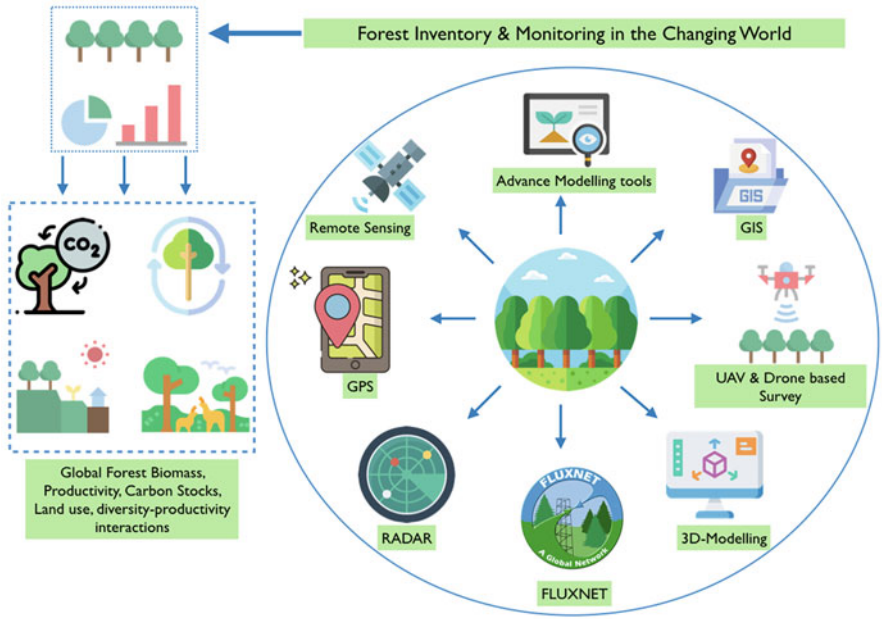


**Fig. 1.2** Technological advancements in monitoring and inventorying forests in the changing world

statistical samples and stand-level data gathering where, sample-based forest inventory is broadly recognized (McRoberts et al. 2010). Though, ground survey-based, inventories in forests are detailed and precise processes of quantification till date, are strenuous, time-taking, costly, and almost impractical for a large forest area (Hussin and Bijker 2000). Remote sensing application has appeared as an important area in forestry research (Corbane et al. 2015). With the beginning of remote sensing backed forest monitoring followed by in-situ observation through flux towers, programmed sensors, and weather stations generates large amount of data that can deliver significant data linked to a landscapes. Forest informatics is close to geomatics for unfolding the spatio-temporal characteristics of forests that includes demonstration of physiological procedures and interfaces from micro to macro levels making it wider than the geomatics. Forest informatics largely covers assessing, monitoring, mapping, and modeling of forests from individual to population level by influencing the procedure of value-added computational proficiencies and informatics. Geographical Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS) provide remarkable methods to map, monitor, survey, classify, characterize, and understand changes as a fundamental part of forest informatics. Various stages of data processing and information flow depicting a typical framework of forest informatics are shown in Fig. 1.2.

RS has become a significant database because of different multispectral and artificial aperture radar sensors and platforms that include unmanned aerial vehicles or drones and satellites to map the diversity of forest variables (Lechner et al. 2020). In the previous few decades, active and passive RS approaches are used to obtain spatially precise 3D point clouds to characterize the outline of the surveyed items this has revolutionized research in the forestry sector (Díaz-Varela and González-Ferreiro 2021). 3D point clouds are increasingly being used to define forests for their measurement accurateness (Hillman et al. 2019). Various applications of RS and GIS in forestry are based on optical remotely detected information, airborne and terrestrial LiDAR, Radar, and Unmanned Aerial Vehicles (UAVs or drones) subject to the scale of mapping and size of the study area. Modeling forest ecosystems and their attributes by the combination of satellite data with machine learning algorithms (MLAs) has been advancement in remote-sensing-based forest resource assessment (Singh et al. 2021). In a recent study, forest biomass was simulated using SAR data from Sentinel-1 and optical data from Sentinel-2 using MLAs (Malhi et al. 2021). Studies are also carried out for forest assessment by using MLA, e.g., Random Forest and Support Vector Machine to project the fire proneness of forests (Gigović et al. 2019). Traditional RS tools including satellite and manned aircraft platforms are also refined in terms of their spatio-temporal and spectral resolutions. The high spatio-temporal resolutions, flexibility, and lower operational costs make UAVs a good alternative to conventional RS approaches (Guimarães et al. 2020). The rapid advancement in remote-sensing technology will result in superior democratization of RS data to support sustainable forest management and conservation in priority areas. A broad variety of RS data and products are available (Table 1.2) that can be used to monitor changing states of forest structure and function and have successfully been tested and applied extensively.

Although, modern ecology is empowered by diverse vegetation indices from operative space-based imageries still current competencies significantly magnify scientific potentials. New observations from space-based imageries allow the estimation and an idea of rough photosynthesis, carbon fluxes, forest fires, evapotranspiration to generate simulated eddy- covariance. These observations are expected to improve our knowledge of the global forest biomass, productivity and carbon stocks, land use, carbon cycle-climate reactions, diversity–productivity interactions to empower upgraded climate predictions. Developments in RS challenge ecologists to communicate data systematized by biome and species to novel data arranged by pixels for developing a theory to report formerly ignored scales (Schimel et al. 2019).

Large datasets of GHGs and energy surface-atmosphere fluxes assessed with the eddy-covariance method (e.g., FLUXNET 2015, AmeriFlux BASE) are extensively employed to standardize models and RS goods (Chu et al. 2021). The global setup of eddy-covariance (EC) flux towers has enhanced our knowledge of the global carbon (C) cycle; however, the setup has a comparatively inadequate spatial range than forest inventory database (Ferster et al. 2015). Fluxnet is a global network of scientists and researchers to share and organize flux data from “micrometeorological tower sites” at several scales (https://fluxnet.org/). Fluxnet is supported by major regional networks existing across the world. The integration of historical databases

**Table 1.2** Remote sensing sensors that may be employed in monitoring forest structure and its functioning

| Multispectral images (Freely available) | | | | | |
|---|---|---|---|---|---|
| Sensor | Swath width | Spatial resolution1 | Period of availability | Temporal resolution | Data sources |
| ASTER | 60 km | 15/30/90 m | 2000-now | 1 day | https://lpdaac.usgs.gov/ |
| MODIS | 2330 km | 250/500/1000 m | 2000-now | Daily/weekly/16 days/monthly composite | https://earthexplorer.usgs.gov/ |
| Landsat TM, ETM | 185 km | 30 m | 1982–2011 | 16 days | https://earthexplorer.usgs.gov/ |
| Landsat 8 OLI/TIRS | 185 km | 30 m | 2013-now | 16 days | https://earthexplorer.usgs.gov/ |
| SPOT | 60/117 km | 10/20 m | 1986-now | 26 days | https://earthexplorer.usgs.gov/ |
| Sentinel 3 | 1270 km | 10 m | 2016-now | <3 days | https://scihub.copernicus.eu/ |
| LISS III | 141 km | 23.5 m | 2006-now | 24 | http://bhuvan-noeda.nrsc.gov.in/data/download/ |
| LISS IV | 70 km | 5.8 m | 2006-now | 5 | |
| AWiFS | 740 km | 56 m | 2006-now | 5 | |
| **Commercial satellites (Available through vendors on payment basis)** | | | | | |
| Ikonos | 11/14 km | 1/4 m | 2000-now | 3 days | https://www.digitalglobe.com |
| Quickbird | 17 km | 2.5 m | 2001-now | Tasked | https://www.digitalglobe.com |
| Worldview 3 | 13 km | 0.60–1.00 m | 2014-now | <1 day | https://www.digitalglobe.com |
| Worlview 4 | 13 km | 0.30 m | 2016-now | <1 day | https://www.digitalglobe.com |
| GeoEye | 15 km | 0.4–1.0 m | 2008-now | 2.6 days | https://www.digitalglobe.com |
| **Hyperspectral images (Freely available)** | | | | | |
| Hyperion | 7.7 km | 30 m | 2000-now | 16 days | https://earthexplorer.usgs.gov/ |
| AVIRIS | 11 km | 4–20 m | 1992-now | 16 days | https://aviris.jpl.nasa.gov/ |
| HysIS[a] | 30 km | 30 m | Nov 2018 | – | https://www.nrsc.gov.in/ |
| PRISMA | 30 km | 30 m | March 2019-now | 15 days | http://prisma-i.it/index.php/en/ |

[a]Data yet not available in public domain

**Table 1.3** Global databases available on FluxNet

| Current databases | Historical databases |
|---|---|
| • AmeriFlux<br>• AsiaFlux<br>• ChinaFlux<br>• European Fluxes Database<br>• ICOS (Integrated Carbon Observation System)<br>• JapanFlux<br>• KoFlux<br>• OzFlux<br>• RusFluxNet<br>• Swiss Fluxnet<br>• Urban Fluxnet<br>• USCCC (US-China Carbon Consortium) | • BERMS (Boreal Ecosystem Research and Monitoring Sites)<br>• Canadian Carbon Program<br>• CarboEurope<br>• CarboItaly<br>• EuroFlux<br>• IMECC (Infrastructure for Measurements of the European Carbon Cycle)<br>• NECC (Nordic Centre for Studies of Ecosystem Carbon Exchange) |

as well as presently active databases is incorporated in database viz., the European Fluxes Database. A few of the regional networks are listed in Table 1.3.

## 1.5 Changing Forest Structure and Functions

In the last more than 8000 years, collective loss of forests has amounted to almost 2.2 billion hectares, decreasing forest cover from 47% to 30% of the planet's surface by 2015 (Runyan and Stehm 2020). Severe human-induced pressures coupled with global climate change have resulted in extraordinary and unforeseen impacts on natural forest ecosystems, demanding innovative ecological engineering approaches, genetic conservation of trees followed by landscape methods that focus on constructing functional landscapes and ecosystems in an economical way (Löf et al. 2019). Despite the immense value of forests, they are undergoing unprecedented rates of deforestation with that is equivalent to an annual loss of 2101 $km^2$/year (Caron et al. 2021). Forests provide a diverse range of ecosystem services at local, regional, and global scales, including hydrological, climatic, biogeochemical, biodiversity, and ecosystem stability and resilience. The long-term damage to natural forests is negatively affecting communities and countries (Runyan and Stehm 2020). Human land use has fragmented the forests across the world, enhancing the edge density and augmenting the presence of edges in natural forest ecosystems. Permanent as well as transient edges in forests have a substantial impact on forest ecosystems that needs to be deliberated explicitly in the analysis and management of these forests (Pöpperl and Seidl 2021). Forest structural changes affect the growth and carbon stock of natural forests (Cheng et al. 2013). Present approximations of $CO_2$ emissions from deforestation and forest degradation are commonly grounded on inadequate evidence and are described by extraordinary ambiguity (Duarte et al. 2020). The spatial disparity in forest structure yields small-scale ecological heterogeneity, which distresses the survival of plants and their propagative routine

(Rodrigues et al. 2014). Jointly, these developments in forest cover and forms are of foremost worry, because of the repercussions for biodiversity conservation, but also a wide variety of critically essential ecosystem services (Brockerhoff et al. 2017). Human-induced pressure has affected the tropical forest ecosystem in terms of degradation, deforestation, and fragmentation (Eguiguren et al. 2019). The concept of forest degradation tends to be addressed in broad terms, as degradation is the result of a progressive decline in the structure, composition, and functions upon which the vigor and resilience of a forest is based (Vásquez-Grandón et al. 2018). Land use change is a mega driver of loss of spatial configuration and inclusive provisioning ecosystem services (Lawler et al. 2014). Loss of habitats, by alteration of tropical forests, has resulted in the biodiversity crisis we are observing today (Estavillo and Pardini 2013). Human-induced interferences have previously triggered ample loss of biodiversity and homogenization (Brockerhoff et al. 2017). Globally, marginalized communities are feeling a deficit of critical ecosystem services especially reduced water provisioning, affecting human well-being because of the loss of natural forests to commercial plantations (Alfonso et al. 2017). Forest ecosystems across Asia are susceptible due to diverse drivers of loss, which enhances the possibility of the elimination of species (Hughes 2017). Deforestation is influenced by several multifaceted direct and indirect causes. Expansion of agriculture (both commercial as well as subsistence) is considered key driver, followed by quarrying, infrastructure buildup, and urban sprawling. In turn, people and financial development initiate the call for agriculture, quarrying, and timber, and supporting infrastructure. Exponential population growth and shifting consumer interests enhance global nutrition demand necessitating a net intensification of arable land under agriculture. Deforestation is exaggerated by other dynamics such as land lease uncertainties, inappropriate governance, low capability of civic forestry interventions, and insufficient arrangement and monitoring (Runyan and Stehm 2020). The deterioration in old-growth forest areas, and the intensification of managed new forest missing natural postdisturbance structure, characterizes foremost alteration in the biological environments of the forest outside their chronological boundaries of changeability. This may bring risk to ecosystem resilience and biodiversity along with the longstanding adaptive ability of these forests (Kuuluvainen and Gauthier 2018). The annual frequency of clear loss of forests has reduced from 7.3 M ha year$^{-1}$ in the 1990s to 3.3 M ha year$^{-1}$ from 2010 to 2015. Natural forest areas have dropped from 3961 M ha to 3721 M ha from 1990 to 2015. While planted forest areas have augmented from 168 M ha to 278 M ha. From 2010 to 2015, tropical forest areas have dropped at a frequency of 5.5 M ha year$^{-1}$, that is 58% of the frequency from 1990s whereas, temperate forest areas have stretched at a proportion of 2.2 M ha year$^{-1}$ (Keenan et al. 2015). It is significant to note that though global magnitudes of tropical deforestation remain distressing and astonishing, they have reduced from 2000 to 2010, and not many tropical emerging economies have lately been through a forest shift from clear deforestation to clear reforestation (Meyfroidt and Lambin 2011). Various case studies have revealed that ecosystem degradation has reduced its capacity to act as a buffer

**Table 1.4** Assessment of benefits and overall trend of various ecosystem services

| Ecosystem services | Benefit | Overall trend |
|---|---|---|
| Food | Positive trend | Ambiguous |
| Freshwater | Negative trend | Negative |
| Moderation of extreme events | Ambiguous trend | Ambiguous |
| Soil fertility | Negative trend | Negative |
| Wastewater treatment | Neutral | Negative |
| Biological control | Positive trend | Positive |
| Pollination | Positive trend | Ambiguous |
| Recreational and physical health | Positive trend | Positive |

Adopted from Shepherd et al. (2016)

against extremes climatic events (MEA 2005). Few prominent services and their global trend are presented in Table 1.4.

An emerging trend of exploitation of ecosystem services and the simultaneous decline in the potential of the ecosystem to maintain their sturdy flow led to irreversible changes (Pereira et al. 2005). Condition overlying-narrow focus on few services led to the loss of other services which sometimes result in the sudden collapse of the system and regime shift (Gordon et al. 2010). Many forest ecosystems are at risk of ecological collapse, which can be defined as a sudden, long-term, and broader change in ecosystem structure and processes that can negatively affect biodiversity and critical ecosystem services (Lindenmayer et al. 2016). Collapse can be reflected in the obvious changes in ecosystem situation, predominantly the speedy degeneration of species populations that are keystone and support ecosystem structure and functions. There also has been a substantial deterioration of biodiversity that has been intensely related to these arrangements and interferences of key ecosystem functions (Lindenmayer and Sato 2018).

### 1.5.1 Deforestation and Forest Degradation

Deforestation and forest degradation are issues of global concern and key indicators and facilitators of loss of natural forest ecosystems (Mitchell et al. 2017). Deforestation leads to replacement of forest land use whereas forest degradation results in reduction of forest canopy cover as well as loss of forest carbon stocks (Shimabukuro et al. 2019). Forest degradation in developing economies, especially the ones in tropical and subtropical zones, is fundamental contributor to global GHG emissions (Pearson et al. 2017). Forest ecosystems can be degraded because of several drivers of loss; these can be direct as well as indirect drivers (Kumar et al. 2021b). Drivers of deforestation are quite similar across African and Asian countries, while drivers of forest degradation were found comparatively of similar nature in Latin American as well as Asian countries. Commercial agriculture has emerged as the mega driver of deforestation that is followed by subsistence agriculture practiced by local communities. Extraction of wood for timber by logging drives forest

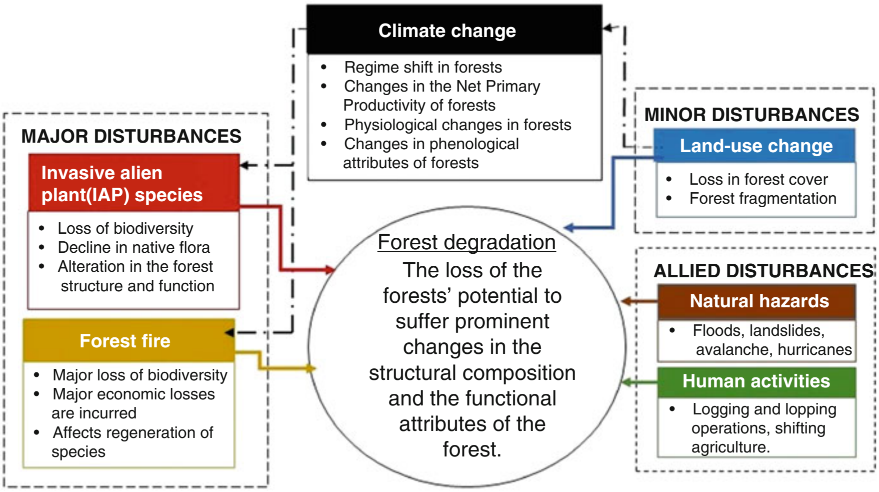


**Fig. 1.3** Deforestation and forest degradation as influenced by multiple drivers of loss of biodiversity and ecosystem services

degradation, followed by collection of fuelwood and for production of charcoal, man-made forest fires, and grazing by cattle (Hosonuma et al. 2012). Deforestation and degradation have significantly reduced the tree carbon stocks; however, tree growth, restoration, and expansion of forests can counterbalance these massive losses (McNicol et al. 2018). The assessment of degradation of forests, its dynamics, and proximate causes can support rapid and early efforts to mitigate GHG emissions to assist formulation of appropriate land use policies (Shapiro et al. 2021). Countries across the world are encouraged to identify potential drivers of deforestation and forest degradation for developing national strategies as well as action plans for REDD+ (Hosonuma et al. 2012). A different disturbance that may lead to degradation of forests is depicted in Fig. 1.3.

Enhanced human-induced interferences in the forested landscapes have blurred the boundary between anthropogenic and natural impacts of forest disturbance and presently both of them exist and impact the ecosystem in a synergistic manner. Understanding of scientists and foresters about forest disturbance dynamics in response to climate change is insufficient, especially about its large-scale interactions and impacts (Seidl et al. 2017). Ecological memory has been considered relevant for ecosystems the way they respond to disturbances that is governed by important legacies that include information as well as material. Disturbance factors that help to preserve these legacies have the capability to enhance ecological resilience for ecosystem recovery. However, these legacies can get lost with the change in disturbance regimes leading to a condition of "resilience debt" that emerges only after the ecosystem gets disturbed (Johnstone et al. 2016). Forest disturbances require specific attention because of their structural complexity to other terrestrial ecosystems viz., agriculture or grasslands (Frolking et al. 2009).

Some of the relevant disturbances that are capable to modify forest structure and functioning are briefly discussed in forthcoming sections.

#### 1.5.1.1 Forest Fire

Massive and widespread fires are result of warm and dry conditions that will be further amplified by increasing frequency and intensity of climate change (Halofsky et al. 2020). In the last few decades, this natural forest fire phenomenon has attracted global attention because of its increasing size, intensity, and frequency (North et al. 2015). As climate change results in enhanced warming disturbance because of forest fire increases too leading to disturbed C dynamics in fire-prone areas. Forest fires will likely affect and bring significant implications for the global carbon budgets and cycles contributing to climate change and enhancing vulnerability (Walker et al. 2020). Forest fires are mostly restricted to the ground and the understory, wherein the canopy does not get affected (Frolking et al. 2009). On the contrary, crown fires ascend to the forest canopy and severely affect the canopy cover in the process (Frolking et al. 2009). Forest fire is capable to affect ecosystem structure, diversity, composition, processes, and functions by identifying fire-adapted plants and replacing susceptible plant species, releasing nutrients and improving biogeochemical cycles, affecting soil properties by changing soil microbial flora, its structure and functions, water associations, and developing diverse heterogeneous mosaics, that can further influence forest fire behavior and ecological processes. Fire can result in loss of massive biomass and many negative consequences viz., postfire soil erosion as well as water runoff, followed by emissions that pollute air environment. However, as a constructive impact forest fire can help to maintain the ecosystem health of fire-dependent ecosystems (Chen 2006). With increasing frequency of forest fires across the world, fire is likely expected to negatively affect diversity of trees in existing forests that are selectively logged. This can affect regional carbon budgets and cycle that will largely affect the global forest carbon sink (dos Santos Prestes et al. 2020). The spatio-temporal understanding of forest fires needs more research to develop strategies for better agriculture yields and to understand postfire successional patterns (Juárez-Orozco et al. 2017). The spatial heterogeneity of fore fire is because of the intensity of the forest fire, rate of spread, and its susceptibility to forest trees (Oliver and Larson 1996). Forest biomass was reported to be reduced by 46% by forest fire and by 80% on reoccurrence of forest fires. Forest regeneration was observed to have lasted for more than 100 years to get restored to prefire state. Productivity of tree biomass and respiration rates were reported to have increased by four times postfire than before because of the presence of pioneer species. It was observed to take more than 150 years for compensating the GHG emissions due to forest fires. Functional diversity was reported to enhance after forest fire; mostly fire-tolerant pioneer species dominate fire-affected area changes the course of forest succession (Fischer 2021). Socio-economic drivers, deforestation, followed by global climate change should be integrated in forest fire research to develop a comprehensive understanding on forest fires (Juárez-Orozco et al. 2017). There are many gaps in our understanding about forest fires and their impact on forest understory, its interaction with fire, and long-term impacts of forest fires. It is critical and relevant to evaluate and develop understanding of present and future response of forest fires on structure and functioning of natural forest ecosystems (dos Santos Prestes et al. 2020).

#### 1.5.1.2 Invasive Alien Species

Globalization followed by rapid upsurge in international transportation and trade has enormously enhanced in invasion risks (Shackleton et al. 2014). Invasive alien species (IAS) are important global and local driver of biodiversity loss (Langmaier and Lapin 2020). Forest fragmentation results in invasion of exotic plants by enhancing their seed dispersal and availability of resources besides the boundaries. These effects differ for different forest age classes and are subjective trait differences of native and nonnative plant species (Dillon et al. 2018). Invasive species are able to affect local biodiversity on multiple scales and diverse ways (Kumar et al. 2019c). In natural forest ecosystems, risks due to IAS comprise of hybridization, disease transmission, and competition among species (Langmaier and Lapin 2020). Ecosystem processes are disrupted from IAS due to decline in native floral richness, and modification of community structure (Hejda et al. 2009). On a larger spatial scale, IAS are inclined to homogenize the region by adversely affective natural course of regeneration, by directly regulating the growth or secondarily by enhancing regeneration struggle (Dyderski and Jagodziński 2020). The complicated interactions within an ecosystem suggest that disturbance at one place by IAS leads to cascading consequences that negatively effect the flow of critical ecosystem services (Charles and Dukes 2008). Human impact on the IAS establishment is prominent and many planted forests are managed by them. Planted and managed pine plantations are less vulnerable to IAS as closely examined, controlled, and managed by humans. Hence, it is claimed that early warning systems for IAS can be included in these managed planted forests (Martínez-Jauregui et al. 2018).

#### 1.5.1.3 Land Use Land Cover Change

Land use and land cover changes (LULCC) moderate and regulate ecosystem services and associated landscape processes (Zhao et al. 2020). LULCC reveals and shapes comprehensive interaction between commercial growth and conservation of biodiversity. By second half of the twentieth century, search of commercial expansion leads to transformation of ~24% of the earth's surface into agriculture and damage to ~35% of coastal mangroves and ~20% of vulnerable coral reefs. During the same time, worldwide GDP augmented sixfold (with a normal 3.9% annual development rate), yet the worldwide "aggregate capital stock" fallen as the economic growth from the reduction of natural capital was frequently consumed than being capitalized in alternate investments (Tesfaw et al. 2018). It is progressively recognized that LULCC is a crucial topic that immediately needs consideration in global climate change (Hu et al. 2019). The LULCC for a region is consequence of its natural and socio-economic characteristics and their spatio-temporal processing (Tewabe and Fentahun 2020). The human-induced interferences on biosphere have tremendously augmented in the last 300 years at an astounding frequency. Histrionic and exponential population growth has come at the price of natural forests and grassland ecosystems. During the previous 300 years, approximations for the global reduction in forested area range from 8 to 13 million km$^2$, that corresponds to 15–25% of the actual extent of 1700 (Goldewijk and Ramankutty 2010). Though alteration of land by people for subsistence livings and other necessities has been there for the last thousands of years; the magnitude, intensity, and frequency of LULCC were far less than in the present. These changes are mega drivers of exceptional alterations in ecosystem structures and processes at local, regional, and global level (Hassan et al. 2016). Frolking et al. (2009) classified land conversion of forests into two categories, permanent as well as temporary. Permanent land conversion referred to the forest land altered to nonforest use permanently, such as oil palm plantations, mining, industrialization, etc. (Fitzherbert et al. 2008). Temporary land transformation was by conversion of forest land for a few years. Human-induced forest disturbance, permanent forest land use transformation are global concerns, but short-term forest conversion is mostly limited to tropical as well as subtropical regions of the world (Lanly 1985). Anthropogenic LULCC distresses global climate as well as terrestrial carbon cycle (Quesada et al. 2018). Progressively, forests are part of international climate change agenda as LULCC leads to loss of forests as well as terrestrial carbon (Syampungani et al. 2014). Accepting the extent, course and means of LULCC are required for recognizing the reasons of alteration and planning efficient strategies and schemes to reduce, halt, and reverse land degradation to achieve land degradation neutrality and by forest landscape restoration (Mekonnen et al. 2018; Betru et al. 2019). Reducing emissions from deforestation and forest degradation (REDD+) plus preservation of forest carbon stocks, sustainable administration of forest ecosystems by enhancing forest carbon stocks in developing countries necessitates evidence on LULCCs and carbon emission drifts from historical to the present and into the forthcoming years (Capitani et al. 2019). Sustainable land management policies for future should consist of learning on the importance of the natural forest ecosystems, participatory efforts in sustainable consumption of forest ecosystem services by introducing alternate sources of sustainable livelihood opportunities from natural forests (Masayi et al. 2021).

#### 1.5.1.4 Climate Change

The prime force which functions to shape the biomes of the world is climate (Hansen et al. 2001). Changing temperature and rainfall patterns followed by aggregate concentrations of atmospheric $CO_2$ will drive significant alterations in natural forests (Kirilenko and Sedjo 2007). There is growing international focus on forests in all the high-level multilateral pledges for nature and from a climate standpoint, this attention on forests is extremely significant. Because of their importance as both carbon source as well as sink, they are ever more in the glare of publicity and have a crucial role to play in the global climate change strategy (Seddon et al. 2019). Climate change has pressed additional stress on the previously lost natural forest ecosystems. However, it is typically unidentified how climate change will distress the spatial distribution of natural forests in the forthcoming years (John et al. 2020). Professionals have ranked the paramount and most probable climate change effects on the forest production that includes: forest health risks enforced by pests and pathogens, dangerous rainfall events, alterations in the forest structure and composition, IAS, and fluctuations in forest productions (Soucy et al. 2021). Significant ecosystem services from natural forests are expected to affect due to climate change, possibly because of the influence of surges in atmospheric $CO_2$ on plant physiology (Yu et al. 2021). Climate change is anticipated to considerably modify tree spatial distribution in coming decades (Dhyani et al. 2018, 2020b; Baumbach et al. 2019). Secondary forests experiencing successional alterations are going to be the main factors in the present global carbon cycle. However, functions of these forests in the forests in warmer situations with greater atmospheric $CO_2$ concentrations are unidentified (Mohan et al. 2012). Climate plays a crucial role functionally in diverse plant processes like phenology (Mohanta et al. 2020; Kumar et al. 2019d, 2021c), net primary productivity, etc. (Kumar et al. 2018). Kumar et al. (2018) described that 80% of the forests in the Indian Western Himalayan region are vulnerable to climate variability, and not even half of them have ample resilience to climate change. Many biogeographical models validate shift of potential forest vegetation to arctic region due to climate change. The equilibrium as well as some other dynamic vegetation models predict this vegetation shift to a fresh accessible zones with promising climate situations will ultimately effect forest growth and replacement of approximately 50% of prevailing vegetation in the north. Growing atmospheric $CO_2$ concentrations, apart from altering the temperature and rainfall patterns, might also upsurge production by "carbon fertilization effect" (Kirilenko and Sedjo 2007). Due to climate change, the occurrence and strength of climate extreme events have also augmented (Stocker 2014). Influencing an ecological outlook of climate extremes is complex due to varied nature of impacts, which vary from in significant distresses to ostentatious disturbances that are able to alter the structure and function of natural ecosystem (Folke et al. 2004). Such major modifications had been observed in the forests of United States of America, where due to an upsurge in the frequency of tropical cyclones, an ecological regime shifted leading to conversion of coastal mangroves to mudflats (Osland et al. 2020). A major limitation to study climate-forest interfaces is the insufficiency of data (Kumar et al. 2018). The limitation merits establishment of inventories, while the difficulties in the understanding of climate change call engagement of modern and advanced scientific tools and technologies.

## 1.6 Structure of the Book

This book volume has 22 chapters on diverse topics related to forest dynamics and conservation and is divided into four sections. The book volume includes a detailed introductory chapter providing background on forest dynamics and conservation science, and innovations for reducing deforestation and forest degradation by Kumar et al. (this chapter). This chapter covers insights on global deforestation and forest degradation issues followed by technological advancements in monitoring and inventorying forest resources. The chapter also deliberates on the ongoing developments on the core themes of diverse forest dynamics and conservation issues. Part I of the book highlights "drivers of deforestation and forest loss" for understanding forest degradation and its drivers that are essential to ensure responsive, effective, and efficient forest activity concerning a more amiable diverseness and climate outcomes presented under seven important chapters (Chaps. 1–7). Samuel (Chap. 2) in the opening chapter of the section presents an overview of different definitions, indicators, assessment methods, and drivers of forest degradation that addresses the need for an apt and clear understanding of this pertinent topic in the warming world. Huettmann and Young (Chap. 3) bring focus to old-growth forest wilderness areas that are on a rapid global decline. He provides insights into science-based sustainable forest management (SFM) that is practiced worldwide through ground truth examples of how the practice is not sustainable on finite landmass. Chatterjee et al. (Chap. 4) provide an overview of synergistic impacts of pollutants, climate change, and decimation of forests and its after-effects, i.e., forest dieback, invasion by invasive species including pests and pathogens, and low regeneration of forest trees through a case study of Gangetic plains of India that is a global ammonia ($NH_3$) hotspot. The chapter by Prieto and Florin (Chap. 5) addresses the growing issue of wildfires and designing a sustainable future by solutions based on forest-society relationships. The chapter addresses these issues by searching for proposals which are based on forest-society relationships, by a novel compilation of the extension and temporal dynamics of forest fires and their major types in the context of main weather, biogeochemical, and plan communities' aspects in a representative case study, and the international scope and decadal evolution of surface affected by forest fires in both absolute terms and in proportion to the total forest surface, followed by understanding the integrated implications of social and economic factors and forest policies. Chapter 6 by Kalpana Giri questions the gender agenda of Nepal's Community Forestry that is at risk due to commercial transitions? The chapter examines the reasons behind such framing and identifies its implications to gender agenda in Community Forestry. The author also suggests revitalizing the gender agenda by accounting for the economic costs of forest management and positioning women and marginalized groups in new economic roles. Chapter 7 by Dhyani et al. addresses an important issue of forest soil microbial diversity or gene pool as the association of the genes facilitates and may also alter important processes such as energy flow, biogeochemical cycles, and signaling secondary metabolites. Authors highlight different components of the forest ecosystem, their interplay, and their impact on soil structure and function, thus affecting different ecosystem productivity. Part II of the book under the title "Forest and Sustainability Concerns" is comprised of five chapters (Chaps. 8–12). The opening chapter in the section by Calixto and Hahn (Chap. 8) presents an overview and perspectives on plant-herbivore interactions in a forest ecosystem to sustain losses. The chapter highlights the plant-herbivorous insect interactions, with a background of how studies focusing on the ecology and evolution of interactions are important to understand the processes that drive species diversity. Authors also discuss the coevolutionary process between plants and insects by describing how plant-herbivorous insect coevolution can promote species diversity and shape ecosystems, and the potential mechanisms by which plants and herbivores might influence the ecosystem structure and biodiversity, which can act as a proxy for conservation measures. Chapter 9 by Sapkota et al. unpacks the social dimension of forestry and its implications to forestry management and discusses multiple roles of community forestry in different contexts, through case studies completed in Cambodia, Myanmar, Nepal, and Vietnam in tackling climate impacts and COVID-19 restrictions. Murthy et al. (Chap. 10) bring in the important dimension of biodiversity and biomass carbon dynamics by presenting insights from long-term monitoring in Western Ghats, India. Authors insist creation of policy, decision, and networking windows to allow the use of information from permanent plots for effective and efficient management of forest ecosystems and making them resilient to systemic and chronic shocks both climate and nonclimate. Chapter 11 by B. Dhanya presents a case study of urban protected forests by projecting the ramifications of urban growth on social-ecological interactions around periurban protected areas (PAs). The authors discuss the implications of urbanization for biodiversity conservation and ecosystem-dependent livelihoods in periurban spaces and suggest ways to integrate protected forests in the urban fabric. Kumar et al. (Chap. 12) are on mapping the extent of invasive species even from pristine settings of Eastern Himalayas, India. Results presented in the chapter demonstrate the suitability of Red-Edge Band of Worldview-2 images to discriminate invasive species in mixed vegetation that can assist in the management of infestation in the high-altitude region. Part III of the volume is dedicated to “Insights to Innovations” to study forest ecosystems and also reduce deforestation and forest degradation. The section covers seven important chapters (Chaps. 13–19) and the opening chapter of this section is by Shukla et al. (Chap. 13). Chapter brings attention to the Groundwater-Dependent Ecosystems (GDE), needs to study them, their classification, identification methods, along with the global advances in GDE’s mapping and groundwater allocation trends highlighting the need for GDE assessment in water-dependent agrarian economies across the world facing water stress due to burgeoning population and subsequent rise in human water demand. Khaiter and Erechtchoikova in Chap. 14 of this section carefully consider the synergistic perspective of advanced scientific methods and tools in sustainable forest management. Framework accommodates various contributing concepts, such as sustainable development, forest ecological-economic-social systems, forest ecosystem services and benefits, forest informatics, precision forestry, adaptive forest management, and data science followed by a nine-step roadmap for practical implementation of the framework. Tyagi et al. in Chap. 15 cover a coherent view and application of dynamic vegetation models for the climate change impact assessment specially to understand widespread implications for the structure and function of vegetation all over the world. Chapter 16 by Harun et al. reflects on Peatland ecosystems through a case study from Indonesia and highlights the role of agroforestry approaches for peatland landscapes restoration. The chapter discusses the performance of six tree-based agroforestry types practiced in the peatland landscape of Central Kalimantan, such as jelutong tree-based agroforestry, agro-silvopastoral, agro-silvo-fishery, and apiculture system of tree-based agroforestry types in Central Kalimantan. Kala and

Mukhopadhyay in Chap. 17 present SmarteR approach for the mapping of invasive plant species and provide an overview on diverse modeling techniques along with model evaluation using R language and platform. Chapter 18 by Singh et al. highlights the challenge of mapping and identifying different tree species based on their canopy characteristics with the high spatial resolution data and presents the artificial intelligence-based semantic segmentation deep learning method to map and identify trees. The chapter also deliberates on the potential of artificial intelligence-based semantic segmentation deep learning method to be utilized for studies of paramount importance like the census of trees. The concluding chapter of this section is by Reddy et al. (Chap. 19) that discusses the application of biophysical, soil, and vegetation indices to better understand forest dynamics and develop strategies for forest conservation. The chapter discusses how remote sensing spectrum imaging techniques can be used to analyze a variety of biophysical and vegetation indices to plan and monitor various forest management operations. Last Part IV of the book volume includes the chapters with a focus on "Advanced institutional provisions and governance framework" for forest dynamics and conservation. Part IV includes three relevant chapters (Chaps. 20–22). Chapter 20 by Adhikari and Baral is a case study from Nepal on World Bank's Forest Carbon Partnership Facility on its Emission Reductions Program (ER-Program). The chapter discusses the mega drivers of forest loss and highlights the potential of ER-Program to address the drivers of emissions-causing deforestation and forest degradation and enhance forest carbon stock, ultimately paving the way for results-based payments for future emissions reductions for Nepal. Scandizzo and Abbasov in Chap. 21 of this section bring insight into the Public Interests and Private Incentives in Designing an Ecological Payment System. The chapter assesses the main opportunities for a Payment of Ecosystem Services (PES) in selected areas of Azerbaijan and investigates its impact, development, and potential through an implementation approach. The last chapter of this section (Chap. 22) by Isa et al. covers the importance of the awareness and Conservation Program at Ecotourism Sites through a case study example from Langkawi Island, Malaysia. The chapter stresses the need for more planned awareness and conservation programs to enable tourists and ecotourism operators to appreciate and have a better understanding of taking care of the environment at ecotourism sites. We are sure this makes a great read for finding diverse concepts and innovations related to forest dynamics, conservation science, innovations, and policies for reducing deforestation and forest degradation all compiled in a single volume.

Through this book volume, editors, as well as authors, expect a satisfactory response and if also possible feedback from readers belonging to diverse backgrounds and fields for encouraging productive critiques, that facilitates intuitive and foresighted professional discussions for forest dynamics, conservation science, innovations, and policies for reducing deforestation and forest degradation by identification of new research issues to fill the existing gaps.

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