IUFRO World Series Vol. 45

FORESTS AS PILLARS OF SOCIAL AND ECONOMIC RESILIENCE

A Global Assessment Report

Editors: Craig R. Allen, Nelson Grima,
Viola Belohrad, and Brendan Fisher

CPF
Collaborative Partnership on Forests

IUFRO
Interconnecting Forests, Science and People



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Funding support for this publication was provided by the German Federal Ministry for Economic Cooperation and Development, the Ministry for Foreign Affairs of Finland, the United States Forest Service, and the Austrian Federal Ministry of Agriculture and Forestry, Climate and Environmental Protection, Regions and Water Management. The views expressed within this publication do not necessarily reflect the official policy of the governments represented by these institutions/agencies or the institutions to whom the authors are affiliated.

Publisher:
International Union of Forest Research Organizations (IUFRO)

Recommended catalogue entry:

Craig R. Allen, Nelson Grima, Viola Belohrad, and Brendan Fisher (eds.), 2025. Forests as Pillars of Social and Economic Resilience. A Global Assessment Report. IUFRO World Series Volume 45. Vienna. 224 p.

ISBN 978-3-903345-36-2
ISSN 1016-3263

Published by:

International Union of Forest Research Organizations (IUFRO)

Available from:

IUFRO Headquarters
Secretariat
Marxergasse 2
1030 Vienna
Austria

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Language editor: Eva-Maria Schimpf

Layout: Jak Wagnon

Cover photographs: *Left* – Community forestry in Guatemala © INAB Guatemala
Centre – Mango tree in Torem village, Burkina Faso © Tree Aid
Right – Kogi village in Colombia © Viola Belohrad

Printed in Austria by Ferdinand Berger & Söhne GmbH, Wienerstraße 80, 3580 Horn

Preface

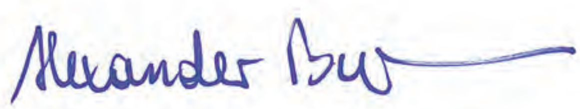
Since its establishment in 2007, the Global Forest Expert Panels (GFEP) Initiative of the Collaborative Partnership on Forests (CPF) has been effectively linking scientific knowledge with political decision-making on forests. GFEP responds to critical forest-related policy concerns by consolidating available scientific knowledge and expertise on these issues at the global level. It provides decision-makers with relevant, objective, and accurate information, and thus, makes essential contributions to increasing the quality and effectiveness of international forest governance.

This report, titled "Forests as Pillars of Social and Economic Resilience", presents the results of the ninth global scientific assessment undertaken within the framework of GFEP. All GFEP assessments are prepared by internationally recognised scientists from varied professional backgrounds and geographical contexts. The publications are presented to stakeholders across relevant international policy fora to support more coherent policies on the role of forests in addressing the environmental, social, and economic challenges reflected in the United Nations Sustainable Development Goals (SDGs).

Given the increasingly rapid, unpredictable, and unprecedented global changes linked to the Triple Planetary Crisis of pollution, climate change, and biodiversity loss, fostering resilience has become a key policy issue. Many organisations have adopted resilience strategies across various policy areas aiming to enhance societal capacities for 'bouncing back' and adapting in the face of shocks and disturbances. Moreover, the capacity to persist, adapt, and transform is considered a fundamental prerequisite for achieving the SDGs.

Forests are among the most vital and versatile ecosystems on our planet and provide critical benefits for human societies. For example, they provide food and livelihoods, regulate climate, and are of great cultural and spiritual importance to communities around the world. This assessment explores how forests contribute to social and economic resilience in the face of disturbance and change, and how societies can, in turn, support and steward resilient forest systems. By focusing on the dynamic interlinkages between forests, people, and policy, the assessment provides a knowledge base for decision-makers, practitioners, and researchers seeking to understand and strengthen just forest-based pathways to resilience.

As the world continues to grapple with multiple intersecting crises affecting forests and people, from environmental polycrisis to increasing inequality and conflicts, we hope this publication will inform, inspire, and support more integrated and equitable approaches to forest policy and practice in the years to come.



Alexander Buck
IUFRO Executive Director

Acknowledgements

This publication is the product of the collaborative work of scientific experts within the framework of the Global Forest Expert Panel (GFEP) on Forests as Pillars of Social and Economic Resilience, who served in different capacities as panel members and authors. We express our sincere gratitude to all of them:

Kofi Akamani, Craig R. Allen, Lord Ameyaw, Mukesh Bhattarai, Rachel Carmenta, Saudamini Das, Maria Mar Delgado-Serrano, Shalini Dhyani, Ida N.S. Djenontin, Amy Duchelle, Joice Ferreira, Ahjond Garmestani, Santiago Izquierdo-Tort, Anne M. Larson, Antoine Libert-Amico, Kathleen McGinley, Mani Nepal, Juan M. Pulhin, James Reed, Juan Rocha, Gabriela Russo Lopes, and Krystyna Swiderska.

Without their efforts and commitments, the preparation of this publication would not have been possible. We are also grateful to the institutions and organisations to which the authors are affiliated for enabling them to contribute their expertise to this assessment. At the same time, we wish to note that the views expressed within this publication do not necessarily reflect the official policy of these institutions and organisations.

We acknowledge, and sincerely thank, the reviewers of the report, whose comments have greatly improved the quality of this publication:

Roberto Andres Bosch, Elena Cantarello, Ellyn Kathalina Damayanti, Lalisa Duguma, Reem Hajjar, Constance L. McDermott, Laura Nikinmaa, Tobias Plieninger, and Alark Saxena.

We also gratefully acknowledge the generous financial and in-kind support provided by the German Federal Ministry for Economic Cooperation and Development, the Ministry for Foreign Affairs of Finland, the United States Forest Service, and the Austrian Federal Ministry of Agriculture and Forestry, Climate and Environmental Protection, Regions and Water Management.

Our special thanks go to the IUFRO Secretariat for providing indispensable administrative and technical support.

Craig R. Allen

Nelson Grima

Viola Belohrad

Brendan Fisher

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List of Acronyms, Units, and Symbols

ACM	Adaptive Collaborative Management
ACOFOP	Association of Forest Communities of Petén, Guatemala
AD	Afro-Descendent
AI	Artificial Intelligence
CAS	Complex Adaptive System
CBFM	Community-Based Forest Management
CBNRM	Community-Based Natural Resource Management
CF	Community Forestry
CFUG	Community Forest User Group
COP	Conference of the Parties
CPF	Collaborative Partnership on Forests
EbA	Ecosystem-based Adaptation
EKC	Environmental Kuznets Curve
ERI	Economic Resilience Index
ES	Ecosystem Services
EU	European Union
EUDR	EU Deforestation Regulation 2023/1115
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest Landscape Restoration
FPIC	Free, Prior, and Informed Consent
FSC	Forest Stewardship Council
FTT	Forest Transition Theory
GBF	Global Biodiversity Framework
GDP	Gross Domestic Product
GFEP	Global Forest Expert Panel
GIS	Geographic Information System
GPS	Global Positioning System
ICT	Information and Communication Technology
IIED	International Institute for Environment and Development
IFM	Integrated Fire Management
ILAs	Integrated Landscape Approaches
ILK	Indigenous and Local Knowledge
ILO	International Labour Organization
IoT	Internet of Things
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IP	Indigenous Peoples
IPLC	Indigenous Peoples and Local Communities
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature

IUFRO	International Union of Forest Research Organizations
JFM	Joint Forest Management
KEF	Kalahan Educational Foundation
LC	Local Communities
MEA	Millennium Ecosystem Assessment
MLG	Multi-Level Governance
NbS	Nature-based Solutions
NGOs	Non-Governmental Organisations
NPP	Net Primary Production
NTFP	Non-Timber Forest Product
PEFC	Programme for the Endorsement of Forest Certification
PES	Payments for Ecosystem Services
PDO	Protected Denomination of Origin
PGS	Polycentric Governance Systems
PSA	Costa Rican scheme for payments for ecosystem services (*Spanish: Pago por Servicios Ambientales*)
REDD	Reducing Emissions from Deforestation and forest Degradation
RRI	Rights and Resources Initiative
SDGs	UN Sustainable Development Goals
SES	Social-Ecological System
SF	Social Forestry
SFM	Sustainable Forest Management
TEK	Traditional Ecological Knowledge
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
VFC	Village-level Forest Committee
WRI	World Resources Institute
WWF	World Wildlife Fund

Chemical Compounds, Units and Symbols

The International System of Units (SI) is used in this publication.

CO_2	Carbon dioxide
EUR	Euro
ha	Hectare
km	Kilometre
m^3	Cubic metre
Mha	Million hectare
USD	United States dollar

1

Chapter 1

Introduction

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Lead Authors: *Kofi Akamani, Rachel Carmenta, Saudamini Das, Maria Mar Delgado-Serrano, Shalini Dhyani, Ida N. S. Djenontin, Joice Ferreira, Anne M. Larson, Kathleen McGinley, and Mani Nepal*

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1.1 Forests for social and economic resilience

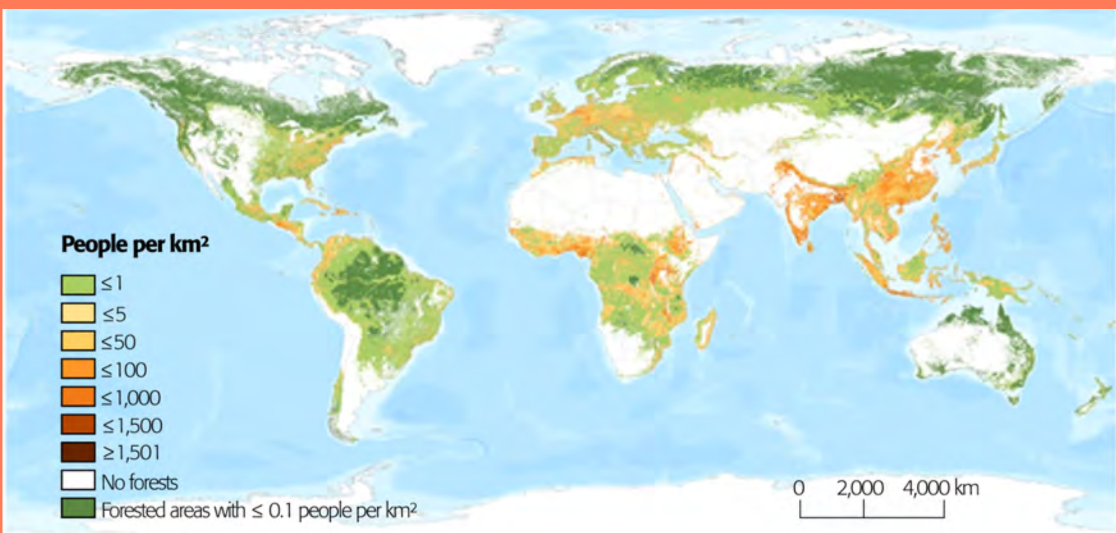
Forest[1] cover constitutes approximately 31% of the terrestrial surface of the Earth (FAO, 2024) and forests contain 80% of the Earth's terrestrial biodiversity (Rizvi et al., 2015). Following FAO's definition (FAO, 2023), in this assessment report forests are understood as land areas spanning greater than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds in situ, not including land that is predominantly under agricultural or urban land use. Forests are identified by the presence of trees and the absence of other land uses, including forests that have been subjected to disturbances such as clear-cut logging, but are expected to recover within 5 years. According to this definition, forests range from natural old-growth *ecosystems* to managed stands optimised for resource yields.

Forests are critical for humanity. Around 4.17 billion people, approximately 54% of the world's population, live outside urban areas that lie within 5 km of a forest (Figure 1.1), the vast majority of which live in *low- and middle-income countries* (Newton et al., 2022). The implications of this close connection resonate across society at every level. People living close to forests often have direct or indirect dependence on the ecosystem goods and services they provide. These range from the provision of food and fibre to microclimate cooling benefits and pest regulation. Forests provide sources of livelihood for the rural poor and the majority of livelihood resources for forest-dwelling, low-income households (Djenontin et al., 2024; TEEB, 2010; Wale et al., 2022). However, forest benefits are not only limited to proximate peoples. The rest of the planets' inhabitants are also impacted by forests and their condition, or '*state*', in both direct and indirect ways. For example, recent estimates indicate that approximately six billion people regularly use non-timber forest products (FAO, 2024; Shackleton and de Vos, 2022).

Forests help maintain the broader health and well-being of human communities through socio-cultural benefits; they moderate the climate, including having an impact on global carbon and water cycles; contribute to hazard prevention; and provide leisure and mental health benefits through recreation and tourism (Akamani et al., 2015). *Reforestation* (and *afforestation*) efforts play a large part of the solutions to the global carbon problem (Bastin et al., 2019; Mo et al., 2023). For example, in order to mitigate climate change impacts, a study found that 28 countries relied on the afforestation, conservation, or sustainable management of forests to increase their carbon sequestration potential (Sato and Nojiri, 2019). Forests also supply goods and services to adjacent and non-adjacent landscapes, creating benefits for those landscapes as well.

Forests may also produce a range of disservices (property and infrastructure damage during storms, human injury and fatality during storms or wildfires, pollen allergies, habitat for wildlife leading to human-wildlife conflicts, increased

Figure 1.1 Global distribution of *forest-proximate people*



Source: Newton et al. (2022)

1 All terms that are defined in the glossary of this report (Appendix 1) appear in italics the first time they are mentioned in a Chapter.

risk of wildfires if not well managed, etc.), though attempts to assess forest disservices are rather limited compared to the assessments of forest services. Similar to beneficial forest services, disservices can be provisioning, regulating, or cultural and vary widely in degree and extent of impact (Ninan and Kontoleon, 2016). Most of such disservice valuation has been for urban landscapes and the value of disservices is viewed as relatively small in comparison, some 5% or less, of the value of services people get from urban forests (Wu et al., 2021). In other words, despite some negative impacts, forests offer a myriad of crucial benefits to humanity, resulting in an overwhelmingly positive overall impact.

Forests and the people who live within, near, or even distant from them constitute complex social-ecological systems (SES); a social-ecological system is composed of both humans and nature interacting at multiple scales. People and nature interact and reinforce the processes and feedbacks that maintain forests and their ability to support the linked human systems (Warziniack et al., 2024). Because many human communities, societies, and cultures have developed within or proximate to forests, forests are an integral component of many societies, and forests and people often represent a tightly coupled *forest social-ecological system* (SES). For example, cultural use of fire in some forests can maintain and renew desirable fire-dependent forest vegetation that benefits humans, and regrowth following fire eventually encourages more fire. As such, humans, fire and vegetation positively reinforce each other. A clear example of this is the longleaf pine forest of the Southeastern United States (White and Harley, 2016). On the other hand, in fire-sensitive forest landscapes, traditional fire management practices among rural communities and Indigenous populations play a critical role in preventing fires from spreading and evolving into uncontrolled wildfires (Christianson et al., 2022; Fischer, 2018; Lake et al., 2017). Forests are home and territory to lifeways that have been shown to be highly consonant with nature, and hence, those human populations can provide significant insight on what forms of *governance*, values, and knowledge can enable people, biodiversity, and forests to co-exist (Carmenta et al., 2023).

Forest SES are experiencing rapid rates of change that challenge their ability to adapt or mitigate that change and be resilient. These challenges threaten the ability of forests to recover from stress and shock and the capability of forests to contribute to social and economic resilience. The concept of *resilience* has been used somewhat differently among scientific communities but captures both the ability to recover from shocks and the dynamics when a critical threshold is exceeded, and recovery may not be possible. The differences in these two definitions are discussed more thoroughly in Chapter 2. Resilience is a positive attribute when it maintains capacity for adaptation, learning, and/or *transformation* (Arctic Council, 2016), and the system is in a desirable state. ***Social resilience*** is the ability of households, communities and cultures to cope, respond, and maintain or enhance their *multidimensional well-being* equitably in response to stresses and disturbances resulting from social, political, economic, and environmental change (Adger, 2000). We define ***economic resilience*** as the ability of the economic system to cope, recover, and reconstruct with equity after a shock, minimising the aggregate welfare losses. Maximizing aggregate welfare is macroeconomic resilience, whereas distributional issues such as vulnerable households suffering more is a consideration in microeconomic resilience (European Commission, 2018; Hallegatte, 2014). **Social-ecological (SES) resilience** is the capacity of interconnected social, economic, and ecological systems to cope with hazards, disturbance, or slower change, responding or reorganising in ways that maintain their essential function, identity, structure, and the capacity for self-organisation. Resilience is a concept rooted in understanding and coping with change in SES and is well-suited for application to forests. In this assessment report we address the questions: 1) How do forests contribute to social and economic resilience, 2) What are the relationships between forests and social and economic resilience, and 3) how resilient are forest SES?

To address the questions above, we first start by framing our work around the concept of social-ecological resilience (Chapter 2 focuses on our framing). We apply our framing to forests and their contributions to social and economic resilience. To do so, we describe forest-people relationships, governance, resilience assessment, and responses to unwanted change. In examining response options and their *resilience-enhancing attributes*, we consider approaches that may maintain or support forests that are in a desirable state (i.e., those with relatively high ecological integrity) and their contributions to social and economic resilience, as well as response options that may provide for positive transformation of forest systems considered to be in an undesirable state, or that experience collapse. In answering these broad questions, we also account for issues of well-being and equity.

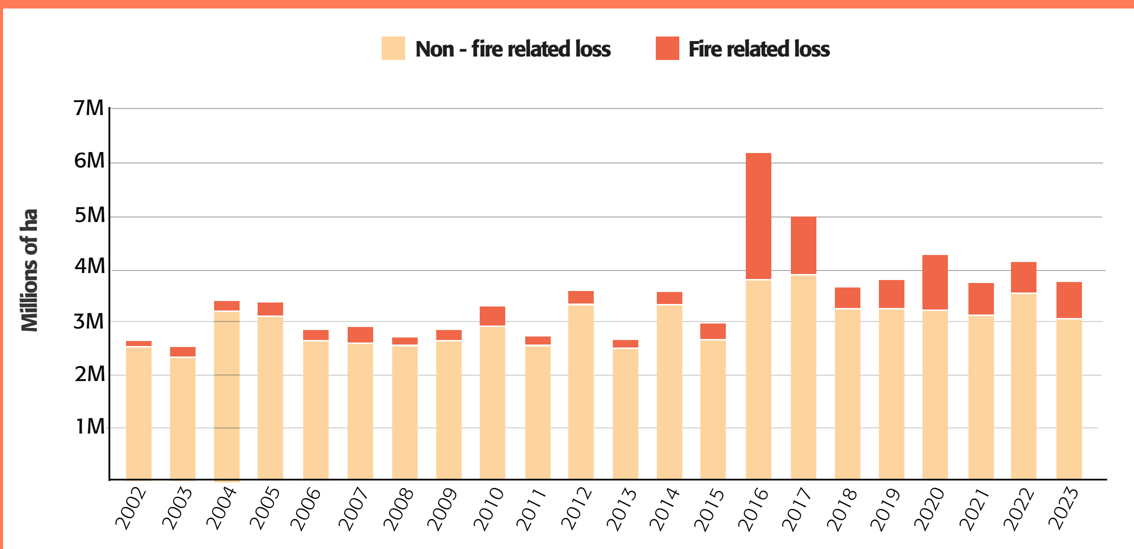
1.2 Sources of change in forests

Forests are increasingly threatened by widespread degradation and fragmentation and that compromises their structure, composition, and function (Estoque et al., 2022) as well as the overall forest extent. The world's forests face increasing pressures from growing demand for forest products and alternative land uses such as agriculture, driven by increasing human populations and consumption and the escalating throughput of economies. Multiple demands on limited forests often force hard and unjustly distributed trade-offs regarding forest uses and benefits. There has been some recent good news for forests in many countries, in particular concerning *deforestation* rates, which have decreased recently (FAO, 2024) in several countries. For example, Brazil achieved striking reductions in deforestation during the mid-2000s to mid-2010s, although rates have fluctuated since then. Yet with ongoing demands for land and resources combined with limited forest governance and changing climate, the future of forests is unclear and demands continued, pressing, and urgent attention. As an example, the rate of loss in some forests, such as tropical primary forests (Figure 1.2) and mangrove forests, which provide critical buffers for uplands, remains a substantial concern.

Forests continue to be under threat from multiple drivers, including global climate change and other disturbances such as species invasions, wildfires, logging, fragmentation, over-extraction of forest products, and conversion of forest to non-forest land uses such as housing or agriculture. Such pressures threaten the relationship between forests and people, and the export of goods, services, and processes that enhance both social and economic resilience. In addition to direct change, such as the conversion of forests to intensive agriculture, global change threatens the resilience, and thus the persistence and sustainability, of forests and the social and economic systems that are directly or indirectly reliant upon them. Human demands on forests are increasing, ranging from additional needs for forest and forest-related products, to increasing populations dependent upon forests for livelihoods and greater needs for space for increasing human populations and infrastructure.

The United Nations has adopted the term Triple Planetary Crisis to capture the inter-related environmental threats of pollution, climate change, and biodiversity loss (Passarelli et al., 2021). Of those three stressors, arguably climate change and biodiversity loss have the most direct impact on forests, but *forest-dependent people* also are affected by pollution of both air and soils, which affect health and well-being, and therefore, both social and economic resilience of

Figure 1.2 Tropical primary forest loss, 2002-2023



Source: WRI (2024)

In Palangka Raya, Indonesia the air quality has dropped severely owing to peatland fires, causing local business closures while wealthier citizens fled the region. Photo © Bjorn Vaughn

affected peoples. Additionally, *forest degradation* itself can lead to air and soil pollution, for example via fires in forests, or runoff from clear cut forests.

Stressors of forests often interact, and the impact on forests can be more than the sum of the individual effects. For example, climate change increases vulnerability to stressors such as forest pest species and to disturbances that would otherwise be recoverable, for example, fire, with burnt forests becoming more prone to subsequent wildfires (Lapola et al., 2023). Fire can also change many of the ecosystem properties such as microclimate or soil properties, including effecting changes that can lead to increasing runoff, and thus, flooding (Certini, 2005). Fire also releases carbon into the atmosphere, reinforcing climate change, which is an example of undesired feedback. The combined influence of forest disturbances and deforestation can cause local extinctions and widespread biodiversity loss (Barlow et al., 2016), inducing feedbacks that further erode forests.

Stressors that affect forests and other social-ecological systems have increased such that local and global tipping points are being approached, and in many cases, may already have been exceeded. Global tipping points, or "planetary boundaries" threaten forests and their relationship with social and economic systems (Rockström et al., 2009). At the planetary scale, six planetary boundaries may have already been crossed: Biosphere integrity, climate change, novel entities, land-system change, freshwater change, and biogeochemical flows (Kemarau et al., 2024; Richardson et al., 2023; Steffen et al., 2015). When critical tipping points, or thresholds, are exceeded, the resilience of a system has been exhausted, and the system rapidly re-organises. Sometimes a system re-organises around the same structures and processes as before (e.g., catastrophic fire in forest resulting in re-establishment of the original forest cover); sometimes a completely different system emerges (e.g., catastrophic fire in forest resulting in the establishment of invasive grass cover). When the latter occurs, it may result in an undesired state of a system, providing fewer goods and services for humanity (Dhyani, 2023; Lindenmayer and Sato, 2018). When the thresholds that are crossed are global, all other smaller scale systems are affected. However, smaller scale systems such as an individual forest or a forest stand, may also have thresholds and may re-organise into a less desirable or undesirable state if those thresholds are exceeded.

Box 1: Urban forests for social and economic resilience

Urban forests, including trees and green spaces within cities and towns, are vital to enhancing social and economic resilience in increasingly urbanised landscapes (Battisti et al., 2024; Landry et al., 2020). They provide an example of the benefits derived from an often-overlooked forest type. More than half of the global population lives in urban areas, a proportion projected to rise to 68% by 2050, and urban forestry has become paramount in promoting sustainable and resilient cities.

Social resilience through urban forests

Urban forests contribute to social well-being by improving public health, community cohesion, and quality of life. Research has consistently linked access to green spaces with reduced levels of stress, lessened urban heat island effects (Borthakur et al., 2020), anxiety, and depression (Huang et al., 2024). Urban forests provide a natural escape from urban stressors, offering settings for physical activities such as walking, jogging, and cycling. Such spaces are particularly critical for marginalised communities that may lack access to private green areas (Sharifi et al., 2021; Wolf et al., 2020).

Urban forests promote social cohesion by serving as communal spaces where diverse populations can interact (Jennings et al., 2024). Such spaces encourage community engagement and provide venues for cultural and recreational activities, thereby promoting a sense of community and collective identity (Vogt, 2020). Urban trees also enhance educational opportunities, offering experiential learning for both children and adults on topics such as environmental stewardship, biodiversity, and sustainability (Diduck et al., 2020).

Studies have shown that equitable distribution of green spaces can reduce disparities in health and well-being across different socio-economic groups (Shukla et al., 2024). Programmes that involve local communities in urban forestry enhance resilience by empowering residents. This is especially true when these initiatives are designed to focus on specific needs of marginalised and most vulnerable populations. Thus, urban forests play a significant part in mitigating social inequalities and enhancing social resilience (Sharifi et al., 2021; Vogt, 2020).

Economic resilience fostered by urban forests

Urban forests are invaluable assets for economic resilience, offering both direct and indirect benefits to urban dwellers and others. From an economic standpoint, urban trees have been shown to increase property values and attract businesses and tourists. Studies estimate that properties with proximity to green spaces can experience value premiums ranging from 5% to 20% (Huff et al., 2020; Patel, 2024; Wolf, 2007). These elevated property values could lead to increased municipal tax revenues, which can be reinvested into further urban improvements and promotion of overall community liveability.

Indirectly, urban forests reduce costs associated with environmental management. For instance, trees mitigate the urban heat island effect, reducing the demand for air conditioning and consequently lowering energy costs for residents and businesses. Additionally, they improve stormwater management by intercepting rainfall and reducing runoff, which helps prevent costly flood damage to infrastructure (Berland et al., 2017).

Urban forests also play a critical function in supporting local economies. Related activities like tree planting and general maintenance of urban green spaces create employment opportunities in landscaping, horticulture, and arboricultural practices. Furthermore, urban forests also offer natural attractions that enhance the cultural and aesthetic appeal of cities (Parajuli et al., 2022; van Leeuwen et al., 2010), which can drive investment and increase economic rents in urban areas.

Urban green space in Vienna, Austria providing a natural escape from urban stressors and an important place for social and recreational activities. Photo © Viola Belohrad

How forest systems respond to change, how resilient they are to change and disturbance, and especially how forests contribute to social and economic resilience is the focus of this assessment. The FAO 2024 State of the Worlds Forest report (FAO, 2024) suggests that one solution to undesired global change is to make forest systems more resilient. What this means is that forest systems, systems of both people and nature, will be able to cope with change without suffering a 'collapse', meaning the loss of forests systems in desirable states. To be resilient, forest systems must have the capacity to mitigate change, adapt to change, or transform to a more desired state if their *adaptive capacity* is exceeded. These options are discussed in the following chapters of this report.

1.3 Scope of the assessment

Objectives

In recognition of knowledge gaps in understanding the contribution of forests to social and economic resilience and the need to further inform policymakers and other interested parties, IUFRO, on behalf of the Collaborative Partnership on Forests (CPF), tasked the Global Forest Expert Panel (GFEP) on Forests for Social and Economic Resilience to conduct a global assessment of current scientific evidence concerning the contribution of forests to social and economic resilience. The results are presented in this report, which seeks to synthesise current knowledge to inform relevant national and international policies and processes relevant to forests.

Approach

This report aims to not only identify gaps in knowledge, but also to make the relationships between forests and social and economic resilience more accessible and visible. In doing so, we cover key aspects of the relationships and provide a synthesised understanding of current knowledge that is broadly accessible and translatable into needed research, action, and policy. Many of the myriad benefits that forest provide humans with have been covered in other IUFRO GFEP assessments (e.g., Forests and Human Health, Forests and Poverty, Forests and Water, Forests and Food Security), and we minimise overlap with those other assessments by having a targeted focus on resilience. Being resilient allows a system to cope with change while still maintaining its essential structures and functions, avoiding undesirable outcomes as much as possible, and providing pathways for desired transformation where change is inevitable.

Our geographic scope is global. Forests are global and co-occur with humanity on all continents except Antarctica. Case studies and boxes highlight some specific bright spots and challenges, but only as examples. We seek to assess the relationships between resilience, forests, and people globally. Doing so means that we present findings that are broad and generally applicable, rather than drilling deeply into relationships between forests and people in particular areas and contexts.

This assessment has been carried out by scientists from around the world with diverse expertise, ranging from ecology and *forest management* to the social sciences applications and resilience thinking. The assessment was conducted by a core group of 14 scientists, with help from 8 additional authors. Our review focuses on syntheses of peer-reviewed literature, while also drawing from lived experiences, and respected global entities such as the Food and Agriculture Organization of the United Nations (FAO). We describe documented relationships and identify gaps in our knowledge to be filled. We forward and discuss response options, providing policymakers with a broad range of potential actions based upon current scientific evidence and knowledge. Response options address ecology, social sciences, including economics and governance, as does our underlying assessment in general.

Chapter synopsis – structure of this report

This report consists of seven chapters, including this **introduction, Chapter 1**. All chapters address the core problem statement regarding the need to have a better understanding of the resilience of forest SES to global change and the contribution of forests to social and economic resilience. A conceptual overview figure is provided in Chapter 2 and referenced throughout. The chapters address a range of scales related to the problem statement; here too Chapter 2 provides an overview and figure that is referenced throughout the report.

Chapter 2 provides the **framing** for this report, particularly in terms of resilience. It provides the theoretical basis for understanding resilience (Holling, 1973), and why resilience has important applied value for understanding change in systems of forests and people. The chapter contrasts the two dominant definitions of resilience, return time versus potential for collapse and emergence of a different type of system (Allen et al., 2019). It outlines concepts such as transformation (Chaffin et al., 2016), the purposeful reduction of resilience in an attempt to guide reorganisation to a desired system state, and *panarchy* (Gunderson and Holling, 2002), a concept underlying resilience that addresses cross-scale change in systems. A number of other concepts relevant to either our assessment, understanding resilience, or both are described, such as *telecoupling* (Liu, 2017). Chapter 2 provides a core list of resilience attributes, which is used in each chapter, though each chapter adds domain-specific attributes as well.

The **relationships** between forests and social and economic resilience are addressed in **Chapter 3.** The focus here is on the nature of the link between forests, and the resilience of social and economic systems to various stressors. Clearly, forests provide goods and services that benefit human well-being and economic prosperity, but the specifics of those relationships are usually vague on the one hand, or lost in very specific analyses on the other. This chapter also discusses some of the key feedbacks between forests and social and economic resilience. The chapter focuses on attributes of resilience that produce desirable and resilient outcomes. These outcomes reflect the system's capacity to respond to, recover from, or adapt to disturbances. They serve as indicators of how well the social and economic systems manage shocks, stresses, and changes, based on the resilience attributes in place.

Chapter 4 focuses on **governance and institutional** aspects of resilience. This chapter addresses the question of how governance and institutions affect the resilience of social and economic systems and mediate the relationships between forests and society. Governance determines, in part, the relationship between humans and their environment and affects resource use and management of forests in fundamental ways. Here, the focus is on governance attributes as well as underlying institutional drivers that influence social-ecological resilience. The chapter starts by highlighting different governance approaches related to managing forest SES and moves on to specifically focus on institutional attributes that influence SES resilience. It then offers a review of both historical and contemporary dynamics of governance to contextualise understandings. Through case studies, the chapter assesses various materialisations of the institutional attributes, and underlying drivers in supporting and/or undermining forest and social and economic resilience. Finally, the chapter provides recommendations on governance approaches to enhance forest SES resilience.

How to **assess resilience** has been, and remains, an open question in resilience science, and is the focus of **Chapter 5**. The ease of calculating return time following disturbance is one reason why many default to the simple definition of resilience as bounce back. But doing so misses an enormous body of theory, ignores nuance, and would fail to account for the dynamics of forests and people as *complex adaptive systems*. Chapter 5 focuses on concepts and frameworks related to assessing resilience, different approaches, including methods and indicators, which have been used by different disciplines in various settings, and the benefits and drawbacks to the approaches that have been forwarded. Critical concepts in resilience assessment are covered, such as scale, spatial resilience, dynamic resilience, tipping points, and alternative stable states. Different approaches to assessing resilience are described, as well as knowledge gaps that exist in this field. The policy implications of these evolving resilience assessment approaches are also discussed in this chapter.

At the core of our assessment is the determination of **response options** for maintaining or improving the resilience of forest SES and their contributions to social and economic resilience. This is the focus of **Chapter 6**. This chapter examines evidence from earlier chapters to forward potential policy or governance responses for improving or maintaining the social and economic resilience of forests, to both specific threats or more generally. Response options vary dependent upon how resilient a system is, and is expected to be in the future. The vulnerability of a given system is a function of the assets available for response and the governance and institutions present. A core assumption is that resilient forests hold increased potential for contributing to equitable social and economic resilience when supported by suitable response options that account for the diverse, complex, interdependent, and multiscale attributes of forests as social-ecological systems. Response options may support forest conservation, expansion, restoration, or sustainable use through diverse mechanisms involving for instance laws, rights, markets, or information amongst others. An overall goal for the chapter is to identify response options and interventions (e.g., policies and policy agendas, institutions, management approaches) with the potential to enhance forests' contributions to social and economic resilience that also support the ecological dimensions of resilience across different settings and scales. The focus is primarily on interventions that include forests and their sustainability, or resilience as a primary target (i.e., we focus on interventions that appear to have forests at their centre). However, some interventions with social or economic goals with their central focus outside of forests are also covered. Both incremental and transformative response options are discussed in hopes of highlighting the mutually supportive pathways towards more resilient forest SES.

We conclude our assessment with **Chapter 7** bringing forward synthetic **conclusions** from the chapters described above.

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2

Chapter 2

Resilience Framing for Forest Social-Ecological Systems

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Abstract

This chapter focuses on how we frame our assessment of forests for social and economic resilience. Forest ecology and management are rapidly transitioning, paralleling rapid global change that affects forests and the services and livelihoods they provide. During much of the twentieth century, forest policy has emphasised sustained yield management that focused on continuous and often maximised supply of timber by relying on experts and centralised institutions to manage forests that were assumed to be relatively stable and predictable. In many cases, this approach resulted in declining quality and quantity of forests, social conflicts, and rural poverty. More recently, forest stewardship has turned to the concept of *sustainable forest management* and this in turn has led to approaches focused on forest resilience. Forests epitomise social-ecological systems; they consist of not only trees but also humans, biophysical elements such as land, water and soil, and importantly, the feedbacks and relationships amongst these components. Social components, ranging from individuals to societies and economies interact with biotic and abiotic components in such a way that changes in one element can drive changes elsewhere, sometimes in unpredictable and non-linear ways. Here, we introduce social-ecological resilience as a concept to strive for in management, and one that recognises the links between forests, people, social systems, and economic systems. We utilise a social-ecological resilience lens to assess forest resilience and specifically the contributions of forests to social and economic resilience. Maintaining resilient forests, social systems, and economies is critical especially in a time when we are experiencing a period of rapid and extreme social, biophysical, and ecological change.

2.1 Introduction

Forest social-ecological systems (SES) face unprecedented challenges for adaptation and survival in the Anthropocene. Global climate change, species invasions, wildfires, logging, fragmentation, over-extraction of forest products and conversion of forest to non-forest land uses such as housing or agriculture threaten forests, their management, and their contributions to social and economic resilience. Forest management has tended towards increasingly complicated and industrialised forest-product systems with increases in efficiency and production of food, feed, fibre and energy. This has been achieved through inputs of fossil fuels for mechanisation and synthetic chemicals (e.g., fertilizers, pesticides), expanding scales of markets, and genetic breeding of a limited set of forest types and cultivars. Other consequences of industrialisation include the consolidation and specialisation of forest production systems, economies of scale pushing the simplification and standardisation of production modes (potentially squeezing out smallholders in the process), increased prevalence of lower diversity and degraded forests, the creation of complex economic and infrastructure networks such as processing, distribution, and markets, and dispossession of many forest-based cultures and associated attenuated values and forest management practices. This has led to more homogenous landscapes, knowledges and cultures, as has the global spread of invasive species that affect both managed and relatively unmanaged forests. Trees themselves are invasive in many systems, which has led to undesired afforestation where trees are invading grasslands or introducing elevated fire-risk to many landscapes. Achieving enhanced productivity can also result in a loss of soil fertility, salinisation, nutrient runoff, decline in biodiversity, loss of biocultural diversity and the autonomy for forest-based and proximate communities, decline in net income, increasing debt, greater income inequality, the loss of small and medium sized forests in some areas, forest fragmentation, and negative impacts on water quality and quantity. The overarching trends of consolidation and specialisation are accompanied by an increase in the frequency of shocks like extreme weather events, extensive fires, and geopolitical crises, which challenges *SES resilience* (Challinor et al., 2017).

In response to these and other challenges and drivers of change, forest ecology and management is rapidly transitioning; changes include embracing complexity and uncertainty, broadening the range of management goals and incorporating diverse knowledge systems and stakeholders. For much of the twentieth century, forest policy has emphasised a sustained yield management paradigm that focused on the continuous, and often maximised, supply of timber by relying on expert science and centralised institutions to manage forests that were assumed to be relatively stable and predictable, with predictability erroneously thought to be enhanced by fire bans (Putz et al., 2022). In many cases this approach resulted in declining forest health, social conflicts, rural poverty, and in some cases, increased flammability. More recently, forest stewardship has turned to the concept of sustainable forest management as a holistic approach to advancing both forest health and human well-being by managing forests to derive diverse social, economic, and ecological values for present and future generations (Faison et al., 2023). One approach to sustainable forest management that has received significant attention in recent decades is ecosystem management. Ecosystem management (Grumbine, 1994) assumes that forests are complex and dynamic systems that interact with human systems in a reciprocal manner across multiple spatial and temporal scales. The overall goal of ecosystem management is to manage forests to meet a range of social, economic, and ecological values while also enhancing the resilience of the coupled social-ecological forest system to cope with change over time. Collaboration among stakeholders across different land ownership types within and across landscapes is also an essential feature of ecosystem management. Diverse systems of knowledge, including across scientific disciplines, and integration of traditional and scientific knowledge, inform ecosystem management. More recently, the concept of climate-smart forestry (Verkerk et al., 2020) has also emerged as an approach to sustainable forest management that seeks to manage forests in a manner that also mitigates climate change effects and allows adaptation with changing conditions. Both ecosystem management and climate smart forestry broaden the scope of forest management to include the provision of multiple *ecosystem services*. These approaches share a recognition that these systems are complex, with ecological and social components equally important, constantly changing (non-stationary), not at equilibrium, and that understanding their response to both fast and slow change is critical. This highlights the need for a deeper understanding of the concept of resilience, its implications for forest social-ecological systems and for forest contributions to social and economic resilience.

As a relatively nascent science like forest stewardship and ecosystem management, both resilience theory and practice are rapidly evolving and multiple approaches and frameworks for assessing resilience have been developed, often mirroring different interpretations of resilience. Resilience has had two somewhat divergent interpretations (see Section 2.2 below), focusing on either the rate of recovery following disturbance (termed engineering resilience, bounceback, or resiliency), or the ability to persist despite disturbance without collapsing (termed ecological resilience, or more recently, social-ecological resilience) (Allen et al., 2019; Nikinmaa et al., 2020). Fragmentation in the use of the term resilience has also occurred due to disciplinary applications and traditions, for example focusing solely on social or ecological resilience. Having a consistent definition of the term resilience is important, because the two primary current definitions precipitate considerably distinct implications for forest management. One suggests that forests are always resilient, and recovery is just a matter of time, whereas the other definition recognises that recovery is not always a given, and that *regime* change can be unavoidable. Here, we utilise the body of theory that is currently referred to as social-ecological resilience (SES resilience), which considers resilience as a measure of a systems' ability to cope with disturbance and change, both of which are increasing with increasing human dominance of the biosphere. Simply defined, SES resilience is the amount of disturbance a system can withstand without crossing a tipping point and organizing into a fundamentally different system state (Holling, 1973). Another way of describing this is that **SES resilience is the capacity of a social-ecological system to absorb and withstand perturbations and other stressors such that the system stays in the same regime and persists, maintaining its essential structure and functions**. It describes the degree to which the system is capable of self-organisation, learning, and adaptation (Gunderson and Holling, 2002; Walker et al., 2004). SES resilience best captures the dynamics of forest social-ecological systems and the tight coupling between humans, human cultures and livelihoods, and forests. Sustainability is a concept closely related to resilience; resilience and sustainability are related in that a sustainable system must be desirable and resilient to stressors, but it is possible that resilient systems can be undesirable and difficult to change.

It is difficult to assess the resilience of a forest system to all stressors combined (i.e., to determine its '*general' resilience*). Assessment is more straightforward when considering the resilience of what, to what, and for whom

(Carpenter et al., 2001). In other words, assessing the resilience of a particular system or part of a system to a particular stressor (*specific resilience*) is more straightforward. For example, asking "how resilient a forest social system is" (general resilience), versus asking "how resilient are individual forest-based incomes to drought" (specific resilience), will provide different answers, and answering the latter type of question is far simpler than the former. Similarly, systems are nested hierarchies, and the extent of the system and the relevant scales need to be defined (for more, see Gunderson et al., 2022). The "for whom" is also critically important. Ecosystem management usually aims for a desirable state, but what is desirable varies amongst different interest or cultural groups. Further, the power, voice, and visibility of stakeholders is uneven giving unequal access to critical management strategies, and these strategies influence the feedbacks between forests and people, and the distribution of benefits and burdens related to forest ecosystem services.

We focus on the resilience of forest SES, forest contributions to social and economic resilience as a component of resilient forest SES, the critical role of feedbacks, and the contribution of forests in providing numerous ecosystem services and derived benefits such as well-being and resilience. These contributions are not only internal to forests but are exported to other systems, both immediately adjacent to forests and to more distant systems that are linked via telecoupling (see Section 2.6.3) to forest social-ecological systems. In the remainder of this chapter, we clarify our framework for forest SES resilience and provide background and definitions for key resilience concepts.

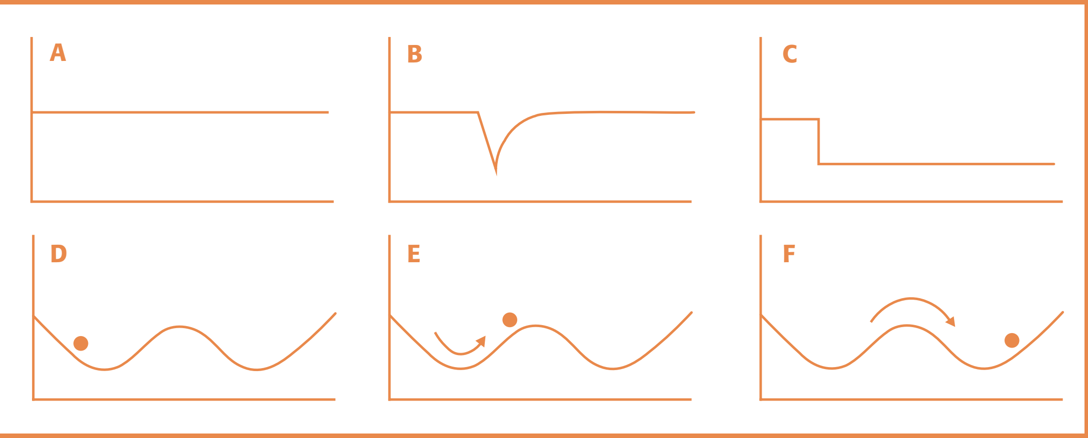
2.2 Resilience as a rate of recovery or as a system property

The greatest difference amongst alternative definitions of resilience is the contrast between the focus on resilience as a rate of return versus resilience as a system property. Resilience as a rate comes from engineering traditions and focuses on the return time of a forest (or other system) following disturbance. It usually focuses on recovery of a particular critical function or assemblage. Resilience as an emergent property follows the definition of resilience provided in Section 2.1 above, and more specifically refers to the extent and degree of disturbance a system can cope with without crossing a tipping point (Holling, 1973), where crossing a tipping point can lead to the emergence of an alternative state of the forest (see also Section 2.6.2), including emergence of non-forest systems, such as grasslands. Conversely, return time or recovery is easy to quantify but makes assumptions that are difficult or impossible to meet, in particular, assumptions of stationarity and of a single stable equilibrium in forest ecosystems. Furthermore, SES resilience includes return time, because most disturbances do not cause a system to cross a critical threshold (Figure 2.1). Quantifying resilience is in its infancy (see Chapter 5) but is advancing rapidly. Quantifying resilience is easiest after disturbance or stress that allows return time to be measured, or the location of a critical threshold identified. Because of this, proposed resilience metrics and assessment approaches are based on both theory and empirical analyses of past disturbance or collapse, and our knowledge of these dynamics is rapidly accumulating.

2.3 Forest contributions to social and economic resilience

Since the adoption of the Forest Principles at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, in 1992, efforts have been undertaken in various parts of the world to develop criteria and indicators for assessing progress towards sustainable forest management (Hickey, 2008). The scope of these assessments goes beyond the goals of conventional sustained yield forest management to cover a broad range of thematic areas: Enabling conditions for sustainable forest management; extent and condition of forests; forest ecosystem health and resilience; forest production; forest biological diversity; soil and water protection; and economic, social, and cultural aspects (ITTO, 2016). In 2006, the Montreal Process Criteria and Indicators were modified to include the resilience of forest-dependent communities as an indicator of social sustainability (Magis, 2010). In spite of this progress, these assessments are confronted with several challenges, including lack of capacity, lack of commitment, lack of enabling policy frameworks, limited stakeholder engagement, conceptual ambiguities, lack of valid and reliable indicators for assessing the social and ecological dimensions of sustainability, and challenges in the integration of assessment mechanisms across scales (ITTO, 2016). Insights from SES resilience can help address some of these challenges.

Figure 2.1 Differences between engineering and SES resilience



Source: Allen et al. (2019)

Models representing the resilience response of systems over time and to disturbances.

In **A** *to* **C** *resilience is shown in terms of a system trajectory (y axes) and time (x axes):*

(A) *A stationary system (no change over time) without disturbance. System trajectory does not change or vary.*

(B) *A stationary single-equilibrium system with disturbance. System trajectory drops with disturbance but bounces back with time. Here, the only metric is the time required to bounce back to equilibrium. Use of this model could lead to the erroneous conclusion that all systems will recover given sufficient time.*

(C) *A stationary single-equilibrium system with an alternative configuration of trajectory. This model fails to capture the potential for systemic changes between regimes that lead to completely different trajectories following disturbance.*

In **D** *to* **F** *resilience is considered from a complex adaptive systems and SES point of view illustrated through a "ball-and-cup" diagram, where balls represent the current condition of the system and each cup or "basin of attraction" represents potential states in which a system can exist:*

(D) *Ball-and-cup diagram of alternative states (cups) in a non-stationary, non-equilibrium system without disturbance. The diagram shows the state of the system (ball), which emphasises its complex adaptive nature, rather than a specific system structure.*

(E) *Ball-and-cup diagram of alternative states in a non-stationary, non-equilibrium system with disturbance. In this case, disturbance (shown by the arrow) does not exceed the resilience of the system. System trajectories are expected to vary but are maintained within a single basin of attraction (that is, it has adaptive capacity conferred by ecological-stability measures).*

(F) *Ball-and-cup diagram of alternative states in a non-stationary, non-equilibrium system with disturbance that exceeds the resilience of the system. The system is moved into an alternative basin of attraction, with completely different system level properties (performance, function, structures, processes, and feedbacks).*

In addition to differentiating the resilience of what, to what, and for whom, SES resilience addresses both social and ecological aspects of resilience. Rarely are resilience assessments equally social and ecological, but SES resilience attempts to remedy and rebalance this trend. Regardless of the level of integration, both social (which includes both material and non-material domains) and ecological aspects of forest resilience need to be considered in thorough resilience assessments. Although integrative measures of SES resilience may be preferred, in operation it is often easier and provides clearer answers to focus on social, ecological, economic, cultural, or other resilience aspects. Being more specific allows for more actionable assessments. Each of these areas can be further disaggregated, for example social resilience could focus on culture, multidimensional well-being, or human health, among others. Here, we are interested in assessing all aspects of forest resilience, and so engage multiple resilience targets, criteria, and indicators but with a strong focus on how and in what way forests contribute to social resilience and economic resilience.

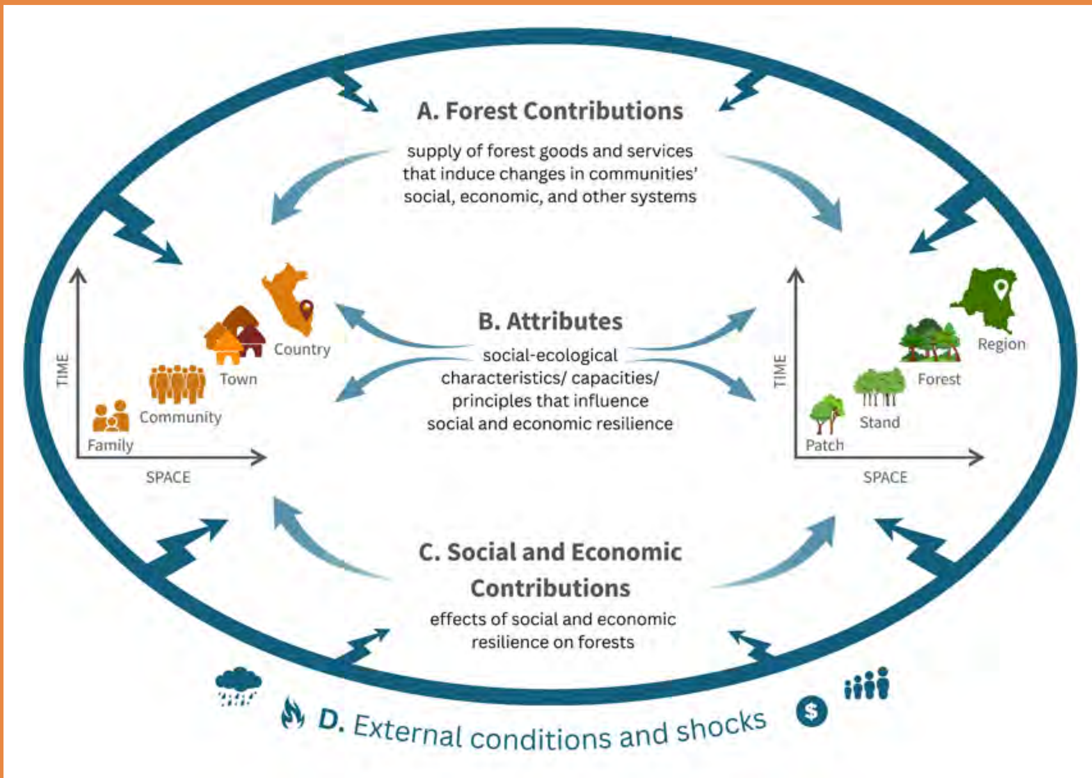
The resilience community has spent 20 years attempting to move from metaphor to measurement by answering the basic question posed in "Resilience of what to what?" (Carpenter et al., 2001; Section 2.3), but mostly for ecosystems at specific scales. The question "Resilience of what?" is also critical for forest SES resilience assessment. The resilience of forest social-ecological systems is important, and a forest system that is both resilient and in a desirable state will likely contribute valuable ecosystem services and help ensure the resilience of both proximate and distant non-forest SES (including social and economic dimensions). Our aim is to assess the resilience of the forest social-ecological systems themselves, but mostly to concentrate on the contribution of forests within the forest SES to the resilience of social and economic components of the forest SES. Resilient forests contribute to the overall forest-based SES, including human social systems and economies. In part, the contribution of forests to social and economic resilience comes from the production and export of ecosystem services (Figure 2.2). Evidence suggests that forests have the potential to contribute to both general and specific resilience (Cantarello et al., 2024). For example, the social and economic resilience of forest-dependent communities is affected by, among other things, the contributions of forest management policies to the *capital assets* and institutions that may shape the collective ability of community members to respond to various drivers of change while maintaining or enhancing community well-being (e.g., Akamani and Hall, 2015). Alternatively, other bodies of literature have focused on the contributions of forest management to the capacity of SES to deal with specific drivers of change. An example is the literature on climate-smart forestry that aims to understand and enhance the capacity of forest management to contribute to climate change mitigation and adaptation mechanisms (Verkerk et al., 2020).

2.4 Social-ecological systems

Forests epitomise social-ecological systems. They exist, in part, as a function of human agency, but are also dependent on biophysical elements such as land, water, and soil, and the feedbacks amongst all these components. Social components, ranging from the actions of individuals to societies as well as economies, infrastructure, policy, and more, interact with biotic and abiotic components such that changes in one element can drive changes elsewhere, sometimes in unpredictable and nonlinear ways. Further, these changes and new system states (Section 2.6.2) can influence decision-making, and the values held and pursued by individuals, communities, and societies, with impacts for forest social-ecological systems. Many approaches to understanding forest social-ecological systems consider forests as engineered systems, with the aim of optimizing the performance of individual components, such as a desired forest product or forest state. Many facets of forest management may increase efficiency but may also increase system rigidity, and thus, susceptibility to surprise, undermining resilience (Puettmann et al., 2009). It was, in fact, C.S. Holling's observation of boreal forest dynamics, with a slow accumulation of biomass and rapid release during budworm outbreaks that gave rise to the concept of ecological resilience, the precursor to SES resilience.

Approaching forest SES with engineering expectations of a stable equilibrium, linear dynamics, and predictable behaviour that can be returned to post-disturbance states, disregards the true nature of forests as complex adaptive

Figure 2.2 Conceptual diagram of the contributions of forests to social and economic resilience

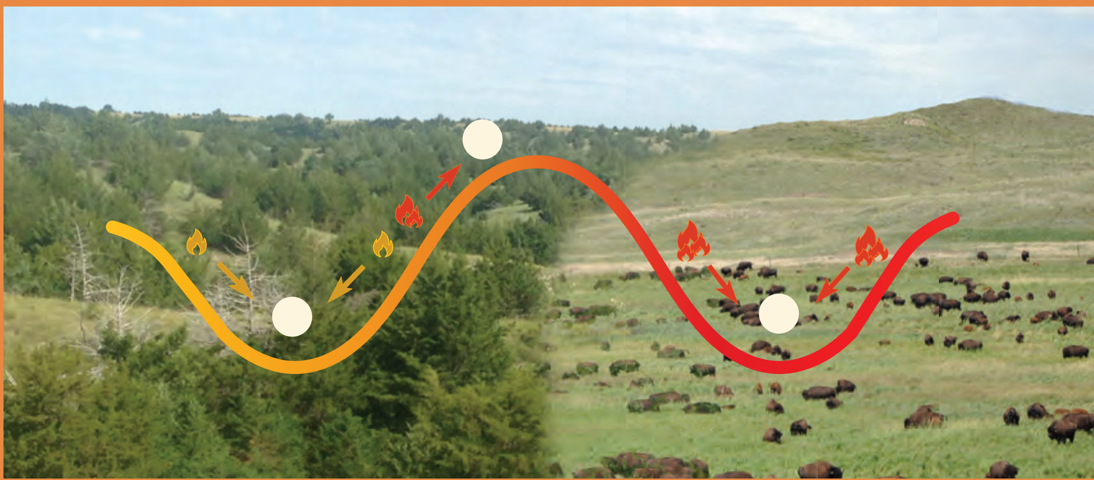


The diagram shows how both the social (and economic) systems (left side of diagram) and the forest itself are multi-scaled with interactions across scales and across the social and ecological components. We focus on different aspects of this diagram in different chapters of this assessment. Core attributes of resilience are listed in Section 2.11; more specific attributes are addressed in following chapters.

systems (CAS). Resilience theory developed as a response and alternative to equilibrium approaches and measures focused on stability. Resilience theory acknowledges that the systems of people and nature that we seek to manage are CAS with non-equilibrium dynamics, multiple stability domains, and non-stationarity tipping points. Forest social-ecological systems are CAS comprised of people and the biotic and abiotic environment that influence and are influenced by one another. As such, they operate out-of-equilibrium, have nonlinear dynamics and emergent phenomena, contain thresholds, include multiple scales of structure and processes, and can exist in multiple states (Gunderson et al., 2022). Viewing forest social-ecological systems as complex adaptive systems with the potential for alternative states is increasingly recognised in forest literature and management (Aszalós et al., 2022; Seidl and Lexer, 2013). Changes in external drivers (e.g., climate) and slow system variables (e.g., soils) can interact with system resilience such that even a small shock can push the system into a new state, where return to its previously defined structures, processes, and functions can be difficult or even impossible. This can be either positive or negative depending on the attributes of the system.

Resilience is appropriate for addressing knowledge gaps and identifying new paths to address the *vulnerability* of forest social-ecological systems across spatial and temporal scales. Because forest SES are characterised by shifting feedbacks among social and biophysical variables and processes that manifest at different scales and at different rates, employing a framework that explicitly recognises forest social-ecological systems as complex adaptive systems better reflects their dynamics (Figure 2.3).

Figure 2.3 Forests as complex adaptive systems that can exist in alternative stable states



Photos © Craig R. Allen

Shown are American Great Plains landscapes that can occur as woodlands or grasslands. Each state of the system is resilient. The graphic embedded within the photos is a ball and cup diagram of system state, where the troughs are basins of attraction, and the ball is the current state of the system. Disturbance or stressors can change the current state of the system, but as long as it stays within the basin of attraction, the system recovers. If the state of the system is moved beyond a critical threshold, it enters a different basin of attraction (in this case, forest becomes grassland). Part of the complexity of forest systems is the potential for forests to exist in alternative stable states (in this case, as forest or as grassland). Here, forests exist with infrequent fires, whereas grasslands emerge when there are frequent fires.

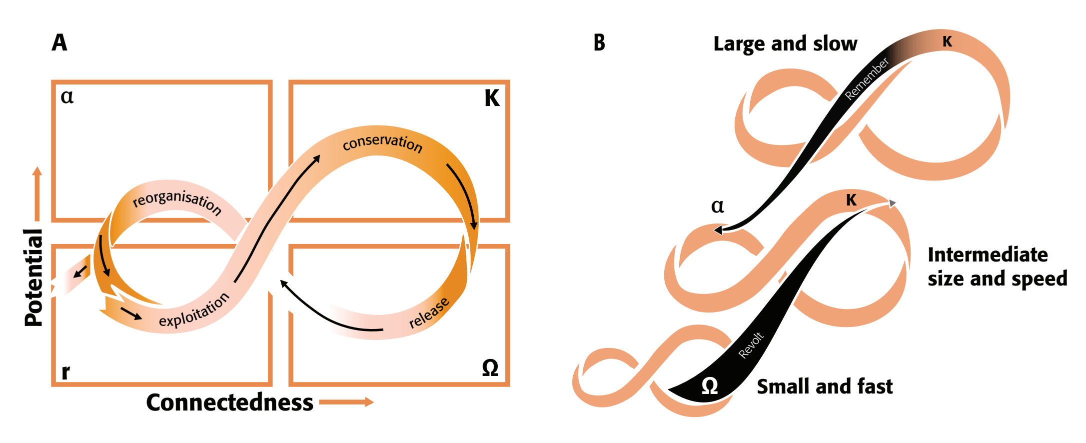
2.5 Cross-cutting issues (chapters 3-6)

Several issues, concepts, and terms are fundamentally important, and are identified, explored, and addressed throughout this assessment. Some have been addressed specifically in this chapter, others we preface very briefly below, as they will recur throughout the chapters that follow. These cross-cutting issues that are prevalent in all chapters are:

- General versus specific resilience: The 'of what, to what, for whom?'
- Scale: The spatial and temporal bounds of a system or process. Both within and across scale dynamics are important to forest resilience.
- Communities' versus wider societal resilience: Forest-dependent livelihoods and cultural ties at local and broader societal levels.
- Feedbacks: Critical in maintaining resilience; they occur across scales, across sectors, across systems, and across social and ecological dimensions.
- Cross-sectoral aspects: Interlinkages with biodiversity, agriculture, ecosystem services, disaster risk reduction, and social protection, among others.
- Equity: Important for social resilience and good governance; key feature of systems generally considered to be desirable or justice-centred.
- Gender: Closely tied to equity, gender dynamics influence access, roles, and outcomes related to forest SES resilience.
- Power: Power relations, especially as related to governance, shape resilience capacities and responses across systems.
- Indigenous and Local Knowledge (ILK), including Traditional Ecological Knowledge (TEK): Deeply rooted in place-based experiences, ILK offers valuable insights into resilience – yet it has often been undervalued and overlooked.
- Types of forests and their specific role(s): We cover forests of all types.

Photo © Viola Belohrad

Figure 2.4 Adaptive cycles and panarchy



Source: Adapted from Gunderson and Holling (2002)

A panarchy (b) is a nested set of adaptive cycles (a). Adaptive cycles occur at discrete scales in a SES, and multiple adaptive cycles form a panarchy. The idea of adaptive cycles and panarchy underlies much of SES resilience theory, with regime shifts occurring both when a system undergoes a complete adaptive cycle, and when scales are changed in a panarchy.

2.6 Theoretical background underpinning resilience

From its early conceptual origins, resilience has developed into a broad body of theory. Below we briefly describe some of that theory, as it is relevant and important for our assessment of forests for social and economic resilience.

2.6.1 Panarchy and adaptive cycles

The concept of panarchy emerged from resilience theory to explain observed patterns and dynamics of SES, as it became clear that SES are characterised by multiple regimes, multiple scales, and interactions within and across scales (Gunderson and Holling, 2002). Panarchy is a hierarchical conceptual model of SES, differing from Hierarchy Theory in that scales are viewed as dynamic, with the potential for change to flow from the bottom-up or top-down, instead of top-down only. A panarchy is a set of nested adaptive cycles, with each adaptive cycle occurring at a specific domain of spatio-temporal scale (Figure 2.4.b) (Gunderson et al., 2022). An adaptive cycle describes system movement through three-dimensional space among four phases that reflect system development over time (Figure 2.4a). The phases are growth, conservation, release, and reorganisation, and describe the accumulation of resources, including the long and slow conservation stage where these cycles are relatively stable and biomass and capital are bound up, leading to a rapid release of the accumulated resources often in response to a shock, and followed by a period of reorganisation (Gunderson and Holling, 2002). *Regime shifts* occur when the system is unable to reorganise into the same system reconfiguration (or 'basin of attraction') after release. In industrial forestry, for example, at the stand scale, forest SES deterministically follow this developmental sequence, short of a shock that destroys the trees prematurely, and it is common to artificially maximise the growth stage with external inputs (mechanisation, fertilizers, and pesticides) to optimise volume of harvest in the release phase.

Forest social-ecological systems are multi-scaled and consist of nested adaptive cycles (i.e., panarchy) (Gunderson and Holling, 2002). Each adaptive cycle reflects spatial and temporal dynamics at a particular scale, so one can conceive of a forest panarchy where adaptive cycle dynamics play out at tree, stand, forest, landscape, and biome scales, reflecting the key scales at which drivers, variables and processes operate and manifest. Cross-scale feedbacks reflect the way that slow variables shape the operating space for smaller scales (e.g., climatic drivers) and provide key system memory during reorganisation (e.g., social knowledge and economic capital), and fast variables can sometimes cascade up to drive change at larger scales (e.g., spread of spatially contagious disturbances such as pest outbreak).

2.6.2 Regime shifts

Regime shifts are often unexpected and are non-linear by nature, thus they have the potential to destabilise both social and ecological components of complex forest social-ecological systems (Scheffer et al., 2001). Regime shifts in forest social-ecological systems at multiple scales, from the forest worker to the production system, have serious implications for security, well-being, and livelihoods. Large-scale regime shifts in systems are relatively uncommon, but are extremely consequential, as in the United States Dust Bowl event of the 1930s that fundamentally changed ecosystems and livelihoods. This event was the consequence of overzealous ploughing of marginal lands that turned extensive tall grass prairies into unproductive land, reducing the resilience of the system, and was followed by drought, which served as the proximate cause that triggered the shift to blowing millions of tons of sand into the air. A source of concern for forests is that they are undergoing degradation at multiple scales, and in many cases, are vulnerable. As such, they are characterised by low resilience or are likely to experience large shocks. In many cases, the industrialisation of modern forest social-ecological systems prioritises optimising for efficiency at the expense of system characteristics that provide SES resilience. Insights from the application of resilience science to natural resource management underscore that a strategy of optimisation for productivity and efficiency leads to practices that defer risks into the future, where smaller perturbations can lead to more consequential collapses at larger spatial and temporal scales. The increased frequency of catastrophic fires in the Western USA, South America, Indonesia, and Australia, amongst others, and the almost total loss of native salmon fisheries in the USA's Pacific Northwest are examples of deferred risk, where a focus on managing for efficiency temporarily maintained stable production but pushed catastrophic collapse into a future that is currently unfolding.

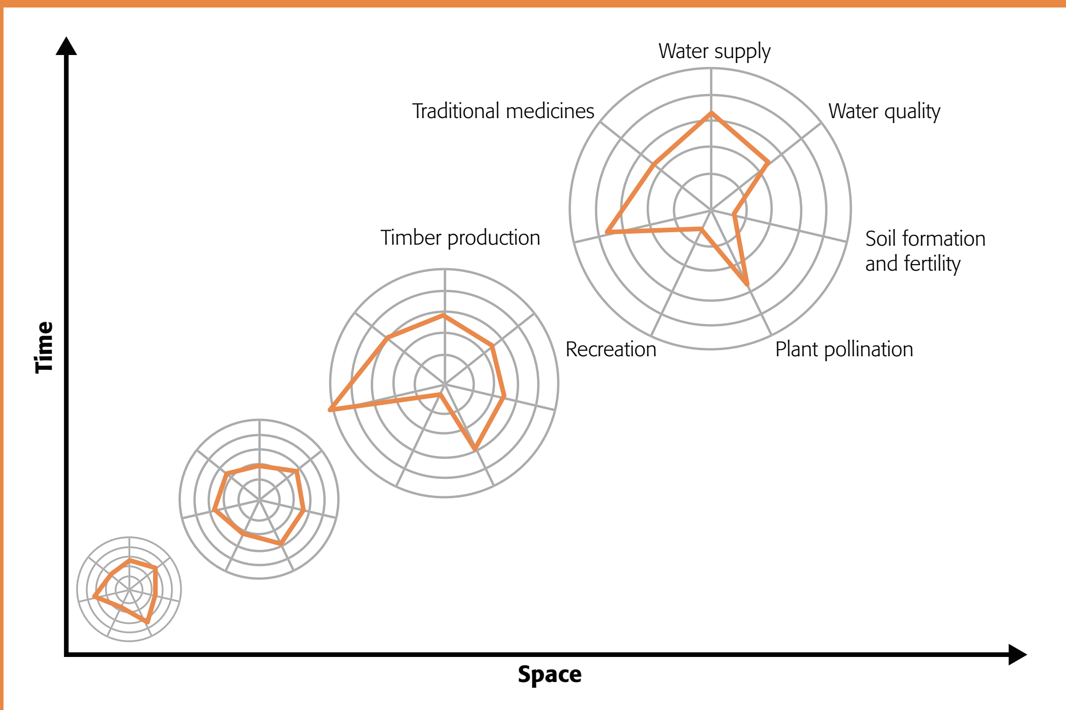
Photo © Viola Belohrad

System-level resilience, such as that of a national forest sector, is based in part on fluctuations and variability at smaller scales, where disturbance provides the impetus for adaptive capacity to develop the potential to maintain functions at larger scales. Yet, fluctuations at smaller scales, such as a forest patch, can affect the livelihood viability of forests and forest inhabitants. Sacrificing individuals, small communities, and forest patches in the quest for desirable resilience at larger scales is clearly problematic, but conversely, national policies that enable resilience of individual producers can lead to collapse at sectoral scales (Walker and Salt, 2012). Defining a regime and determining factors affecting resilience at one scale will need to consider the human and ecological trade-offs at other spatio-temporal scales (Figure 2.5).

Evaluating regime shifts that can occur when resilience is lost requires characterizing the underlying system drivers, slow variables and the dynamics arising from feedbacks among slow and fast variables (Biggs et al., 2012). Feedbacks between slow and fast variables, such as soil organic matter and forest biomass, shape the system's response to shocks (e.g., extreme weather events, geopolitical crisis, pandemics) and determine whether the system can buffer the shock or is pushed over a tipping point (Dakos et al., 2015).

Identifying leading indicators of undesired regime shifts is an urgent research focus for ecology and critical for humanity. Because undesired regime shifts (a desired regime shift with human agency is a *transformation*) often have negative consequences for humans, it is generally in humanity's interest to prevent these regime shifts and avoid the thresholds that separate regimes. Thus, there has been much focus on identifying leading indicators of regime change, some with promise, though most are criticised for identifying a regime shift after it is too late to prevent the shift (Dakos et al., 2015).

Figure 2.5 Examples of trade-offs across spatio-temporal scales



Trade-offs occur both within and across scales. For example, within a scale, an emphasis on timber production may necessitate decreased recreation and soil formation (upper right). Similarly, emphasizing water quality at a lower scale may reduce timber production at that and larger scales.

2.6.3 Telecoupling

Regime shifts are often abrupt, surprising, and undesirable for humans and nature (e.g., collapse of fisheries). In an increasingly connected world, regime shifts do not occur in isolation. Accelerating global change has heightened awareness of regime shifts and alternative stable states that may follow regime shifts, and earth system scientists are now seriously identifying the likelihood of regime shifts at regional and planetary scales beyond those traditionally studied in isolated systems such as lakes (Steffen et al., 2018). Telecoupling recognises the potential of SES, even those separated by time and space, to interact with one another laterally and/or vertically (between scales; cascading effects) (Liu, 2017). For example, conversion of Amazon Basin forest to soybean production simultaneously has global-scale influences on climate and commodity markets (affects near-to-distant SES), meso-scale influences on biodiversity, health, and employment (affects near-to-midrange SES), and local-scale influences on soil nutrients, cultures, and animal movements (affects near SES) (Barlow et al., 2018; Sun et al., 2017). The strength of these effects across scales is likely to depend on the scale at which the (for example) rainforest-to-cropland regime shift is occurring.

2.6.4 Other concepts

Other core SES resilience concepts used through these chapters include: **adaptive capacity**, a potential of SES activated in response to a crisis or opportunity that provides a flexible and effective response to changing circumstances or to a shock, so it is a function of the options available but also of an entities' willingness or ability to engage those alternatives (Angeler et al., 2019); **cross-scale resilience**, the presence and distribution of functional diversity and functional redundancy within and across system scales that acts to maintain function despite shocks (Peterson et al., 1998); **coercion**, the ways and degree to which internal processes of self-organisation are replaced by external inputs and mask the loss of resilience (Angeler et al., 2020); and **spatial regimes**, such as shifting climatic regions, or spatially contagious processes like invasion and disease spread (Roberts et al., 2019).

2.7 Resilience for whom – values

The role of human values is key to considering forest resilience. For example, while resilience is not considered normative, the concept of 'desirable state' is heavily influenced by preferences, and decisions based on profit-maximisation can (and have) heavily undermined the state of the world's forests. Often, value-misalignment (or cost-shifting) leads to locked-in forest management, because those that benefit (in material terms) from forest exploitation, are not those that suffer the (material, relational, and subjective) burdens of forest degradation, and the former often have more political power (Carmenta et al., 2017; Lapola et al., 2023). Preferences reflect values that people hold for nature and can influence decisions, resource management and allocation, and policy making. Further, forests represent many values for humanity (i.e., relational and material values) and potentially, values outside of those 'for' humanity (i.e., intrinsic values). The Millennium Ecosystem Assessment (MEA, 2005) placed the goods and services derived from forests (the ecosystem services valued by society) into four categories: Supporting, provisioning, regulating, and cultural services. There are multiple initiatives to account for these benefits monetarily. The Economics of Ecosystems and Biodiversity (TEEB, 2010) initiative of the United Nations Environment Programme mainstreamed these values by making a strong case for policymakers to account for ecosystem services in the decision-making process, making them a part of the national income accounting. More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) offered an extended typology of the plural values of nature, identifying three main groups of specific values of nature. These are the instrumental values (goods that can be used), the intrinsic values (nature has a value just for the fact that it exists, regardless of humans giving it a value or not), and the relational values (the people-nature relations, and people-people relations that are only possible as mediated by embeddedness) (Chan et al., 2016). The IPBES has documented the decline in nature's capacity to contribute to these values as a result of the environmental crisis, which it refers to as a values crisis, and principally the dominion of material values (and associated quest for capital accumulation) in the dominant development model (IPBES, 2019). Because values influence decisions and preferences, the changing state of forests, and therefore, the values associated with them, will induce new modes of practices, people-nature relations, and thus, forest states, in unending interaction and feedback.

Normative aspects

SES resilience is not normative in that it is simply a measure of a system's ability to cope with disturbance without shifting to an alternative state. However, what state of a system is desired is highly normative and also depends on perspective and positionality. Different social groups in the same forest SES may value very different forest states, and different forest states provide different suites of ecosystem services, degrees of well-being, and a myriad of other benefits as well as distribution of harms or burdens. Thus, determining what is and what is not a desirable system state is critically important, and the selection of one desired state creates winners and losers, as well as trade-offs among ecosystem services.

2.8 Resilience in economics

Economic resilience is defined as the ability of the economic system to cope, recover, and reconstruct, and therefore, to minimise welfare losses after a shock (Hallegatte, 2014; Noy and Yonson, 2018; Xie et al., 2018). Minimizing aggregate welfare loss is an aspect of macroeconomic resilience, whereas distributional issues like vulnerable households suffering more and being less resilient are aspects of microeconomic resilience. Households, communities, business sectors, and the state are the provisioning actors, and economic resilience of these actors is about their level of coping, speed of recovery, and degree of adaptation to stress. In economics, resilience has two components: static or instantaneous resilience, which is the ability to limit the magnitude of immediate production losses for a given amount of asset losses (coping); and dynamic resilience, which is the ability to reconstruct and recover fast (recovery and adaptation). Note, however, that different economic models value different outputs very differently (see Section 2.7 on values).

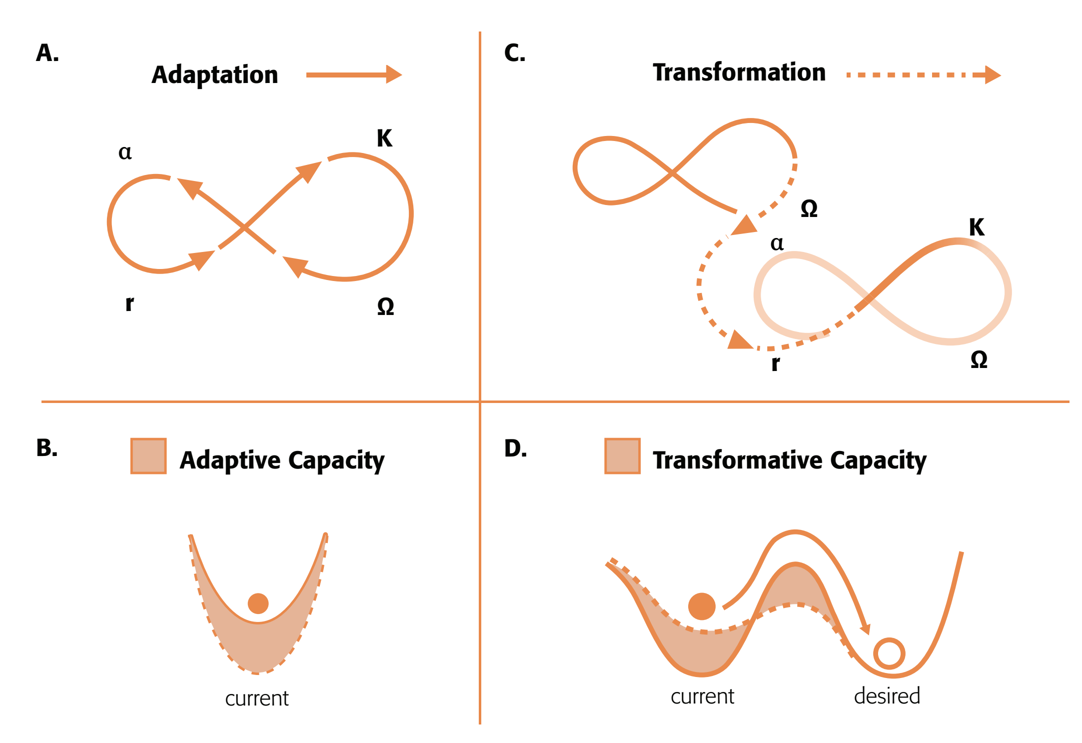
2.9 Vulnerability in forest social-ecological systems

Vulnerability concepts have their roots in the field of risks and hazards research. Vulnerability is often posited as the opposite, or inverse, of resilience (Adger et al., 2005). Systems with low resilience are vulnerable to regime shifts and other unwanted change. Vulnerability is therefore defined as the susceptibility of a system to being harmed from exposure to various stresses. Vulnerability has three key components: the exposure of a system to a given threat (the extent to which the system experiences the threat); the sensitivity of the system (the degree to which the system is likely to be affected by the threat); and the resilience of the system (the capacity of the system to absorb disturbances while maintaining its essential structures, functions, and feedbacks). Just like resilience, vulnerability is shaped by contextual factors, such as the availability and access to effective institutions and capital assets that determine the system's adaptive capacity. The resilience and vulnerability of forest ecosystems and other SES may be influenced by natural and anthropogenic drivers of change across scales, including climate change, natural ecosystem dynamics, policy implementation, technological change, demographic transitions, market dynamics, changing socio-cultural values, and so forth. Like resilience, vulnerability needs to be specified to have value; that is, vulnerability of the same forest may differ when considering different threats (e.g., climate change versus market forces). SES responses to these different threats may occur at different scales and may require the mobilisation of different kinds of resources and institutions to shape adaptive capacity (Keskitalo et al., 2011).

2.10 Role of 'transformation' in changing undesirable but resilient systems to desirable systems

Resilience theory has rapidly developed and expanded to include additional related ideas such as adaptive and transformative capacity. In a primer on key resilience traits in social systems, Cinner and Barnes (2019) noted ongoing debates about what constitutes adaptation (staying in the same regime) versus transformation (deliberately inducing a regime shift). Given the likely increase in non-linear and abrupt changes in our forested social-ecological systems, and the potential that undesired alternative states may emerge, and given the undesirability of many current forested landscapes (e.g., fire suppressed landscapes) transformation may be the only viable response to accelerating environmental change in some instances. Transformation is the process of intentionally shifting a social-ecological system to a more desirable, novel, self-organizing state, with its own unique set of structures, processes, and feedbacks (Jozaei et al., 2022). It is this human intention to shift a system to a more desirable state that distinguishes transformation from other types of regime shifts resulting in alternative forest (or non-forest) states. Transformation may occur when windows of opportunity open for people to erode the resilience of the current undesired system in order to push it into a new, desired alternate state (Figure 2.6). The range of future possible social-ecological system configurations is a

Figure 2.6 Differences between the dynamics of adaptive and transformative capacity for adaptation (A and C) and transformation (B and D) in social-ecological systems



Source: Michaels et al. (In press)

(A) Adaptation describes the response of a system to external stressors. It is associated with the adaptive cycle comprised of four distinct phases: growth or exploitation (r), conservation (K), collapse or release (Ω), and reorganisation (α). The adaptive cycle exhibits two major phases: the fore loop, from r to K, which is a slow phase of growth and accumulation; and the back loop, from Ω to α, which is a rapid phase of reorganisation that can lead to renewal.

(B) The degree to which a system (dot) can adapt and remain in the current basin of attraction (solid line) is linked to its adaptive capacity, which is the potential of a system to modify its resilience in response to change. Building adaptive capacity (shaded area) increases the state space of the current state (dotted line).

(C) Transformation is the process of intentionally shifting a system to a more desirable, novel, self-organizing state, with its own unique set of structures, processes, and feedbacks. Here there is a disruption of the current adaptive cycle (solid line) during the collapse or release (Ω) phase. It is during this window of opportunity that a new system can manifest during the reorganisation (α) phase, giving rise to a new desired adaptive cycle (paler area).

(D) The range of possible future systems afforded to transformation is a function of a system's transformative capacity, which is the potential for a system to be intentionally shifted to a new, self-organizing, desired state. A characteristic of transformative capacity is that it erodes the resilience of the current system (solid line) by either shallowing the current basin of attraction, or by lowering the resistance threshold between the current and desired state (shaded area, dotted line), such that the new desired state (hollow dot) can emerge.

function of a system's transformative capacity (Garmestani et al., 2019). The capacity for transformation may be shaped by the availability of capital assets, incentives, and opportunities for learning and experimentation among other factors. Emerging governance mechanisms, such as transformative governance (Chaffin et al., 2016), offer promise for addressing the critical requirements for transformation in SES.

2.11 Resilience attributes

Much has been written regarding system properties, principles, or attributes (henceforth referred to as 'attributes') that may affect or enhance resilience. Numerous lists of these properties have been forwarded in the scientific literature across a broad range of disciplines, often for very different ends or uses. Therefore, it is not surprising that there are differences within these lists as they vary from theoretical attributes contributing to general resilience to very applied attributes focused very much on the resilience of what to what (e.g., the resilience of communities to disease outbreak). In order to help sort these various attributes and apply them to the question of the contribution of forests to economic and social resilience, we generally agree with and use Meuwissen et al.'s (2019, p.5) definition of *resilience attributes* as "the individual and collective competences and the enabling (or constraining) environment that enhance one or more resilience capacities (robustness, adaptability, transformability), and, more broadly, general resilience", but we think that such attributes are also appropriate for specific resilience in many cases.

Below, we provide a list of some of the more commonly referenced attributes of resilience that have been forwarded. This list is not entirely comprehensive in the sense that when resilience concepts are applied to narrower domains, different attributes may be suggested, but there tends to be a large degree of overlap among them. Similarities arise because many attributes, especially of general resilience, are largely agreed upon within the scientific community, but differences arise as authors get more specific. Where differences are apparent, these relate both to how attributes are defined and to their focus and emphasis. For example, some lists emphasise characteristics of the system (e.g., Meuwissen et al., 2019), while others highlight very specific attributes (e.g., Maclean et al., 2014) appropriate only under some conditions. Additionally, the emphasis shifts depending on whether the discussion centres on the ecological or social dimensions (e.g., Biggs et al., 2012; Maclean et al., 2014) of resilience, or on both. Given our focus, we centre our assessment on the following core resilience attributes that are commonly accepted to be important across a variety of domains:

- **Diversity:** Diversity underlies resilience. Diversity should be considered both within and across scales. With diversity, **redundancy** is also important and may be especially important when it occurs at different scales in a system, in which case, redundancy serves as a cross-scale reinforcement. Redundancy is when a component of diversity, such as a function (e.g., pest control) is represented by more than one thing. For example, when considering functional diversity in avian species, gleaning insectivores are represented by many species and are especially useful when a disturbance at a smaller scale scales up, as is the case with forest insect outbreaks. Generally, more diversity and cross-scale redundancy enhance resilience.

- **Connectivity:** Connectivity and **modularity** both affect the flow of things and information through SES, both beneficial and harmful. Connectivity refers to the amount of connections in a system, and modularity is the internal division of the system into differentially connected parts. The 'right' amount of connectivity and modularity varies by system and by disturbance. Generally, a moderate degree of both, connectivity and modularity, enhances resilience.

- **Feedbacks:** Feedbacks are critical in maintaining self-organisation in a social-ecological system such as a forest. Beneficial feedbacks need to be identified and maintained.

- **Learning:** Learning, including **innovation** and creation of **novelty**, refers not only to social systems, but to ecological systems as well, which adapt and evolve following disturbances.

- **Capital** or assets: Physical, human, natural, social, and financial resources underpinning resilience; refers not only to finances but also to system elements such as biomass.

- **Polycentric governance:** Governance originating from multiple sources. *Polycentric governance* and the opportunity for **participation** at multiple levels is also beneficial for resilience.

- **Adaptive capacity**: Both social and ecological. Systems with a high adaptive capacity change over time in response to changing conditions. Adaptive capacity is a latent property of systems, which is different from learning or adaptation.

This list serves as the backbone of resilience attributes in general terms. As needed in the following chapters, this list is expanded upon. Possessing attributes associated with resilience is beneficial where the system is in a desired state. However, as one narrows the focus from high-level general resilience, to specific resilience, to specific disturbances, one can be more precise in determining resilience attributes. For example, when identifying attributes with particular relevance to forests and social and economic resilience. In the chapters that follow, these general attributes are the basis for understanding resilience, but additional attributes appropriate for the topic of the individual chapters are introduced as needed in those chapters.

One additional focus of particular importance in a resilience assessment is 'scale'. Not all attributes are relevant at every scale, and therefore, the identification of the scale of application is critical.

2.12 Chapter conclusions

Social-ecological resilience is a useful approach for a global assessment of forests because it focuses on general system properties that are common across forest social-ecological systems. It measures the ability of these systems to cope with change without collapsing and illuminates ways to navigate change. Resilience practice has matured (though is still rapidly evolving), and perspectives from multiple disciplines have been incorporated. Resilience theory now embraces SES dynamics and social aspects such as agency, well-being, diversity, equity, and more. A resilience approach focuses on ensuring desired outputs and benefits, such as stable social systems with individual and aggregate well-being, over a wide range of conditions under widely varying circumstances.

Resilience is an emergent property of complex systems, and put simply, is the amount and/or extent of disturbance or stress a system can cope with before it collapses and reorganises into a new state. Resilience is a system property and a body of theory, and as such, it encompasses ideas such as bounceback (return time, resiliency), alternative stable states, transformation, adaptation, and more. Many attributes of resilience have been proposed, but we base our assessment on a core list of resilience attributes, supplemented as needed in particular chapters. Attributes that are based on the understanding of resilience as bounceback are very different from attributes that consider bounceback as only one aspect of resilience. Within the literature focused on the broader concept of social-ecological resilience, there is commonality among many resilience attributes, but there are also many differences. Differences generally arise from different approaches and needs within sub-disciplines. Therefore, we focus in this assessment on a basic set of core attributes that are common across the focal areas of our chapters; additional attributes that are useful in particular chapters are introduced in those chapters.

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Northern mixed forest with rich understory. Photo © Craig R. Allen

3

Chapter 3

Relationships Between Forests and Social and Economic Resilience

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Abstract

This chapter examines the complex and multifaceted relationships between forests and social and economic resilience. It presents a novel framework to systematically categorise and analyse these interactions by defining a typology of four interlinked relationships: i) forest contributions to social and economic systems; ii) social and economic attributes of resilience; iii) effects of social and economic resilience on forests; and iv) external conditions and shocks shaping resilience. The chapter highlights the diverse ways in which forests support and impact social and economic systems among forest-dependent and other forest-proximate and *distal communities*, emphasising how contributions (both positive and negative) vary across contexts and scales. It also explores how resilience is shaped (both positively and negatively) by a set of key social and economic attributes, such as institutions and governance, participation, social learning, social networks, and economic assets and capital. Additionally, it explores how socio-economic and environmental dynamics create feedback loops between forests and social and economic resilience, leading to diverse and unexpected outcomes. Finally, the chapter examines the influence of external conditions and shocks (including climate change, market forces, changing societal demands, and technological shifts) in shaping the relationship between forests and people, and influencing social and economic resilience.

3.1 Introduction

The role of forests as providers of ecosystem services is increasingly well-documented, yet their direct contribution to fostering and supporting social and economic resilience remains underexplored. Several challenges contribute to this knowledge gap. First, the social dimensions of resilience have received significantly less attention compared to the ecological dimensions (Cantarello et al., 2024; Forzieri et al., 2021; Lecina-Diaz et al., 2021). Second, numerous conceptual frameworks and metrics aim to quantify and assess the resilience of social-ecological systems and their capacity to manage changing conditions, stresses, and unexpected events (see Chapter 5). However, since resilience is a complex and multidimensional concept, it is difficult to evaluate directly. Resilience is thus often assessed using proxies or specific and siloed indicators, but more integrated and holistic indicators are more challenging to use and less often explored. Further, the challenge of establishing a meaningful approach to identify causation makes it difficult to fully explain the complex processes that shape resilience or how resilience influences the functioning of social-ecological systems, of which social and economic resilience is a sub-component (Biesbroek et al., 2017).

In this chapter, we aim to evaluate the evidence documented in the scientific literature regarding the potential of forest social-ecological systems (SES) to contribute to social and economic resilience. We deliberately focus on how forests contribute to the social and economic resilience of human societies and less on the ecological dimensions of forest resilience. At the same time, we acknowledge the existence of feedback loops (both positive and negative) where, for instance, resilient forests enhance communities' resilience and vice versa in a reciprocal relationship, a process illustrated in climate change adaptation studies (e.g., Locatelli et al., 2008; Pramova et al., 2012). These feedback loops are explored in the final section of this chapter.

To assess the relationships through which forests contribute to social and economic resilience, we developed an integrative framework allowing us to systematically categorize and analyse these interactions by defining a typology of four interlinked relationships (see Figure 3.1):

A. Forest contributions to social and economic resilience.

B. Resilience attributes of forest SES including communities and economies.

C. Effects of social and economic resilience on forests.

D. External conditions and shocks affecting forest SES.

Using this framework as a guiding structure, we conducted a targeted review of the scientific literature with a particular focus on empirical research that sheds light on mechanisms, pathways, or case studies demonstrating forest SES resilience linkages. We aimed to select studies ensuring that they collectively reflect diverse geographic and institutional contexts.

3.2 Contextualising the relationships between forests and social and economic resilience

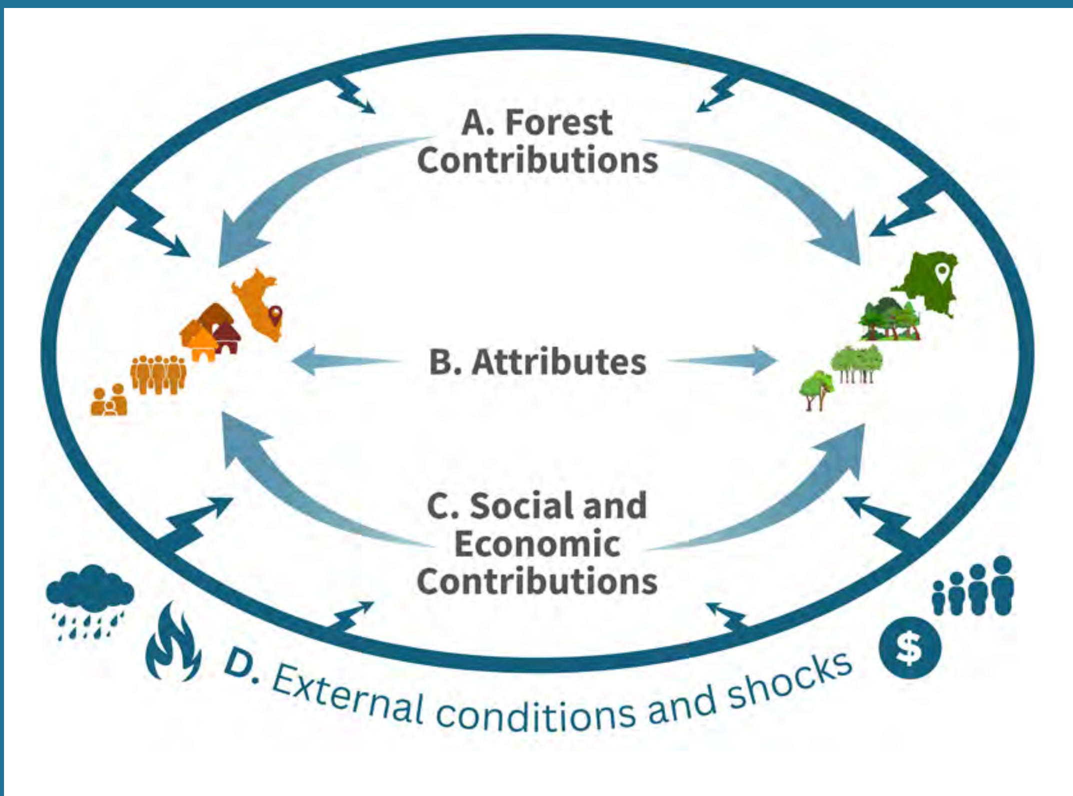
This chapter introduces a framework that explicitly links forests to social and economic resilience, providing new insights into their complex and dynamic relationships (Figure 3.1). The framework builds on, and expands, several existing frameworks that have addressed ecological resilience, or more narrowly, focused on social-ecological systems (e.g., Cinner and Barnes, 2019; Libert-Amico et al., 2022; Viñals et al., 2023). This framework offers a more integrated perspective by addressing a key gap in the literature: the lack of a clear, systematic understanding of how forests contribute to social and economic resilience across different contexts. Unlike previous approaches, it uniquely emphasizes the interplay between forests and the resilience of social and economic systems for a range of communities operating at different spatial and temporal scales, thus shedding light on aspects of this interplay that have received little attention in the literature so far.

The framework is structured around four interlinked relationships, which are here below described, and further analysed in detail in the next sections of the chapter:

A. Forest contributions to social and economic systems

Forests provide diverse goods and services that directly and indirectly support social and economic systems and are distributed among a range of forest-dependent and other forest-proximate and distal communities. These can

Figure 3.1 Conceptual diagram of the relationships between forests and social and economic resilience



Taking Figure 2.2 as a starting point (see Chapter 2 for a more detailed description of the elements in the Figure), here we focus on the relationships between forests and social and economic systems as affected through SES attributes.

include provisioning goods and services, such as timber and non-timber forest products; regulating services, such as carbon sequestration or water harvesting and purification; supporting and habitat services, such as habitat for wildlife and biodiversity; and cultural services, such as spiritual and cultural values or health and well-being. In turn, such forest goods and services can induce multiple and diverse changes within the communities' social, economic, and other systems, for instance in the form of income stream, crop yields or cultural integrity.

B. Attributes of resilience that affect the relationships among the components of forest SES

The resilience of social and economic systems is shaped, both positively and negatively, by specific attributes that determine their capacity to anticipate, respond to, and recover from shocks and stressors. These attributes include diversity, connectivity, learning, capital and assets, and adaptive capacity, among others (see Chapter 2 for a list of resilience attributes).

C. Effects of social and economic resilience on forests

The interplay between forests and social and economic resilience operates through dynamic feedback loops. Changes induced by forests on social and economic systems and their resilience, in turn, have implications on forests. On one end of the spectrum, resilient social and economic systems can promote sustainable forest management practices, thus contributing positively to forests' resilience. On the other hand, non-resilient social and economic systems characterised by issues such as weak governance and unsustainable profit maximisation can produce negative pressures on forests through actions such as overharvesting or illegal activities. Yet, other trade-off combinations are possible where non-resilient systems contribute positively to forests, and resilient systems degrade them.

D. External conditions and shocks affecting resilience of forest SES

External drivers arising from broader scale forces, such as climate change, global economic trends, and shifts in policy, often have profound implications on the resilience of forests and social and economic systems. For example, climate-induced events like droughts or wildfires can severely affect forest ecosystems and disrupt livelihoods and lifeways dependent on and integrated with forests. Yet, these external conditions can also create opportunities that may deliver improvements. For example, increasing recognition of the role of forests in mitigating climate change by storing and sequestering carbon has spurred international funding and initiatives to support forest conservation, which can provide resources that enhance both forests and social and economic resilience.

3.3 Contributions of forests to social and economic systems

The contributions of forests extend beyond their immediate ecological functions, providing a wide range of goods and services to different communities and holding their own intrinsic value (IPBES, 2019). From the Millennium Ecosystem Assessment (MEA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB, 2010), to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)' Values Assessment (Pascual et al., 2023) and beyond, there has been much work on the multiple and diverse types of goods and services provided by forests to human societies at different scales. Forests contribute to well-being, economic stability, and environmental sustainability through a variety of ecosystem services that can be classified into supporting, provisioning, cultural, and regulating services (MEA, 2005). More recently, these benefits have been characterised as nature's contributions to people and recognised through specific types of values: instrumental, relational, and intrinsic (Pascual et al., 2023). These benefits have been defined as "adaptation services", specific ecosystem services that reduce climate risk by reducing exposure and vulnerability and enhancing resilience (Colloff et al., 2020; Jones et al., 2012).

Yet, the relevance of forest ecosystem services for society varies depending on the attributes and forest relationship of the communities involved. On a global scale, 95% of all people outside urban areas (around 4.17 billion people) lived within five kilometres of a forest in 2019, and 75% (around 3.27 billion people) lived within one kilometre of a forest (Newton et al., 2022). Forest-dependent communities, also referred to as forest-reliant communities (Newton et al., 2022), are those whose livelihoods, cultural practices, and lifeways are closely tied to forest ecosystems. These communities, which often include Indigenous communities and

Bagyeli man collecting medicinal bark in Cameroon. Forests are an important source of medicinal plants, particularly for many Indigenous forest communities. Photo © Viola Belohrad local populations in low- and middle-income countries rely directly on forests for resources such as fuelwood, timber, non-timber forest products, and essential ecosystem services such as water regulation and carbon sequestration. In high-income countries, forest dependency may also manifest through employment in forest-related industries such as timber and forest management (Hajjar et al., 2014). Forest-proximate communities are those who live in or near forests, regardless of their reliance on forest resources (Newton et al., 2022). While some forest-proximate people may actively depend on forests for their livelihoods, others benefit more indirectly through ecosystem services such as water supply, air quality regulation, and recreational opportunities. Distal communities refer to broader societal groups that, despite being geographically distant from forests, still derive significant benefits from global ecosystem services, including climate regulation, carbon sequestration, and biodiversity conservation.

Overall, forest-dependent and forest-proximate communities experience more immediate and tangible benefits from forests, while distal communities benefit from more indirect ecological functions. Provisioning services, such as timber collection, fuelwood gathering, and food harvesting, are especially critical for forest-dependent and forest-proximate communities, though they also support distal communities through global supply chains. Regulating services such as water cycle regulation and climate regulation are vital for both forest-dependent and forest-proximate communities, with some services extending to distal communities as well. In turn, cultural services, including spiritual values and tourism, primarily benefit forest-dependent and forest-proximate communities, but can also have wider societal importance such as through health benefits and cultural exchange, and can provide values across generations. Finally, regulating services such as carbon sequestration, biodiversity conservation, soil erosion control, pollination, or pest management offer essential benefits to all communities, but services such as climate resilience and livelihood support matter the most to forest-dependent and forest-proximate communities.

While resilient forests provide multiple benefits, research has also shown that they can generate disservices, meaning negative impacts on human societies that arise from ecological or biological processes. These disservices can be categorized as intermediary or final disservices, depending on their type and nature. Some disservices highlighted in the literature (Hamada, 2014; Liang et al., 2017; Petri et al., 2016) and classified based on Opoku et al. (2024), are as follows:

Aesthetic and environmental issues:

- Spread of invasive species.
- Artificially created urban green areas counteracting with water conservation efforts.
- Nuisances from accumulation of organic debris (leaves, branches, fruits, and decaying matter).
- Unmanaged urban green areas causing multiple hardships to day-to-day life of people.

Safety and security issues:

- Human-wildlife conflict.
- Forest wildfires.
- Infrastructure conflicts (damage to property and infrastructure during storms or other natural events).

Health issues:

- Human injuries or fatalities during storms and floods.
- Pollen allergies.
- Smoke exposure.
- Biting insects and other animals.

Mobility and infrastructure issues:

- Imposition of high costs related to management, environment, and energy (ecological disturbances, risk management, nursery production, planting, pruning, removal, and disposal generating carbon dioxide and other greenhouse gas emissions, including emissions from vehicles and tree care equipment).
- Increasing the cost of maintenance of human-made infrastructure adjacent to forests (e.g., regular pruning around electric lines).

These disservices from forests, which seem to be most relevant for forest-dependent and other forest-proximate communities, are mostly being discussed in the context of urban green spaces or urban forests, and there is limited evaluation of these disservices. However, the limited evaluations support the view that services from forests outweigh the disservices (Potgieter et al., 2019). Whilst we could not find studies that specifically quantified how forest-related services compared against disservices, Wu et al. (2021) showed that the economic gains from ecosystems in Beijing outweigh costs of disservices by approximately 20 times.

In turn, forest goods and services can induce a range of changes within the social and economic resilience of forest-dependent and other forest-proximate and distal communities. Below (Table 3.1) we provide some examples of potential changes induced by forest contributions. These examples are not exhaustive, but rather illustrative of the manifold and diverse changes that forest contributions can induce on social, economic, and other dimensions of human well-being. These examples help visualising how forests contribute to economic systems by generating income and employment through timber and non-timber forest products, forest-based tourism, and natural resource markets. Socially, forests support health and well-being, enhance food security, and sustain cultural and relational values, including day-to-day cultural activities, sacred practices, and community cohesion. Additionally, forests reduce disaster risks and climate-related costs by stabilising ecosystems and acting as protective buffers.

Leaf litter harvesting to support traditional agriculture in India. Photo © Shalini Dhyani

Table 3.1 Forest-induced changes to social and economic systems

The first two dimensions ("income and employment" and "forest-based tourism") are economic, while the remainder are social.

Dimension	Data Points
Income and employment[1]	▪ Between 3.5 and 5.8 billion people make use of or are dependent on Non-Timber Forest Products (NTFP) globally (Shackleton and de Vos, 2022). Collection is not only for subsistence and culture but generates economic return. For example, the international trade of pine nuts and forest mushrooms was worth USD 1.8 billion in 2022 (FAO, 2024). ▪ Global wood production is at record levels, at about 4 billion m^3 per year. In 2022, an estimated 2.04 billion m^3 of roundwood were harvested and 1.97 billion m^3 were harvested for wood fuel (FAO, 2024). ▪ About 33 million people (1% of global employment) are estimated to work directly in the formal and informal forest sector (FAO, 2022). ▪ The forest sector has significant economic multipliers, with value-added multipliers of 2.12, employment multipliers of 2.53, and labour income multipliers of 1.96, varying across countries (Li et al., 2019). ▪ Small-scale agriculture in forest mosaic landscapes is a major source of local and regional food production, generating income as well as nutritious food security, biodiversity, and cultural vitality (Ricciardi et al., 2021; Sunderland and O'Connor, 2020).
Forest-based tourism[1]	▪ Revenue-sharing reforms in China improved rural income equality via forest tourism (Song et al., 2020). ▪ Conservation areas or ecotourism positively impact household welfare, especially in developing economies (Yergeau et al., 2017). ▪ Forest tourism trends vary by region, with growth in Finland and declines in Japan and the USA (Ahtikoski et al., 2011; Balmford et al., 2009).
Natural resource markets[2]	▪ Globally, more than 1.6 billion people depend directly on forests for their livelihoods and the level of dependency of the poor on forest ecosystems is very high. Of that more than 1.6 billion people, some 300 to 350 million are Indigenous People who live within or in close proximity to dense forests and depend almost entirely on forests for subsistence (World Bank, 2016). ▪ Ecosystem services and other non-marketed goods from forests and other ecosystems account for between 47% and 89% of the total source of livelihood for rural and forest-dwelling poor households (TEEB, 2010) ▪ Wild foods contribute 4% of the household income across 24 tropical countries (Hickey et al., 2016). ▪ Forests act as safety nets during economic and environmental shocks, providing supplemental income during droughts (Noack et al., 2019).

1 Relevant to all communities
2 Relevant to forest-dependent and other forest-proximate communities

Table 3.1 Continued....

Dimension	Data Points
Health and well-being[1]	▪ Forest therapy reduces stress and improves mental health (Grilli and Sacchelli, 2020). ▪ Intact forests regulate vector-borne diseases, supporting public health (Estifanos et al., 2024). ▪ In forest-dependent communities the contribution of forests to relational, subjective, and material well-being is higher than for those communities who no longer have access to their forests (Carmenta et al., 2023).
Food security and nutrition[2]	▪ Proximity to forests improves dietary diversity due to access to wild foods (Olesen et al., 2022). ▪ Forest foods provide essential nutrition during droughts, ensuring food security (Meyer, 2023).
Cultural and relational values[1]	▪ Forest ecosystems support cultural practices, enhancing community cohesion and resilience (Delgado et al., 2023). However, not all forests are equal, and the value of forests may depend not only on proximity but also on management and property regimes (Nepal et al., 2017). ▪ Sacred forests have ecological, cultural, and climate benefits, requiring conservation approaches that integrate traditional practices (Ormsby and Bhagwat, 2010).
Disaster risk reduction and climate-related cost reduction[1]	▪ Mangroves dissipate wave energy and act as buffers against coastal storms, reducing flood damage and lowering disaster response costs (Menéndez et al., 2020). ▪ Coastal and mountain forests stabilize soil, protecting against landslides and extreme weather (Das, 2020). ▪ Through storm protection, forests are expected to reduce climate-related costs by up to 35% in the European Union by 2050 (Gren, 2015). ▪ Urban trees provide substantial urban cooling, reducing the heat island effect (Schwaab et al., 2021) as well as saving energy due to decreased consumption for cooling (Moss et al., 2019).
Social equity[2]	▪ Market pressures on NTFPs can reinforce socio-economic inequalities, disproportionately benefiting wealthier households (Gerrish and Watkins, 2018). ▪ Access and secure rights to forest territories and customary lands help restore equity imbalances by, for example, enabling resistance, persistence, and autonomy of local communities (Kenrick et al., 2023).

3.4 Social and economic attributes of resilience

The ability of communities to maintain or achieve resilience and navigate the transformation towards sustainable resource use is influenced by a range of social and ecological attributes (see Chapter 2), as well as by the broader political economy. In this section, we draw on selected studies worldwide spanning diverse socioeconomic and ecological contexts to examine various resilience outcomes, both positive and negative, mediated by these attributes.

3.4.1 The role of social attributes in strengthening resilience of social-ecological systems

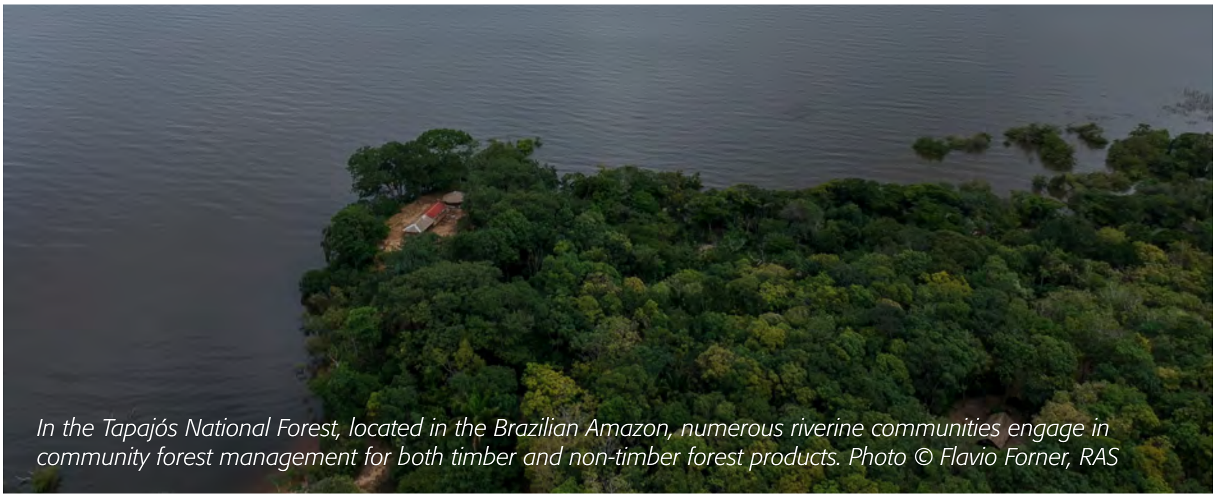
Institutions and governance

Resilience in forest social-ecological systems is significantly influenced by the structure and functionality of institutions and governance that articulate and coordinate key decisions of forest management and use. Effective institutions can play a critical role in shaping desirable resilience in many different ways, for example through the establishment of equitable property rights and rules, which regulate resource use and management and determine how returns are shared among individuals, families, and communities (Ostrom, 1990; Rahut et al., 2015). They also define enforcement mechanisms, which impact actors' decisions to comply with institutional rules, and in turn can promote sustainable resource use and equitable distribution (Adhikari et al., 2004). Institutions can also create a status quo which may be undesirable (not just and not sustainable) and yet resilient to change (see Section 3.5.1).

Effective institutions will often require a decision-making process that fosters transparent and equitable outcomes and relies on the capacity of actors to adapt to changes by learning, sharing knowledge, and adjusting responses and institutions (González-Quintero and Avila-Foucat, 2019). ***Adaptive governance*** is a flexible, inclusive, and iterative approach to managing SES amid uncertainty and change. It emphasizes learning, collaboration, and the capacity to adjust policies and institutions over time based on new knowledge and evolving conditions (Adger, 2003). Integrating multiple stakeholders, including governments, local communities, NGOs, and private actors, fosters cooperation and decentralised decision-making.

Additional emerging features of resilience identified in the literature include **diversity, polycentricism, connectivity**, and **decentralisation** (Carabine and Wilkinson, 2016). Polycentric governance, which involves decentralised and multi-level decision-making, enhances adaptability and collective action, while ensuring that solutions are developed close to the source of problems, which may generate more desirable outcomes.

Connectivity among institutions across scales facilitates the effective flow of resources and information, enabling synergies between local-level insights and broader policies. For instance, in the Brazilian Amazon, multi-partner governance systems in a Sustainable Use Reserve (Tapajós National Forest) have demonstrated effectiveness by integrating technical, legal, and training support for community forest management (Espada and Vasconcellos Sobrinho, 2019). This cooperation involved government agencies, non-profit organisations, social movements, local universities, and a timber



In the Tapajós National Forest, located in the Brazilian Amazon, numerous riverine communities engage in community forest management for both timber and non-timber forest products. Photo © Flavio Forner, RAS company. Similarly, decentralised governance in Nepal's collaborative forest management model has facilitated equitable access to forest resources, supplying timber and fuelwood for distant households (Rai et al., 2017). Nepal's long-standing decentralised forest management programme (community forestry) has promoted widespread social and environmental benefits across the country, reducing deforestation and alleviating poverty (Oldekop et al., 2019).

However, decentralisation alone is insufficient (Libert-Amico and Larson, 2020); and if not properly implemented, it can lead to inflexible, non-adaptive governance, and to various undesirable outcomes. Reforms associated with the devolution of power to local communities, often ill-informed and contextually inadequate, have led to mixed outcomes, triggering conflicts in some forest communities, including in Cameroon, India, and Nepal (de Blas et al., 2011), while being highly successful in other cases, such as the Petén in Guatemala (Stoian et al., 2018). The literature highlights cases where centralised authorities obstruct or extend their control under the guise of decentralisation, impose costly policies on local communities, and enable elite capture, where powerful actors manipulate the system for their own benefit (e.g., Lund et al., 2018). It is not uncommon that forest resource access is biased toward privileged groups (e.g. Rai et al., 2017). Without mechanisms for guaranteeing ethical, financial, and political accountability, decentralisation risks marginalising the most vulnerable. These are widespread problems, as exemplified in Ghana's co-management programmes that led to unequal access to information and opportunities for the poorest households (Akamani et al., 2015). Such failure was attributed to weak and poorly connected local institutions.

Effective governance systems exhibit both **institutional diversity** and strong connectivity across multiple levels, provided that the complexity of governance arrangements does not compromise cost-efficiency (Ros-Tonen et al., 2018). A diversity of institutions (toward polycentricity) can reduce the likelihood of institutional failure, despite associated challenges (Akamani et al., 2015). In the forests of Cameroon's Congo Basin, civil society organisations have played a pivotal role in bridging gaps left by government agencies, and in building capacity to implement climate change commitments (Brown et al., 2010). Similarly, the Xingu Indigenous Reserve in Brazil illustrates the importance of alliances and institutional connectivity to address external threats like deforestation, while preserving Indigenous ways of life (Brondizio et al., 2009). Cooperation among local institutions produced several benefits for the Indigenous communities in the Xingu Indigenous Reserve, but a broader institutional connectivity across scales would be necessary to align with the ecological connectivity across the entire basin, pressured by agribusiness on the reserve borders (Brondizio et al., 2009) (see Chapter 4 for a discussion on institutional fit). In this case, it could enhance learning processes among distinct actors, strengthen integration across policy levels, and facilitate the co-production of solutions on a broader scale, as previously highlighted in this section.

Despite the importance of governance and institutional features in building SES resilience, increasing complexity, implementation costs, bureaucracy, and the involvement of more diverse actors introduce **additional challenges and burdens** (Estrada-Carmona et al., 2024). Striking a balance between various objectives is a challenging task, as it requires ensuring that every relevant stakeholder is fairly represented and has access to a wide range of institutions, and that some form of consensus or agreed trade-offs can be reached (Reed et al., 2021). Furthermore, addressing imbalances in power and gender, employing adaptive management informed by participatory outcome monitoring, and breaking down traditional administrative, jurisdictional, and sectoral silos are all crucial steps. Collaborative multi-stakeholder platforms, as well as organizations and individuals who serve as connectors, are vital for overcoming these challenges, but are not a panacea as they can also reproduce power imbalances and much depends on the vision being pursued (Larson et al., 2022; Ros-Tonen et al., 2018).

The historical trajectories of various governance approaches and their consequences are also thoroughly documented and analysed in Chapter 4. Relevant case studies illustrate how weak institutions and ineffective governance arrangements can lead to misguided policies, incentivise illegality, disproportionately burden vulnerable populations, and ultimately, undermine SES resilience. This includes uneven levels of resilience, particularly among poorer individuals and households, as well as heightened gender vulnerabilities for women and girls (Ravera et al., 2016). For example, a study on resilience and vulnerabilities to climate change in nine African countries found

Box 3.1 Women in forest regeneration

The story of Mrs Bhagirathi Devi from the village of Manar, in the Champawat district of Uttarakhand state, India, is an example of women regenerating a forest to build community resilience. With a denuded village forest and men migrating to cities in search of employment, the women of the region suffered by walking kilometres to fetch water and fodder. Mrs Bhagirathi Devi took the challenge on by herself, and initiated attempts to regenerate the forest. Her years of continuous hard work and deep understanding of the ecology of the region resulted in a lush, green forest cover with water sources bouncing back, and plenty of fodder available. Now, men are migrating back to the village and water availability is generating new sources of income. Additionally, women are nowadays considered equal partners in income generation (NABARD, 2021).

Mrs Bhagirathi Devi, fondly called 'the Forest Mother of Manar', has successfully led forest regeneration efforts in Manar Village, Uttarakhand State, India. Photo © Saudamini Das

that female-headed households were highly vulnerable to food insecurity and faced greater challenges in adapting their livelihood practices to economic and climatic risks (Perez et al., 2015). Women have less access than men to common property resources, as well as less control over land, which is often of poorer quality (Fisher and Naidoo, 2016). On the other hand, positive contributions of women's participation in institutionalised decision-making and forest resource conservation are crucial for strengthening social-ecological resilience (see example in Box 3.1) (Agrawal and Chhatre, 2006).

This evidence highlights the importance of designing and implementing just and effective governance approaches to harness opportunities that drive socioeconomic resilience and positive transformative changes in forest regions (World Bank, 2024).

Addressing tenure insecurity has proven to be a successful strategy in preserving ecosystem services and ensuring their sustainable management (FAO and FILAC, 2021). With secure tenure rights also comes the opportunity to engage in and benefit from climate finance, forest markets, and other land-based investments. Relevant governance mechanisms include economic incentives, repurposing agricultural subsidies, technical support, and context-specific forest and land tenure regulations (Wong et al., 2020).

Participation, engagement and social learning

Meaningful stakeholder participation and engagement fosters more sustainable and integrated management of resources (Okumu and Muchapondwa, 2020). Strategies for engaging stakeholders as a means to enhance adaptive capacity through knowledge sharing and capacity building have been pursued in a broad range of social-ecological contexts, as in the context of "Model Forests" (Elbakidze et al., 2010) and Community-Based Natural Resource Management (CBNRM, see Box 3.2). These approaches emphasize participatory and sustainable management of natural resources, often involving diverse stakeholders, including local communities, government agencies, NGOs, and researchers. The "Model Forest" is based on a collaborative process that fosters partnerships and serves as a forum for addressing challenges in sustainable forest management, aiming to enhance the adaptive capacity of local social-ecological systems to navigate uncertainty and change. Success hinges on the extent to which local institutions effectively partner with local communities, as evidenced by experiences in protected areas in Indonesia (Shivakoti and Shivakoti, 2008). CBNRM aims to enhance resource management outcomes by promoting broad participation of local communities in decision-making and integrating local knowledge systems into management processes (Armitage, 2005). This approach involves the collective use and management of natural resources by groups with a self-defined identity, guided by mutually agreed strategies that seek to balance conservation goals with local development efforts (Fabricius, 2004). However, numerous studies have documented failures in CBNRM due to a range of factors (e.g., Milupi et al., 2017). Uneven local participation and limited knowledge exchange are among the key challenges undermining resilience in CBNRM, as observed in local communities in Mexico and Colombia (Delgado-Serrano et al., 2018).

In a completely different context, self-organized intentional communities living in forested areas in the USA demonstrate how investment in institutional frameworks can create virtuous cycles of social learning, collective decision-making, and enhanced resilience to disturbances (Fleischman et al., 2010). In a study of *REDD+* interventions across 14 tropical countries, it was suggested that increased participation and new decision-making bodies can in principle enhance adaptability of forest communities,

Box 3.2 Approaches and challenges in Community-Based Natural Resource Management (CBNRM)

Two main approaches to CBNRM can be identified in the literature (Shackleton et al., 2010), each with varying degrees of success (e.g. Fabricius, 2004). CBNRM initiatives emerged as donor-driven alternatives to top-down resource management and conservation strategies (Armitage, 2005), aiming to support long-term sustainability through broad participation of community members and resource users in decision-making (Zanetell and Knuth, 2004). Bottom-up approaches to CBNRM resulted from community members' efforts to create new political opportunities to regain control over resources, and for social justice (Ruiz-Mallén et al., 2015). The top-down approach derives from international pressures to combine conservation and development, accelerated by the Brundtland Report, the Rio Earth Summit in 1992 and subsequent United Nations conferences, and the failure of exclusionary and command-and-control approaches (Andrade and Rhodes, 2012). Since then, a variety of conservation strategies, including some parks and protected areas approaches, have included local participation.

However, according to empirical research (e.g., Dressler et al., 2010), many CBNRM only function on a small scale and face numerous difficulties, including elite capture, a restricted devolution of fiscal authority, and opposition from forest officials who feel that CBNRM have undermined their professional authority. Their success depends on effective community participation, legal recognition of community rights, and addressing local socioeconomic needs (Delgado-Serrano et al., 2018), highlighting the importance of bottom-up initiatives.

for example through increasing network ties and connectivity across scales (Hajjar et al., 2021). However, rigid rules and carbon contracts have sometimes constrained communities' ability to manage uncertainty. Additionally, the reduction in livelihood diversity, driven by the prohibition of many activities under REDD+, might be detrimental to socioeconomic resilience overall (Hajjar et al., 2021). Barriers to effective community participation, as in Ghana's co-management programme, hinder the ability to build substantial resilience, highlighting the urgent need for stronger support mechanisms for participation (Akamani and Hall, 2015).

Social networks

Robust and diverse social networks are foundational for fostering adaptive capacity, effective responses, and long-term resilience in social-ecological systems (Ostrom, 1990). Social networks play a critical role in fostering socioeconomic resilience within forest communities by facilitating collective action (Adger, 2003), for example by conserving ancestral seeds (Box 3.3). These networks, often defined as social capital, encompass the quantity and quality of relationships and cooperation that help manage risks and seize opportunities. Several features of social networks are expected to contribute to resilience, including network type, quantity, diversity, trust, and reciprocity (Habibov and Afandi, 2017). A greater number of connections among individuals increases opportunities for social support, trust, and information sharing. However, the quality of collaborative ties is especially important, for example in the context of disaster management (Bodin et al., 2022). ***Network diversity*** refers to the different types of social capital, such as bonding ties (close relationships) for coping with challenges and bridging ties (connections to diverse groups) for accessing new knowledge and opportunities (García-Amado et al., 2012). Trust and reciprocity strengthen cooperation and collective action, which are essential for responding to pressures such as changing climate and socioeconomic challenges (Torche and Valenzuela, 2011). While formal organizations play a significant role in governance and decision-making, socio-cultural factors, such as norms, values, and identities, influence the efficacy of these networks in resilience-building. For example, research by Bauer et al. (2022) showed that resilience was higher among low-income Indigenous households in the Bolivian Amazon that had stronger mutual support and social capital, and that participation in community forestry activities strengthened horizontal connectivity among households and promoted the development of social capital within the community. In Nepal, households' membership in local community forest user groups helped promote planting more trees on private land (Nepal et al., 2007). In contrast, the weakening of social ties caused by Payment for Ecosystem Services (PES) schemes in rural households in China, may reduce resilience by diminishing livelihood diversity and cause widespread rural-to-urban migration (Wang et al., 2021). In any case, future changes are expected in an increasingly interconnected world, where translocal social networks (connections between communities across regions) could enhance resilience by promoting resource sharing and knowledge exchange. This is facilitated by increased mobility, connectivity, and long-term migration in the *Global South* (Rockenbauch and Sakdapolrak, 2017).

3.4.2 The role of economic attributes in strengthening social and economic resilience

Economic asset ownership is relevant to resilience, providing households with financial security and the means to withstand and recover from adverse events such as climate, political, and economic shocks. In forest-dependent communities, households with more economic assets are better equipped to manage crises and maintain consumption during hardships. Low asset levels increase vulnerability to food insecurity and shocks (Schipper and Langston, 2015). Wealthier societies may exhibit entirely different patterns, as seen with high-capital forestry actors in France, which also seem to have limited adaptive trajectories (Sansilvestri et al., 2020).

The potential of forests to contribute to community economic systems has been explored in previous sections, including their role in generating income and employment through timber and non-timber forest products, forest-based tourism, and natural resource markets. Economic resilience, reflected in assets, savings, investments, or credit, can be derived directly from forest resource markets, though the extent of this varies greatly and is highly context dependent. Forests have been shown to act as a safety net during shocks (especially for the most asset-poor communities), as a buffer for communities affected by agricultural shocks in the Brazilian Amazon, and as a support for households' food security with limited insurance

BOX 3.3 Custodians of Ancestral Seeds in Medellín, Colombia

The Custodians of Ancestral Seeds (*Custodios de Semillas Ancestrales*) is a collective social network of young people committed to environmental conservation and the rescue of ancestral knowledge in the forests surrounding Cerro La Asomadera, in the Commune 9 of Medellín (Colombia). This organization's mission is to safeguard and preserve both the biodiversity of the forest and the traditional knowledge related to its care. Their work includes educational and interpretive tours in the area, where they highlight the importance of native trees and pollinators, promoting the planting of native species as a strategy for ecological restoration and strengthening ecosystems. They also promote food sovereignty through the management of functional orchards and the responsible use of natural resources. One of the pillars of their work is environmental education, transmitting the importance of caring for the local flora and fauna through practical activities such as seed collection and dispersal, the creation of sanctuaries for pollinators, and the use of natural ferments in food. The commitment of the Custodians of Ancestral Seeds is not limited only to the preservation of the natural environment but also seeks to strengthen the social resilience of the community, promoting the active participation of the local inhabitants in each of its initiatives.

Special thanks to Juan Diego Betancur for his contributions to this box.

Social networks, such as the Custodians of Ancestral Seeds in Colombia, are foundational for fostering adaptive capacity, effective responses, and long-term resilience in social-ecological systems.
Photo © Custodios de Semillas Ancestrales

options affected by weather shocks in Malawi (Wunder et al., 2014). Even households with alternative coping mechanisms often rely on forests to diversify their strategies (Meyer, 2023). Household income diversification and access to credit are key factors influencing the range of climate change adaptation strategies in forest communities in Vietnam (Sen et al., 2020).

In vulnerable populations, more economic assets can exacerbate inequalities, as seen in Tanzania, where forests help mitigate market shocks primarily for those with better insurance coverage (Andrews and Borgerhoff Mulder, 2022). In Ghana, greater capital leads to unequal participation in a community forest program (Akamani and Hall, 2015). However, well-implemented participatory programmes (see example in Box 3.4) can change these negative prospects. For instance, in one case in Ethiopia, nearly 38% of annual household income was derived from forest resources under a participatory forest management programme (Gatiso, 2019); while in Nepal, 37% of households access public forests (mainly community forests) and 48% use private trees for meeting their needs (World Bank, 2024). Encouragingly, a positive feedback loop emerges: the more households rely on forest resources for their livelihoods, the more they value these resources and actively participate in their management (Gatiso, 2019). A greater reliance on natural resources for livelihoods was linked to increased collective action, fostering stronger cooperation among community members. This pattern aligns with the principles of commons governance outlined by Dietz et al. (2003). These examples show that transformative changes, such as decentralised and collaborative governance systems strengthened by robust and diverse social networks and meaningful stakeholder engagement, can shift the current unsustainable system and unlock the potential of forests to promote positive resilience outcomes (Garrett et al., 2024).

Despite the significant contributions of forests to local communities, numerous studies have found that their overall contribution to household income remains relatively low across different scales, from local to global (e.g., Camilotti et al., 2020 for the Amazon; Hickey et al., 2016 for 24 countries). This limited economic role is driven by multiple factors, including constraints on harvesting, restricted access, and weak market integration. Such context reveals longstanding structural conditions in developing forest regions, where historical economic models relied on ecosystem conversion instead of sustainable forest use and restoration. Overcoming these entrenched practices requires dismantling numerous practices to transform the current political and social system, thereby unlocking the full potential of forests to foster social and economic resilience. Several recommendations apply across many forest regions. For example, credit programmes could be redirected from conventional to forest economies, financing mechanisms could be improved to better support forest-proximate and dependent communities, research on sustainable harvesting could be funded, and market bottlenecks and logistical constraints could be addressed. Above all, governance arrangements centred on forest-reliant communities must orchestrate these transformations (Garrett et al., 2024).

3.5 Social and economic contributions: Effects of social and economic resilience on forests

In previous sections, we have focused our attention on how the goods and services provided by forests affect social and economic systems (Section 3.3) and how this influences resilience when combined with certain social and economic attributes (Section 3.4). While in this chapter we primarily focus on the social and economic dimensions of resilience, we acknowledge the critical role that ecological resilience attributes play in shaping socioeconomic resilience outcomes. The contribution of forests to community resilience is deeply tied not only to their ecological integrity, but also to how forest resources are used, their diversity and abundance, and their spatial distribution, which then further influences relationships and outcomes. Furthermore, the perception of ecological depletion, including forest loss and degradation, combined with poverty, serves as a crucial catalyst for collective action (Akamani, 2023).

Ecosystem diversity enhances community resilience by providing a range of species and resources that sustain essential ecosystem functions despite environmental changes or disturbances, and these functions are often critical in feedback loops. Diverse ecosystems also offer multiple recovery pathways, ensuring that if one species or resource is impacted, others can fulfil similar roles. This diversity also strengthens the ecosystem services that communities depend on, reducing their vulnerability to shocks and increasing their adaptive capacity in the face of climate and socioeconomic challenges (Biggs et al., 2015).

Box 3.4 Successful community forestry program in Nepal

Nepal presents a compelling example of increased forest cover alongside reduced poverty (Oldekop et al., 2019). In response to accelerating deforestation, the government launched the Community Forestry Program in the late 1980s, with the dual objectives of halting widespread deforestation and providing livelihood opportunities to forest-dependent rural communities. Today, more than 23,000 Community Forest User Groups (CFUGs) manage over a third of the country's forest area. While the success of the Community Forestry Program is a major factor behind the increase in the country's forest cover, other socioeconomic changes have also played a significant role. For instance, households involved in CFUGs have started planting trees on their private land to meet daily needs of fodder and firewood (Nepal et al., 2007). About 48% of households now rely on private trees for these resources, which has helped to reduce pressure on local forests (Balasubramanya et al., 2025; World Bank, 2024).

Another key factor contributing to the rise in forest cover has been the out-migration of rural youth in search of employment opportunities, leading to the abandonment of agricultural land in many areas (Karki Nepal et al., 2023). This fallowing of land has been linked to the recovery of forests, particularly in the mid-hills of Nepal (Oldekop et al., 2018). One estimate suggests that intensive forest management practices, as practiced in community forestry, enhance socioeconomic resilience of forest-dependent communities and reduce the opportunity costs of forest conservation (Rai et al., 2022).

In Nepal, community forestry programs have contributed to increasing the country's forest cover and to enhancing socioeconomic resilience of forest-dependent communities. Photo © Mukesh Bhattarai

In parallel to social connectivity, ecological connectivity plays a crucial role in maintaining key ecological interactions, such as pollination, seed dispersal, and the function of wildlife corridors and networks (González-Quintero and Avila-Foucat, 2019). The relevance of alignment between institutional and ecological connectivity has been demonstrated in cases such as the Brazilian Indigenous Reserve in the Xingu region (Brondizio et al., 2009). A growing body of research highlights that environmental governance outcomes depend on how well the interactions among actors align with patterns of ecological connectivity. For instance, in wildfire management, the alignment of landscape-level patterns of wildfire transmission with the coordination among organizations managing these lands has been shown to influence risk mitigation outcomes (Hamilton et al., 2019). This example underscores the importance of **integrating social and ecological connectivity in governance frameworks** to achieve resilience.

Considering the complex interplay among these various ecological and socioeconomic dimensions, this section focuses on how the resilience (or lack thereof) of social and economic systems impacts forests and their resilience. Box 3.5 highlights an example of how reciprocal interactions between people and the environment can create resilient bio-cultural landscapes that provide important economic benefits.

3.5.1 Effects of forest-dependent and other forest-proximate communities on forests

For forest-dependent and other forest-proximate communities, the literature suggests that (non) resilient social and economic systems can have both positive and negative effects on forests. This is represented in Table 3.2 which provides a simplified typology and examples of such relations. The best-case, 'win-win', scenario occurs when the social and economic system is resilient and the effect on forests is positive. One such example relates to sustainable timber extraction in community-based forest management.

Tropical forests are global hotspots for biodiversity and ecosystem services but are also major sources of revenue livelihoods for forest-dependent people. Research has documented trade-offs between conservation goals and poverty alleviation of forests used for timber extraction where timber exploitation is carried out unsustainably, which causes forest degradation (Schaafsma et al., 2014). Certification and community-based forest management (CBFM) emerged as instruments that can promote both, though these may not necessarily be applicable to all cases of forest management. Soares-Filho et al. (2016) identified a potential market for trading 4.2 million hectares of certified forest outcomes with a gross value of USD 9.2 billion in Brazil, mainly in Mato Grosso and São Paulo. However, it is worth noting that certification and community-based forest management have not always proven successful in providing stable income or alleviating poverty for forest-dependent and other forest-proximate communities, as they are susceptible to challenges like limited market access, changing timber prices, and uneven distribution of benefits among communities. A study by Buřivalová et al. (2017) found that even if certification brings substantial environmental benefits and some improvement to the welfare of communities, it is at the cost of reduced short-term financial profit. Similar results were found by Delgado-Serrano (2017) and Delgado-Serrano et al. (2018) in CBFM in Mexico and Colombia.

Yet, what we define here as a 'win-win' scenario may still be undesirable if the social and economic system is resilient but unjust. For example, in Colombia, armed guerrilla groups, such as the Revolutionary Armed Forces of Colombia (FARC in Spanish), have contributed

Table 3.2 A typology of feedback loops		**Effect on forests**	
		Positive	**Negative**
Social and economic system	**Resilient**	Community-based forest management (CBFM) that promotes sustainable timber harvesting and provides a local livelihood and income source	Agro-industrial production providing stable income but driving deforestation
	Non-resilient	Mass migration leading to land abandonment and forest regrowth	Social and economic vulnerability leading to resource overexploitation

Box 3.5 Contributions of Protected Denomination of Origin (PDO) to social, economic, and ecological resilience

The *Dehesa* landscape in Spain, known as *Montado* in Portugal, is an *agroforestry* system where the historical reciprocal interactions between people and the environment have shaped a unique bio-cultural landscape. In this savanna-like pasture system, *Quercus* species, such as holm oaks, cork oaks, and gall oaks coexist with crops or pastures. The Dehesa is also considered a High Nature Value (HNV) farming system based on traditional, local management practices.

The highest value-added product of the Dehesa is Iberico ham, derived from pure Iberico pigs raised in extensive grazing systems and fed on oak acorns, along with other forest resources during the fall season. This traditional feeding method contributes to the ham's exceptional quality, flavour, and nutritional value. However, due to its prestige and high economic value, there have been frequent attempts to mislabel and sell hams that do not originate from Iberico pigs or Dehesa-based grazing systems, undermining the authenticity of the product.

To protect this heritage and guarantee authenticity, Protected Denomination of Origin (PDO) certifications play a crucial role by establishing strict traceability systems that ensure the origin, production methods, and unique characteristics of the products. The 'Los Pedroches PDO', located in Southern Spain, enforces rigorous standards that require the use of pure and endangered Iberico breeds, an extensive grazing period in the Dehesa, limits the stocking density to a maximum of one pig per hectare, and ensures that all processing stages take place within the designated territory. These hams are marketed at higher prices and are primarily produced by small farmers, processors, and cooperatives with strong regional ties.

Despite its cultural and economic significance, the Dehesa faces several threats and challenges. Climate change is increasingly affecting acorn production, while tree ageing and lack of proper management contribute to the system's gradual degradation. Additionally, the spread of holm oak pests and overgrazing by livestock further exacerbate these issues. Socioeconomic pressures also threaten the sustainability of the system. Rural depopulation, the lack of generational renewal, and unfair competition are growing concerns. In this context, PDO-regulated production ensures fair market conditions and traditional practices that provide benefits to both people and nature, preserves the natural ecosystem, limits the number of animals grazing, and contributes to the social and economic resilience of Dehesas.

The Dehesa landscape in Spain is an agroforestry system where the historical reciprocal interactions between people and the environment have shaped a unique bio-cultural landscape. Photo © Pedro Moreno, COVAP to forest conservation in certain key critical areas through methods based on coercion and violence. Studies suggest that the presence of such armed groups have in some cases limited deforestation by limiting economic activities or by restricting access to forested areas and enforcing de facto conservation practices, partly to maintain forest cover as a means for concealment and mobility (Murillo-Sandoval et al., 2021). Though resilient, in the sense that they impose a stable and enforced form of land control that restricts deforestation and maintains forest cover over time, these practices can come at significant social and economic costs, including displacement of communities, restricted livelihoods, and ongoing insecurity. This example thus highlights how a resilient system can promote forest conservation but still be undesirable.

A 'lose-win' scenario occurs when the social and economic system is non-resilient but the effect on forests is positive. One example is the pattern of rural emigration in Nepal, where international mass migration in search of employment has led to family members who do not migrate to depend heavily on remittances as a means to support their livelihoods without the need to cultivate marginal land (Oldekop et al., 2018). Such mass emigration, however, has been associated with growth of forest cover (Oldekop et al., 2018) despite a high opportunity cost of conserving forests (Rai et al., 2022). When family members move out of villages, labour shortages force households to keep land fallow (Karki Nepal et al., 2023), where forest regeneration could happen naturally or with assistance.

A 'win-lose' scenario, where the social and economic system is resilient but the effect on forests is negative, could emerge in contexts where there is social or economic stability, but forest management or agricultural practices are environmentally unsustainable. An example is Brazil's soybean expansion in the Amazon. Whilst growing global demand for soybeans has contributed to the country's GDP and provided a key and stable livelihood source for many producers (though we note that overreliance on a single livelihood source could be considered non-resilient), it has also driven deforestation to clear land for large-scale soy cultivation, causing significant loss of forest cover and biodiversity (Nepstad et al., 2008).

Finally, 'lose-lose' scenarios are characterized by non-resilient social and economic systems and negative effects on forests. Here, examples abound of how issues like poverty and weak governance lead to the overexploitation of resources, including land conversion for monoculture plantations (Austin et al., 2017), illegal logging and other illegal activities (Cerutti and Tacconi, 2008), slash and burning and overharvesting (Nepstad et al., 2008), and the encroachment of agricultural activities into forested areas (Vieilledent et al., 2013).

While useful, we note here that the typology presented in Table 3.2 simplifies the complexity of these feedback loops. In a study in Gorgoglione, Italy, Kelly et al. (2015) illustrated the complexity of factors and interactions shaping social and economic resilience and its implications on forests. The authors demonstrated how the interplay between economic, political, institutional, social, cultural, and natural factors at the community level affected the ability of communities to adapt and adjust decision-making pathways towards resilience. The study took place in a typical Mediterranean forest and shrubland social-ecological system characterized by a mixture of agricultural and forest landscapes prone to land degradation issues linked to both anthropogenic (deforestation, overgrazing, forest fires) and natural (soil erosion, droughts, climate aridity) causes. The study highlighted the importance of considering the complexity and diversity of interacting factors to fully understand feedback loops and their outcomes in diverse forested landscapes.

3.5.2 Effects of distal communities on forests

Whilst local management practices and governance structures are critical in shaping feedback loops among forest-dependent and other forest-proximate communities, broader macroeconomic factors and cultural shifts play a more substantial role for distal communities. Though contested empirically, theories like the Environmental Kuznets Curve and the Forest Transition Theory shed some light on potential feedback loops associated with distal communities.

The Environmental Kuznets Curve (EKC) suggests an inverted U-shaped relationship between economic growth and environmental degradation: early stages of economic development lead to increased pollution and deforestation, but as societies become wealthier, they prioritize environmental protection, leading to a decline in degradation (Dinda, 2004). Yet, there is little empirical support to the EKC except for some pollutants in certain regions (Stern, 2004).

The Forest Transition Theory (FTT) proposes a similar pattern to the EKC but focuses explicitly on forest cover: as countries develop economically, they move from forest loss to forest recovery, undergoing a U-shaped pattern (Rudel et al., 2010). Empirical evidence of a forest transition has been observed in parts of Europe and East Asia. For instance, in France, forest cover increased following industrialization and urbanization, as agricultural land was abandoned and environmental policies were strengthened (Mather, 1992). However, the FTT is contested, especially in low- and middle-income countries where deforestation continues despite economic growth. In Brazil, for instance, the expansion of soybean farming and cattle ranching in the Amazon has led to continued deforestation even as the country's economy has grown (Nepstad et al., 2008).

To conclude, for the theories presented above, the empirical evidence that both supports and disputes them illustrate the complex and context-dependent nature of feedback loops of distal communities on forests. Macroeconomic and cultural shifts can either degrade or restore forests, depending on their characteristics and their interactions with other local-to-global factors. Additionally, there are inherent mismatches in the timeframes of social and economic resilience (potentially manifesting within months or years) versus forest dynamics, which unfold over decades. Our framework accounts for these interactions taking place at multiple spatial and temporal scales.

3.6 External conditions and shocks shaping resilience

Global factors such as climate change, economic markets, new technologies and trends, and international policy frameworks indirectly shape the relationship between forests and people and influence social and economic resilience.

3.6.1 Climate change effects on forest SES

Climate change is expected to intensify the frequency and intensity of extreme events, leading to large disruptions in forest ecosystems, significant economic losses in the forestry sector, and intense effects on the social and economic resilience of forest-dependent and other forest-proximate communities and forest owners (Fettig et al., 2023). In addition to extreme events, climate change implies a series of slow-onset events that also undermine the resilience of forests, such as changes to temperature and precipitation seasonal patterns, sea-level rise, soil salinization, or glacial retreat, with impacts on biodiversity and the distribution of pests and diseases (IPCC, 2022).

The economic consequences of climate change for forests are projected to be severe. Projections in Central American countries indicate that ecosystem service declines of 24–62% could result in annual economic losses ranging from USD 51 to 314 billion until 2100, with particularly severe impacts on montane and dry forests. These losses could represent up to 335% of the gross domestic product for the lower-middle-income countries in the region, with strong impacts on the social and economic resilience of forest-dependent and other forest-proximate communities (Baumbach et al., 2023).

Droughts are likely to play a central role in altering forest growth, productivity, and species composition. The ecological resilience of forests to drought varies widely as a function of species composition, geographical location, and climatic conditions. Studies indicate that mixed forests generally exhibit higher resilience compared to monospecific stands (Gazol et al., 2018).

Another concern is the shifting distribution of tree species due to climate change. For instance, between 21% and 60% of European forest lands are projected to be suitable only for Mediterranean oak forest types by 2100 (Hanewinkel et al., 2013), which offer lower economic returns for forest owners and the timber industry while also reducing carbon sequestration capacity (Lindner et al., 2010; Thuiller et al., 2011). The adaptive capacity of European forestry varies significantly across regions. It is relatively high in the boreal and temperate oceanic regions, more constrained by socioeconomic factors in the temperate continental region, and most limited in the Mediterranean, where large forest areas remain extensively managed or unmanaged (Lindner et al., 2010), further reducing economic profitability and resilience.

Climate change is already affecting forests globally (Olsson et al., 2019), and combined with non-climatic drivers, they drive degradation, which renders forests more susceptible to climate change itself. A recent study by Forzieri et al. (2022) found that up to 23% of intact, undisturbed forests are deemed to have reached their threshold for abrupt decline and are experiencing a further reduction of resilience.

A dynamic global forest model developed by Tian et al. (2016) suggested that rising temperatures and CO^2 levels will lead to a 30% increase in forest growth by 2115. However, this gain will be accompanied by increased forest dieback, with net effects varying by region and time period. By 2050, global net primary production (NPP) is projected to rise by 12%, reaching a 30% increase by 2110, with temperate regions such as the European Union and the USA experiencing the most significant gains. However, China is expected to see only modest gains and even a slight reduction in NPP by 2050. While the most significant proportional increases in forest productivity are projected to occur in tropical and subtropical regions due to higher investments in plantation forests, these regions will also face the most significant levels of dieback. This growth may enhance economic resilience by boosting supply and fostering investment and employment in the forestry sector.

Extreme climate events have significant impacts on forest health. Studies by Brando et al. (2014) and Fu et al. (2013) indicated that feedback loops involving droughts and forest fires heighten the risk of Amazon forest dieback. Conversely, Good et al. (2013), drawing on long-term experimental data, argued that Amazon dieback remains unlikely but still possible. Furthermore, while increased investments in plantation forests will contribute to higher forest output, timber prices are projected to decline by 15-30% by the end of the century (Tian et al., 2016), reducing profitability for forest-dependent and other forest-proximate economies. Pulpwood prices will see the sharpest declines, although saw timber prices are also expected to fall. Climate mitigation policies and efforts may slow these changes, but their role is uncertain. They can reduce the impact of changes on timber markets, curbing growth gains and also limiting dieback, but their effects are uneven due to the mentioned influences of climate change on both forest dieback and growth. Hence, it is difficult to predict climate change effects on timber supply and social and economic resilience.

Other forest disturbances, such as wildfires and pathogen outbreaks, are also exacerbated by climate change. Warmer temperatures and reduced moisture availability have been linked to increased fire and insect outbreaks, particularly in temperate and boreal regions (Brecka et al., 2018). These disturbances have substantial economic consequences, affecting short-term market stability, sector growth, and investment strategies.

In some ecosystems, forest resilience to wildfires is declining as increased moisture stress and unfavourable post-fire conditions hinder tree regeneration, elevating the risk of conversion to non-forest landscapes (Stevens-Rumann et al., 2018). A study in the Rocky Mountains, USA, revealed significant declines in post-fire tree regeneration in the 21st century due to reduced seedling densities and increased regeneration failures. Dry forests are particularly vulnerable to post-fire conversion to non-forest states due to their limited climatic tolerance. Climate-induced reductions in forest density and extent have critical implications for ecosystem services, social stability, and economic resilience (Sass-Klaassen et al., 2016).

Tian et al. (2016) also examined the impact of forest fires, noting a substantial increase in fire and dieback activity in Russia. While the European Union, USA, and Canada face proportionally similar increases, their smaller forest areas result in lower absolute impacts. In contrast, Southeast Asia and Brazil are projected to experience relatively modest increases in wildfire activity compared to the temperate and boreal regions.

Pathogen outbreaks, intensified by climate change and globalization, pose further threats to both forest ecosystems and socioeconomic stability. These outbreaks disrupt forest composition, affect ecosystem functions, and generate significant economic costs due to lost timber, increased management expenditures, and reduced ecosystem services (Freer-Smith and Webber, 2017). Addressing these threats requires inter- and transdisciplinary collaboration and adaptive management approaches to mitigate the adverse social and economic consequences of these disturbances.

The implications of climate change for rural livelihoods and Indigenous communities are significant. Corporations and forest owners in high-income countries can be less affected due to their capacity for adaptation. However, in more fragile forest-dependent and other forest-proximate communities, the effects of climate-induced shifts in forest productivity and climate risks will have important effects on their social and economic resilience, threatening employment and incomes (Fettig et al., 2023). The loss of biodiversity and ecosystem services jeopardises traditional livelihoods such as non-timber forest products harvesting. Additionally, increasing demand for carbon sequestration and wood-based products may escalate

Climate change is expected to intensify extreme events such as droughts. Photo © Viola Belohrad competition for forest land, intensifying land-use conflicts and conservation disputes. Expanding plantation forestry to meet these demands could displace local communities and further reduce biodiversity.

The uneven global distribution of climate-induced forest losses may disrupt supply chains and trade patterns, creating increased uncertainty and vulnerability for the forest sector. The socioeconomic resilience of communities reliant on forests will depend on the implementation of adaptive management strategies that consider both ecological and social factors (Bottero et al., 2021; Pardos et al., 2020). It is important to acknowledge the uncertainties inherent in climate change projections. Much of the data presented are extracted from current research relying on models and estimations, which are subject to variability due to differences in climate scenarios and projection methodologies (Reyer et al., 2017). Additionally, most studies do not fully account for potential adaptation measures that could mitigate these impacts. In summary, climate change presents complex and multifaceted challenges for forest-related social and economic resilience worldwide, affecting their ecological stability, economic viability, and social well-being. While models and projections provide valuable insights, significant uncertainties remain, highlighting the need for continuous monitoring, adaptive management, and policy interventions to safeguard forest-dependent and other forest-proximate communities and industries in the face of ongoing climate change.

3.6.2 Markets and supply chain effects

Markets and supply chains for forest products are crucial in enhancing social and economic resilience, particularly for forest-dependent and other forest-proximate communities. Market opportunities provide income sources for forest owners and rural communities, generate employment opportunities, and foster economic stability. Estimates based on FAOSTAT trade and production data indicate that the global forest production value exceeded USD 1,500 billion (FAO, 2022). However, the global forest product market has undergone profound transformations in the 21st century, shaped by structural changes related to value-added development and employment, growing demand for innovative products, and shifting trade dynamics, with China and other Asian countries emerging as key players (Long et al., 2019).

Economic crises significantly impact the forest sector, influencing demand, pricing, and market stability, thereby affecting social and economic resilience. Since forestry is a long-term investment, the sector is relatively slow to adapt to economic shifts. Changes in demand, prices, and exchange rates can intensify the vulnerabilities of forest-dependent and other forest-proximate communities, limiting their ability to implement adaptive management strategies (Kelly et al., 2015). The effects of economic downturns vary by region. For example, Austria's forest-based sector performed better during an export crisis than during a locally driven economic downturn (Schwarzbauer et al., 2013). In Indonesia, economic crises prompted increased forest clearing by small farmers seeking financial security (Sunderlin et al., 2001). Similarly, in the Brazilian Amazon, financial crises underscored the necessity of policies supporting both formal and informal forest economies (Canova and Hickey, 2012). Socioeconomic factors, including political, institutional, and cultural dynamics, play a crucial role in determining how forest-dependent and other forest-proximate communities adapt to economic shocks.

Between 1990 and 2015, the total global forest area declined from 4.28 to 3.99 billion hectares, reducing the percentage of global forest cover from 31.85% to 30.85%. In the same period, planted forests expanded significantly from 167.5 million hectares (Mha) to 277.9 Mha, representing an increase from 4.06% to 6.95% of the total forest area. This expansion was most pronounced in the temperate zone, particularly in East Asia, followed by Europe, North America, and Southern and Southeast Asia (Payn et al., 2015). Similar trends of gains and losses in tropical forests have been identified, with increases in planted forest areas but limited tree cover gains due to shifts in forest management policies and the devaluation of extensive, degraded natural forests (Fagan et al., 2022; Sloan et al., 2019).

Future projections suggest that the planted forest area will continue to grow (Nepal et al., 2019). Projections (modelled over the next 55 years for 180 countries under five socioeconomic scenarios) from the Fifth Assessment of the Intergovernmental Panel on Climate Change (IPCC) indicate that by 2070 the global planted forest area could range from 379 Mha under a relatively poor and unequal world scenario to 475 Mha under a relatively wealthier and more equal world scenario, representing increases of 46% and 66% compared to 2015. However, the increase in planted forests is projected to lower product prices by 12% by 2070, while global forest product production and consumption could increase by as much as 3.3%. The growth in production will not be evenly distributed; China, India, and Indonesia may see forest stocks rise by up to 18%, while Brazil, Argentina, and Chile could experience planted forest area growth of 28–68%, driven by high investment returns. Africa's planted forests could expand by up to 137% due to abundant available land for afforestation, whereas Europe and North America may see growth of 29–40%.

The projected rise in the expansion of planted forests and wood production could have both positive and negative implications for social and economic resilience. On the positive side, increased forest plantations could mitigate supply shocks, reduce dependence on natural forests, and stabilise global timber markets. Expanding forestry activities, particularly in Asia, South America, and Africa, could generate employment in timber harvesting, processing, and related industries, supporting economic diversification (Zhang, 2019). Rising timber demand may encourage landowners to preserve and expand forests rather than convert them to other land uses, promoting long-term sustainability. Additionally, increased wood production in export-driven regions such as South America and Asia could enhance national revenues through global trade (Long et al., 2019).

On the other hand, declining global timber prices and market volatility could impact profit margins and marginalise traditional forest-dependent and other forest-proximate communities (Levers et al., 2021). Increased demand for forest land in South America and Africa may lead to land-use conflicts, displacement of local populations, and competition with agriculture. These effects could also impact small-scale foresters in developed economies, such as North America and Europe, who may struggle to compete with large-scale plantations in emerging markets. Corporate-driven expansion could further undermine the social and ecological resilience of smallholders (Rudel, 2009) and Indigenous communities (Hofflinger et al., 2021). Moreover, intensive plantation forestry in regions like Brazil, Indonesia, and Africa could negatively impact biodiversity and water resources, reducing forest health, community well-being and ecosystem resilience (Gómez et al., 2023).

Another critical trend influencing social and economic resilience in forest supply chains is the rise of the bioeconomy and circular economy sectors, particularly in forest-based bioenergy and biofuel supply chains (Cambero and Sowlati, 2016). The use of forest biomass, including residues from forest operations and wood manufacturing, along with biofuels, can reduce carbon emissions and support renewable energy targets (Favero et al., 2020). The conversion of forest biomass into bioenergy and biofuels provides environmental, economic, and social benefits, reinforcing socioeconomic resilience. However, challenges such as high supply chain costs (Cambero et al., 2015), raw material competition (Bryngemark, 2019), and potential soil carbon losses (Achat et al., 2015) must be considered. To maximize carbon benefits, biofuels must be derived from waste biomass or degraded lands rather than from land-clearing activities (Fargione et al., 2008). Effective policies and strategic supply chain optimisation are crucial for ensuring sustainability in forest-based bioenergy and biofuel production, as well as social and economic resilience.

Additionally, shifts in the construction sector are increasing the demand for bioeconomy-driven wood products, particularly engineered wood products such as laminated timber (Heymsfield et al., 2024). Changes to the International Building Code in 2021, allowing wood buildings up to 18 stories, have stimulated the demand for mass timber. Projections suggest that between 2020 and 2060, global mass timber consumption could increase by 8–58 million m^3 annually, depending on the scenario, driving up softwood lumber production by 8–53 million m^3 per year and increasing timber prices by 2–23% (Nepal et al., 2021). While growing demand implies increased harvesting, forest stock is expected to remain stable due to rapid biomass regrowth (Abed et al., 2022). The economic value of forest land may rise, discouraging deforestation. Additionally, the substitution of traditional concrete and steel with mass timber could provide significant carbon benefits (Nepal et al., 2024; Pasternack et al., 2022).

The forest sector also plays a key role in the transition to a circular economy by promoting sustainable practices, optimising resource use, minimising waste, and encouraging the reuse and recycling of materials derived from wood products. Some researchers introduced the concept of wood cascading, which involves the sequential use of wood products to maximise resource efficiency (Mair and Stern, 2017). Finland and Canada are pioneers in developing high-value circular economy products that support the sustainability of forest-based

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industries (e.g., Jarre et al., 2020; Näyhä, 2019). In Brazil, the circular economy approach has led to extensive use of wood waste for energy generation and efficient transformation of raw materials into finished products, ranging from 60% efficiency in primary processing to nearly 100% in recycling and energy production (da Silva et al., 2020).

While the circular economy and bioeconomy models offer significant potential, they also present challenges. These innovative paradigms might promote economic development but not necessarily enhance social and economic resilience, particularly for Indigenous and forest-proximate communities. These communities often face cultural, economic, and logistical barriers that make adaptation difficult (Mies and Gold, 2021). Technological advancements in forestry have increased capital requirements, creating disparities in economic opportunities (van Kooten et al., 2019). Additionally, balancing economic, environmental, and social objectives remains complex. The bioeconomy and circular economy models enhance ecological resilience by improving resource efficiency and reducing environmental degradation. However, these changes in forest use can conflict with the preservation of cultural heritage and traditional practices and be out of the economic possibilities and capabilities of forest-dependent and other forest-proximate communities. Addressing the challenges of market fluctuations, industrial concentration, and social adaptation remains essential for ensuring the long-term sustainability of the forest sector and the resilience of forest-dependent and other forest-proximate communities. The successful implementation of these strategies requires localized approaches that respect community-specific needs and contexts and ensure equitable market access, workforce adaptation, and sustainable forest management. However, challenges in governance, policy frameworks, and stakeholder collaboration must be addressed to maximise these benefits and avoid the perpetuation of power imbalances.

3.6.3 New social demands

The societal demand for voluntary certifications, wood traceability systems, codes of conduct, and market exclusion mechanisms in forest-risk supply chains play a critical role in shaping social and economic resilience. Certified forests may also play a role in conserving biodiversity for some taxa and in some settings and in maintaining ecosystem services such as clean water, air quality, and climate regulation (Matias et al., 2024). These mechanisms have the potential to enhance resilience by fostering sustainable forestry practices, increasing market access, and improving community well-being. These benefits reduce the vulnerability of communities to climate change and environmental degradation, further reinforcing social and economic resilience. Among these initiatives, forest certification schemes, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), have demonstrated their ability to enhance resilience by promoting biodiversity conservation, market access, and community well-being. However, as noted by Garrett et al. (2021), the effectiveness of such mechanisms is often variable and context dependent.

From an economic resilience perspective, forest certification can improve market access and competitiveness, allowing companies to enter new markets and maintain their existing ones. It enhances credibility and access to international markets with rigorous sustainability requirements. Certified forests also attract investments from environmentally conscious investors and institutions, supporting long-term financial viability while reducing legal and financial risks associated with deforestation, land disputes, and unsustainable practices (Rickenbach and Hansen, 1995). Long-term certification can stabilise forest management by mitigating economic pressures and facilitating export opportunities (e.g., Klarić et al., 2023). Furthermore, certification can enhance supply chain reliability by ensuring that wood sources are legally harvested, sustainably managed, and fully traceable. This compliance enables businesses to meet strict environmental regulations, including the Regulation on Deforestation-free Products of the European Union (Marciniak et al., 2024) and the USA Lacey Act, reducing the risk of trade restrictions while strengthening the credibility of certified forest products.

However, while certified products often obtain price premiums, the increase is not always substantial (Buřivalová et al., 2017; Wolff and Schweinle, 2022). Challenges such as high costs and limited market incentives, particularly in tropical regions, must be addressed to fully realize the benefits of certification (Ehrenberg-Azcárate and Peña-Claros, 2020). To enhance certification's effectiveness, improved data collection and broader impact, indicators are necessary (van der Ven and Cashore, 2018).

In terms of social resilience, certification aims to support livelihood protection and job stability by ensuring fair wages, safe working conditions, and long-term employment in the forestry sector, which would promote job security and income stability, particularly for rural and Indigenous communities. Certification can enhance community services, such as education, medical services, and infrastructure, as seen in Mexico (García-Montiel et al., 2022). It also attempts to promote community engagement, which can improve relations between forestry businesses and local communities, as observed in Australia and Chile (e.g., Tricallotis et al., 2018). Additionally, certification can foster the empowerment of local and Indigenous groups by upholding land tenure rights, encouraging community participation in decision-making, and requiring Free, Prior, and Informed Consent (FPIC) to ensure equitable benefits from forestry activities (Humphries and Kainer, 2006). By promoting transparent land-use policies and responsible corporate behaviour, certification can reduce conflicts over land use and enhance social equity, including gender equality and the inclusion of marginalised groups (e.g., Loveridge et al., 2021). Furthermore, in Indonesia, FSC certification was associated with improved community health by a 5% reduction in deforestation and a 31% decline in air pollution, alongside a decrease in firewood dependence, respiratory infections, and malnutrition, all of which are key factors in strengthening social resilience (Miteva et al., 2015).

The social benefits of forest certification are also linked to its ability to reduce environmental degradation and support community well-being. Through sustainable forest management practices, certification can improve soil quality, enhance water retention, and foster biodiversity. These improvements contribute to long-term yield stability and reduce vulnerability to climate-related disturbances, such as pest outbreaks and diseases. Finally, other trends such as Nature-based Solutions (NbS) and Ecosystem-based Adaptation (EbA) are gaining momentum. They can be defined as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience” (European Commission, 2015, p.1). When their ecosystem services are recognized and facilitated as part of a climate change adaptation strategy, forests can be a key component of EbA. Forests, as providers of Nature-based Solutions, offer a multifaceted approach to addressing climate change, enhancing biodiversity, and improving human well-being. These solutions leverage natural processes and ecosystems to provide benefits such as climate change mitigation (acting as carbon sinks), biodiversity conservation, and improvement of human well-being (Anderegg et al., 2020; Seddon et al., 2021). Urban forests have a special significance as NbS in supporting public health, since contact with forest ecosystems has psychological, physiological, and social well-being benefits (Roeland et al., 2019) that contribute to social resilience. From an economic perspective, well-managed forests can prevent hazards and risks. However, the effectiveness of these solutions depends on adaptive management, the scientific assessment of risks, and inclusive policy frameworks that consider the needs and rights of local communities (Cohen-Shacham et al., 2019).

3.6.4 Technological trends affecting the management of forest SES

Digital technologies have emerged as powerful tools to enhance the adaptive capacity of forests, ensuring their sustainability and strengthening social and economic resilience (FAO, 2024). Satellite and sensor-based technologies and advanced support decision systems play a significant role in optimising forest-based supply chains, monitoring hazards and forest status, and improving efficiency and sustainability through better data collection and decision support (e.g., Müller et al., 2019). They are particularly used in precision forestry, wildfire management systems, and forest health monitoring.

Precision forestry involves the use of advanced technologies and data-driven tools such as satellite imagery, LiDAR, drones, and AI-powered analytics to optimise forest management (Fardusi et al., 2017). These technologies enable foresters to make informed decisions regarding harvesting, reforestation, and resource allocation, minimising waste and maximizing productivity. By implementing precise monitoring techniques, forest managers can reduce the ecological footprint of logging operations while increasing economic efficiency. These techniques facilitate continuous cover forestry, a method that has shown higher economic returns and faster recovery from disturbances compared to traditional clear-cut systems (Castro et al., 2021; Knoke et al., 2023). This approach enhances the economic resilience of forest management systems by improving recovery rates after disturbances and promotes sustainable practices that ensure long-term economic gains for local communities dependent on timber and non-timber forest products.

With climate change exacerbating wildfire frequency and intensity, digital technologies have become essential in preventing and managing these disasters. Optical remote sensing technologies, including terrestrial, airborne, and spaceborne systems, are used for early fire warning and detection. Satellite-based thermal imaging, machine learning algorithms, and Internet of Things (IoT) sensors (sensors integrated into devices that can share captured data in real time) help detect wildfires before they escalate (Barmpoutis et al., 2020). Additionally, real-time monitoring, data analytics and predictive modelling improve response strategies, allowing authorities to allocate resources efficiently and minimise economic losses and environmental degradation, and improve social well-being (preventing casualties and health-related problems).

Airborne optical and thermal sensors, such as hyperspectral cameras and thermal cameras, are becoming more affordable and widely used for detecting and monitoring wildfires from both manned and unmanned platforms (Allison et al., 2016). GIS platforms enable real-time tracking of fire service vehicles, fire patrol aircraft, and weather conditions, aiding in the operational planning and resource allocation for firefighting efforts (e.g., Kinaneva et al., 2019). Unmanned aerial vehicles (UAVs) equipped with deep learning-based computer vision algorithms can detect wildfires at early stages, reducing the risk of uncontrollable fires (Bouguettaya et al., 2022). UAVs with vision-based and spatial localisation systems provide real-time detection and precise location data of fires, enhancing early intervention capabilities (Lu et al., 2022). Mixed air-ground mobile networks, involving UAVs and personal electronic devices with wi-fi connectivity and GPS, help firefighters obtain real-time images of hot spots and improve communication in challenging terrains (Barrado et al., 2010). Finally, intelligent software agents are designed to formalise knowledge in forest fire prevention and fighting, demonstrating their utility in realistic firefighting scenarios (Jaber et al., 2001). These modern tools for wildfire management improve the sustainability and efficiency of forest operations, ultimately impacting both the economic and social dimensions of forestry. By protecting forest-dependent and other forest-proximate communities and industries from the devastating impacts of wildfires, these technologies contribute to greater social and economic resilience.

Forest health monitoring is also crucial for maintaining the resilience and stability of forest ecosystems, which are increasingly threatened by anthropogenic influences and climate change. In the last decades, cyclical damage caused by certain pests has been exacerbated by extreme environmental events, as well as the emergence of new agents capable of causing high tree mortality (Ecke et al., 2022). Recent advancements in technology have introduced various methods for monitoring forest health, including remote sensing, UAVs, AI-driven disease detection, automated pest monitoring and machine learning that provide essential insights. These technologies offer efficient means to assess forest conditions over large areas and various temporal scales, and provide consistent data over time (Torres et al., 2021). Remote sensing tools facilitate the early identification of stress factors, including pest infestations, diseases, and climate-induced droughts, allowing for timely interventions (e.g., Ecke et al., 2022).

UAVs have emerged as a flexible and cost-effective tool for forest health monitoring, capable of providing high-resolution data that traditional remote sensing platforms may not achieve. UAVs are particularly useful for capturing detailed imagery below cloud cover and in dynamic forest environments. However, challenges remain, such as the need for more multitemporal monitoring, increased use of hyperspectral and LiDAR sensors, and the development of standardised workflows to ensure data uniformity (Dash et al., 2017; Ecke et al., 2022). Machine learning techniques offer advanced methods for analysing complex datasets. These techniques can help in estimating critical vegetation parameters such as moisture content and chlorophyll levels. The rapid evolution of AI tools and computational resources continues to enhance the capabilities of remote monitoring systems (Estrada et al., 2023).

Data science approaches, including digitalization and standardization, are crucial for developing a scalable multi-source forest health monitoring network. However, the integration of in situ data is essential to enhance the accuracy and applicability of these data, necessitating standardisation of data collection and workflows (e.g., Navarro-Cerrillo et al., 2020). Ensuring the long-term health of forests is fundamental for preserving ecological integrity. Healthy forests, in turn, support local economies by sustaining biodiversity, ecotourism, and traditional livelihoods, thereby reinforcing community livelihoods and the socioeconomic resilience of forest-reliant populations. However, despite significant progress in technological advancements, several challenges persist in forest health monitoring, such as the need for better integration of different monitoring approaches, the development of user-friendly tools for decision-making, and the establishment of a legally accepted framework for new information products in forestry (Lausch et al., 2017; Pause et al., 2016).

The integration of digital technologies in forest management is reshaping how we interact with and protect these critical ecosystems. By harnessing the power of precision forestry, wildfire management systems, and forest health monitoring, societies can build resilience against environmental threats while ensuring economic and social resilience. As climate change continues to challenge forest stability, investing in digital innovation will be key to securing the future of forests for generations to come. However, these technologies request important investments, but also high-level digital skills at national and local level, both at the decision centres and at the operational/ground level to be effective. Furthermore, which digital technologies might make a significant difference and for whom and with what resources is still open and contentious (e.g., Singh and Srivastava, 2024). Other important challenges are limited internet access, bureaucratic obstacles, and the delayed responses of state environmental agencies.

The literature on the impacts of these technologies in the Global South and in community-based forestry is limited and quite recent. Lewis Hood and Gabrys (2024) discussed how real-time environmental monitoring technologies (e.g., deforestation alert systems) structure the way Shipibo communities in Peru interact with and respond to forest changes. The authors criticise how digital forest technologies, while useful for environmental monitoring, can reinforce colonial power structures by shaping what kinds of knowledge and temporalities are considered legitimate. However, they also highlight how Indigenous communities are actively using and reconfiguring digital tools to assert sovereignty over their lands and futures (Libert-Amico et al., 2022). Even if not focused on digital forestry technologies, Turnbull et al. (2023) analysed Indigenous-led digital initiatives, such as counter-mapping projects that use drones and aerial imagery to document land grabbing and resource exploitation. These initiatives are crucial in ensuring that digital technologies do not reinforce historical patterns of exclusion and exploitation and that Indigenous knowledge systems are not sidelined in favour of Western digital data-driven approaches. Indigenous data sovereignty and Indigenous data governance should be prioritised (Williamson et al., 2023) in the deployment of digital technologies that enhance forest-related social and economic resilience.

3.7 Chapter conclusions

In this chapter, we explored the multifaceted relationships between forests and social and economic resilience, presenting a novel framework to understand the dynamic interactions between the provision of ecosystem goods and services and their significant contributions to human well-being, from forest-dependent to other forest-proximate and distal communities. Drawing on evidence from different geographic contexts, we presented how forests act as critical safety nets for vulnerable populations while providing essential resources to broader communities. Forests are central to the socioeconomic and environmental systems of human societies, with their roles varying across contexts and scales. Effective management, adaptive governance and sustained resilience benefits require a deep understanding of these diverse roles, including the conditions under which forests contribute to building resilience versus those where they fail to do so.

Building resilience in forest-dependent and other forest-proximate communities necessitates an integrative approach that addresses social, economic, and ecological dimensions. Governance, participatory management, social networks, and equitable economic opportunities are crucial for fostering adaptive capacities and sustainable outcomes. While participatory forest management programmes worldwide illustrate the potential for virtuous cycles of conservation and community benefit, external pressures such as economic shocks, climate change, and social inequalities continue to challenge resilience. Adaptive governance systems, inclusive strategies, and strong social cohesion are essential to counter these pressures and to ensure that forests remain a source of resilience. The interplay of socioeconomic and environmental factors create dynamic feedback loops between forests and their dependent communities. Positive examples, such as sustainable community-based forest management, highlight the potential for win-win scenarios, yet challenges like inequitable benefits and market barriers persist. Conversely, non-resilient systems, such as those associated with rural outmigration, sometimes inadvertently relieve pressure on forests, though they could potentially create negative spillovers on forests on other territories. These examples underscore the complexity of forest-community interactions and the need for context-specific strategies.

Finally, global dynamics, including climate change, market forces, changing societal demands, and technological shifts, further shape the relationship between forests and people and influence social and economic resilience. Innovations such as digital technologies and Nature-based Solutions offer promising pathways to enhance forest resilience and climate adaptation, but they require equitable access, supportive policies, fair financing, and a focus on community-led processes that prioritize local needs and interests. As social-environmental pressures intensify, transformative changes that emphasie collective action, social equity, and environmental sustainability are essential to unlocking forests' full potential to support resilient and thriving communities.

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4

Chapter 4

Analysis of Forest Governance and Institutions for Social and Economic Resilience

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Abstract

Governance and institutions shape relations among people and between people and ecosystems, and are thus central considerations in the resilience of forest social-ecological systems (SES). This chapter reviews key concepts and models of governance and institutions that shape ecological, social, and economic resilience. Governance models range from centralised to decentralised and multilevel, polycentric systems, although in practice, many of these still maintain or struggle with enduring centralising tendencies. This analysis raises questions about who benefits and who loses, and how 'desired' outcomes may vary by actors and across scales, and hence, how governance can enhance resilience as well as foster transformation towards greater equity and well-being. The chapter also outlines critical governance and institutional attributes and principles, as well as underlying drivers or determinants that can undermine or support forest SES resilience, emphasising that these relationships are not currently systematically understood. To contextualise evidence of how governance systems and approaches have shaped forest SES resilience, the chapter briefly traces the history of forest governance and institutions before turning to contemporary trends, noting that current manifestations cannot be separated from colonial and post-colonial legacies. Finally, drawing from a wide variety of case studies, the chapter offers tangible examples illustrating the presence and effects of the institutional attributes, principles, and underlying drivers, ultimately emphasizing that these governance characteristics may be observed alone or in combination, and can either support or undermine desired SES resilience or transformation. Recognising how resilience is complex, multi-dimensional, and dynamic, and the active role of governance and institutions, the chapter concludes with a few recommendations on the need for corrective, inclusive, equitable, and adaptive multi-level and multi-centre governance, in which past and future inequities and injustices are adequately addressed for socially-just forest SES resilience.

4.1 Introduction

Forest governance encapsulates the various international, national, subnational, local, and cross-scale dynamic governance processes and institutions that shape decisions affecting people-forest relationships. Governance and institutions are central to the relationships between humans and forests, acting as fundamental determinants of use, relational behaviours, and management outcomes (Armitage et al., 2012).

This Chapter focuses on the role of governance and institutions in shaping the resilience of forest social-ecological systems (forest SES resilience). That is, both forest resilience and the social, economic, and cultural resilience of people who depend and engage directly and indirectly with forests. The overarching question we address here is: **how do governance processes and institutions shape forest SES resilience?** In answering this question, this Chapter offers an understanding of the kinds of governance and institutional approaches and systems that hinder or enhance the resilience and/or transformation needed in response to shocks affecting both forests and dependent social and economic systems at multiple scales. It draws specific attention to important influential institutional attributes and principles.

Much of the existing academic literature on governance, in relation specifically to forest SES resilience, focusses on the importance of **stakeholder participation as a principle** and the positive potential of **adaptive governance as an approach**, and more concretely adaptive management approaches, without comprehensively addressing underlying institutional arrangements (e.g., Cantarello et al., 2024; Knoke et al., 2023; Nikinmaa et al., 2023). Beyond forest SES, there is more extensive academic literature on governance and institutions in reference to water SES and fisheries SES, as well as other conceptual thinking on environmental governance for resilience. Whether considered as either standalone or interdependent, natural resource systems and their social and economic components are extremely complex and dynamic SES, with cross-scale interactions and feedback loops (Chapters 2 and 3). As such, attention to institutional attributes and principles that steer positive adaptive cycles and panarchy in building forest SES resilience or transformation is important.

The next section reviews definitions and theoretical concepts in relation to governance and institutions of forest SES, including complexities around SES governance for resilience. Section 4.3 offers a framework for analysis and evidence synthesis of the institutional attributes and principles that mediate the relationships between forest resilience and socio-economic resilience. Section 4.4 discusses both the historical dynamics of forest governance and institutions and the contemporary trends in forest policies, underscoring their influences on forest SES resilience. Section 4.5 reviews concrete evidence of institutional attributes and principles as observed in existing governance approaches and systems to illustrate how they support or fail to support forest SES resilience. Section 4.6 concludes the Chapter with recommendations and ways forward.

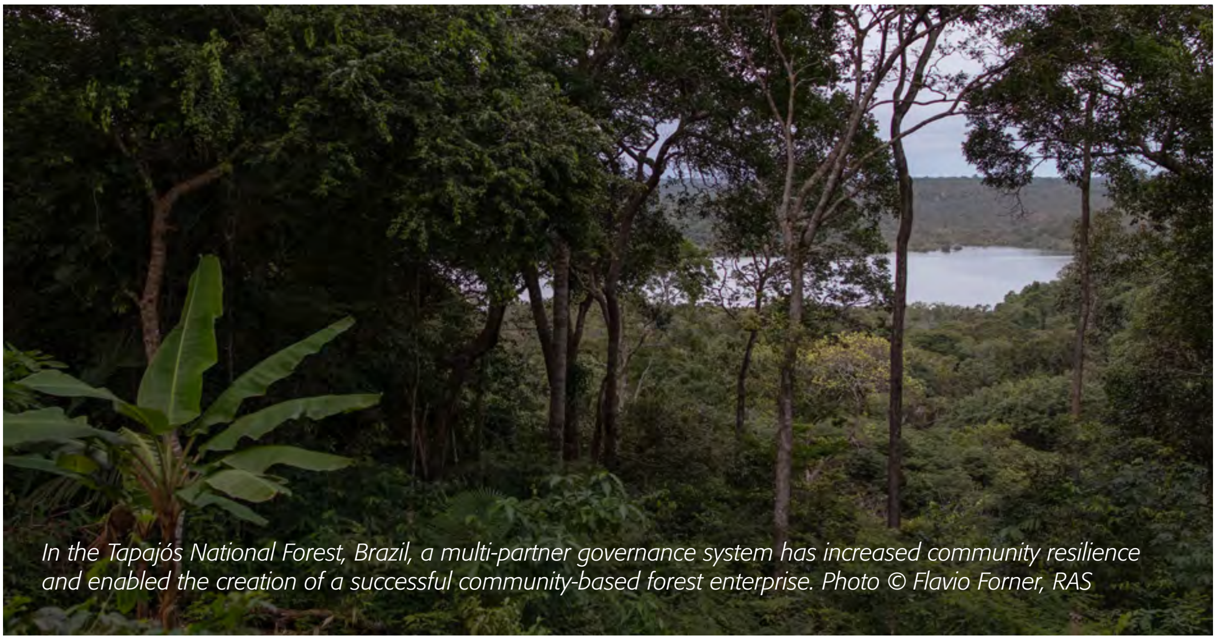
4.2 Governance and institutions of forest SES: Definitions, complexities related to resilience, and knowledge gaps

Governance refers to the sets of formal and informal socio-institutional arrangements, regulatory processes, policies, and mechanisms through which individuals and/or groups of actors exercise their rights and obligations, interrelate at multiple scales and levels, and mediate their needs and interests over time (e.g., Colfer and Pfund, 2011). Simply put, in the context of forest SES resilience, it is the way in which decisions and rules, including rules about decision-making processes, are made, by whom, how and why, and how these shape the management and use of forests and related outcomes (Larson et al., 2021). Governance, management approaches and, as explored in Chapter 6, 'response options' thus affect forests and their resilience (for instance, what policies and regulations contributed to the current state of the forest?). Governance also affects the relationship between forest resilience and social and economic resilience (for example, who benefits or loses from current conditions or management policies, how, and why?). Formal and informal governance institutions, from both the forest sector and sectors that influence forests, steer forest SES priorities. They influence perspectives on forests, if and how to respond to shocks, and what is done (or not done) to support resilience.

4.2.1 An overview of forest SES governance approaches and systems

Diverse approaches and systems of governance may be distinguished, from centralised to decentralised, as well as market-based, polycentric, and *multi-level governance* systems, which we elaborate on in this section.

Centralised governance approaches are mainly state-led, or in some cases private sector-led (privatisation), with top-down and even authoritarian decision-making processes. Centralised systems concentrate power, tend to be less accountable to local populations and may discourage input into decision-making (e.g., Ribot et al., 2006). Historically, decision-making over forests has been highly centralised, as will be discussed in Section 4.4.



In the Tapajós National Forest, Brazil, a multi-partner governance system has increased community resilience and enabled the creation of a successful community-based forest enterprise. Photo © Flavio Forner, RAS

Decentralised governance approaches reflect various forms and levels of citizen participation in resource governance (e.g., Larson, 2003; Zulu, 2013, 2012). They involve some degree of responsibility-, authority-, and power-sharing with subnational state authorities and/or devolution (partial or complete) to non-state actors such as communities and other civil society actors (e.g., Larson, 2003; Zulu, 2013, 2012). Decentralised, participatory natural resource governance approaches that exhibit power devolution to local communities have been termed 'community-based natural resource management' (CBNRM) (Dressler et al., 2010). In relation to forests, examples include diverse schemes known and loosely assigned as community forestry (CF), joint forest management (JFM), social forestry (SF), community-based forest management (CBFM), community conservation, etc. (e.g., Baynes et al., 2015; Duguma et al., 2018; Rakatama and Pandit, 2020). While typical of the Global South, these models of forest governance can also be encountered in the *Global North* (e.g., Hajjar et al., 2024; Lawrence et al., 2021; McGinley et al., 2022).

Addressing resistant top-down elements in 'participatory' governance approaches, **rights-based governance approaches** have emerged with greater emphasis on human rights principles, including rights to land and territory and self-determination (Prouchet et al., 2023). Importantly, rights-based governance approaches are largely associated with the ancestral forest lands and resources held and managed by local communities (LCs), Indigenous Peoples (IPs), and Afro-Descendent (AD) Peoples, where applicable, and have been collectively proven to be consilient with low intensity anthromes (human-shaped biomes) and successful biological and cultural diversity and forest conservation (Garnett et al., 2018; Kothari et al., 2019).

Governance approaches that leverage capitalist market-focused instruments are denoted as **market-based approaches** (Lemos and Agrawal, 2006). Market-based governance approaches seek to incentivise and shape human behaviour through regulatory and incentive schemes, including certification, voluntary standards, benefit-sharing to the various parties involved, and/or cash transfers that address variously environmental, social, and/or economic issues (e.g., Scheba, 2018; Shen et al., 2023).

As environmental governance evolves and becomes more complex, the neat separation of the approaches described above does not often exist in practice, as more commonly **hybrid forms of governance** span the state-market-community continuum, and different approaches co-occur in the same context (Lemos and Agrawal, 2006). Often established with the apparent intention to address the limitations of single-centred decision-making authority, hybrid forms of governance involve public-private governance arrangements (e.g., forest concessions), private-social governance mechanisms (e.g., payment for ecosystem services, REDD+, ecotourism), and public-social governance arrangements (e.g., forest co-management, community concessions, community conservancies) (see Lemos and Agrawal, 2006 with authors' update). A variety of institutional arrangements, including rights and decision-making rules, are codified in various ways in these hybrid forms of governance.

Polycentric governance systems (PGS) refer to most complex environmental governance contexts where multiple and/or nested actors or centres of (semi-)autonomous decision making are engaged in the management of public or collective goods (e.g., Thiel, 2023). A fundamental characteristic of polycentric governance is the overlapping of jurisdictions between these decision-making centres. These overlaps may refer to physical boundaries (e.g., forest landscapes that straddle multiple administrative jurisdictions), the interdependence of policy issues (e.g., deforestation, land degradation, biodiversity loss), or the functions of decision-making authorities. In complex forest SES, coordination between multiple actors is needed to slow or stop biodiversity loss, climate change impacts, and ecological degradation, and to achieve sustainability. In a well-functioning PGS, an overarching set of rules helps to address issues of institutional fit, promote adaptive capacity, and mitigate risk failure through deliberate and purposeful redundancy (e.g., Baldwin et al., 2024; Berardo and Lubell, 2019; Carlisle and Gruby, 2019; Morrison et al., 2019). **Good institutional fit** refers to the geographical, ecological, political, and social congruences and alignments needed between the governance institutions, natural resources being managed, and associated communities. Considerations include (e.g., Carlisle and Gruby, 2019; Epstein et al., 2015; Guerrero et al., 2015):

i. The size, spatial scale, and temporal scale of the resource (geographical fit);

ii. The ecological characteristics and functions of the resource (ecological fit);

iii. The jurisdictional scope of the governance institutions (political fit); and

iv. The alignment of the governance institutions to the interests, values, beliefs, and needs of the resources users (social fit).

The multiscalar nature of PGS, involving interactions among multiple actors at different levels of social and institutional aggregation (Berardo and Lubell, 2019; Carlisle and Gruby, 2019), is often characterised as **multi-level, cross-scale governance** (e.g., Di Gregorio et al., 2019; Saito-Jensen, 2015). For example, policies and regulations, from global agreements to national to local community governance institutions, and from both within and outside the forest sector, shape forest SES management processes and outcomes.

Multi-level governance (MLG) of forest SES considers the intricate relationships between governmental, corporate, and civil society players at different levels, as well as the institutions that connect higher echelons of social and political organisation. A growing interest in MLG of forest SES is not only linked to globalisation, regionalisation, and multinational environmental accord negotiations, but more so to a greater understanding of the operation of connected forest SES as well as a growing awareness of the inadequacies that result from failing to consider cross-scale dynamics in forest SES (e.g., Arts et al., 2016; Gallemore et al., 2015; Rantala et al., 2014). MLG approaches focus on better integrating both the horizontal (at the same level) and the vertical (from local to global) linkages that exist in human-environment interactions, while also better considering conflicts related to the management and use of environmental resources (forests in this case). Governance scholars also address MLG from the idea of '**nested governance**', as articulated in Elinor Ostrom's pioneering work on the design principles for effective management of the commons (Ostrom, 1990). According to Brondizio et al. (2009, p. 84), "nesting of local and larger institutional arrangements to accommodate the goals and interests of groups organised at different levels" is referred to as '**nestedness**' or '**nested enterprises**'. These layered arrangements are the result of multiscale representation, negotiation, and decision-making processes. According to Adger et al. (2005), resource systems that are integrated and well-linked, nested within networks, legal systems, agendas, regimes, and other national and international agendas, are more robust and resilient than those that have fewer but stronger linkages.

Both PGS and MLG involve integration across scales and sectors to overcome the fragmentation challenges observed with decentralised governance and the authoritarian nature of centralised governance. Nevertheless, MLG also faces a number of challenges: the time and experimentation dimensions needed for policy reform and implementation; juggling competing interests; learning; enforcing rules and making sure that tasks delegated to various actors at various levels are carried out; the significance of trust, strong leadership, and negotiation skills in promoting multi-level collective action; and the centrality of power in the distribution of resources, responsibilities, and accountability among actors (e.g., Larson and Lewis-Mendoza, 2012; Rantala et al., 2014). The creation of multiple centres of decision-making may simply hide inequalities in power, including inadequate stakeholder participation and unequal control over decision-making (e.g., Lazdinis et al., 2019). Nonetheless, when PGS and MLG systems work well, they involve changing relations in power and authority along three lines (Piattoni, 2009):

a) Decentralisation through power devolution to local governments;

b) Greater and effective power sharing between the state and civil society; and

c) Increased multi-lateral, international coordination mechanisms over state authority.

4.2.2 Forest SES governance and resilience: Complexities and knowledge gaps

The numerous biophysical, demographic, economic, and institutional aspects influencing the conditions of forests imply that complex, intricate interactions shape forest SES resilience (e.g., Cantarello et al., 2024; Nikinmaa et al., 2023). Understanding how the forest SES governance approaches and systems defined above determine forest SES resilience raises a number of issues that contribute to the complexity of the analysis.

Akamani et al. (2015) argued that the role of institutions in building community resilience (the ability of communities to respond to drivers of change while maintaining or enhancing community well-being) has not received enough attention. Drawing from the broader literature on SES governance, the authors highlighted potential roles of institutions in building the resilience of forest-dependent communities, including enhancing access to information, providing incentives, facilitating the mobilisation of resources, and providing opportunities for collective action (Brondizio et al., 2009).

Bingeman et al. (2004) asserted that institutions are the vehicles through which resilience can be enhanced or compromised. These authors also stressed the ability to build and increase capacity for learning and adaptation as an institutional response to forest pressures and one of the three defining characteristics of resilience (the two others being the threshold of affordable change to incur without losing structural and functional characteristics, and the degree to which the system is capable of self-organisation).

This take on institutional responses for SES resilience aligns with the concept of **dynamic institutional efficiency**, which relates to enhancing the efficiency of the process of institutional change, that is, the process of transition leading to a more appropriate institutional configuration or the open-ended evolution of institutions in situations of persistent uncertainty (Dedeurwaerdere, 2007). By underscoring reflexive learning, and the enforcement of new norms of cooperation as two important elements of dynamic institutional efficiency, this author argued that the creation of incentives for permanent adaptation and innovation through processes of social learning and normative change is an important aspect of institutional analysis that explains how institutions support forest resilience.

Sharpening the idea of institutional efficiency for resilience, Aligica and Tarko (2014, p. 52) asserted that resilience depends on "innovative and creative sociocultural adaptations" that are made possible by "flexible and polycentric institutional processes". They argued that:

1) Institutions are key to social and economic systems' resilience, which includes not only responses to environmental shocks but also "endogenous socio-economic developments";

2) Social rules constitute institutional arrangements and are thus the "conceptual backbone" of resilience;

3) Institutional design focusing only on efficiency tends to over-plan for risk (what is known), and thus increase vulnerability to uncertainty (what is not known); and

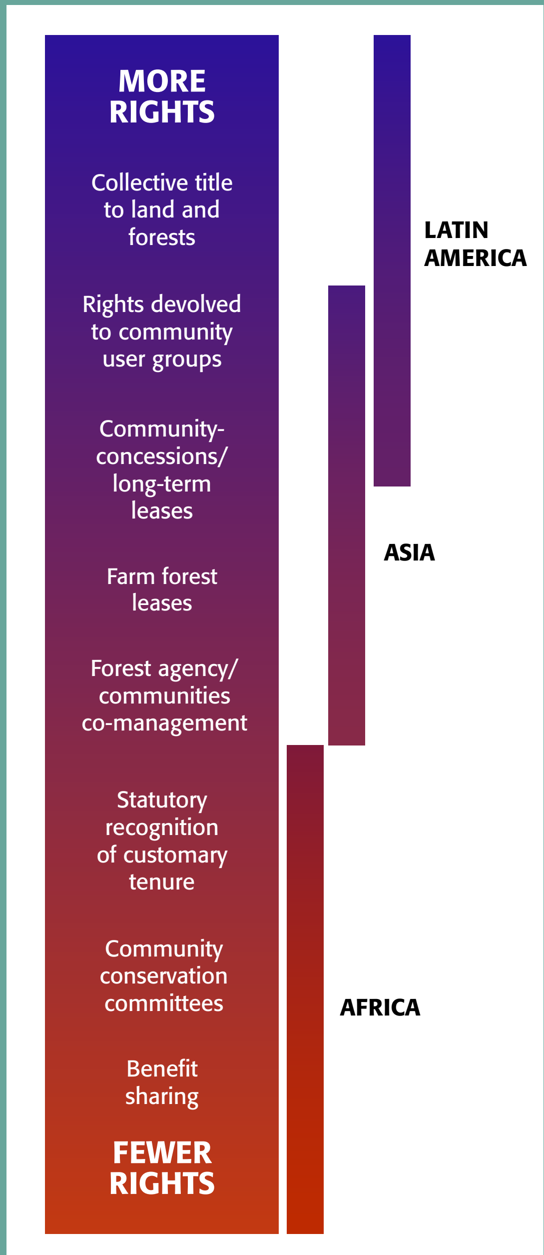
4) That not all rules are conducive to innovation and flexibility.

Dedeurwaerdere's work (2007) underscored an important nuance between resilience thinking for biophysical and for social systems. While resilience addresses the problem of the 'why and the how' of structural change, and focuses on the interactive nature of a system and its dynamic social and ecological environment, it is important to note that resilience and adaptability in social systems differ from adaptive capacities in biophysical systems (Young et al., 2006). An important difference is the intentionality of actors in social systems and the ways this intentionality leads to the building of institutional devices that are supposed to cope with new problems. The author argued that, still, intentionality and institutional design per se are not enough to enhance the resilience of the social systems. He noted that the resilience of social systems will require reflexive learning processes that are able to generate a revision of beliefs in coping with the mismatches, discontinuities, non-linearities, and thresholds that are likely to be revealed with the adaptive cycles, panarchy, and potential regime shifts, in the ecological and social systems.

Literature from Bolivia (Walsh-Dilley, 2020) and elsewhere places inequality and power at the heart of discussions of vulnerability and resilience, arguing that resilience thinking tends to focus on external shocks while the 'internal dynamics of social systems' also affect 'how vulnerability is produced'. This includes 'the distribution of assets, social and demographic differentiation, and the governance of resources'. This aligns with (Ribot, 2013, p. 49), who wrote that "[Vulnerability] is produced by on-the-ground social inequality; unequal access to resources; poverty; poor infrastructure; lack of representation; and inadequate systems of social security, early warning, and planning. These factors translate climate vagaries into suffering and loss". Therefore, the question of 'resilience' immediately becomes a political question. Forest governance and management has only rarely prioritised local ecological, social, economic, and cultural needs and preferences (i.e., beyond timber or external, far-removed elite's material values), and local populations have more often been systematically excluded.

In a nutshell, the considerations of governance and institutions in forest SES resilience are not well or systematically understood. Saikia and Jiménez (2023) noted that articulations of how institutional systems influence the achievement of forest SES resilience are often limited to underscoring the intricacies of the capacities to control non-linear systems and the constancy of change, as well as "the complexity inherent in articulating pathways of change in competing for social interests". These articulations also lack questioning of the underlying decision-making institutions, including, for instance, resource tenure rights issues, which are often essential for understanding the distribution of power and decision-making. Figure 4.1 provides a useful illustration of different governance models, in this case in relation to forest tenure rights as commonly granted to collective communities across Africa, Asia, and Latin America, often as part of decentralisation processes or some form of community-based forest management / CBNRM. It is meant to be illustrative, not exhaustive, but it shows a continuum from those models that grant fewer or weaker rights to those granting more or stronger rights; the different models are overlapping and may also occur in tandem. For the purposes of this Chapter, it is important to note that these different models may be referred to using similar terminology, for example, regarding rights recognition or devolution, yet it is clear that the institutional conditions vary widely.

Figure 4.1 Common models of forest tenure reform



Source: Larson et al. 2022

Different governance models exist in a continuum of fewer rights to stronger rights and may have a degree of overlap.

Photo © Alexander Buck

4.3 Framework for analysis and evidence of forest SES resilience

Forest SES governance processes and institutions mediate observed forest SES resilience. Yet, the necessary governance and institutional attributes that foster forest SES resilience (i.e., the resilience of forests and of linked social and economic systems), are less emphasised. Social resilience is institutionally determined, in the sense that institutions permeate all social arrangements. At the same time, institutions fundamentally regulate economic resilience in terms of system structure and distribution of assets. Moreover, institutions influence what and how ecological processes can/should be managed and who manages them (e.g., Kelly et al., 2015; May, 2022). Therefore, understanding the governance and institutional attributes that contribute in various ways to the resilience of both forest and socioeconomic systems is important. Forest SES resilience can thus be examined through proxy governance features and institutional articulations (Kelly et al., 2015; Saikia and Jiménez, 2023).

Our review of the literature on governance for SES resilience (not just limited to forest resources but including water and others), coupled with the authors' own knowledge and experiences, suggests a number of critical governance and institutional attributes (e.g., Brown, 2022; Nikinmaa et al., 2023; Saikia and Jiménez, 2023). Additional underlying drivers, which undermine or enable SES resilience, either internally or externally, also emerge from the scholarship on natural resource governance. They are sine qua non conditions for the functioning or the operationalisation of the institutional attributes of SES resilience listed below. These underlying institutional drivers include power relations, gender issues, tenure rights, incentive policies, enforcement capacities, capital assets, and more (e.g., Archer et al., 2020; de Luna et al., 2019; Ramcilovic-Suominen and Kotilainen, 2020; Sukmawati and Widana, 2022). We summarise these governance and institutional attributes and the underlying drivers and characteristics in Table 4.1.

The attributes and underlying institutional drivers or determinants for SES resilience variously reflect many known features of (i) adaptive governance (Saikia and Jiménez, 2023), (ii) transformative governance (Chaffin et al., 2016), and/or (iii) good governance (Bedi et al., 2014), which combine resilience characteristics such as robustness, redundancy, recovery, sustainability, risk mitigation (Zolli and Healy, 2013), and even potential regime shifts (Chaffin et al., 2016). First, acknowledging the limit of governance models that assume linear and equilibrium states for SES, **adaptive governance** is deemed more suitable for dynamic SES, helping to maintain (current) desired regimes through adaptive management and institutional changes (Koontz et al., 2015). According to the Stockholm Resilience Centre (2016), adaptive governance involves connecting actors and institutions at multiple levels to enable the effective stewardship of ecosystems in the face of shocks or disturbances, along with fostering flexibility, self-organisation, collaboration, learning, experimentation, and other aspects of the above listed governance attributes. Second, **transformative governance** is called for when there is an acknowledged need to actively shift degraded or inequitable SES to more desirable, new SES regimes, including by deliberately altering the existing defining structures and processes (Chaffin et al., 2016; Garmestani et al., 2019). Transformative governance builds on adaptive governance but focuses exceptionally on actively triggering regime shifts to new and more desirable SES regimes. As Chaffin et al. (2016) noted, transformative governance requires institutions to disrupt existing system drivers and introduce new ones to foster innovation and positive change. This governance approach involves high risk tolerance, significant investments, and restructuring of economies and power relations. Third, in terms of **good governance**, Bedi et al. (2014, p. 41) argued that, just as "resilience is almost always found in the presence of good governance, so too resilience is almost always found in the presence of widespread and equitable development opportunities for all members of society".

While adaptive governance (for complex SES) and good governance (for public administration) may share overlapping features in terms of participation, accountability, transparency, deliberation, and rule of law/impartiality, good governance does not always consider critical features of adaptive governance, such as responsiveness, effectiveness and efficiency, and equity and inclusiveness (Saikia and Jiménez, 2023). Also, in comparing adaptative governance and transformative governance, Chaffin et al. (2016) noted that transformative governance requires additional capacities such as exemplary leadership, innovation, and systemic investments as important institutional attributes of resilience.

Table 4.1 Governance and institutional attributes of SES resilience and their underlying institutional drivers

Governance/Institutional attributes	Explanation
Polycentric, multilevel, and networked governance	Multiple centres of decision-making operating at different levels/scales, with decentralised capacities, deliberative democracy, mechanisms for coordination of interactions across different levels/scales, and conflict resolution mechanisms.
Participation	Involvement of diverse stakeholders (state/government, non-state, civil society, local communities, Indigenous Peoples, private sectors, etc.).
Collaboration	Joint and coordinated efforts among diverse stakeholders and governance structures.
Self-organisation and networks	Autonomous organisation, along with multifaceted cross-scale interactions for communication, trust building, knowledge sharing/diffusion, etc.
Adaptive and flexible processes	Flexible, dynamic, and adjustment/adaptability in decision-making processes to accommodate feedback loops within the SES and external disturbances or information. Institutions should be able to respond with agility and flexibility to shocks and change.
Innovation from learning	Continuous improvement and adaptation of management practices based on success and/or failure, lessons/experiences and experimentations (drawing on institutional memory). Continuous improvement of requirements for new thinking for innovative changes/solutions.
Equity and inclusion	Ensuring all voices are heard meaningfully, while building cohesion and ensuring fairness and equitable development opportunities.
Knowledge systems in use	Consideration of plural epistemologies and ontologies, reflecting a leverage of both Indigenous and traditional knowledge systems and values in conversation with Western scientific knowledge.
Social learning	Sharing of knowledge and experiences among stakeholders as social training processes to increase know-how and enhance capacity.
Accountability	Responsibility for actions/decisions and impacts, and for openness. Institutions need to uphold rules for accountability.
Legitimacy	The perception that the process (procedural) and outcomes (distributional) are seen as fair and acceptable, with legitimate process usually seen as leading to legitimate outcomes. Institutions need to uphold rules for legitimacy and fairness.
Transparency, trust, low corruption	Greater levels of trust can enable adjustments towards resilience. Even when changes are inconvenient, citizens are more likely to comply if they trust that actions are taken for the right reasons. Low level to no corruption is important, as corruption hampers government action by incentivising self-serving behaviour.
(Nested) Exemplary leadership	Exemplary champions at multiple levels/scales in the governance system, with conducive political capabilities and influence. Leadership is crucial in enhancing resilience, as good leaders can not only adapt but also forge partnerships to advance resilience efforts.

Table 4.1 Continued....

Underlying institutional drivers	Explanation
Power relations	Capacity and agency of various people to hinder and/or support the design, processes, and outcomes of governance. People hold and wield power, but power can also be discursive (through knowledge and narratives), and power is also embedded in structural political economy, institutions, and policies.
Demography issues	The differentiated dynamics between social categories defined variously by biology, class, races, etc., including men, women, youth, adults, migrants, and Indigenous Peoples.
Tenure rights	Regimes and patterns of access and ownership rights to resources that define exercise of control and/or exclusion over management and use.
Incentive policies	Mechanisms and processes that motivate good and/or bad behaviours.
Enforcement capacity	Entity's ability (typically that of a government or regulatory body) to effectively enforce adherence to laws, regulations, or policies. This includes the necessary resources, authority, and capabilities to detect and investigate violations and impose appropriate sanctions.
Capital assets	Means mobilised at different scales (household, community) to shape, transform, and maintain socioeconomic development. In particular, social capital refers to informal social relations and networks that can be more critical than formal ones in fostering resilience.

Moving forward, we will examine which of the identified institutional attributes and principles of SES resilience, including related underlying institutional determinants, are present in existing governance approaches and systems around the world and how their implementation affects forest SES resilience. Before that, we will revisit the historical and contemporary trends of governance mechanisms and policies shaping the management and use of forests to offer context for their effects on resilience.

4.4 State of forest governance and institutions: Historical dynamics and contemporary trends

Current forest governance institutions and processes, including their inclusivity or exclusivity, networks, and trust norms, all contribute to the resilience of forest SES. However, those institutions and processes are embedded in history. Understanding the cultural context of institutional adaptation, as well as the diversity of knowledge systems associated with such institutional development is crucial (e.g., Aligica and Tarko, 2014).

This Section explores some of the dynamics that have shaped the types and nature of contemporary forest governance institutions and processes in selected regions. We begin with how colonialism weakened many traditional or customary social systems and increased vulnerabilities, with legacies that are still relevant, and follow up with more recent trends in forest governance and policy. Although this is presented somewhat sequentially, the dynamics are overlapping and co-occurring, with aspects that may have faded but still have a lasting institutional legacy.

4.4.1 Historical analysis of forest SES governance and institutions

History and context affect the nature of forest governance institutions (Kimengsi et al., 2022) as well as their capacity to respond, to decide, and to implement decisions, which in turn reflect the resilience of the institutions themselves. This section briefly examines the nature and effects of forest governance under colonialism before turning to post-colonial policies of (mostly partial) decentralisation and community-based forest management; and the effects of parallel processes of globalised markets, privatisation, and 'fortress conservation'. We then move from the Global South to trends in Europe, USA, and Canada.

The making and legacies of colonial forest management

The creation of state-controlled governance and institutions dates back to the colonial eras, when local resource and land use practices were deemed inherently detrimental (Bassett and Crummey, 1993; Blaikie and Brookfield, 1987; Brookfield and Padoch, 1994), and/or missing the potential for extraction prioritised by the colonial mind frame and values (Watts, 2012). The articulation of national timber (or wood fuel) and global environmental catastrophe narratives also influenced the seizure of customary lands (Bassett and Crummey, 2003). Local resource consumers encountered forestry as a 'science of empire' in various contexts and times, while being consistently portrayed as the problematic land and resource users (Barton, 2001; Griffiths and Robin, 1997; Grove, 1996). Racial superiority, together with economic interests, drove the colonial occupation and usurpation of rural lands, especially of Indigenous Peoples and other collective/customary communities (Larson et al., 2022; Sunderlin and Holland, 2022).

Fundamental changes in the governance and policies of lands and forests included land dispossessions to establish networks of forest reserves and national parks (e.g., Zimmerer, 2006). This led to the enclosure of the commons, the historical (and ongoing) process of converting common-pool resources (common land or resources that are accessible to all members of a society/community) into state or privately owned property, with significant changes in property regimes and resource access (e.g., Mudombi-Rusinamhodzi and Thiel, 2020). Other components were the creation of Forestry Departments to supervise applications of 'scientific forestry' principles for timber production and wildfire control (Barton, 2001), and the obstruction of the production and marketing of non-timber forest products deemed not industrialisable and profitable (Wardell and Fold, 2013).

Extending into post-colonial eras are forest concessions, another hallmark of centralised state- or private-led forest governance as seen in Central Africa (see example in Box 4.1), West Africa and in Latin America (Karsenty et al., 2008). Its evolving versions in contemporary eras epitomise a colonial toned public-private partnership, or a surrogated management approach, (Karsenty, 2016; Mangarella, 2021), with some reforms to allow limited levels of community participation (Karsenty and Vermeulen, 2017).

Significant social, economic, and environmental implications ensued (Griffin, 2023), including land and forest resources restrictions, and massive tenure insecurity for Indigenous Peoples and local farmer communities. Walsh-Dilley (2020) argued that colonial legacies undermine resilience today, as the loss of access to assets, such as to common lands, also led to the loss of collective social institutions, people-nature relationships, and knowledge. Despite local resource users' resistance tactics to defend and uphold their rights, neoliberal policies further wrecked resilience capacities as they reduced the capacity for collective action, while increasing extraction, debt, and soil degradation (Blaikie and Brookfield, 1987).

The materialisation of decentralised approaches and their challenges

In response, among others, to the failures of centralised forest management, the mid- to late-20th century saw a turn toward decentralised forest management models (Agrawal and Ostrom, 2001; Plummer and FitzGibbon, 2004). Decentralisation proponents believed that local governments would be more responsive and accountable than central governments, and would make better decisions regarding public goods because they are more knowledgeable about local preferences and conditions. At the same time, a number of studies raised concerns about elite capture (e.g., Andersson and Gibson, 2007). In theory, these reforms should have improved institutional conditions for resilience, but the results were mixed. Examples of a variety of forest-related decentralisation reforms follow.

Governance reforms supporting forest decentralisation in Africa often included the delegation of (some) control over natural resource governance to local administrations. Tebkew and Atinkut (2022) conducted a review of literature on decentralised forest governance in Tanzania, Kenya, Uganda, and Ethiopia. They found that initiatives intending to improve effectiveness of decentralisation and enhancing ecological benefits were not being implemented properly; and that although some forests were stable, most forest governance reforms failed to

Box 4.1 Forest concessions in Gabon

Gabon's dominant governance model for its large, dense humid forest of over 22 million ha (approximately 85% of the country's land area) is forest concession. Gabon exhibits a historical orientation to and clear contemporary choice for industrial forestry development whereby forests are conceded to mostly foreign private actors for logging (Karsenty and Ferron, 2017). This governance model allows forestry companies to acquire several forest concessions up to 600,000 ha, with each sized between 50,000 and 200,000 ha; though in reality, companies are often granted more forest lands than legally authorised (Legault and Cochrane, 2021). Forests under concession regime in Gabon are guaranteed by the legal permits provisioned in the Law No 16/01 and Art 106 (Nguimbi, 2018; Yobo and Ito, 2016). In number, Gabon has granted between 97 and 150 forest concessions to major investors including China, France, Lebanon, Malaysia, and Switzerland (Karsenty and Ferron, 2017). This approach focuses on extraction and mostly excludes local participation, also excluding many attributes of resilient governance (Table 4.1), and may lead to less resilient forest SES.

Figure 4.2 Gabon's dominant forest governance model are logging concessions (in orange), which mostly exclude local participation and many attributes of resilient governance

Source: GFW (2025). Global Forest Watch (GFW) dataset last updated in 2019.

address forest sustainability. Overall results for both forests and livelihoods were highly context specific. Importantly, with only one exception (Tanzania's Duru-Haitemba community-based forest management), the government retained property rights to land and forests. The study calls for a thorough understanding of existing local institutions, and forest governance based on multilevel institutional design, actor cooperation, and regional integration (Tebkew and Atinkut, 2022).

Similarly, a study of CBNRM in Cameroon's humid forest zone showed uneven environmental and socioeconomic outcomes, identifying local level institutions as a major barrier to success (Brown and Lassoie, 2010). Both, inherited positions and newly created institutions, were problematic in their own way. Community forest legislation elevated forest management committees dominated by local elites, without internal credibility or legitimacy, over village chiefs (a holdover from colonial power) and those with traditional cultural authority, such as clan or lineage heads. The authors argue that the best option is a combination of traditional authorities and elected officials selected in accordance with standards for local legitimacy, and accountable to a local democratic government.

Some of the earliest cases of government-initiated CBNRM, or in this case social forestry initiatives, began in India, the Philippines, and Nepal; notably, the initial motivations of these programmes were to restore degraded lands and forests, rather than recognise rights (e.g., Nayak and Berkes, 2008; Sarin, 2010). India included elements of decentralisation tied to CBNRM models, such as the prominent Joint Forest Management (JFM) programme started in 1991, in which village communities were given the responsibility to protect forest and wildlife resources in partnership with the Forest Department (Sundar et al., 2001). Under JFM, Village-level Forest Committees (VFC) were formed in villages within five kilometres of a targeted, degraded forest block, and each committee was allocated degraded forest areas for management under the guidance of the Forest Department. Land allocation had little (if anything) to do with land rights, and local and Indigenous forest practices and management institutions were undermined (Nayak and Berkes, 2008).

Community-based forest management in the Philippines also produced mixed results, with particular challenges in achieving environmental and social justice, or poverty alleviation goals (e.g., Dressler et al., 2010). A case study of the Northern Negros Natural Park, in the Visayas Region, found that local factors such as lack of conservation experience and priorities, and policy and institutional factors such as lack of government support and collaboration, hindered the success of two government-led forest conservation initiatives (Cagalanan, 2015). Similarly, the experience of Indigenous communities in Saranggani Region illustrates how households in lower economic and political strata were further disempowered by the government's decision to declare their ancestral lands as public or agricultural lands (Zapico et al., 2019).

Nepal may have followed the most exceptional trajectory, beginning in much the same way as India and the Philippines, but since that time devolving significant rights to community forest user groups (CFUGs) through multiple legislative reforms. The national federation of CFUGs, FECOFUN, claims three million households and sixteen million forest users as members. It is organised into 23,000 CFUGs, which manage a third of the country's forests (Oldekop et al., 2019; World Bank, 2024).

In Latin America, CBNRM and forest decentralisation were largely separate though often parallel processes. Through decentralisation, power was given to local governments over forest management, as in Bolivia, but Pacheco (2004) found that the process was entirely top-down, and the central government controlled the definition of resource rights, regulations, forest concessions, and taxes. Across Latin America, forest decentralisation was limited by both the financial resources and the real power and authority granted to subnational governments (e.g., Andersson et al., 2006), not unlike decentralisation across Asia and Africa (Ribot et al., 2006).

At the same time, community-based forest management led to some exceptional situations. For example, 80% of Mexico's forests are located on communal 'ejidos', with both positive (Bray et al., 2012) and mixed (Delgado-Serrano et al., 2018; Delgado-Serrano, 2017) results for community forest enterprises. Another exceptional case is that of Guatemala's community forestry concessions under 25-year renewal contracts in the Peten, which have provided clear benefits for both people and forests (Stoian et al., 2018). These are the cases that have significantly broken away from colonial legacies, and comparatively have more institutional attributes of SES resilience.

Palm oil plantation in Sabah, Malaysia. In many Global South countries, globalisation induced new deforestation dynamics and the expansion of large plantations producing for consumers in far-off markets.
Photo © Viola Belohrad

Privatisation, globalised markets, and 'fortress conservation'

The implementation of decentralisation reforms in the 1980s and 1990s concurred with developing countries' global debt crisis (Ribot, 2002; Shackleton et al., 2002). As a response, privatisation and liberalisation following structural adjustment policies across Latin America, Africa, and Asia left national governments with limited public resources, including in the forest sector. This threatened the resilience of their economies, with social repercussions. Privatisation policies resulted in new waves of 'enclosures' and a surge in forest concessions, such that citizens lost access to forest resources vital to their well-being (e.g., Dickovick, 2011).

Reinforcing the damage of the debt crisis and its ill-responses, globalisation induced new deforestation dynamics allowing land grabs through large agricultural investments (e.g., Carmody and Taylor, 2016). While small-scale farmers led tropical forest clearing in Southeast Asia and Latin America during the 1960s-1980s, with state support, globalisation and urbanisation in the 1980s shifted the agents of deforestation in the rainforests of Brazil and Indonesia to often well-capitalised ranchers, farmers, and loggers producing for consumers in far-off markets (Rudel et al., 2009).

From the conservation side, a backlash in favour of strict biodiversity conservation, following heated debates from the XII World Forestry Congress of 2003, undermined the earlier waves of community conservation schemes to meet sustainable development policies (e.g., Jones, 2006; Roe, 2008). Especially in Africa, 'fortress conservation' policies, with resurgent protectionism, prioritise removing Indigenous and other traditional communities from newly established parks (e.g., Duffy et al., 2019), problematising people and heightening the protection of wildlife through Western ideals of the environment (Brockington, 2002).

These multiple trends undermined decentralisation and devolution efforts, slowing the development of institutions that better foster SES resilience at multiple levels. Still, notwithstanding the reinforcing centralisation tendencies, community-based approaches typically co-occurred with forms of privatisation and strict conservation. For instance in Gabon, forest concessions, co-management around national parks, and community forestry regimes all co-exist. This exemplifies differentiated levels and forms of involvement, control, and rights of local community, private sector, and state, respectively reflecting a continuum of benefit-sharing (concessions), responsibility/power-sharing (national parks), and power-devolution (community forestry) (Karsenty and Ferron, 2017; Yobo and Ito, 2016).

Europe is one of the most forest-rich regions in the world, with forest covering around 39% of the EU land area. Photo © Viola Belohrad

Dynamics of forest governance and institutions in Europe

Europe is one of the most forest-rich regions in the world. The European Union (EU) had over 160 million hectares of forest in 2021, representing 39% of the EU land area, which grew by an estimated 5.3% since 2000. For some EU countries, such as Finland, Sweden, Slovenia, Estonia, and Latvia, forests cover over half of the national territory. In absolute terms, Sweden, Finland, and Spain have the largest forest areas (European Commission, 2024). Here, the shift from centralised to more decentralised forest governance is somewhat similar to the other world regions, but with greater emphasis on private ownership. At the same time, the region reflects a growing interest in multiple values of forests, including some of the attributes fostering sustainability and forest SES resilience.

Poland offers an example of historically centralised forest governance that has shifted toward more participatory approaches and multiple forest values. Even after the transition from a socialist to a democratic regime, forest governance was top-down (Niedziałkowski and Chmielewski, 2023). A multitude of new actors, claims, and disputes have emerged, including a 'well-being discourse' that emphasises the cultural roles and environmental services of forests over the provision of goods, and a growing resolve to influence local environmental decisions (Niedziałkowski and Chmielewski, 2023). New actor networks have emerged, including local activists in the Polish forest governance system as a new advocacy group, while the public forest administration has made some adjustments to respond to local requests (Niedziałkowski and Chmielewski, 2023).

Overall, European forests (excluding the Russian Federation, where all forests are publicly owned) are 56% privately owned (UNECE and FAO, 2020). Forest governance moved from centralised command-and-control to market-based, self-regulatory, and voluntary measures based on certification schemes. Shifts in values have led to shifts in priorities from 'timber production' towards 'multifunctional' forests, in response to the biodiversity conservation, climate change, bioeconomy, and health and well-being agendas associated with forests (e.g., Hackett, 2013). Hence, private forest owners who have often used their rights for timber production now face conflicting environmental and social demands from other forest users (Caicoya et al., 2023). In Sweden, deregulated government policies emphasise 'freedom with responsibility', translating the responsibility of reaching multiple goals to the forest owners themselves (Johansson and H. Keskitalo, 2014).

Dynamics of forest governance and institutions in USA and Canada

In USA and Canada, forest management and conservation are governed by a broad spectrum of legal, institutional, and economic measures involving public, private, and civil society sectors, reflecting diverse ecosystems and complex land tenure histories. For instance, in Canada, approximately 94% of forestland is publicly owned and managed, primarily by provincial and territorial governments. In contrast, private forest ownership accounts for 56% of the total forest area in USA (Oswalt and smith, 2014). Both countries have similar (colonial) legacies with regard to their Indigenous populations.

Public lands in Canada share the overall goal of sustainable forest management (SFM) and include addressing Indigenous interests and public consultation (NRCan, 2025). Most timber production in Canada occurs on these public lands, some subject to Aboriginal or Indigenous title. "These forest management systems represent the evolution of colonial government decisions to retain public ownership of forests..., while permitting logging through leases or licenses" (Wyatt, 2008, p. 172). At the same time, Aboriginal governments and communities are increasingly assuming roles of responsibility over ancestral lands, though this has not been fully reflected in law (e.g., Egunyu et al., 2020). In recent decades, there has been a shift toward marketisation, decentralisation, and increased public participation (Fuss et al., 2019), the latter supported through forest-sector advisory committees and direct decision-making through community forest boards (Egunyu et al., 2020).

In USA, public forests account for 42% of total forest area and are mostly managed for multiple uses (e.g., production, recreation, conservation) (Abrams, 2022; McGinley and Cubbage, 2017), and tribal forestland only accounts for about 3% of total forest area. Logging and other management is regulated mostly by state governments supporting practices such as SFM through technical assistance and incentives. Private property rights afford landowners significant discretion to determine forest uses and objectives.

CBNRM also takes various forms in the country, ranging from temporary use or management rights to outright communal ownership (e.g., Charnley and Poe, 2007). Historical examples include communally managed forests on Tribal lands, community grant lands in the pre- and early Spanish colonial Southwest, and municipal forests in the Northeast (e.g., Baker and Kusel, 2013). Community forests are currently expanding (Hajjar et al., 2024), thanks to increased access to funding, supportive policies, technical assistance, and practitioner networks (Frey et al., 2024). Some community-based organisations have secured a greater role in forest decision-making and stewardship on federal lands, particularly in the West (Davis et al., 2020). Similar to Canada, forest governance in USA has shifted toward greater marketisation and increased public participation to advance sustainability and resilience across private and public lands, as have efforts to engage with emerging and compounding issues, such as climate change, land use, and water conservation.

4.4.2 Trends in contemporary governance: A focus on forest-related policies

Initiatives since the turn of the century represent some attempts to right past wrongs, such as the concentration of authority over forests in central governments, the usurpation of the forest and land rights of local and Indigenous Peoples and the undermining of customary institutions, leading to an emphasis on multi-level governance and multi-stakeholder processes.

These trends present both opportunities and obstacles for forest SES resilience. On the one hand, forests may never before have featured so prominent on the global agenda. The growing recognition of the importance of forests for climate change mitigation, biodiversity, health, and biocultural diversity (Djenontin et al., 2024; Kleinschmit et al., 2024) is unprecedented, to the extent that there is not enough land area to meet the global commitments (Dooley et al., 2024, 2022). Additionally, there is greater recognition of the legitimacy of Indigenous' and local communities' land rights claims, and their important presence and role in the world's remaining forests. Moreover, although still insufficient to bring about the changes needed, funding to the forest sector has increased, including a new tropical forest fund launched at the G20 in 2024 and a USD 300 billion carbon finance commitment agreed at the 19th Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC COP29) in 2024. On the other hand, commitments on paper are often not put into practice, and when they are, they may not be done so in ways that respect the governance and institutional attributes of resilience laid out in section 4.3.

The following sub-sections review multi-level governance approaches, including *Payments for Ecosystem Services* (PES), REDD+, and *Forest Landscape Restoration* (FLR). We also examine new trends related to the recognition of Indigenous Peoples' and Local Communities' land rights, and the European Union's forest regulations. We cover some of these topics generally, others are illustrated by examples where exemplary cases exist. Additionally, the implementation of these ideas varies across countries and regions, and some areas that are implementing an approach may nonetheless lack good data.

Multi-level governance approaches

As local communities became more interconnected with global forces and networks, the turn to multi-level governance (MLG) has offered a new opportunity to tackle complex multi-scalar issues to enhance forest SES resilience, but the inherent risks, pressures, and implementation challenges of MLG reduce this prospect (Mwangi and Wardell, 2013). Examining India's case of MLG as an example from the Global South, Singhal (2002) argued that power disparities have increased due to the diversity of actors, their disparate capacities, interests, and influential positions, as well as issues of inefficiency, corruption, and unstable politics.

Embodiments of MLG in Europe with a mix of traditional state authority, polycentric structures, stakeholder participation, and evolving policy frameworks offer a good example (Lazdinis et al., 2019; Nichiforel et al., 2020; Sergent et al., 2018). Yet, the potential to drive ecological, social, and economic resilience is challenged by fragmentation and weak institutional and policy coordination (Elomina and Pülzl, 2021).

New Zealand illustrates positive MLG facets as the country used various cross-sectoral policy reforms and regulations to foster sustainability in the absence of a comprehensive national forest policy since the 1990's. Analysis of the country's forest sustainability policy identified three pathways, including the preservation of indigenous biodiversity, economic development without adverse environmental impacts, and monitoring of environmental quality (Leach et al., 2010). In such a neo-liberal setting, policy responses have fostered 'stability' and 'resilience' with forest sustainability.

The potential of MLG approaches to tackle interrelated concerns and achieve multiple socio-environmental benefits have been further leveraged through international forest governance, with multilateral mechanisms and global environmental strategies. These include, for instance, forestry-based schemes addressing trading in commodities and conservation needs, climate change mitigation, as well as landscape approaches for integrated governance.

Payments for ecosystem services

We illustrate Payments for Ecosystem Services (PES) by describing the case of Costa Rica, a country that has advanced this approach more comprehensively than most others. Costa Rica's pioneering approach to forest conservation began in the 1970s in response to growing concerns over timber resource depletion. Drawing on market-based governance perspectives operationalised with an MLG approach, initial measures focused on providing tax incentives to expand timber plantations, which were later extended in 1986 to include smaller landowners. These policies laid the groundwork for the comprehensive 'Pago por Servicios Ambientales' (PSA) programme, formalised under Forestry Law 7575 in 1996 (Castro et al., 2000). This law established a framework for direct payments to landowners, often known as PES, compensating them for the environmental services provided by their forests that lack conventional market valuation (Wunder, 2013). Further supported by international funding, including the World Bank, the PSA programme stands as a model for government-led PES initiatives globally. Despite its successes, challenges remain, including sustainable funding mechanisms and balancing conservation priorities with social equity objectives. Nevertheless, Costa Rica's PSA has set a benchmark for integrating ecosystem services into national policy frameworks, showcasing the potential for PES to drive both environmental and socioeconomic transformation towards forest SES that are both desirable and resilient.

REDD+ mechanisms

Launched by the United Nations in 2008 as a climate change mitigation option in the forest and land use sector, and later institutionalised in the 2013 Warsaw Framework and in Article 5.2 of the 2015 *Paris Agreement*, REDD+ policy mechanisms promote the idea of protecting and increasing forest and tree cover to leverage their carbon sequestration and sink potential (Brockhaus et al., 2012). With quantified and confirmed emission reductions as the basis for payments, REDD+ programmes have progressed from readiness and piloting to implementation (Pearson, 2021). To date, more than 60 countries have created REDD+ plans, carried out pilots, and/or established forest monitoring and reporting systems, safeguard systems, and benefit-sharing mechanisms (UNFCCC, 2025; Wong et al., 2019).

Early criticisms of REDD+ emphasised that related interventions often overlap with existing decentralised institutional arrangements, altering local institutions by weakening some, strengthening others, and creating new ones through new rules and practices focused solely on carbon-related functions (e.g., Gizachew et al., 2017). Such institutional reconfigurations and narrowed valorisations of forests as new forms of exclusion prompted questions about the compatibility of REDD+ top-down mechanisms with decentralised and multi-level governance arrangements (Asiyanbi, 2016). Moreover, while in some contexts REDD+ has brought benefits through increased network ties, connectivity across scales, and increased participation in decision-making that enhance adaptive management, it has also reduced the adaptive capacities of some local communities and institutions, especially when facing external disturbances such as climate variability and unexpected shocks (Munroe et al., 2019). Restrictions on traditional forest practices that support subsistence livelihoods, rigid rules, and communities' natural capital locked into carbon contracts have limited communities' ability and agency to manage uncertainty and build resilience (Beymer-Farris and Bassett, 2012; Hajjar et al., 2021; Leach et al., 2010).

Additionally, REDD+ initiatives undermine the intimate interactions between local, social, and ecological systems as they often overlook the critical role of local human-environment relationships in fostering forest and institutional resilience, particularly in addressing the impacts of large-scale disturbances such as climate and market/economic variability (Viñals et al., 2023). Overall, while REDD+ created a new space for multi-level interactions and new alliances (Rodriguez-Ward et al. 2018), it has produced mixed effects on environmental resilience (i.e., ineffectiveness at reducing deforestation and supporting sustainable management for carbon sequestration) and on social and economic resilience with minimal social benefits for Indigenous Peoples and Local Communities (IPLCs) (e.g., Boyd et al., 2023; Demarchi et al., 2023; Malan et al., 2024; Wunder et al., 2024). Lessons from REDD+ mixed effects suggest that for REDD+ to effectively play a role in integrated, polycentric, and multi-level governance, more attention must be paid to grassroots actors and Indigenous Peoples' and Local Communities' power and authority over territory, and to underlying issues and incentives for land-use change.

Forest and landscape restoration approaches

Forest Landscape Restoration (FLR) emerged as a new paradigm to recover/restore the ecological damages affecting forest resources while enhancing human well-being (e.g., Mansourian et al., 2021). Stemming from a WWF and IUCN-led workshop in the 2000s, the FLR paradigm has been fostered by the Global Partnership on Forest and Landscape Restoration (GPFLR) since 2003 (Besseau and Christophersen, 2018; Djenontin et al., 2020). With additional momentum and policy appeals following the Bonn Challenge and the New York Declaration on Forests to restore 350 million hectares by 2030 (e.g., Laestadius et al., 2015), FLR is bolstered by the 2021-2030 United Nations Decade on Ecosystem Restoration that brings in new actors (e.g., Aronson et al., 2020; FAO et al., 2021). Several regional flagships, with substantial country-level restoration commitments are registered, including the 20X20 initiative in Latin America, the AFR100 in Africa, the Agadir Commitment in the Mediterranean countries, and the ECCA30 in Europe (Fagan et al., 2020).

Despite various discourses and practices (e.g., Djenontin et al., 2025; Reinecke and Blum, 2018), the FLR paradigm materialises new thinking about managing interconnected land use crises with a landscape approach (e.g., Mpofu et al., 2023; Reed et al., 2017; Sayer et al., 2013). Related landscape-scale interventions epitomise polycentric, cross-sectoral, and multi-level governance approaches to combat deforestation, biodiversity loss, and climate change while addressing development needs (Bixler et al., 2018; Djenontin and Zulu, 2021), although in practice, many initiatives do not follow these principles.

In addition, trade-offs between expected ecological and social outcomes from FLR interventions are often not accounted for and are neglected (Hua et al., 2022). Concerns about undermining biodiversity with large-scale monoculture tree plantations have emerged (e.g., Bond et al., 2019; Di Sacco et al., 2021; Klaus, 2023), although tree plantations support human well-being and poverty reduction in some cases (e.g., Choksi et al., 2025; den Braber et al., 2024; Mensah et al., 2024). Similarly, risks of negative outcomes for the billions of nature-dependent people who could lose access to their livelihoods and land tenure when landscapes are restored are also underscored (Fleischman et al., 2022; Schultz et al., 2022). Indeed, many areas marked for restoration coincide with Global South regions characterised by high poverty rates, limited livelihood opportunities, inadequate infrastructure, and sometimes minimal basic services (Erbaugh et al., 2020; Fedele et al., 2021; Newton et al., 2020). Addressing such trade-offs and concerns calls for effective restoration governance and institutional arrangements, which however, receive scant attention (e.g., Djenontin and Zulu, 2021; Wiegant et al., 2022). Minimising and avoiding both ecological and social and economic risks requires effective adaptive, inclusive, and equitable governance that considers the ecological properties of targeted ecosystems, as well as the aspirations, livelihoods security, and well-being needs of related social systems (Elias et al., 2022, 2021; Löfqvist et al., 2023; Osborne et al., 2021).

Achuar village in the Ecuadorian Amazon. In 1992, the Ecuadorian Achuar were granted legal titles to 680,000 hectares of their ancestral territory, with the exception of the underground resources. Through their activism, the Achuar have protected their territory against oil exploitation and focused on developing sustainable livelihood opportunities, becoming pioneers in community-based eco-tourism. Photo © Viola Belohrad

The recognition of Indigenous Peoples' and Local Communities' resource tenure rights

Another important forest (and land) policy trend is the greater recognition of Indigenous Peoples and Local Communities (IPLC) and their ancestral land rights, as well as growing scientific evidence of forest resilience under their stewardship (e.g., Dickson-Hoyle et al., 2022; Reyes-García et al., 2022; Santini and Miquelajauregui, 2022). Globally, from 2015 to 2020, more than 100 million hectares of Indigenous Peoples (IP), Afro-Descendent (AD), and Local Communities' (LC) lands were formally recognised, with some progress in 39 countries out of 73 studied (RRI, 2023).

In Latin America, the roots of IPLC land rights recognition date back to the Mexican Revolution, which led to a land law that recognised agrarian and 'ejido' communities as early as 1915 (Larson et al., 2022). The first Indigenous 'comarca' in Panama was recognised in the early 1950s, followed by the formal recognition of Indigenous territorial rights in the 1972 Constitution. Peru recognised collective tenure and began titling Indigenous communities in 1974. A number of other countries in the region followed suit.

These and other wins would not have been possible without the international Indigenous movement and its allies, including important international conventions. For example, the International Labour Organization (ILO) Convention in 1989 (C169) recognised the rights of Indigenous and Tribal peoples to their lands and territories, and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) in 2007 recognised the right to self-determination. Although many countries in Asia and Africa failed to sign ILO C169, the vast majority of nations adopted UNDRIP (Larson et al., 2022). Since 1990, most African countries have passed new constitutions and land laws supporting decentralised and collective land rights (Alden Wily, 2018). In 2021, the parliament of the Democratic Republic of Congo passed a law, almost unanimously, recognising the rights of Indigenous Peoples, a rare success on the African continent.

In USA, many Tribal nations have advanced in their struggle to achieve recognition of the rights outlined in treaty language, to increase their stewardship over a variety of landscapes and to reintroduce practices that had been suppressed by colonial powers (Abrams, 2022). Some are regaining control over ancestral lands, including forestlands, both on and off Tribal trust lands, as well as participating in co-management of federal forest land and acquiring new forestland through 'fee simple purchase' (Dockry and Hoagland, 2017; Lucero and Tamez, 2017).

European Union forest regulations to enhance resilience

To build resilience in light of multiple challenges, the European Union's (EU) strategy for 2030 affecting forests is both green (a flagship of the European Green Deal) (European Commission, 2019) and digital (GALILEO and COPPERNICUS Services; e.g., for fire and forest monitoring). Within the EU, the Nature Restoration Law (EU, 2024) aims to restore 20% of the EU's land and sea areas in need of restoration by 2030, and 100% by 2050, while contributing to climate mitigation and adaptation objectives and international commitments. The regulation, which will take effect in 2026, includes binding restoration targets for specific habitats and species, although it is being contested as too ambitious. The EU also has included National Recovery and Resilience Plans (NRRPs) in the NextGenerationEU programme, where some member states have included policies supporting forest multifunctionality (Bottaro et al., 2024). The EU Regulation 2023/1115 on deforestation-free products (EUDR) has the broadest reach, including for many Global South countries. Under the regulation, any operator who places certain commodities on the EU market must be able to prove that they do not originate from recently deforested land and have not contributed to forest degradation. As a major consumer of the seven commodities linked to deforestation and forest degradation that the EUDR regulates (cattle, wood, cocoa, soy, palm oil, coffee, and rubber, as well as some of their derived products, such as leather, chocolate, tyres, or furniture) the EU aims to halt its contribution to deforestation. Nevertheless, one of the main concerns about the regulation is the potential exclusion of smallholders and IPLCs from supply chains (Zhunusova et al., 2022). Using an analysis of the regulation's theory of change and statistics on trade and attempts to reduce deforestation through supply chain interventions, Muradian et al. (2025) argued that the EUDR is unlikely to have more than a symbolic effect. The start date has been delayed until December 2025 due to internal and external pressures linked to the difficulties of ensuring due diligence.

4.5 The potential of existing forest SES governance systems and approaches for forest SES resilience

Current governance approaches and institutional arrangements, including ownership, rights, and decision-making over forests, are built upon colonial legacies, past power structures, and the marginalisation of forest-dependent peoples (see Section 4.4). Several of the illustrated examples challenge the common assumption that resilience is necessarily desirable, given at times the need for transformation.
This Section builds on the forest SES governance variables supporting resilience outlined in Table 4.1, first presenting examples of institutional attributes (Section 4.5.1), followed by examples of underlying institutional drivers (Section 4.5.2). Through multiple case studies from the literature, we offer evidence of where and how specific attributes or underlying drivers, alone or in combination, have positively or negatively affected both forests and people, ultimately supporting or undermining desired SES resilience or transformation. The cases exemplify how SES resilience is complex, multi-directional, and dynamic.

4.5.1 Evidence of intertwined institutional attributes and drivers of forest SES resilience

This section presents case studies and examples that highlight different institutional attributes supporting forest SES resilience. These approaches utilise attributes and drivers of SES resilience as listed in Table 4.1 as well as incorporating additional practices as expanded upon below. As in section 4.4.2, we cover some of these topics generally, while others are illustrated with examples. The implementation of these ideas, and documentation of them, vary widely.

Adaptive and networked governance

Akamani et al. (2015) used qualitative data from two forest-dependent communities in Ghana to highlight potential barriers to the effective performance of forest management institutions that limited their ability to build community resilience, including lack of political will, lack of motivation, inadequate incentives, and limited capacity. To address some of these institutional challenges, the authors recommend a transition towards adaptive forest governance, an institutional arrangement that connects actors across multiple scales in an ongoing process

of learning and adapting to change over time. Such a transition calls for measures to enhance community well-being through the pursuit of integrated forest management goals, as well as building local institutional capacity through the nurturing of multi-level institutions that start from the local level.
Booher and Innes (2010) used the example of the California Bay-Delta Program (CALFED) in USA to demonstrate the effectiveness of complex adaptive network governance over traditional hierarchical governance. They equate hierarchical governance with representative democracy, and adaptive governance with deliberative democracy, and argue that the latter is more robust and adaptable, "potentially resilient, as it has both the capacity to maintain its viability and the capacity to evolve. With sufficient diversity, the heuristics evolve, the agents adapt to each other, and the system can reorganise its internal structure without the intervention of an outside agent." Actor interactions are dynamic and collaborative, and planning is non-linear, supporting self-organising behaviour.

Self-organising and innovation for environmental justice

Self-organising behaviour is a central feature of governance for resilience in the cases of adaptive co-management in Sweden and Canada, where local groups' self-organising in response to environmental events builds vision, trust, and capacity over time (Olsson et al., 2004). Olsson et al. (2004) proposed that "the self-organizing process of adaptive co-management development, facilitated by rules and incentives of higher levels, has the potential to expand desirable stability domains of a region and make social-ecological systems more robust to change."

Using the example of Canada's Pacific herring fisheries, Salomon et al. (2019) demonstrated how three historical governance regimes (Indigenous local control, colonial centralisation, and environmental justice approaches) show varying impacts on resilience characteristics like diversity, connectivity, adaptive learning, participation, and polycentric governance. The authors found significant declines in resilience from the Indigenous to the colonial era. Although the recent shift to environmental justice was too new to see resilience impacts, the authors identified the presence of a number of preconditions for a positive governance transformation for improved resilience.

Participation and social learning in polycentric governance

The case of joint forest management in the Flanders region of Belgium shows how an area dominated by small-scale forests with fragmented ownership moved from an ineffective incentive scheme to successful adaptive and resilient management through what Dedeurwaerdere (2007) refered to as a participatory hierarchy. The author highlighted institutional design and reflexive learning as key elements in developing dynamic institutional efficiency. "Dynamic institutional efficiency focuses on enhancing the efficiency of the process of institutional change, that is the process of transition leading to a more optimal institutional configuration or the open-ended evolution of institutions in situations of persistent uncertainty" (Dedeurwaerdere, 2007, p. 2). Greater participation and negotiation lowered transaction costs, fostered the identification of collective preferences, and supported collective decision-making. Reflexive learning played a key role, building on forest owners' interests and needs, and developing a clear learning agenda and regular participant evaluation of the learning process itself. The result was "impressive outcomes in a relatively short period" (Dedeurwaerdere, 2007, p. 8).

Flexibility and inclusion in collaborative adaptive management

Managing forests as adaptive systems requires moving past the idea/model of strict command-and-control. Integrated approaches inspired by the focus on adaptation in complex systems theory can be transformative. Flexibility is important given the characteristics of complex adaptive systems, such as uncertainty, non-linearity, and threshold behavior, as is bottom-up control through cross-scale hierarchies (e.g., Fahey et al., 2018; Messier et al., 2019; Puettmann et al., 2016). Foresters may need greater flexibility to be prepared for unpredictability, taking into account management options and the consequences across multiple scales, from local neighborhoods to landscapes (Puettmann et al., 2016).

Bingeman et al. (2004) provided an example from Manali, Himachal Pradesh, India, underscoring the importance of flexibility and inclusiveness in imposed institutions and institutional structures. A variety of institutional responses to forest pressures positively contributed to SES resilience and sustainability, including the work of Mahila Mandai (the village women's organisation/ forum, common at the village level throughout India) in forest management and monitoring, adoption of JFM policies and practices, upholding local rules over contradicting higher level Forest Department rules, strengthening local institutions, establishing firewood depots, and adopting alternative energy sources. The authors also identify the lack of rule enforcement and corruption as institutional failures that eroded SES resilience.

Knowledge systems in use, accountability, transparency and legitimacy

The Ikalahan are an Indigenous people who have lived historically in the Kalahan Forest Reserve, a watershed covering 15,000 hectares of their ancestral land in Nueva Vizcaya, Northern Philippines. The Ikalahan struggles for recognition and land rights represents an important success story in several ways (see Box 4.2). First, the Ikalahan's Indigenous knowledge and practices and traditional governance systems serve as a foundation for conservation, cultural preservation, and resilience (de Luna et al., 2019). Their traditional knowledge was reinforced by state recognition of their territorial rights in a way that allowed them to integrate traditional values and culture, including forest regulation, into local governance. This contrasts with the many cases in which land rights come with new regulations and conditions imposed by the state that undermine local knowledge and rules. The Ikalahan culture and practices were crucial in strengthening the resilience of both their forests and community members. Ford et al. (2020) argued that the interconnected roles of place, agency, institutions, collective action, Indigenous knowledge, and learning helped Indigenous Peoples to cope and adapt to environmental change. The Ikalahan experience is also a governance success story, through institution-building and innovations that assured accountability, transparency, and legitimacy in the way decision-making authority is exercised.

Accountable and legitimate leadership or authority are always a challenge, and are no less so in Indigenous territories and communities. In the context of Indigenous rights recognition, the state needs to identify the authority or entity receiving the recognition (e.g., a land title). Larson et al. (2015) compared cases across Nicaragua (Northern Caribbean Coast Autonomous Region), Bolivia (the Guarayos Native Community Land), and the Philippines (the case of the Ikalahan). While illustrating rising competition and conflict following the recognition of Indigenous communities as territory or forest rightsholders, the authors compared the role of the state, the overall processes, and outcomes. Key points from their analysis are that:

1) Merely recognising an existing authority was not possible for any of the three cases, as there was no existing governance institution at the scale required for the territory. An option is to scale up the existing institutions, however this process takes time;

2) It is important that entities chosen as authorities are identified through a legitimate selection process by the communities involved (e.g., elections);

3) Even when communities elect their representatives and legitimise the authority of their chosen institution, there may still be instances of conflicting interests;

4) The election of entities at the territory level may lead to ambiguity and an overlap or conflict with state administrative jurisdictions like provinces and municipalities; and

5) Legitimacy of representative authorities may break down without the establishment of effective accountability and control mechanisms (e.g., for transparency, or to fight corruption).

Leadership and innovation

The Association of Forest Communities of Petén, ACOFOP, in Guatemala is one of the most emblematic cases of community leadership and organising that resulted in the largest, oldest, and most successful cases of community forest management in the world. When the Maya Biosphere Reserve was created in 1990 Marcedonio Cortave, winner of the Elinor Ostrom award, led a broad coalition that fought for and won the communities' rights to use and manage forests in the buffer zone of the reserve. Founded in 1995, ACOFOP fought their case in a turbulent post-war era, taking advantage of the provision for land reform in the 1996 peace accords to press their case to the Protected Areas Council CONAP. By 2001 they had won 12 25-year community concession contracts totalling 500,000 ha (e.g., Lopez Illescas, 2025).

Box 4.2 Ikalahan's Indigenous knowledge systems and practices, and traditional governance as foundations for conservation, culture preservation, and resilience

Key factors contributing to the Ikalahan's success in preserving biodiversity, culture, and overall resilience within the Kalahan Forest Reserve include the state's recognition of Indigenous rights through secured land tenure, traditional governance (which led to the creation and enforcement of community rules on forest regulation), and the integration of traditional values and culture into the Kalahan educational system.

To protect their lands from land grabbers and speculators, the Ikalahans incorporated themselves as the Kalahan Educational Foundation (KEF) in 1973 (Villamor and Lasco, 2006). This incorporation followed the Ikalahans' legal battle to have the government recognise their ancestral land claims, predating the Indigenous Peoples Rights Act of 1997. Their legal victory resulted in the issuance of Memorandum of Agreement No. 1, which recognised their ancestral domain rights (Pulhin et al., 2008). The KEF was granted full authority to manage and protect the watershed. Although the ancestral land is communal, individual families are allocated their own plots to manage, adhering to community rules and regulations. These policies include the prohibition of chemicals, restrictions on tree cutting and slash-and-burn practices without permits, and a ban on transferring land claims to non-Ikalahan members.

The Ikalahan's history, culture, and traditional knowledge on resource management are passed on to the younger generation through the Kalahan Academy (Dolom and Serrano, 2005). This ensures that future generations understand their identity and responsibilities towards their lands. The Kalahan Academy has also become a learning centre for other Indigenous communities in the Philippines. The Ikalahans were the first indigenous community recognised by the Philippine government as partners in forest resource management. Their watershed forest remains a model of sustainable Indigenous forest management. The Indigenous community's efforts have led to ecological, economic, and food security, as well as the continued practice of Indigenous knowledge systems, all of which contribute to the Ikalahans' socioeconomic resilience (de Luna et al., 2019).

ACOFOP is an association of very diverse organisations, and its perseverance is impressive. Its leadership role has also had to change and expand over time, and they continue to juggle multiple needs. In the early years, ACOFOP played a crucial role as political advocate in broadening community rights by fighting for and defending the concessions. Later, they had to lead the members through the formalisation process and shift toward more technical aspects of operation, with the support of a number of NGOs. ACOFOP still represents the concessions both nationally and internationally, serving as the central interlocutor between the state and the communities (Monterroso and Larson, 2013). The political battles have continued as well, due to threats from ranchers, drug traffickers, and attempts to shut down the concessions altogether.

Despite these challenges, multiple studies have demonstrated the benefits both for local communities and forest conditions. For example, Blackman (2015) found that overall, the mixed-use concession areas of the Maya Biosphere Reserve were more effective at slowing deforestation than the strict protection zone. Stoian et al. (2018) outlined the substantial economic benefits to participants in the concession agreements. Butler et al. (2023) traced the innovations leading to new investments in non-timber forest products.

Equity and inclusion

A comparative study of ecological and economic zoning processes in two states of Brazil demonstrates the significant benefits of a more equitable and inclusive approach to land and forest management (Gonzales Tovar et al., 2021). Based on extensive interviews with participants as well as some non-participants, the approach in the state of Acre was almost unanimously seen as equitable, especially by the groups generally considered the most marginalised in such processes (Indigenous and traditional communities). In Acre, Indigenous territorial representatives "considered the process to be successful in promoting transparency, a collective future vision of Acre, and a transition from times of conflicts ... to improved relationships" (Gonzales Tovar et al., 2021, p. 8). There were a number of reasons for this, including the history of the region and particularly the political support from the state for forest peoples and their well-being. Political support translated into concrete actions, such as taking meetings to the field rather than always requiring rural representatives to travel to the capital, creating separate spaces to work with territory leaders directly, and developing specific IP-relevant initiatives (e.g., an ethno-zoning map developed by IP for their territories). Both Indigenous Peoples and state agency participants said the process had changed the way they see each other. And notably, non-participants from Indigenous and traditional communities thought the process and results "were equitable and democratic and felt well-represented in the commission, as they trusted their representatives and the organizers" (Gonzales Tovar et al., 2021, p. 8). The process and results were very different in the second site, in the state of Mato Grosso, where power relations emerged from a different history and context and a strong agribusiness alliance dominated and derailed the process; one interview even referred to the process as Machiavellian (Gonzales Tovar et al., 2021).

4.5.2 Evidence of the underlying institutional drivers that affect forest SES resilience

We provide here relevant case studies that illustrate some of the underlying institutional drivers that influence the functioning or the operationalisation of the institutional attributes of SES resilience.

Power relations and resilience

A case in Laos shows how power relations shape an imbalanced level of resilience among individuals and households (Ramcilovic-Suominen and Kotilainen, 2020). Power relations, both horizontal and vertical, exercised through direct and indirect ways, significantly influence the social-ecological outcomes of village livelihood development grants intended to support community resilience. According to Ramcilovic-Suominen and Kotilainen (2020), the livelihood development grant intervention, which aimed at changing the livelihood and land use practices of villagers who are engaged in shifting cultivation, ultimately undermined the ability of village members to benefit from it. Notably, vertical power relations between villagers and higher authorities limited villagers' rights to use and access land and forest resources, and in turn affected the community's ability to maintain food sufficiency and livelihoods. Within the village, horizontal power relations benefited the members of the village authorities, forest village committees, ethnic majority groups and male community members who had more power, a stronger political position, and/or social status. These members of the community had better access to information and resources, they were more food-sufficient, and had better livelihoods, which translated to increased resilience to shocks or disturbance as compared to villagers with less power.

Other illustrations of power imbalances come from the phenomenon of 'Deity forests' in India, which exemplifies challenges to some institutional attributes of SES resilience such as participation (purported to mitigate inequities). The phenomenon illustrates inequities linked to successful traditional conservation practice that, at times, lead to economic hardship for already poor households, (see Box 4.3). The issue of how low-income people in villages cope with stress and with not being able to access forest products needs deeper exploration.

Gender and resilience

The impacts of shocks or disturbances to forest SES, such as an extreme weather event or an epidemic/pandemic, are very different for those members of society with wealth in comparison to those with lower income; this further depends on gender, age, caste, and/or other aspects of identity (Smyth and Sweetman, 2015). It has been widely recognised that women and girls have distinct vulnerabilities, rooted in gender inequality, power relations, and the social roles attributed to women and girls in different contexts. Gender inequality and gendered norms that manifest, in part, in reduced access to forest resources intensify vulnerability, particularly when their livelihoods, stability, and well-being are hit hard (Smyth and Sweetman, 2015), and they can be disproportionately affected by disasters (Pournik et al., 2012).

Improving forest SES resilience, then, means addressing gender inequality. Women's rights must be upheld and promoted, and resource and institutional support should be provided to support and strengthen women's resilience (Smyth and Sweetman, 2015). Programmes and decision-makers should be mindful of gendered nuances, and recognise the significant role women often play in fostering resilience (Kumar and Quisumbing, 2014; see also example in Box 4.4), despite sometimes exceptional vulnerabilities.

Box 4.3 Deity Forests in India: Balancing successful traditional conservation practice and negative implications for household income

Two types of Deity forests exist in India. Type I are the sacred grooves where the forest patch belongs to the Deity permanently, and no extraction of forest resources is allowed. The forest patch is managed by the specific religious trust, is usually ecologically rich and undisturbed, a source of high biodiversity, and often the source of perennial water sources. Type II Deity forests are mostly visible in the state of Uttarakhand in the Indian Himalayan region. It is an age-old practice in the region to offer the village forest to the local Deity for a fixed tenure of either five or ten years, and take vows not to enter the forest or do any extraction of forest resources such as fuel wood, fodder, or any other NTFP during this period. Type II Deity forests are declared if there is illegal felling of trees, encroachment, or uncontrolled extractions of forest resources leading to forest quality deterioration, and if the village administration, the Panchayat, is unable to control the illegal activities (e.g., Nepal et al., 2018). The village head, along with other villagers, go to the temple of the village Deity with a written undertaking of offering the forest to the Deity. Then this letter is hung before the Deity for the said tenure. The people's trust and fear of the Deity ensures that the forest is left undisturbed and regenerates during this period. After the end of the promised duration, people again go in a group and take back the letter after completing the rituals. Scholars have documented that this practice leads to successful conservation (Guneratne, 2012). However, in some cases, the establishment of this Type II Deity forest has led to heightened vulnerability from distress and deprivation of the village poor due to reduced access to forest resources (Shyamsundar et al., 2018).

Box 4.4 Women in leadership for forest resilience in Uganda

Uganda's forest policy is explicit about securing the tenure rights of women, increasing their participation in decision-making and addressing norms that drive exclusion (Mwangi, 2017). Through an Adaptive Collaborative Management (ACM) approach, which helps groups identify joint problems, envision goals and act on them, an action-research project worked with community women and men to substantively increase women's participation in forest user groups. The results included strengthened women's tenure rights to forests and trees, both on farms and government forest reserves; increased women in leadership positions; increased confidence levels of women leaders with several moving to public careers; and 82 acres of degraded forest replanted (Mukasa et al., 2016; Mwangi, 2017). "Capacity-building, inclusion of men in mixed groups, effective facilitation, and developing bridging social capital contributed to achieving this level of gender-equitable transformation" (Mwangi, 2017, p. 1).

In Uganda, women are leading tree planting activities to restore degraded landscapes.
Photo © SWAGEN,Uganda

Dis-incentive policies underlying management failures and low resilience

Case studies from the Philippines illustrate policy dis-incentives that led to increased deforestation and forest degradation in the 19th century, post World War II, ultimately undermining SES resilience (Boado, 1988). While 55% of the country's land area, equivalent to 16.6-million hectares, were covered with rich forest lands in 1982, the Philippines experienced rampant and severe deforestation and forest degradation that resulted in critical shortages of potable water, devastating floods, dust storms, heavy soil erosion, and drying up of rivers. This ultimately led to threats to health, safety, and livelihoods of communities, particularly poverty-stricken and cultural minority households in rural and upland areas.

Boado (1988) documented that several government-imposed policies, particularly the land classification system utilised, allowed for the conversion of forestlands and provided incentives for logging, which led to decreased forest cover. Logging was justified as an important part of the country's export economy (forest taxation was and is an important input to government revenue). In 1980, forestry sector activities were listed in the investment priority plans, and tax credits, exemptions, and other incentives were provided to producers and exporters, as well as to domestic forest product developers. Further, the government's efforts to develop agriculture led to forest conversion, affecting forested land. Other reported dis-incentive factors included: 1) political and administrative factors: there was no sustained political support for conserving forests during this time, funding for forest programmes were not supported, and the forestry administration lacked the staffing it needed, with poor logistics, corruption, and low morale; and 2) social and cultural factors: Filipinos at that time lacked conservation ethics and utilised forest land to expand agricultural areas through shifting cultivation.

Tenure rights and equity

Although often overlooked, tenure rights (to land, forests, and forest resources) are a key institutional foundation influencing forest SES resilience. For example, if rights are not secure, decisions are likely to be made on short-term time horizons; if community rights are not respected, IPLCs may risk their lives to prevent encroachment. Tenure rights are also highly complex: different entities may hold different sets of rights to the same resources (e.g.; a community might hold the land rights while the state holds the rights to the trees or the timber, or the state might hold the land rights and grant use rights to communities for the forest; see Figure 4.1). Further, formal law and policy may not recognise customary tenure systems.

In a comparative study of four sites where tenure reform was implemented in the Philippines, Pulhin et al. (2008) demonstrated the importance of securing land tenure rights in determining the success of a community-based forest management initiative, showing that the transfer of bundle of rights to local communities resulted in socioeconomic and environmental gains and benefited both the government and communities.

Another comparative analysis of forest tenure reforms in ten countries in Africa (Burkina Faso, Cameroon, and Ghana), Asia (India, Nepal, and the Philippines), and Latin America (Bolivia, Brazil, Guatemala, and Nicaragua) concluded that reforms should start from the needs of the communities, complement already existing local regulations, and avoid promoting contradictory policies or regulations (Larson and Pulhin, 2012). They concurred with Fitzpatrick (2005) that tenure reforms should be based on an assessment of issues affecting the communities and current forest conditions.

Assets to maintain or build forest SES resilience

Capital assets, including human, financial, physical, natural, social, and political, represent the means that are mobilised across space and time by individuals, groups, or organisations to build resilience while facing shocks and disturbances (e.g., Frankenberger et al., 2007; Scoones, 2013). Governance and institutions often shape how varying capital levels can be leveraged for the socioeconomic resilience of forest-dependent communities (Frey et al., 2021; Saxena et al., 2016). Saxena et al. (2016) applied the lens of capital assets to forest-dependent communities in India, demonstrating that enhancing social and human capital is crucial for building community resilience in the context of climate change, and therefore, policies focused on strengthening local institutions, fostering community networks, and providing education and training can improve the adaptive capacity of communities. In another example, Baral and Stern (2011) highlighted that human and social capitals are positively related to the resilience

In Cameroon, many forest communities such as the Indigenous Bagyeli face threats from land grabbing given that Cameroonian laws do not recognise their customary land rights. Photo © Viola Belohrad of local resource conservation entities, such as the conservation area management committees in Annapurna Conservation Area, Nepal. The authors found that trust, help networks, and member tenure are particularly important in enhancing the resilience of community-based conservation organisations, especially during disturbances like the Maoist insurgency. Natural capital (the resource base in the conservation area, including pastures, water bodies, shrubs, and forests) shows a parabolic relationship with resilience, where moderate amounts of natural capital are most beneficial for forest SES resilience.

4.6 Chapter conclusions

This Chapter set out to examine how governance and institutions hinder or enhance forest SES resilience, or foster the necessary transformative change. Among other things, it has outlined a number of institutional attributes and underlying drivers affecting resilience, placing them in the context of historical and contemporary trends related to forests and forest peoples, and exploring a series of examples from the literature. The chapter helps us to identify the opportunities, including policy levers and institutions, that we can draw on to support greater resilience for social and economic systems in relation to forests at multiple scales, as well as the challenges ahead.

Resilience depends on history and current context. Although there have been some attempts to improve institutions for SES, such as devolving and securing tenure rights for local peoples, the overriding historical tendency has been to undermine local people's control over and relationship to forests, to blame local people for deforestation, to manage the forests without taking local people into account, and to break up commons and customary systems. Even with decentralisation and CBNRM, the colonial legacies can persist.

Contemporary policies and trends, such as REDD+, usually begin by repeating past mistakes, such as pushing toward exclusionary top-down approaches rather than working with local people, adapting to context, and supporting community-managed forest landscapes. At the same time, REDD+ was used as an opportunity by IPLCs to fight for land rights and, in a few cases, to promote their own REDD+ initiatives. Now there are commitments and growing infrastructure to support direct financing to these grassroots organisations, and not always through intermediaries. Multi-stakeholder dialogues and processes, while still far from perfect, in many cases are a new norm. FLR initiatives are increasingly recognising the importance of supporting local livelihoods and not just planting monoculture plantations.

Examples of the governance and institutional attributes that shape SES resilience, including the underlying institutional drivers, are more likely to be seen in democratic governance systems. Almost by definition, we are less likely to see these characteristics under centralised regimes. It raises the question as to whether and how centralised systems might demonstrate SES resilience.

We also note that it is difficult to observe all of the attributes in a single governance approach, and there is no single 'perfect' example of institutions for forest SES resilience. There is also a scale component. Whereas broader initiatives tend to start out with top-down governance, different attributes and behaviours are adopted for implementation at local scales; hence the outcomes vary in their support for resilience. Bearing this in mind, the attributes in the design of governance approaches and institutions for SES resilience would take us much further, as would giving sufficient attention to the underlying institutions and structures undermining resilience, such as the roots of power imbalances. These institutional attributes can be designed or observed at multiple scales (from local to global) within a governance system, and are influenced by context and power. However, it is important to note that change for resilience will have to be multilevel. We should not fall into the 'local trap', as communities are often in dialogue with the subnational and national state, NGOs, and the private sector, and they are deeply affected by external policies and the decisions and actions of external actors.

What are the levers of change? It is likely that global initiatives, such as new incentive schemes (e.g., Brazil's tropical forest fund), REDD+ and carbon finance, or FLR are going to continue, and there is a need to continuously re-assert the attributes that support SES resilience. When new initiatives appear on the horizon, we need to act much more quickly to drive them toward resilient processes and institutions based on past experiences. An example might be the EUDR, where smallholders and small countries need to be supported, not excluded. Where transformative change is unlikely, or unlikely to support SES resilience, we need to leverage forward-thinking individuals and governments at all levels.

Research needs to understand better the 'how' of institutions that support resilience or transformative change. The measurement of costs, burdens, and benefits needs further development to provide evidence on the long-term effects of investments on governance processes and institutions supporting resilience. We need strengthened capacities to understand complex systems and work holistically across disciplines, and with non-Western worldviews, knowledge systems, and practices (alternative epistemologies and ontologies) for locally contextualised, accountable, responsive, and equitable forest SES governance approaches, including monitoring and learning for adaptative governance for just forest SES resilience.

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5

Chapter 5

Assessing Resilience in Forest SES

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Abstract

In the past three decades a suite of frameworks have been developed to assess or quantify resilience. We reviewed the literature to analyse the conceptual frameworks, methodological approaches, and indicators for assessing forest SES resilience from social, economic, and social-ecological systems perspectives. Our analysis revealed that ambiguities and inconsistencies exist in the definition of resilience across the three perspectives. While definitions of resilience from a social-ecological systems perspective encompass the capacity to cope, adapt and transform in response to drivers of change without compromising critical system functions, definitions of resilience from social and economic perspectives tend to emphasise the ability of communities to absorb disturbances and to recover from shocks while maintaining and/or enhancing community well-being. Our review also shows that all three perspectives employ research methods that broadly fall under qualitative, quantitative, and mixed methods approaches. However, while assessments of social resilience draw from all three methodological approaches, studies on economic resilience tend to be predominantly quantitative and involve both objective and subjective quantitative approaches. Studies on social-ecological resilience have also made advances in the use of quantitative approaches to measure some attributes of social-ecological systems. However, the use of qualitative approaches has also been gaining recognition in the assessment of social-ecological resilience. Our analysis of resilience indicators across the three perspectives also revealed challenges in the development of indicators for assessing thresholds and other attributes of complex adaptive systems. In all, our findings highlight the need for further work aimed at harmonising and refining the conceptual and methodological protocols for resilience assessment. Also, the use of effective institutional mechanisms for engaging relevant stakeholders in the assessment process, including Indigenous Peoples and forest-dependent communities, will be essential in mainstreaming the importance of the resilience concept in forest SES.

5.1 Introduction

Recent decades have seen the popularisation of the resilience concept across several disciplines, including ecology, psychology, and community development (e.g., Allen et al., 2019; Ross and Berkes, 2014). Within the field of ecology, a modification of the concept was introduced by C.S. Holling in the 1970s in his seminal article “Resilience and Stability of Ecological Systems”. While the widespread interest in resilience has the potential to stimulate dialogue across disciplines, measurement and quantification of resilience have remained a challenge, and real-world applications of the concept in resource management policies and practices are rare (Grafton et al., 2019). The challenge with the measurement of resilience has been attributed to the conceptual ambiguities created by the different interpretations of the resilience concept from different disciplinary perspectives, the existence of competing frameworks in the literature, as well as methodological challenges in the operationalisation of the concept (Angeler and Allen, 2016; Jones et al., 2021; Nikinmaa et al., 2020). In addition to the challenge of measuring the qualitative aspects of resilience, the resilience of a given social-ecological system can arguably best be understood through the lens of actors in the local context in order to capture the diversity of needs and priorities in different settings, and this begs the question of “resilience of what to what and for whom?” (e.g., Cutter, 2016). A number of efforts have been made to reconcile the different meanings of the resilience concept in order to enhance its measurement and application in decision-making (e.g., Allen et al., 2019; Grafton et al., 2019), although ambiguities persist in the existing literature.

The development of robust approaches to assessing resilience is critical for enhancing the application of the concept in the effective management of natural resources in a manner that also addresses stakeholder needs (Cantarello et al., 2024; Jones et al., 2021; Nikinmaa et al., 2023; Pimm et al., 2019). The need for robust assessment protocols is particularly relevant at the monitoring and evaluation stages of the resource management process. Monitoring exercises are usually undertaken during plan implementation processes to determine how well planned activities are being executed. Evaluation, on the other hand, is a systematic process for assessing the outcomes of plan implementation processes (Plummer and Armitage, 2007). Moreover, a shift has been occurring towards greater recognition of the need for stakeholder involvement in the evaluation process (Plummer and Armitage, 2007). In this chapter, we take stock of trends in the development of frameworks, methods, and indicators for resilience assessment across the social, economic, and social-ecological systems research. Although the primary focus of the chapter is on forest SES, the discussion shall be enriched by drawing from the wider body of resilience literature whenever necessary. The Chapter begins with an overview of the relationships between sustainability and resilience measurement, followed by a review of overarching concepts in resilience assessment. Next, a detailed review of resilience assessment from the social, economic, and social-ecological perspectives is provided with an emphasis on the evolving frameworks, methods, and indicators for resilience assessment in each field. Following this, we present a synthesis of key findings and recommendations.

5.2 Resilience and sustainability

5.2.1 Differences between resilience and sustainability

Resilience and sustainability are two closely related concepts that are sometimes used interchangeably, although differences exist in how researchers treat these concepts (Redman, 2014). The concept of sustainable development refers to development that addresses the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987). Central to the definition of sustainability is the notion of ecological limits and the need to address basic human needs, such as food, clothing, shelter, and so forth. Other key attributes of the sustainable development concept include adopting a holistic approach to development that addresses social, economic, and ecological goals, embracing a long-term perspective in development planning, planning at multiple geographic scales with a particular focus on communities of place, and utilising governance mechanisms that promote stakeholder participation (Holden et al., 2014; Wheeler, 2013). Although the operationalisation of the sustainable development concept through policy initiatives has had varied results (Sachs, 2012), the sustainable development idea has been critiqued for various flaws, including failure to embrace social-ecological complexity, persistence of sectoral approaches to development, over-emphasis on technological fixes, failure to address underlying problems, including over-consumption, and inadequate consideration of social and ecological heterogeneity (e.g., Stafford-Smith et al., 2018). As such, the sustainable development agenda is often considered a reformist agenda, with the implementation of some sustainability projects amounting to greenwashing rather than seeking radical change toward more sustainable and equitable futures (e.g., Akamani, 2020). Also, because the sustainable development goals are static in a non-stationary world, process-based resilience goals could be a better approach (Scown et al., 2023). As a response, some researchers have called for greater consideration of the resource systems upon which humanity depends (Folke et al., 2016).

5.2.2 The role of forests in social and economic resilience

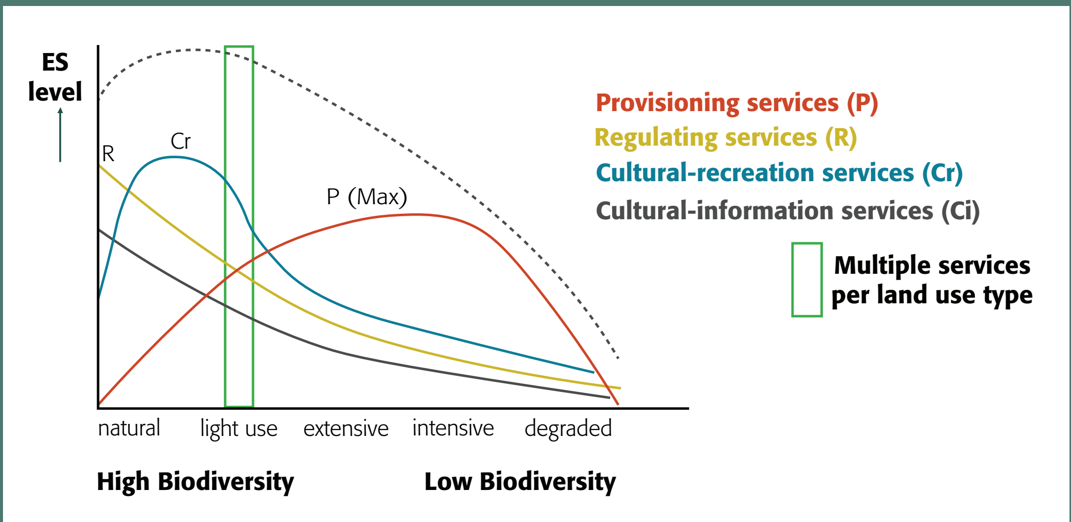
Healthy forests provide critical benefits for human societies that touch every aspect of human life, from providing suitable environments for human settlements, to enhancing human health and economic well-being. Forests enrich human life through the provision of ecosystem services, which, along with tangible benefits like food, medicines or livelihoods, also provide multiple intangible benefits that help human societies in alleviating the effects of climate change impacts and other natural disasters (Knoke et al., 2023). Forests also provide socio-cultural benefits to Indigenous communities who consider their origins and identities as tied to the forest landscapes in which they live. Thus, forests contribute to societal resilience in many ways, including protection from extreme weather, provision of resources, storage of carbon, conservation of biodiversity, mitigation of climate change, prevention of the spread of diseases, and contribution to spiritual and cultural knowledge. Globally, more than 1.6 billion people depend directly on forests for their livelihoods and the level of dependency of the poor on forest ecosystems is very high. Of that more than 1.6 billion people, some 300 to 350 million are Indigenous People who live within or in close proximity to dense forests and depend almost entirely on forests for subsistence (World Bank, 2016). Billions of both rural and urban populations depend on forest resources for food, traditional and modern medicines, construction materials, energy sources, etc. (Jenkins and Schaap, 2018). The United Nation's initiative on

"The Economics of Ecosystems and Biodiversity" (TEEB) showed that ecosystem services and other non-marketed goods from forests and other ecosystems account for between 47% and 89% of the total source of livelihood for rural and forest-dwelling poor households (TEEB, 2010). The United Nations Forum on Forest categorises forest ecosystem services and benefits into seven prominent groups: Biodiversity; carbon; watershed services; soil conservation; recreation and cultural; socio-economic benefits; and high conservation value (Jenkins and Schaap, 2018).

Researchers have identified a total of 55 ecosystem services and benefits derived from forests that enhance human well-being (MEA, 2005). Healthy forests provide these services in abundance to society and help building the economic and social resilience of communities. Healthy forests contribute to building the economic and social resilience of communities by providing multiple inputs, such as basic materials for life (e.g., food), security (e.g., from disasters), good health (e.g., clean air), and a healthy social environment, including trusting relationships (Table 3.1 in Chapter 3 summarises forest contributions to social and economic systems). Resilient communities, in turn, contribute to the health and resilience of forests through sustainable management of forest resources.

There are trade-offs among the ecosystem services provided by forests as illustrated in Figure 5.1. The flow of ecosystem services depends on the resilience or the health of the forest, which, in turn, depends on the effectiveness of forest management. Overexploitation of forests for provisioning services, which are tangible and marketable, diminishes the capacity of the forest to supply supporting services, and this further limits the flow of regulating and cultural services. Figure 5.1 describes these trade-offs among ecosystem services and brings attention to the importance of effective management regimes in maintaining forest health and ensuring the sustainable provision of ecosystem services. Society receives the highest level of ecosystem services when the forest use is balanced.

Figure 5.1 Trade-off between ecosystem services (ES) depending on forest use



Source: Adapted from Braat and De Groot (2012)

The individual and summed ecosystem service provision levels vary with the intensity of forest use. The 'x' axis shows the level of exploitation of the forest and the consequent loss of biodiversity. The 'y' axis shows the level of ecosystem services the society gets corresponding to each level of exploitation. As forest use increases from light use to intensive use, provisioning services increase and the other three (two types of cultural services and regulating services) decrease as does the sum of services (shown by the dotted line). The dotted line represents the sum of all services (P+R+Cr+Ci).

5.2.3 Why assess resilience?

As has been noted previously, the development of robust assessment protocols is essential for the effective application of the resilience concept in resource management (e.g., Jones et al., 2021). Within the forest sector, criteria and indicators are widely used to guide the implementation and assessment of progress towards sustainable forest management (e.g., Jalilova et al., 2012). With its origins in the 1992 Earth Summit in Rio de Janeiro, criteria and indicators have since been adopted by several international organisations and dozens of national governments around the world (e.g., Wijewardana, 2008). While the broad thematic areas covered in criteria and indicators provide a holistic approach to managing forests to address diverse values among present and future generations, existing constraints include inconsistencies in the interpretation of key concepts, slow and uneven progress in implementation, over-emphasis on national level assessments neglecting sub-national forest management unit levels, challenges in the integration of assessment findings into programmes and policies, and lack of institutional capacity, including lack of trained personnel for data collection, analysis, and information dissemination (e.g., ITTO, 2016; Wijewardana, 2008). Importantly, the application of resilience thinking in forest resource management in recent decades has led to the search for appropriate assessment tools (Nikinmaa et al., 2023). For instance, the resilience of forest-dependent communities is now recognised as an indicator of sustainable forest management (Magis, 2010).

There are several **reasons why a resilience-based assessment approach is essential for advancing sustainable management of forest SES**. First, resilience assessments enable actors in a given social-ecological system to **learn about the dynamics of the system**, including gaining knowledge about uncertainties from the drivers of change that shape the resilience and vulnerability of the system. Such knowledge could inform effective management mechanisms for adapting to change and managing uncertainty (Pimm et al., 2019; Quinlan et al., 2021). For instance, some resilience assessments are based on scenario and modelling, where a community identifies common challenges that increase risk of losing something valuable to them, and develops strategies to protect or maintain desired conditions. Second, resilience assessments could be **used as part of adaptive management processes** to serve the purpose of evaluating the efficacy of policy and management interventions in social-ecological systems (e.g., Angeler and Allen, 2016). As such, resilience assessments can help prioritize the allocation of scarce resources by providing information on when and where policy and management interventions are most valuable (Holling and Sundstrom, 2015). Third, resilience is an emergent property of social-ecological systems, and as such, maintaining resilience often requires collaboration among diverse stakeholder groups with shared or conflicting interests. Resilience assessments can help identify potential stakeholders with whom one needs to cooperate in order to achieve desired goals, such as enhancing the provision of ecosystem services, and recognition of cultural values, as well as the intrinsic value of nature (Jones et al., 2021; Rocha et al., 2022; Rocha, 2022). Fourth, resilience assessments are also **essential for forecasting future changes in complex social-ecological systems** (Spears et al., 2015). Although the assessment of thresholds in social-ecological systems is challenging (Pimm et al., 2019), negative consequences can occur from crossing such thresholds. Resilience assessments can help in the detection of subtle changes in social-ecological systems towards a tipping point. Such early warning signals could help avoid catastrophic changes (Spears et al., 2015). Finally, resilience assessment is important because it **allows stakeholders to look at the whole system**, thereby reducing the challenges and unintended consequences associated with a focus on one part of the system or one process only.

5.3 Forest SES assessment concepts

5.3.1 General versus specific resilience

Assessing forest resilience and the impact of resilient forests on other systems both near and far is clearly important, but also difficult. Progress has been made, and resilience scientists now recognise the importance of clarifying some aspects of resilience assessment that should be considered prior to conducting an assessment. As covered in Chapter 2, resilience assessments can be either general or specific. Specific resilience takes into account the resilience of what, to what (Carpenter et al., 2001), and for whom (Cutter, 2016; Le Dé et al., 2021), and is often preferred. This approach identifies the system or attribute being considered, the disturbance in question, and who is affected. A specific resilience approach might ask "How resilient is tropical dry forest to fire in a changing climate, and how does this affect indigenous livelihoods?". Adding the 'for whom' into assessments recognises that what is valued in systems depends on and varies amongst different stakeholder groups.

5.3.2 Scale

Scale is another critical facet in resilience assessment that needs to be identified prior to conducting the assessment, because complex systems (such as forests) are multi-scaled. Resilience and vulnerability varies with scale, impacts of disturbance can scale down or up (Gunderson and Holling, 2002), and management and policy interventions need to match the scale of assessment and inference. Scale has both temporal and spatial dimensions, and multi-scale spatial and temporal observations are critical components of resilience assessment data, serving as a guide to multi-scale management decisions (Angeler and Allen, 2016).

5.3.3 Resilience as a dynamic property

Resilience is neither a static property nor a fixed ability of an individual or system. Instead, resilience is dynamic and can fluctuate and evolve over time based on context and various factors such as the availability of resources, physical state and/or capacity, and mental state of communities and individuals involved. As established in the previous sections, resilience varies depending on the spatial and temporal scales and the complexity of the systems and interrelationships. This variability highlights the limits of what we can anticipate and respond to amidst contemporary environmental and social crises.

5.3.4 Tipping points and feedbacks

A fundamental question for any resilience assessment is if the social-ecological system under study is prone to a regime shift (see Chapter 2). A regime shift occurs when resilience is low, in which case a system can cross tipping points and end up with a completely different structure and function. Examples include the shifts from forest to savanna, from deciduous to coniferous forests, or changing regimes in the frequency of forest fires. However, a key process that decides whether a system tips or not is the existence and strength of feedbacks. Feedback is reinforcing if it amplifies the original signal or balancing if it dampens it. Reinforcing feedbacks are often responsible for out-of-equilibrium dynamics and destabilisation of systems, while balancing feedbacks are responsible for close-to-equilibrium dynamics that are likely to maintain the system in its same state, such as oscillations. For a new regime to exist, often the balancing feedbacks stabilising the previous regime have been weakened, a set of reinforcing feedbacks have destabilised the original regime (become stronger than the balancing feedbacks), and the new regime has a different type of balancing feedback that stabilises it.

5.3.5 Relative resilience

A relative resilience approach is simply one that seeks to compare resilience across similar types of systems, at similar scales. The idea is that there is no integrative measure of resilience broadly applicable across sites, so comparative assessments are useful in that they allow policymakers to assign resources to those systems most in need. A relative resilience approach can utilise any resilience assessment process.

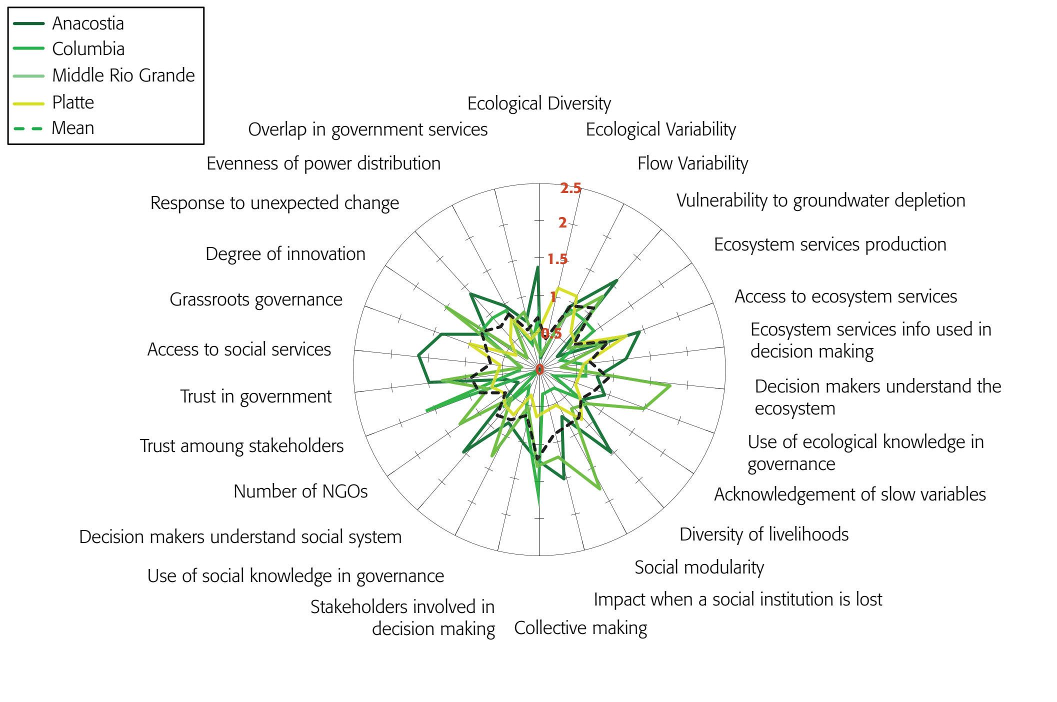
5.3.6 Coerced resilience

Social-ecological systems and their resilience reflect self-organisation. Often, that is due to critical processes and their feedback; for example, fire is a critical process in maintaining many forest types. When those processes are lost, the system may collapse (often with a lag), but the system may be maintained by strong management intervention; for example, by hand or mechanical removal of mid-level structures in savannas after fire loss. This defines a coerced regime (Angeler et al., 2020), one that has lost its self-organisation but is maintained through heavy human intervention that mimics, but does not replace, the lost processes. Such systems are prone to slow degradation, and unless coercion is accounted for, may lead to erroneous conclusions in resilience assessments. Agricultural systems, including forests, are examples of systems that are frequently coerced to function with particular outcomes in mind.

5.3.7 Uncertainty

There is much uncertainty in assessing resilience, but this is rarely acknowledged and even more rarely accounted for. Uncertainty comes from parameter estimation, model estimates, variability in social and ecological parameters, and many other sources. Where surveys are utilised to help understand resilience, which is common, uncertainty can be assessed by determining variability

Figure 5.2 An example of how to incorporate uncertainty into resilience assessments



Source: Allen et al. (2018)

In a project comparing four watersheds in USA (Anacostia, Columbia, Middle Rio Grande, and Platte) participants filled-in a series of survey questions on resilience-related aspects of their respective watersheds, scoring on a Likert scale of 1 to 5 (1 being least resilient and 5 being most resilient). The spider diagram shows variance in resilience scores for individual survey questions by watershed basin (continuous line). The dotted line reflects the mean value from the four watersheds. Variance in resilience scores, a measure of uncertainty, increases with distance to the centre of the diagram.

across survey respondents, and by requesting respondents to assess their own uncertainty in their responses (Figure 5.2; Allen et al., 2018). Explicitly quantifying uncertainty in resilience assessments guides actions by highlighting areas where more learning is required, and tempering responses where uncertainty is high. In other words, it may guide action by suggesting actions to enhance resilience where uncertainty is low, and learning where uncertainty is high.

5.4 Approaches to resilience assessment

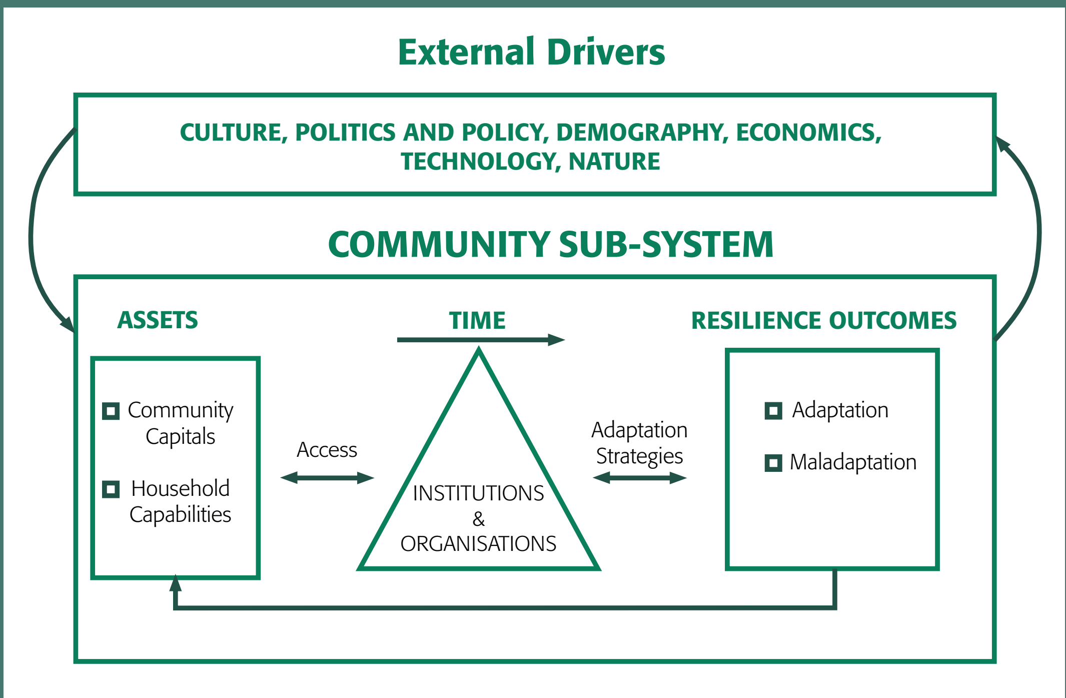
This section provides a review of resilience assessment across the social, economic, and social-ecological systems. Under each disciplinary perspective, the discussion will focus on the evolving frameworks, methods, and indicators for resilience assessment with the aim of identifying methodological advances and knowledge gaps. Many resilience assessments combine aspects from social, ecological, or economic resilience assessment approaches and combine them in ways suitable for particular needs and settings.

5.4.1 Assessing resilience of forest-dependent communities

The resilience of forest-dependent communities has gained recognition in recent decades as a key indicator of sustainable forest management (Magis, 2010). However, research on the sustainability of forest-dependent communities has a much longer history. For several decades, the sustainability of forest-dependent communities in the USA was studied and promoted based on the concept of community stability. The concept of community stability has its origins in Germany and emphasised constancy in income, employment, and other economic measures of community well-being (Akamani, 2012). Forest policies, such as the Sustained Yield Forest Management Act of 1944, explicitly identified community stability as a goal of forest management. Under this policy, the stability of local communities was to be promoted through the predictable supply of timber from well-managed federal forests to local mills. However, following decades of implementation, shortfalls of the community stability concept, including a narrow focus on economic measures of community well-being, lack of recognition of community agency, and flawed assumptions about the stability and predictability of human communities and forest ecosystems have become clearer (Donoghue and Sturtevant, 2007).

As part of the transition from sustained yield forest management to ecosystem-based forest management in USA in the 1990s, the concept of community resilience has emerged as a promising framework for understanding the sustainability of forest-dependent communities (Beckley et al., 2002; Harris et al., 1998; Kusel, 1996). The community resilience concept is based on the assumption that forest-dependent communities are complex social-ecological systems that are exposed to multiple drivers of change to which they must adapt in order to be sustainable (Akamani, 2012; Magis, 2010). Community resilience could, therefore, be defined as the ability of communities to collectively respond to drivers of change without compromising community well-being (Harris et al., 1998). As depicted in Figure 5.3, insights from the existing literature have highlighted the role of key determinants of community resilience, including the attributes of drivers of change, presence of various capital assets and

Figure 5.3 The 'Community Resilience Model'



Source: Adapted from Akamani (2012)

The model depicts the process and outcomes of community responses to drivers of change as a function of differential access to assets and institutions.

Box 5.1 Resilience of Indigenous Peoples

Indigenous Peoples share deep social, cultural, and spiritual ties to their territories, including land, waters, and associated spiritual environments. Their livelihoods, health, and well-being are closely linked to their activities within these territories. This strong connection brings unique considerations for understanding how they respond to climate and environmental changes (Ford et al., 2020). Indigenous Peoples, estimated at 476 million worldwide across 90 countries, are stewards of around 40% of all protected areas and ecologically intact landscapes (Garnett et al., 2018). However, research on the resilience of Indigenous Peoples and their diverse coping mechanisms remains limited and fragmented (Ford et al., 2020).

A recent systematic literature review identified six common factors that influence the resilience of Indigenous Peoples to environmental change: place; agency; institutions; collective action; Indigenous knowledge; and learning (Ford et al., 2020). These factors were found to be determined by livelihood conditions and various drivers of change, including demographic, social, cultural, and political change across varying spatial and temporal scales. More importantly, these factors are grounded on the natural capital assets, including lands and territories, that Indigenous communities rely on to construct their livelihoods and respond to shocks. Indigenous Peoples are not isolated from socioeconomic and environmental drivers of change but are in fact faced with development interventions and the impacts of various drivers of change that threaten their right to self-determination.

Indigenous knowledge and learning are mutually reinforcing. Indigenous knowledge, informed by accumulated experiences, such as in resource use and land management, is a major source of resilience (e.g., McElwee et al., 2020). Learning is experiential, where repeated and continued exposure and response to environmental conditions and changes allow communities to cope, respond, and adapt, thereby enhancing their resilience (Ford et al., 2020). The integration of Indigenous knowledge systems into resource management practices can be enabled where institutions, such as co-management, exist to engage communities meaningfully (Houde, 2007).

effective institutional mechanisms, arenas for community interaction and collective action, community history and context, among others (e.g., Akamani, 2023; Beeton and Galvin, 2017). From the community resilience approach, community well-being is operationalised using various capital assets that capture economic and non-economic dimensions: social capital; human capital; natural capital; economic capital; and physical capital (e.g., Akamani, 2012). Community resilience is also thought to be shaped by the presence of effective institutions that are considered essential for the mobilisation of capital assets in communities' response to drivers of change (Akamani and Hall, 2015).

A closely related concept to community resilience is the concept of community capacity, which has been defined as "the collective ability of residents in a community to respond to external and internal stresses, to create and take advantage of opportunities, and to meet the needs of residents, diversely defined" (Kusel, 1996, p. 369). Similar to community resilience, the community capacity concept embraces the dynamic attributes of forest-dependent communities, adopts a multi-dimensional approach to assessing community well-being, and emphasises the agency of community members to collectively respond to drivers of change (e.g., Paveglio et al., 2009). For instance, a community capacity model proposed by (Beckley et al., 2008) for studying resource-dependent communities emphasised the availability of capital assets, the role of community catalysts as threats and opportunities, and arenas for interaction created by existing institutions as factors influencing the process outcomes associated with community responses to drivers of change. In all, it appears that these evolving frameworks for assessing the sustainability of forest-dependent communities draw from older traditions of social science research, such as those on well-being, quality of life, livelihoods, and capabilities in rural communities and households, as well as the emerging literature on social-ecological systems research (e.g., Smith et al., 2012). These trends are reflective of the broader literature on community resilience (e.g., Ross and Berkes, 2014). Specific considerations for assessing the resilience of Indigenous Peoples are highlighted in Box 5.1.

5.4.2 Assessing community resilience in forest SES

The assessment of resilience in forest-dependent communities and other types of resource dependent communities is shaped by several choices, including choice of concepts, paradigms, scale, methods, and indicators. Research on forest-dependent communities and other resource-dependent communities is also influenced by social science research traditions, such as those on well-being and social indicators (Kusel, 1996; Parkins et al., 2001). Broadly speaking, three types of research approaches can be identified in the literature on the resilience of forest-dependent communities and community resilience in general: qualitative approaches; quantitative approaches; and mixed methods approaches.

Qualitative research is foundational for understanding the nuanced social, cultural, and institutional dimensions of resilience. The qualitative research approach generally seeks to gain an in-depth understanding of socio-cultural phenomena based on the lived experiences of the research participants (Bryman, 2016). The qualitative approach also provides the tools for understanding relationships in socio-cultural phenomena that may be difficult to study using conventional reductionist methods. Under this approach, the use of methods, such as participant observation, document review, focus group discussions, and key informant interviews are particularly useful for capturing the lived experiences of community members and uncovering the processes that drive resilience. These methods are useful for exploring areas of consensus and disagreement regarding community perceptions on the process and outcomes of community responses to various drivers of change. For example, as part of a larger study, Akamani et al. (2015) conducted key informant interviews to examine how forest-dependent communities in Ghana responded to the implementation of collaborative forest management. Their study uncovered institutional shortfalls in the design and implementation of the programme that have limited the successful adaptation of communities to the programme. Their study highlighted the need to prioritise institutional capacity building and the well-being of communities in order to enhance the contributions of the programme to community resilience. Beeton and Galvin (2017) also generated data from key informant interviews in a qualitative study that combined case study and grounded theory to explore the barriers and opportunities for adopting wood-based bioenergy and its implications for the resilience of forest-dependent communities in the state of Montana, USA. The results highlighted the influence of community history and context, as well as individual and group values in shaping the transition process. While qualitative methods provide rich, contextual insights, they often lack generalisability and require significant time investments. Nonetheless, they are ideal for understanding the social-ecological complexity of resource-dependent communities. The qualitative approach may also be used as part of a mixed-methods approach to gain a comprehensive understanding of the resilience of resource-dependent communities (e.g., Akamani and Hall, 2019).

Qualitative research may be underpinned by various research paradigms, including constructivism, critical theory, and participatory action research. While much of the existing studies using the qualitative approach is informed by constructivism, the use of participatory action research has been gaining prominence owing to its ability to engage stakeholders and incorporate local knowledge into resilience research (Ross and Berkes, 2014). By providing avenues for research participants to interact with scientists as equal partners throughout various stages of the research process, participatory action research provides opportunities for community empowerment, creating awareness of the sources of undesirable/unjust community conditions, as well as enhancing access to the resources and opportunities for overturning such situations (Cornish et al., 2023). The use of participatory action research can also foster shared ownership of research findings, making them highly relevant for community-driven resilience planning. For instance, in their analysis of the adaptive responses of forest-dependent communities in the Ukrainian Carpathians, Melnykovych et al. (2018) combined participatory techniques with other research methods within a relevant conceptual framework. The participatory techniques were used to engage a broad range of stakeholders, including government representatives, small businesses, representatives of the forest industry, and community representatives through the organisation of stakeholder workshops. Within the broader community resilience literature, Berkes and Jolly (2001) employed participatory methods to explore the climate change resilience of the Inuvialuit people in the community of

Sachs Harbour in Canada's Western Arctic. While participatory methods are effective in fostering inclusivity, they require skilled facilitation to address potential power imbalances and to ensure equitable engagement within communities. Other challenges associated with participatory action research include high levels of capacity requirements in terms of time and resource commitment, potential for research fatigue on the part of communities, and difficulty of scaling up findings due to reliance on research methods that are suited for local case studies (Rocha et al., 2022).

Quantitative methods focus on collecting data that can be analysed statistically with the aim of testing hypotheses on cause-effect relationships and aspire for generalisability beyond specific contexts. As such, results from such studies are well-suited for drawing comparisons across regions with shared attributes. The choice of indicators for data collection is an important consideration in quantitative studies, and also entails confronting questions on what is to be evaluated and who is doing the evaluation (Kusel, 1996). Some authors have categorised the broad range of approaches for selecting indicators into expert-driven and top-down versus locally-derived and bottom-up approaches (Parkins et al., 2001), whereas others depict them as subjective versus objective approaches (Béné et al., 2016). Objective approaches assess resilience through the analysis of data on tangible variables by neutral third-party evaluators independently of the perceptions of community members themselves (Tariq et al., 2021). These approaches often involve the analysis of data on socio-demographic variables, such as income, employment, poverty rates, and other variables that are easy to measure. In the USA, for instance, much of the earlier work on the stability and resilience of forest-dependent communities focused on the county level due to the availability of secondary data (Kusel, 1996). As an example, Haynes (2003) developed an index for the adaptability of forest-dependent communities in the USA using county level data on variables, such as population density, economic diversity, minority status, and national forest acres. While data gained through the quantitative approaches may lend themselves to generalisation, the use of such aggregate data at larger geographic scales may mask variations at lower levels of social organisation. Such objective measures may be important measures of well-being and resilience from the perspective of the external observer, but may not reflect the existing state of well-being and resilience, as perceived by actors in a given context (Kusel, 1996). Importantly, the top-down and expert-driven nature can make the resilience assessment process non-participatory, and hence, less empowering to communities (Quinlan et al., 2021).

In contrast with the objective approach, the subjective approach to social indicators for well-being and resilience assessment involves the perspectives and judgements of the community members themselves, capturing individual self-assessments regarding their households, communities, and social systems (e.g., Tariq et al., 2021). As such, the subjective approach offers opportunities for a bottom-up approach to indicator development that involves relevant actors in the process. By relying on self-reported measures rather than secondary sources of data, the subjective approach is also useful for generating data on intangible variables related to perceptions and beliefs, such as social cohesion, trust, and other social dimensions (Saja et al., 2018). For instance, as part of large-scale scientific assessments that informed the introduction of ecosystem-based forest management in USA, Harris et al. (1998) collected community self-assessment data through the organisation of community workshops in 198 rural communities to understand the resilience of communities in the Pacific Northwest USA. Similarly, Akamani and Hall (2015) utilised household survey data and a community resilience model to assess the impact of Ghana's collaborative forest management programme on household resilience in two forest-dependent communities. When combined with other locally appropriate research methods, the subjective approach can also facilitate a bottom-up approach to developing locally relevant indicators for well-being and resilience assessment. Objective and subjective measures are not mutually exclusive; rather, they complement each other, providing a more comprehensive assessment of community resilience. For instance, in the study conducted by Harris et al. (1998), community self-assessment data were combined with secondary data on selected community socio-demographic variables to provide a comprehensive account of changing community conditions in the region. However, the collection of data using a combination of objective and subjective approaches can be expensive and difficult to execute successfully (Artell et al., 2013).

Mixed methods research approaches have emerged as a preferred strategy for resilience

Box 5.2 Community forestry and specific resilience in Nepal

There is widespread understanding that community-based forest management systems hold the potential to address deforestation while providing ecological, social, and economic benefits to forest-dependent communities. Nepal's community forestry programme, initiated in the late 1970s and strengthened by the Forest Act of 1993, is widely regarded as a pioneering and successful model of community-based forest management. While substantial research has examined various aspects of community forestry, there is limited understanding of how these programmes perform under conditions of extreme uncertainty, such as natural disasters and climate change impacts (Gentle et al., 2020; Sapkota et al., 2022). Bhattarai (2024) addressed this gap by investigating the impact of Nepal's community forestry programme on the resilience of forest-dependent communities, with a particular focus on specific resilience in response to the 2015 earthquake.

The study was conducted in two rural communities, each represented by a community forest user group (CFUG): Ghaledada Ranakhola CFUG and Ratamata CFUG, both located in Nepal's Gorkha District. In 2015, Nepal experienced a major earthquake with a magnitude of 7.8, followed by multiple aftershocks, resulting in over 8,800 deaths and widespread displacement (NPC, 2015). The study area falls within the region most severely impacted by the earthquake, which caused significant human and infrastructural losses. The study was informed by the Community Resilience Model (Akamani, 2012), and based on a mixed-methods approach, combining qualitative and quantitative data collection techniques. Data for the qualitative component of the study were generated through the review of documents, as well as interviews with 27 purposively sampled key informants from two rural communities in the Gorkha District of Nepal, whereas quantitative data were collected through the administration of a survey questionnaire to 237 households that were selected using the systematic random sampling technique.

Findings from the qualitative component of the study revealed that access to timber through the community forestry programme played a central role in supporting community members' recovery and reconstruction efforts following the earthquake, as respondents expressed satisfaction with the availability of timber at concessional rates. Beyond timber, responses indicated that social and human capital, fostered through participation in community forestry programmes, also contributed to community resilience. For instance, certain responses pointed to the enhanced links of social capital with external organisations, a result of community forestry participation, which played a role in bringing recovery and reconstruction projects to their communities. Respondents also highlighted the increased human capital, manifested in enhanced leadership capacity and the improved ability of community members to voice their concerns, learnt through active participation in community forestry decision-making processes, as another factor that contributed to the adaptive capacity of community members in dealing with external organisations after the earthquake. Quantitative analysis further showed that household participation in the community forestry programme was positively associated with two of the three earthquake resilience measures, while bridging social capital and physical capital each had a significant positive effect on one of the three earthquake resilience dimensions. These findings underscore the importance of community forestry programmes in enhancing the post-earthquake resilience of forest-dependent communities.

In Nepal, a mixed-methods approach was used to determine the impacts of a community forestry programme on the general and specific resilience of rural communities. Photo © Mukesh Bhattarai research (Ross and Berkes, 2014), as they integrate qualitative and quantitative insights to provide a comprehensive understanding of complex phenomena. Informed by the paradigm of pragmatism, the mixed methods approach allows the researcher to combine methods across the qualitative and quantitative research traditions, such as interviews, surveys, and document reviews within a single study without the constraints imposed by the philosophies that underpin these two research traditions. Within the mixed methods approach, qualitative and quantitative methods can be combined in a sequential or concurrent manner and sometimes used in combination with a theory (Creswell, 2003). For example, Melnykovych et al. (2018) used a mixed methods approach, involving the combination of methods, such as document review, interviews, participatory techniques, and the analysis of quantitative data in a sequential manner to understand the adaptive responses of forest-dependent communities in the Ukrainian Carpathians. In another sequential mixed-methods study, Bhattarai (2024) used key informant interviews and a household survey to investigate the impact of a community forestry programme on the general and specific resilience of communities in rural Nepal (see Box 5.2). While the use of a mixed methods approach allows researchers to capture diverse dimensions of resilience, the complexity of this research approach can require significant planning and resources.

5.4.3. Assessing economic resilience

Economic resilience largely focuses on minimising economic welfare loss from shocks over time. It focuses on the ability of an economic system to recover from, withstand, and adapt to shocks, disruptions, or stress as these are quantifiable end points, though economic systems can exist in alternative stable states. Robustness, the ability to resist shocks and disruptions, influences resilience. Resilience does not prioritise efficiency. Efficient economic systems aim to maximise flows with minimum stock, whereas resilient economic systems advocate for maintaining sufficient buffer so that production can jump start soon after a shock event, and thus encourage redundancies (Brunnermeier, 2021).

Economic resilience has both macro and micro connotations, reflecting the ability of the economy as a whole to cope, recover from, and reconstruct after a shock, as well as the economic resilience of individual households or firms (micro units), and their ability to cope with or recover from a shock and adapt to changing economic circumstances (Hallegatte, 2014).This happens by building the coping and adaptive capacity of both micro- and macro-level economic entities to enable them to cope with short-run shocks and to adapt to changing circumstances, as well as strengthen their ability to respond to potential future shocks (Elmqvist et al., 2019).

Rose (2004) categorised the capacities that shape economic resilience into two components: (i) inherent (ability under normal circumstances), and (ii) adaptive (ability in crisis situations due to ingenuity or extra effort). These capacities are, in turn, shaped by a multiplicity of factors. One example are social contracts that minimise negative externality (e.g., social fragility and social inequalities), and encourage social cohesion to withstand future shocks and contribute positively to economic resilience. Free markets, government mandates, and social norms also help in strengthening social contracts and in ensuring micro-level resilience. Building resilience at the macro-level can be enabled with innovations, robust educational systems, stable financial markets, controlled inflation, etc. (Brunnermeier, 2021).

Studies show that for economic development and climate change adaptation, the resilience approach is the most suitable pathway to poverty reduction, development, growth, and sustainability (Adams et al., 2015). The Stockholm Resilience Centre emphasises the maintenance and development of seven principles for building general resilience, and these are applicable to economic activities and economic sectors as well: (i) maintaining diversity and redundancy; (ii) managing connectivity; (iii) managing slow variables and feedback; (iv) fostering complex adaptive system thinking; (v) encouraging learning; (vi) broadening participation; and (vii) promoting polycentric governance (Stockholm Resilience Centre, 2016).

Approaches for assessing economic resilience

Traditionally, economic growth as measured by Gross Domestic Product (GDP), has been synonymous with strength, preparedness, and recovery of economies, but the literature depicts that GDP is not enough to face current and future shocks in a resilient manner. It is too inadequate an indicator to reflect resilience or to deal with crisis like climate change, ecological disasters, or even income inequalities (Dasgupta, 2021). Though there is global discussion on a suitable measure of well-being, GDP and per capita income are still being used widely for measurement as well as for international comparisons. The need for an indicator beyond GDP is being reflected in multiple forums that call for a welfare indicator that is inclusive of well-being and sustainability, or the resilience of societies (Hayden, 2025; Managi et al., 2024).

The efforts to study and measure economic resilience witnessed a boost after the COVID-19 pandemic. The pandemic, the macro-economic crisis, and the escalating climate and environmental emergencies in recent years pushed the need for measuring economic resilience and for solutions to build long-term resilience in economies. Multiple indicators are being used to measure economic resilience, some notable ones being regional income equality (income distribution), economic livelihood diversification, Economic Resilience Index (ERI), risk sharing or coping mechanisms present in the economy (e.g., saving rates, insurance, borrowing capacity, social protection systems). The ERI developed for the European Union is the most comprehensive so far.

The European Commission used a resilience table (resilience dashboard), to assess the resilience of European Union member states across different dimensions and to help identify areas for policy action aimed at enhancing the transition to a more sustainable future. This approach was not developed for forest SES but can be applied to them. The resilience table assessed resilience by combining data from four different dimensions of European Union economies: social and economic; environmental; digital; and geopolitical (European Commission, 2021a). This table used indicators on inequality, social exclusion, household saving rate, health, education, unemployment, government debt, and government investment to GDP ratio (European Commission, 2021b). The main drawbacks of the resilience table were the difficulty of compressing multiple factors into a single number, and the lack of a reference economic state (GDP being a bad reflector of resilience). To overcome these issues, the new ERI was developed to provide a single number reflecting resilience (Hafele et al., 2023).

ERI was based on the theoretical framework developed by Hafele et al. (2023) and is based on the consideration that a resilient economic system should have three distinct features:

1. Absorption (absorb the shock in short-term);

2. Recovery (recover from the shock to pre-shock situation in medium or long-term);

3. Adaptation (adapt to the shock by having a better post-shock performance level) (e.g., Manca et al., 2017).

Households, communities, businesses, and the state are the provisioning actors of an economic system, and the interconnected flows among them maintain the economy. Each of these actors need to have abilities to develop technology and skills, access financial and natural resources, create and develop knowledge and innovations, maintain stable institutions, and distribute activities in a way that the system as a whole is cohesive and has resilient features. The ERI uses 27 different economic indicators, divided into six dimensions, and produces a single number between zero and one, indicating the level of preparedness to face a future calamity and the level of economic welfare loss resulting from that. The six dimensions are:

- Economic independence (sophisticated economic production process, energy independence, export market diversity, supply chain vulnerability, natural resource access);

- Education and skills (skills, reskilling, quality of education, research and development);

- Financial resilience (corporate finance, household finance, public finance, financial equality);

- Governance (government effectiveness, quality of institutions, international collaborations, welfare state quality);

- Production capacity (employment, Information and Communication Technology (ICT) capacity, innovation, investment);

- Social progress and cohesion (democratic participation, power balance between employer and employee, employment quality, gender equality, people at risk of poverty, social exclusion, regional cohesion, trust).

The factors considered under these dimensions address shock absorbing capacity, adaptation to the new scenario, and recovery. ERI, being a dimensionless (unit free) decimal number, helps in cross-country comparison. Hafele et al. (2023) measured this index for the 25 European economies and found the Scandinavian countries to be the most resilient followed by some of the central European countries. Some of Europe's largest and historically strongest economies are seen to be resilience poor: for example, France (ranked 11 out of 25), Spain (18), and Italy (19). The countries having a high resilience score are also seen to have high absorption, high recovery, and high adaptation scores.

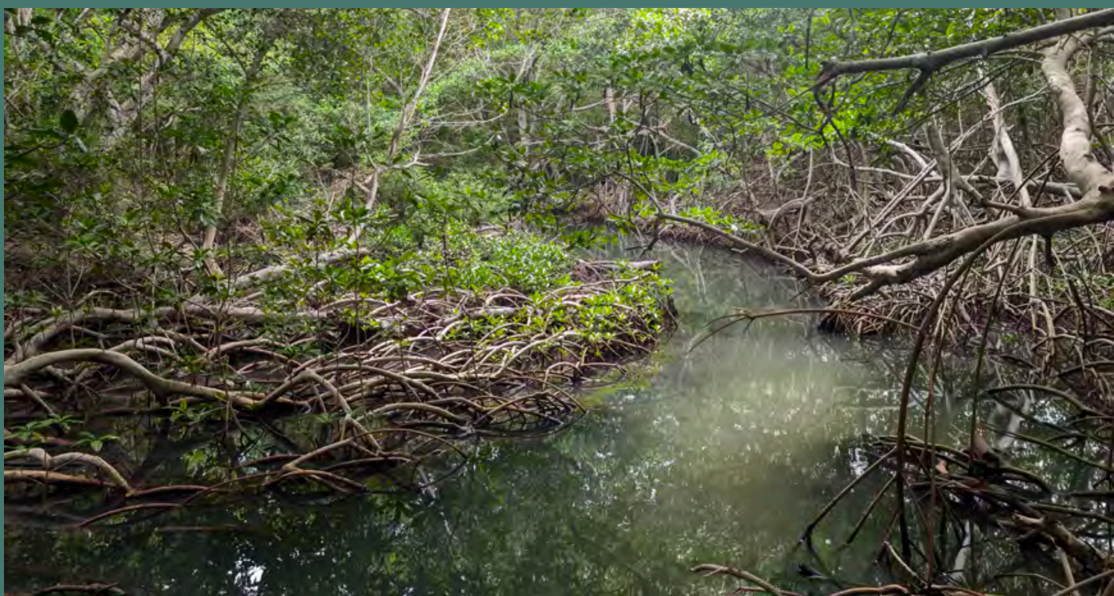
ERI measures the economic resilience that aims for a good life for all within the planetary boundaries. Thus, it can help economies to implement policies that increase resilience rather than the GDP.

The economic contribution of forest ecosystem services

Putting a monetary value to the benefits derived from forest is another approach to measure economic resilience. Forests provide ecosystem services to society and these services increase well-being both directly and indirectly. The provisioning, cultural, and regulating services are final services used by the society and supporting services are intermediary services to these three services. The provisioning services are directly used and provide direct benefits, whereas the regulating and cultural services provide indirect benefits. The supporting services, being intermediary, are not valued to avoid double counting. Depending on the type of service, a plethora of approaches have been developed to enumerate a value. Box 5.3 and 5.4 offer two cases studies showing applications of forest ecosystem service valuation.

Box 5.3 Critical functions of mangroves in coastal protection and impacts on human well-being

Storm protection by mangrove forests is well established and well researched with the application of theoretical models, field observations, numerical simulations, as well as statistical analyses (e.g., Bryant et al., 2022). Das (2011) and Das and Vincent (2009) used econometric models and multidisciplinary data to show that mangroves protected human life during the Indian super cyclone in 1999. Multidisciplinary data used in the study included data and models from different disciplines like meteorology (cyclone parameters, wind models), hydrology (river and drain network), oceanography (storm surge models), fluid dynamics (wind stress), geography (topography, elevation, remote sensing data), disaster management (cyclone warning, shelter network, evacuation), economics (population, asset holding, economic damage, lives loss), etc. The econometric models estimated damage functions and showed that the death toll would have increased by more than 50% if the mangroves were not there during the cyclone, and that deaths averted by mangroves are comparable to deaths averted by cyclone shelters. Das and Crépin (2013) measured the averted house damage during the same cyclone and found the house damage suffered in mangrove-protected villages to be much lower than those of unprotected villages.



Economic assessments have provided evidence on the role of mangrove forests in reducing the impacts of cyclones. Photo © Viola Belohrad

Box 5.4 Forests and the resilience of Himalayan mountain communities to climate-induced water stress

Communities living at higher altitudes, especially in the Himalayas, are dependent on forest for most of their day-to-day basic requirements. Das et al. (2019) studied the relationship between forest cover and water availability in three watersheds in the Kailash Sacred Landscape region of the Himalayas; Hat Kalika and Chandak-Aunlaghat in the Pithoragarh district of Uttarakhand, India, and Gwalek in the Baitadi district of Nepal. On average, these areas are 2,000 meters above sea level, and here, the natural water fountains are the sources of potable water. Erratic rainfall and increased temperatures in recent years are causing water stress in summer in these areas, as many streams are drying up. This region has different types of forests, such as chir pine (*Pinus roxburghii*), which are exotic, as well as broadleaved species and deodar (*Cedrus deodara*), which are native to the region. The study examined the households' belief of chir pine forest areas being more water stressed compared to broadleaved and deodar forest by measuring the coping costs of households for collecting, cleaning, and storing water for household consumption in summer. Results showed that the water collection time and other coping costs for water collection, treatment, and storage for villages surrounded by deodar, deodar mixed with pine, broadleaf mixed with bush, or broadleaf mixed with pine forests are much lower compared to those experienced by villages surrounded by chir pine forest, irrespective of elevation, aspect, or model used in estimation. The differences in water collection time equaled to a wage income loss of between USD 31 and USD 318 in India, and between USD 23 and USD 238 in Nepal (per year and per household). Deodar and broadleaved forests are native to the region, while chir pine is an alien, invasive species, which highlights the role of native forests in ensuring more resilient livelihoods. Valuing nature provides a pathway for assessing such economic resilience.

5.4.4 Spatial resilience approaches for forest SES

Spatial resilience is "the contribution of spatial attributes to the feedbacks that generate resilience in ecosystems and other complex systems, and vice versa" (Angeler and Allen, 2016, p. 618). A related concept is that of spatial regimes, which is the idea that complex SES have a non-stationary spatial dimension. Given that many forest disturbances are spatially contagious, such as fire and insect outbreaks, understanding the velocity of these disturbances can provide time for action. Where one regime is replacing another, for example tree invasions transforming into grasslands (Roberts et al., 2019), focusing on the movement of regimes can provide decades of early warning. Other early warning indicators of loss of resilience and collapse have been criticised for signalling only after it is too late for action.

Cumming (2011a) and Angeler and Allen (2016) proposed a general framework for analysing spatial resilience of a social-ecological system (See Figure 5.4 and Table 5.1). The primary internal elements of spatial resilience in this framework include: (a) the spatial arrangement of system components and interactions; (b) the spatial properties of a system (size, shape, number, and nature of system boundaries); (c) spatial variation in internal phases; and (d) unique system properties that are a function of location in space. Meanwhile, the external elements include: (a) context; (b) connectivity; and (c) spatial dynamics (Cumming, 2011b).

While the roadmap appears simplistic, advancing the understanding of spatial resilience requires understanding the relationships within landscapes between resilience and internal and external elements, identifying boundaries of function scaling domains, identifying thresholds and tipping points, and more. Additionally, challenges exist regarding the availability of spatial and temporal data necessary for comprehensive understanding of system dynamics (Angeler and Allen, 2016). Spatial resilience assessment can be done following the roadmap proposed by Angeler and Allen (2016) (See Table 5.1).

Various spatial models can be utilised to understand spatial resilience in social-ecological systems. There are five general areas or sub-areas of spatial resilience that can be explored with applicable models (Cumming, 2011a). Note that the applicability of the models is not limited to an area or theme. This demonstrates how landscape ecology and other disciplines can be linked and utilised to analyse the different areas of spatial resilience in social-ecological systems.

Figure 5.4 General framework for the analysis of spatial resilience showing its nested nature from local to global

Source: Cumming (2011a)

Table 5.1 Steps for assessing spatial resilience (Angeler and Allen, 2016). Spatial approaches are often applied with other resilience assessment approaches to capture social-ecological and economic system properties relevant to resilience

Steps	Description / definition
(1) Identify system and disturbance	Identify resilience of what, to what
(2) Define spatial regimes/ boundaries	Determine spatial regimes, which define system spatial limits and emphasise self-similarity in patterns that give rise to spatial manifestations of system boundaries
(3) Delineate internal versus external elements	Identify internal and external elements associated with the scale of analysis
(4) Quantify local diversity and complexity	Assess local measures of diversity and complexity, as well as metrics such as patch diversity, class diversity, topographic variability, and related metrics from landscape ecology
(5) Identify thresholds and/or state transitions	Quantify magnitudes of processes that cause abrupt changes in ecological response dynamics
(6) Identify ecological networks and functional connectivity	Consider and characterise influence of networks and functional connectivity in the system, and opportunities for manipulating connectivity or network function
(7) Assess permeability	Not all patches and landscapes are equivalently permeable, and assessing barriers and bridges to the movements of processes and organisms is important
(8) Identify information processing across internal and external components	Identify information exchange within and across internal and external elements, and how they influence steps linking stimulus/perturbation to response capacity
(9) Characterise ecological memory	Determine antecedent conditions or states and their capacity to influence present or future states, conditions, or ecological responses

5.4.5 Temporal aspects of resilience assessments

The temporal dimension of resilience focuses on the time scale implications of occurrences or disturbances, as system resilience is shaped by interaction of short- and long-term processes. Temporal assessments usually focus on recovery aspects of resilience. Often overlooked in the discussion of resilience and multiscale analysis, the temporal complexity of social-ecological systems is an important aspect to short-term variability, and long-term climate change. The temporal dimension may refer to a system's resilience during pre-event conditions, during the event, and during post-event, and relates to a system's response to historical events and even recent short-term shocks.

Gupta and Verma (2024) published a multi-scale temporal classification of resilience levels showing the time-dependent metrics in the context of extreme events affecting the resilience of power supply systems that could also be utilised in the context of socio-ecological systems resilience. The classification presents five sub-states of a system: the initial resilient state (pre-event) showing high level of resilience; the event progress state and degradation state (during event) showing a decrease in resilience; and the restoration state and adaptation state (post event), where an anticipated response leads to an increase in resilience. The classification highlights how resilience is dynamic and varies at different states or time periods, for example how a coastal forest might recover following hurricane impacts.

In a time series, one would be able to detect quick recovery times for resilient systems (Scheffer et al., 2009). The statistical approaches used with that aim are known as early warning signals, which come from the study of dynamic systems. Additionally, a variety of indicators exist for temporal and spatial data (Dakos et al., 2012). Recent studies have used these types of methodologies to assess the resilience of forests at different scales and different datasets regionally (Bochow and Boers, 2023) and globally (Feng et al., 2021; Rocha, 2022; Smith and Boers, 2023). These approaches, however, have some limitations. Their interpretation is limited by the availability of data, measurement error, and lack of ground truth, and only a few have addressed statistical features to enable unbiased comparisons. Another limitation is that these remote sensing-based approaches can learn very little about features of resilience related to adaptations and transformations. Moreover, they also signal after it is too late to effect change.

5.5 Indicators for assessing resilience

The development of valid and reliable indicators remains an essential task in understanding and enhancing the resilience of forest-dependent communities (Magis, 2010). Indicators can be characterised as qualitative or quantitative measures of one or more dimensions of a criterion of interest (Loomis, 2002). Indicators also represent the standards by which decisions are made about alternative policy choices (Cubbage et al., 2016). In research on community resilience, as in other fields of social science research, the choice of indicators is shaped by the conceptual frameworks informing the evaluation process. Much of the earlier work on the assessment of resilience in forest-dependent communities was somewhat atheoretical, and largely driven by data availability (e.g. Haynes, 2003). Since then, a number of frameworks have been developed to guide resilience assessment efforts in forest-dependent communities (e.g., Melnykovych et al., 2018) and these frameworks have been operationalised in various contexts using a variety of methodological approaches (Table 5.2).

Table 5.2 Selected approaches and indicators for resilience assessment

We list approaches based on a subset of case studies that have utilised various approaches and indicators for resilience assessment. Those approaches have resulted in a number of indicators that are useful in assessing resilience. A more comprehensive (but not exhaustive) list of approaches and indicators is available as an online resource (www.iufro.org/programmes/scipol-forests-for-social-and-economic-resilience-2025).

Case study description	Methodological approaches	Examples of specific indicators
Framework for assessing the impact of community forestry on the resilience of communities in the Philippines (Jarzebski et al., 2016)	Mixed methods (Quantitative: household survey, use of satellite images and GIS data; Qualitative: interviews)	▪ Natural Capital (e.g., forest cover and health, accessibility of forest resources to individuals) ▪ Socio-cultural capital (e.g., number of individuals in cooperative networks, social network in the community, trust in local community and local government, traditional knowledge) ▪ Economic capital (e.g., income diversity, income dependency on local resource, savings, equity in income distribution, mobility)
The capacity of Tsimane' households in the Bolivian Amazon to cope with, and adapt to climate change in the face of conservation policy implementation, market forces and other drivers of change (Ruiz-Mallén et al., 2017)	Quantitative method (household survey)	▪ Governance and social assets (e.g., community participation, community position, investments) ▪ Human assets (e.g., formal education, local ecological knowledge) ▪ Financial assets (e.g., savings, subsidies) ▪ Natural assets (e.g., forest cleared for agriculture, fallow lands cleared for agriculture)
The role of social capital in building the adaptive capacity of three rural forest-dependent communities in response to various drivers of change in Washington State, USA (Harrison et al., 2016)	Qualitative method (interviews)	▪ Bonding social capital (e.g., relations among individuals with shared attributes within a given community community) ▪ Bridging social capital (e.g., relations among individuals with differing attributes within a given community ▪ Linking social capital (e.g., relations among individuals outside one's community)

While progress is being made towards the development of frameworks and indicators for assessing resilience in forest-dependent communities, much of the existing research tends to be informed by a conceptual framing that is consistent with general resilience (i.e., community capacity to respond to all kinds of drivers of change while maintaining or enhancing desirable community conditions). For instance, Hajjar et al. (2021) employed a general resilience approach in assessing the impact of REDD+ programmes on forest-dependent communities. In another study, the Community Resilience Model (Akamani, 2012) was applied in assessing the impact of Ghana's collaborative forest management program on the general resilience of communities and households in southern Ghana (Box 5.5).

5.6 Synthesis and gaps

This section provides a synthesis of key findings on resilience assessment of forest SES. We focus on the frameworks and tools for resilience assessment, as well as a synthesis of existing knowledge gaps. There are differences and similarities in resilience assessment utilised from social, economic, and social-ecological perspectives. Some of these differences are derived from disciplinary perspectives that emphasise recovery aspects of resilience rather than the full complement of resilience theory such as the ability to stay in the same system state despite disturbances or the ability to transform. Given that most disturbances do not cause forest SES to cross a critical threshold and reorganise into a different state, this seemingly limited approach captures the dynamics of forest SES response to disturbance in most circumstances.

5.6.1. Methodological advances

The methods for resilience assessment across the various disciplines could be categorised in diverse ways, but broadly fall under qualitative, quantitative, and mixed methods approaches. The assessment of social resilience tends to draw from fields such as social indicators research, well-being, quality of life, and social impact assessment. Drawing from this rich tradition of social science research, existing research approaches involve the use of various methods, such as document review, observation, individual, and group interviews to generate data for gaining an in-depth understanding of phenomena within particular contexts. Quantitative approaches have also involved the use of objective measures, often from secondary sources, as well as data from surveys on the subjective perceptions of study participants on key indicators. Mixed methods approaches, involving the integration of qualitative and quantitative approaches, are also used to provide rich insights into complex phenomena. The assessment methods for economic resilience are primarily quantitative and seem to encompass both objective and subjective quantitative approaches, given the emphasis on the use of quantitative data from secondary sources and from survey research that capture perceptions of respondents on variables of interest (Jones and d'Errico, 2019). The assessment of social-ecological resilience also relies on methods drawn from both qualitative and quantitative approaches. Recent decades have seen significant progress in the development of novel techniques for quantifying various aspects of the resilience concept, including spatial resilience and uncertainty (e.g., Allen et al., 2018). Quantitative data for these assessments are collected using a variety of methods, ranging from remote sensing to the administration of surveys. The use of qualitative approaches, including participatory action research, has also been gaining recognition, as a response to the need for stakeholder engagement in resilience assessment processes.

5.6.2. Knowledge gaps

A key challenge in the assessment of resilience appears to be the differences in its conceptualisation within and across disciplines. While the resilience concept is now widely embraced across the ecological, social, and economic sciences, it appears that attributes of complexity, such as emergence, scale, non-linearity, and path dependence have not received enough attention in the way resilience is conceptualised in the social and economic sciences. For instance, existing conceptual frameworks for assessing the sustainability and resilience of forest-dependent communities do not sufficiently address the attributes of community complexity (Akamani, 2023), and mechanisms for coping, adaptation, and transformation are not well-understood. Even within the field of social-ecological systems research conversations on resilience versus stability continue to draw supporters to either side (Grafton et al., 2019; Pimm et al., 2019). These conceptual ambiguities impede progress towards measurement and practical application of the resilience concept.

Box 5.5 Co-management and general community resilience in Ghana

A mixed methods approach was employed to evaluate the impact of Ghana's collaborative forest management programme on the general resilience of communities and households. Data were collected from two forest-dependent communities in the Ashanti region using document review, key informant interviews (n = 39), and a household survey (n = 209). The study was designed to simultaneously test a proposed Community Resilience Model (Akamani, 2012), as well as a new measurement instrument for assessing household resilience (Akamani, 2011).

The results from qualitative data at the community level showed variations in the impacts of the programme within and across the various community capital assets that shape general community resilience, although the overall impact of the programme was judged by key informants as moderately positive. At the household level, results of statistical analysis of the survey data showed a decline in most household assets during the implementation of the programme across the two communities, suggesting that the community level benefits of the programme may not have been equitably distributed at the household level (Akamani and Hall, 2019). The determinants of general resilience outcomes at the household level were analysed through regression analysis, and the results showed that community location and household asset endowments prior to the implementation of the programme were the most important predictors of most outcome variables (Akamani and Hall, 2015). This highlights the importance of history and context in shaping resilience outcomes. Consistent with findings in the broader literature on community resilience (e.g., Stotten et al., 2021), the results from this study show that forest-dependent communities are complex adaptive systems that are characterised by cross scale interactions, path-dependency and other attributes. Recognition of this complexity is essential in informing policies that nurture resilience while reducing vulnerability in forest-dependent communities around the world (Akamani, 2023).

Interviews at the community level revealed variations of the impacts of Ghana's collaborative forest management within and across the various community capital assets that shape general community resilience. Photo © Kofi Akamani

The development of indicators for assessing some aspects of the resilience concept has been challenging across all the three perspectives analysed in this chapter. Although social-ecological systems research has made progress in developing methodological protocols for assessing resilience (Allen et al., 2018; Chuang et al., 2018), some researchers have argued that some of the concepts, such as thresholds/tipping points, are not useful for decision-making because they are very hard to observe, measure, and distinguish from background noise in real world data (Hillebrand et al., 2023, 2020). In view of these challenges, studies on transformations in social-ecological systems typically rely on historical and retrospective data (Rocha et al., 2022). The measurement of social thresholds is equally challenging (Christensen and Krogman, 2012), and as a result, most community resilience studies do not pay enough attention to transformative change.

Another challenge with current resilience assessment methods is the lack of well-developed institutional mechanisms for the meaningful involvement of relevant stakeholders in the assessment process (Jones et al., 2021). The problem may, in part, be rooted in the historical legacies of top-down expert-driven approaches to monitoring and evaluation that focused narrowly on objective and quantifiable measures of policy outcomes (Plummer and Armitage, 2007).

Another reason is that participatory methods may be less feasible to employ when dealing with issues involving a variety of stakeholders dispersed across larger geographic scales.

5.6.3 Future approaches: Moving from social, ecological, and economic indicators to truly integrative measures for social-ecological systems

Our review of resilience assessment frameworks, methods, and indicators across the social, economic, and social-ecological systems perspectives has revealed that each discipline has its conceptual and methodological blind spots, making it challenging for a single discipline to develop the tools required for a holistic understanding of the dynamics of forest ecosystems and their resilience outcomes. In response to this problem, scientists and policymakers are increasingly focusing on the integration of knowledge across disciplines. Miller et al. (2008) call for epistemological pluralism in research on social-ecological systems and for advancing knowledge integration through various forms of disciplinary collaboration. Beyond disciplinary collaboration, others have called for weaving together knowledge systems that represent scientific and non-scientific ways of knowing (Visseren-Hamakers and Kok, 2022).


Photo © Viola Belohrad

Transdisciplinary research as an approach to resilience

Cross-disciplinary research in the form of multidisciplinarity, interdisciplinarity, and transdisciplinarity offers promise for understanding the different spatial and temporal dynamics of social-ecological systems (e.g., Visseren-Hamakers and Kok, 2022). These approaches help to break down issues, prioritise actionable interventions, and facilitate the engagement of multiple stakeholders in co-creating desirable futures.

Multidisciplinary studies are those in which researchers from different disciplines investigate a common problem using research tools that are unique to their discipline, such as theories and methods (e.g., Miller et al., 2008). Interdisciplinarity involves researchers from multiple fields of study who work on a common research problem based on a common set of terminology, methodological protocols, and conceptual frameworks to understand and unpack complex systems (MacLeod and Nagatsu, 2018; Tabacchi and Termini, 2017).

Transdisciplinarity entails the fusion of epistemologies and theoretical perspectives across relevant disciplines to address unique research challenges that could not be addressed within the traditional domains of the participating disciplines (e.g., Hofkirchner and Schafranek, 2011). Some authors embrace a much broader framing of transdisciplinarity that goes beyond cross-disciplinary collaboration. In this sense, transdisciplinarity goes beyond engaging experts and key decision-makers and ensures that all relevant stakeholders are involved, providing an equal platform for the resilience discourse (Jahn et al., 2012). This broader perspective aligns with the ideals of participatory action research. Transdisciplinarity can be applied in the assessment of resilience of social-ecological systems. It can serve as a potential tool to develop strategies that address the complexity and dynamism of these systems as they progress towards resilience.

Integration of local and traditional knowledge

The weaving together of knowledge systems that brings together scientific and non-scientific ways of knowing is another promising approach to addressing existing challenges in resilience assessment. Traditional knowledge refers to the coherent body of knowledge, beliefs, and practices that local communities have accumulated over time and pass down from one generation to another through cultural transmission mechanisms (Berkes et al., 2000). Local knowledge encompasses knowledge held by a group of people about their local environment that often includes traditional and scientific knowledge (Olsson and Folke, 2001). Both traditional and local knowledge are increasingly being recognised as essential for understanding the dynamics of complex social-ecological systems (Folke et al., 2002), and for advancing transformative governance (Visseren-Hamakers and Kok, 2022). The use of traditional and local knowledge in resilience assessment can help reduce costs, empower communities, and contribute to better understanding of early warning signals and other attributes of social-ecological complexity (e.g., McElwee et al., 2020). However, the integration process is often constrained by the unequal power relations and lack of trust between scientists and holders of traditional knowledge, including Indigenous Peoples, challenges in data integration, as well as differences in values and epistemologies (Houde, 2007). Overcoming these challenges will require the use of effective governance mechanisms, such as adaptive governance, with the capacity to engage actors across levels in an ongoing process of managing conflicts as well as learning and adapting to change.

5.7 Chapter conclusions

In this Chapter, we analysed the evolving approaches to resilience assessment across various disciplines with the aim of identifying areas of progress and avenues for further advancement. Sharifi (2016) proposed a framework for evaluating assessment tools based on the extent to which they: 1) address multiple dimensions of resilience; 2) account for cross-scale interactions; 3) capture temporal dynamism; 4) address uncertainties; 5) employ participatory processes; and 6) develop action plans. Based on this framework, it could be concluded that there is a lack of congruence in the definition and measurement of resilience across disciplines. Existing frameworks and indicators for resilience assessment in the social and economic sciences do not sufficiently account for environmental variables, whereas resilience assessments from the social-ecological systems perspective also do not adequately capture the socioeconomic dimensions of resilience. Regarding spatial and temporal scale, some progress has been made in integrating these attributes into social-ecological resilience assessments, although the scale concept has not yet received enough attention in the assessment of social and economic resilience. While a limited number of studies on social-ecological resilience have explicitly addressed issues of uncertainty (e.g., Allen et al., 2018), it appears that not much progress has been made in accounting for uncertainties in resilience assessment across the various disciplines, as reflected in challenges in the measurement of thresholds and other attributes of complexity. Similarly, the integration of participatory approaches into resilience assessments has not been widespread. Although the social sciences have a longer tradition of relevant research (e.g., participatory action research), the integration of these existing approaches into resilience assessment has been slow. Moreover, we found that the assessment of resilience is largely done in a retrospective manner, with rare instances of resilience assessments being integrated into plan preparation and implementation processes in a forward-looking manner. In all, the results highlight the need for further refinement of the conceptual and methodological tools for resilience assessment, as well as the development of more effective mechanisms for engaging stakeholders in the assessment process.

As adoption of resilience assessment increases across a variety of resource management arenas in different parts of the world, a more tailored, context-specific approach to indicator development may be necessary to ensure that resilience assessment protocols are salient for the problems in particular contexts.

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6

Chapter 6

Options for Enhancing the Contributions of Forests to Social and Economic Resilience

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Abstract

In this Chapter we identify the resilience-enhancing potential of management and governance interventions, or 'response options' that have forests at their core or that could address forest social-ecological systems, for instance, by seeking to improve forest extent, condition, and biodiversity. Interventions may be focused on reducing the drivers of deforestation and degradation or on enhancing and amplifying positive forest-based actions (e.g., governance, social, cultural). We identify response options that may contribute to improvements in forest condition and/or the reduction of drivers of forest decline and degradation. We consider a range of more common and more nascent response options, and the overarching frameworks that may support their application. We examine resilience-enhancing response options by incorporating widely recognised social-ecological, resilience-enhancing attributes and placing an emphasis on well-being, including social and economic attributes, which have so far received less focus or, in some cases, been supplanted by environmental, legal, or technical priorities. We also consider the scale at which interventions are applied and their propensity to support incremental or transformative change, as well as the potential for divergent outcomes in the Global North versus the Global South. We explore whether common interventions are sufficient and if there are additional options that hold promise for enhancing resilience. Further, we identify intervention adjustments or calibrations that may be required to increase their resilience-enhancing potential, and point to cross-cutting elements and approaches that may advance forest contributions to social and economic resilience in particular, and to social-ecological system resilience more broadly.

6.1 Introduction

Achieving the goals of the global sustainability agenda relies on enhanced social-ecological resilience across systems and scales (Chapters 1 and 2). Social-ecological system (SES) resilience is particularly important given increasingly unprecedented and interconnected stresses (e.g., from slow-onset events associated with human-driven abiotic, biotic, and climatic disturbances), shocks (e.g., sudden extreme events such as extreme weather events, market crashes, geopolitical crises, pandemics), and stressors (e.g., aggravating trends that influence the level of risk) (e.g., Djoudi et al., 2022; FAO, 2022; Libert-Amico et al., 2022; McGinley et al., 2022). Further, resilient forest social-ecological systems (forest SES), comprised of ecological, economic, and social dimensions, have the potential to make vital contributions to sustainable futures (Burton, 2025; Timko et al., 2018; and see Chapter 2).

Social-ecological system resilience can be supported and enhanced, but also may be constrained or deterred, by governance and management interventions through a variety of means, tools and approaches (e.g., incentives, deterrents, creating access, shifting norms) (Walker et al., 2004; and see Chapters 3 and 4). These interventions can influence and alter forest SES dynamics in multiple ways, for instance, by enhancing or impeding system capacity to cope or adapt to change, and by providing or precluding pathways for transformation when desired or necessary (Allen et al., 2019; McGinley, 2017; Reyers et al., 2022). Building resilience has emerged as a prominent approach in management and governance interventions, particularly for preventing, preparing for, responding to, and recovering from stressors and shocks across a broad range of systems, sectors, contexts, and scales (e.g., Lin, 2019). However, in practice, resilience-building efforts tend to be siloed across or within sectors and focused on system subcomponents (Chapter 5) (e.g., ecological over socio-economic aspects), which may lead to fragmented, short-term solutions that address symptoms, rather than root causes (e.g., United Nations, 2020).

In this Chapter, we focus on identifying governance and management interventions, or 'response options', with potential to support or enhance forest resilience and forest contributions to social and economic resilience. Building on preceding Chapters, we identify key attributes needed for enhancing forest contributions to social and economic resilience and explore the ways in which a range of response options demonstrate these resilience-enhancing attributes. We draw on social-ecological resilience theory (Chapter 2) and the relationships, flows, and feedbacks between forests and people in forest SES (Chapter 3), including forest governance and institutional dynamics that appear to foster or enable resilience (Chapter 4). We also draw on insights on how to assess resilience, and the attributes and associated measures that may be most relevant and monitored for enhancing resilience (Chapter 5).

The contributions of this chapter are threefold. **First**, we identify key attributes ascribable to a given intervention for enhancing social and ecological resilience and incorporate and examine a response option's resilience enhancing potential based on this core set of resilience-enhancing attributes. These attributes are described and explored in Section 6.3. **Second**, we explore the resilience-enhancing potential of prominent forest-focused response options aimed at mitigating deforestation or forest degradation, or both, many of which aim to address a range of other threats or drivers. Response options, as filtered through these core resilience-enhancing attributes, and their application to prominent forest-focused interventions, represent a key contribution of this Chapter, with utility intended for practitioners and researchers interested in considering a given response option's potential to enhance resilience. **Third**, we summarise key cross-cutting factors and frameworks that may be useful in orchestrating the cross-scale and cross-sector considerations, and combinations of response options that are likely necessary to successfully enhance the roles of forests in social and economic resilience.

We take this approach while recognising the expanding evidence that wealth accumulation linked to the dominant capitalist development model can drive environmental collapse (IPBES, 2024a; WWF and IUCN, 2000), which likely requires a cross-sectoral focus on the levers of transformation directed at a system-level transformation, and which may require new, rare, or seemingly radical approaches (IPBES, 2024a). The IPBES (2024) transformative change assessment identifies disconnection from and domination over nature and people, the concentration of power and wealth and prioritisation of short-term individual and material gains as underlying causes of the decline of nature (including of forests). Analysing these drivers is beyond the scope of this Chapter or the broader assessment. Nevertheless, support for resilient forest SES and small-scale incremental changes through readily available or enhanced interventions can contribute to system-wide shifts.

6.2 Drivers of deforestation and degradation and potential responses

6.2.1 Complex drivers interact across scales and generate cascading impacts on forest SES

While increases in forest cover and partial reductions in deforestation rates have recently been reported for some regions (FAO, 2024; WRI, 2024), these patterns remain globally variable (e.g., Luttrell et al., 2013). In general, the state of forests and their diversity (both biological and cultural) are declining, particularly in relation to old-growth and primary forests (McDowell et al., 2020). Worldwide, forests are threatened not only by deforestation and land use change, but also by various drivers of forest degradation. Degradation can surpass the extent of deforestation at local, national, and larger scales, and is more difficult to measure and monitor (Gao et al., 2020; Lapola et al., 2023; Lloret et al., 2022). Furthermore, in many cases, where new forest areas occur, they are often fragmented patches with lower diversity, limited habitat connectivity, and lower presence of native species than traditional forests (Navarro-Cerrillo et al., 2019). In Europe, for example, forest cover is increasing, however, this forest expansion is largely attributable to increases in plantation forests, which are less diverse than native forests, and to areas revegetated by invasive species that encroach on abandoned agricultural land and increase flammability (Martin et al., 2020). Overall, these trends in forest cover and quality globally indicate that the current governance and management interventions have not prevented nature's decline, appear insufficient to secure sustainability and resilience into the future, and may not be fit for purpose, a statement determined to be 'well established' and evidenced (IPBES, 2024a).

A multitude of drivers threaten forest resilience globally and include present actions (e.g., unsustainable extraction, land use change and conversion, infrastructure projects, land speculation), future risks (e.g., land speculation and development projects), and increasingly, sudden or repeated shocks (e.g., drought, fire, species invasion, economic recession, global pandemics), many of which are exacerbated by climate change. We refer to these pressures and stressors as 'drivers'. Key in relation to forest resilience are deforestation and degradation drivers, which can be both proximate and distant (e.g., Barlow et al., 2018; Marques, 2020) (Table 6.1). Deforestation and degradation drivers are understood as two distinct but interrelated

Table 6.1. Common proximate and distant drivers of deforestation and degradation (summary from Chapter 1

PROXIMATE DRIVERS OF:	
Deforestation	Degradation
▪ Commodity and agriculture expansion ▪ Urban, peri-urban, settlement expansion ▪ Land abandonment ▪ Oil and mineral extraction ▪ Road and infrastructure development	▪ Unsustainable logging/wood product extraction ▪ Unsustainable non-wood product extraction (non-wood plant materials, animals) ▪ Fire regime change ▪ Pest and disease regime change ▪ Droughts, floods, storms
DISTANT DRIVERS OF:	
Deforestation	Degradation
▪ Consumption-driven demand for meat ▪ Consumption-driven demand for livestock, poultry feed ▪ Revenue-seeking investment/shareholders in commodity production ▪ Trade regulations	▪ Demand for timber/wood products ▪ Demand for non-wood products ▪ Climate change

processes impacting forests (Lapola et al., 2023) that undermine forest resilience and have cascading impacts on forest contributions to social and economic resilience (Chapter 3). Further, although deforestation and degradation manifest locally, they are connected to drivers that may be local but are often operating across scales, linked to, for example, the demand of distant consumers connected via global markets (e.g., commodity and agriculture expansion) (e.g., IPBES, 2024). As outlined in the Section 6.1, the fundamental and overarching drivers of deforestation and forest degradation are understood to be connected to the dominance of material values over ecological or social well-being, and tied to the capitalist model of accumulation and growth (Costanza, 2022).

Not only are there multiple drivers of deforestation and degradation, but these pressures on forests often interact, creating cascading impacts with feedback loops that can further curtail the resilience of forests and introduce rapid change to new and undesirable states. For example, climate change is a cross-cutting driver that induces multiple impacts, including increasing forest vulnerability to pests (Ramsfield et al., 2016) and conditions of flammability (e.g., lower humidity, higher wind speeds, higher temperatures) (Jones et al., 2024). Flammability itself can be further exacerbated by management interventions (e.g., fire suppression), generating propensity for wildfires, which release carbon, can impair forest structure, reduce biodiversity, and through feedbacks, further drive climate change and flammability (Jones et al., 2024; Shaw et al., 2022).

Climate change also affects social and economic systems, including communities living within forests, by, for instance, generating changes in disease exposure or reducing forest product yields. The impacts associated with climate change may exacerbate existing vulnerabilities or generate new pressures on households, communities, and regions that may look to forests to offset the associated burdens, resulting in unsustainable options for forest use (Brondízio et al., 2016). The multiple stressors and their cascading impacts affecting forests and other social-ecological systems may be reaching local, regional, and global tipping points that significantly (or severely) threaten forests and their relationship with social and economic systems (Lovejoy and Nobre, 2018). Similarly, tipping points in socioeconomic systems can trigger considerable changes in forests. For example, having reached thresholds of population density and congestion, Indonesia's capital city of Jakarta will be relocated from the island of Java to the heavily forested island of Borneo (Jong, 2024). Thus, this social tipping point and the subsequent policy response in Jakarta are likely to have very clear and direct impacts on the forests of East Kalimantan, where the city is to be relocated, and thereby on the social and economic resilience of forest-dependent and proximate communities that are part of the social-ecological system.

More recent attention is focusing on positive tipping points (i.e., transformations) that may arise from socioeconomic contexts, and that enable '**brightspots**' (Cinner et al., 2016; Lenton, 2020; Lenton et al., 2022). Brightspots are positive

Box 6.1 Biocultural heritage territories, Indigenous values and holistic well-being: Scaling out the Potato Park decolonial approach for climate resilience of Kenya's forest landscapes

Biocultural heritage territories are landscapes that are collectively self-governed by Indigenous Peoples and local communities based on customary laws. They are guided by ancestral holistic well-being concepts that encompass the well-being of the human, natural, and sacred worlds, and by core values such as reciprocity, balance, solidarity, and collectiveness, with nature and within society, which are common to many Indigenous cultures (Swiderska et al., 2020).

Biocultural heritage territories seek to protect and restore complex adaptive biocultural systems, including traditional ecological knowledge, to enhance ecological, socio-cultural, and economic resilience. Biocultural systems include traditional knowledge, biodiversity, landscapes, cultural and spiritual values, and customary laws that are inter-connected and inter-dependent in the worldviews and practices of many Indigenous Peoples. Biocultural heritage territories have been defined as "land use mosaics encompassing Indigenous and traditional land tenure, production and exchange systems, cultural identity, community organisation, and simultaneous goals of endogenous development and biodiversity conservation" (Swiderska et al., 2020, p. 2).

The Potato Park is an emblematic biocultural heritage territory established by six Quechua communities in the Cusco region of Peru in 2000, with support from the Asociación ANDES from Peru and the International Institute for Environment and Development (IIED) in UK. By restoring agrobiodiversity and conserving mountain ecosystems, the Park has enhanced food security and incomes, and improved resilience to climate change and other shocks (e.g., COVID-19), despite severe climate change impacts in the high Andes (e.g., the lower planting line for potatoes has risen by over 200 metres in 30 years due to rising temperatures and soil pests). The Potato Park has established a resilient biocultural economy based on baskets of products and services, and has built strong collective institutions that have defended land rights and influenced regional laws. It is anchored in the Andean Ayllu concept, where balance and reciprocity are needed between the human, wild, and sacred worlds to achieve holistic well-being (Sumaq Kausay), and in decolonising action-research methodologies.

The Potato Park in the Cusco region of Peru, an emblematic Quechua biocultural heritage territory, has contributed to restoring agrobiodiversity and conserving mountain ecosystems, leading to enhanced food security and incomes, and improved resilience to climate change and other shocks. Photo © Krystyna Swiderska

Box 6.1 Continued….

The Potato Park model has been scaled out successfully to other Andean communities in Peru, but scaling to other contexts has proved more challenging. In coastal Kenya, IIED and the Kenya Forestry Research Institute (KEFRI) have been supporting 10 Mijikenda villages in the Rabai region to establish a biocultural heritage territory to protect the sacred Kaya forests and their agrobiodiversity, thus enhancing climate resilience, livelihoods, and rights.

Kaya forests are traditionally protected by a Kaya Council of Elders, but are being degraded due to poverty, population density, lack of enforcement of forest laws, and significant weakening of traditional culture and institutions under colonial and post-colonial administrations. Kaya elders' rules are sidelined by young people in particular, but also by middle-aged people. Village elders are now appointed by the government, which means that villages no longer have the autonomy to develop their own rules. This is very different from the example in Peru, where decolonisation movements and Indigenous governance systems are strong.

However, a biocultural heritage territory association has been established in Rabai, linking Kaya elders and village elders at landscape level and seeking to empower Kaya elders. This aims to enable the region of Rabai to speak with one voice, and to better defend its territory against growing external pressures (e.g., mining). The process to establish the biocultural heritage territory has helped to increase the respect for Kaya elders amongst youth, empowered women in decision-making, and strengthened sustainable livelihoods. It also enabled a few inhabitants from Rabai to visit the Potato Park in Peru and learn first-hand that a different world is possible.

Kaya elders in Rabai performing a ritual during a biocultural festival, Kenya. Photo © Krystyna Swiderska outliers where – despite the potential for forest resilience to be undermined and degraded – positive outcomes are encountered. Such brightspots have been assessed and identified in forests and other systems (e.g., marine) (Cinner et al., 2016). For instance, recent work in the Brazilian Amazon has demonstrated the socioeconomic factors (e.g., cohesion, autonomy) that have enabled the persistence of desirable and resilient forest-people relationships (i.e., brightspots) that have proven capable of withstanding degradation and deforestation pressures (Brondízio et al., 2021; de Castro et al., 2024; Russo Lopes, 2023). Brightspots, also referred to as 'seeds of a good Anthropocene', offer considerable potential for learning and scaling to improve the resilience and desirability of other systems and contexts (Londres et al., 2023). However, scaling up these often-isolated brightspots can be challenging (Box 6.1), raising the central questions (resilience of what, to what and for whom?) that face the resilience policy, research, and practice communities consistently (Ndalilo et al., 2022).

6.2.2 Forest-focused response options

Forest-focused governance and management interventions may target deforestation, forest degradation, or both, along with other proximate and distant forest threats. These interventions may focus on forest protection (including biodiversity), expansion, restoration, or sustainable use through diverse approaches that harness markets, laws, rights, information, resource management, and other tools (see Chapter 4). Through a review of the literature and consultation amongst the Chapter authors, we identified and categorised existing and emerging forest-focused interventions along with a few key social or economic interventions with their central focus outside of forests focus, but which may influence the state of forests and their role in contributing to social and economic resilience. In Table 6.2, we list these key interventions and organise them according to their principal intervention logics (i.e., resource management; economics/markets; rights/tenure; other legal/ regulatory; information). We recognise that

Table 6.2 Key response options designed to address deforestation, forest degradation, and other forest threats, organised by intervention logic

Forest, landscape and tree management-based	Economic and market-based	Rights and tenure-based	Other legal and regulatory	Information-based
▪ Ecosystem management ▪ Adaptive (collaborative) management ▪ Climate smart forestry/ natural climate solutions (NCS) ▪ Integrated fire management* ▪ Forest landscape restoration* ▪ Agroforestry*	▪ REDD+ ▪ Payments for ecosystem services ▪ Forest certification* ▪ Debt-for-nature swaps ▪ Forest bioeconomy and circular economy* ▪ Universal basic income	▪ Protected areas, land-sparing, and biocultural land sharing* ▪ Community-based forest management, co-management and adaptive collaborative forest management* ▪ Recognising and securing Indigenous Peoples' and local communities' land and resource rights* ▪ Forest concessions	▪ Supply- side law/ policy (e.g., land use/forest zoning, forest regulations, best management practices (BMPs), harvest limits, EU Nature Restoration Law) ▪ Demand-side law/policy (e.g., EU Deforestation Regulation*, US Lacey Act, Australian Illegal Logging Prohibition, public wood product procurement policies)	▪ Digital technologies* ▪ SFM criteria and indicators ▪ Forest monitoring, assessment, and reporting

**Response options examined in this chapter to understand their resilience enhancing potential (Section 6.5). We have chosen to focus on options most likely to affect forest SES resilience while also addressing threats to forests.*

there are other, yet similar ways to categorise interventions (e.g., Bemelmans-Videc et al., 2017) and that several interventions may be categorised under multiple intervention logics (e.g., Adaptive Collaborative Management may be designed as a resource management approach that incorporates rights-based, economic, and other intervention logics). We developed this categorised list of management and governance interventions to help organise our assessment of resilience-enhancing response options and found it to be effective for this purpose, but we would caution against utilising the categorised list or associated findings as a means for evaluating the resilience-enhancing potential of different intervention logics themselves.

Forest-focused response options may be applied in isolation or in combination, creating 'bundles' of interventions in complex, integrated, and nexus approaches (Carmenta et al., 2021; Gunningham, 2019; Malan et al., 2024; Reed et al., 2016). Ultimately (and ideally), these interventions would account for the complexity of social-ecological dimensions and dynamics, thereby generating co-benefits additional to the intended target outcome. For instance, interventions to enhance food production may have positive co-benefits for forests or biodiversity.

Still, forest-focused interventions can produce unintended or undesirable outcomes for forest SES. Furthermore, intended and unintended intervention outcomes (both co-benefits and negative outcomes) are likely to be connected through feedbacks across scales through processes such as telecoupling (Liu et al., 2013). Trade-offs within or between governance and management interventions may also occur, for example generating socioeconomic benefits whilst incurring ecological burdens or vice versa. Interventions may also focus on subsystem resilience (i.e., economic, ecological, social resilience) at suboptimal levels, particularly where a narrow subsystem focus leads to conflict between different stakeholders, uneven distribution of benefits and burdens across and within systems, and trade-offs with measurable negative impacts between subsystems (e.g., Nikinmaa et al., 2023; Preiser et al., 2018).

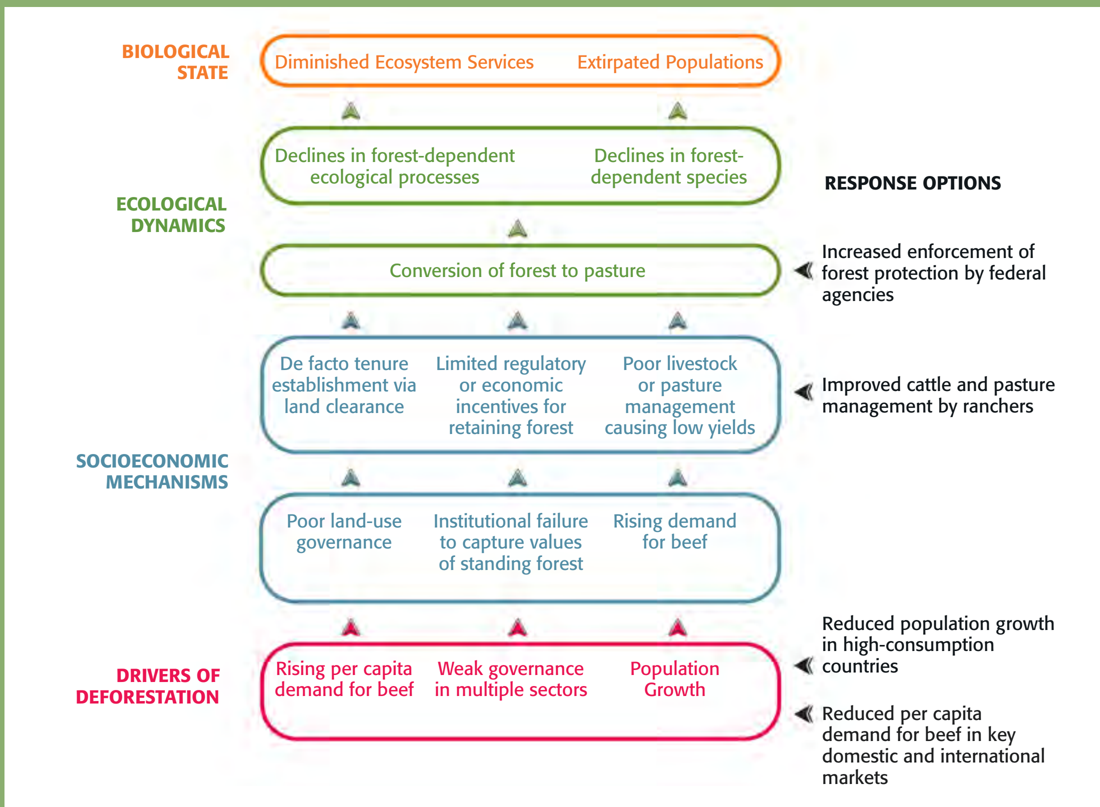
Understanding intervention outcomes, connections, and trade-offs is important to resilience-enhancing efforts. Where a response option fails to generate desired outcomes, or introduces negative impacts, a transformation of the response itself may be required (Akers and Yasué, 2019). In determining desired (and undesired) outcomes or states of resilience and the appropriate response options for enhancing or transforming these traits, the question "resilience of what, to what, and for whom?" becomes central (Walker et al., 2004). Of course, defining the desired (or undesirable) state of resilience is inherently subjective and context dependent, it involves multiple perspectives, and it may be susceptible to power imbalances or asymmetries (Cutter et al., 2008). Critically reflecting on these dimensions of resilience requires attention to ethics and justice. Indeed, these attributes have been placed at the centre of transformations to sustainability, and transformation of the system or the intervention itself may be necessary where multiple perspectives and fairness are not present (Martin et al., 2020).

Disentangling the various aims (i.e., what point in the system is being targeted and based on what logic) of different response options and their associated outcomes can be challenging. Some interventions are formulated with a single aim or purpose, such as protecting biodiversity or enhancing forest-based livelihoods, but most have multiple aims or goals (e.g., climate change mitigation + biodiversity conservation + poverty alleviation) (Estrada-Carmona et al., 2024; Londres et al., 2023). Specifically, some interventions appear well-placed to target particular threats (e.g., community-based forest management to address unsustainable logging and non-timber forest product extraction), while others appear to have weaker alignment with the root cause of the threat. As an example, REDD+ was initially framed as a market-based instrument for carbon emissions reductions, but in its implementation, it has mostly sought to reward communities as a measure to mitigate deforestation and degradation-induced climate change, although they are a relatively small contributors to carbon emissions (Angelsen et al., 2017; Hajjar et al., 2021). This misalignment between aim and application is aptly reflected in the title of a recent study on the subject: "REDD+: If communities are the solution, what is the problem?" (Skutsch and Turnhout, 2020). Jurisdictional approaches to REDD+ surmount this critique by encouraging low-emission development strategies and interventions at broader scales beyond the project or community level (Hajjar et al., 2021).

Other responses are cross-cutting approaches that appear to hold potential to address multiple drivers, such as conservation basic income, integrated landscape management, payments for ecosystem services, or One Health initiatives. For instance, recent analyses have demonstrated how increasing healthcare provision in local communities has led not only to health and well-being benefits, but also to reduced pressures on forest assets for cash, which was previously needed to address healthcare needs, and subsequently declines in deforestation rates were observed (Ravikumar and Zhu, 2025). Meanwhile, some of the indirect drivers of deforestation and degradation are even less directly connected to forest-focused interventions. Yet, interventions to (for example) realign material measures of progress within our economies towards well-being measures would likely have considerable impacts on forest resilience (Costanza et al., 2020).

The proximate and distant drivers of deforestation and degradation are themselves influenced by multiple factors (e.g., pricing, subsidies, collective action, value systems, and decision-making of consumers) that operate across scales and are far too complex to address with individual, site-level, or siloed response options (IPBES, 2024b). Recent research has documented how such approaches may be pursued, for instance, in Connected Conservation models (see Section 6.5.1), and threat chain analyses (Balmford et al., 2021), which deconstruct various policies and actions across scales that combine to influence a given deforestation or degradation driver (Nielsen et al., 2021) (Figure 6.1). These approaches make it possible to begin discerning where interventions along the 'threat chain' may be inserted to generate desired responses, and how they can be

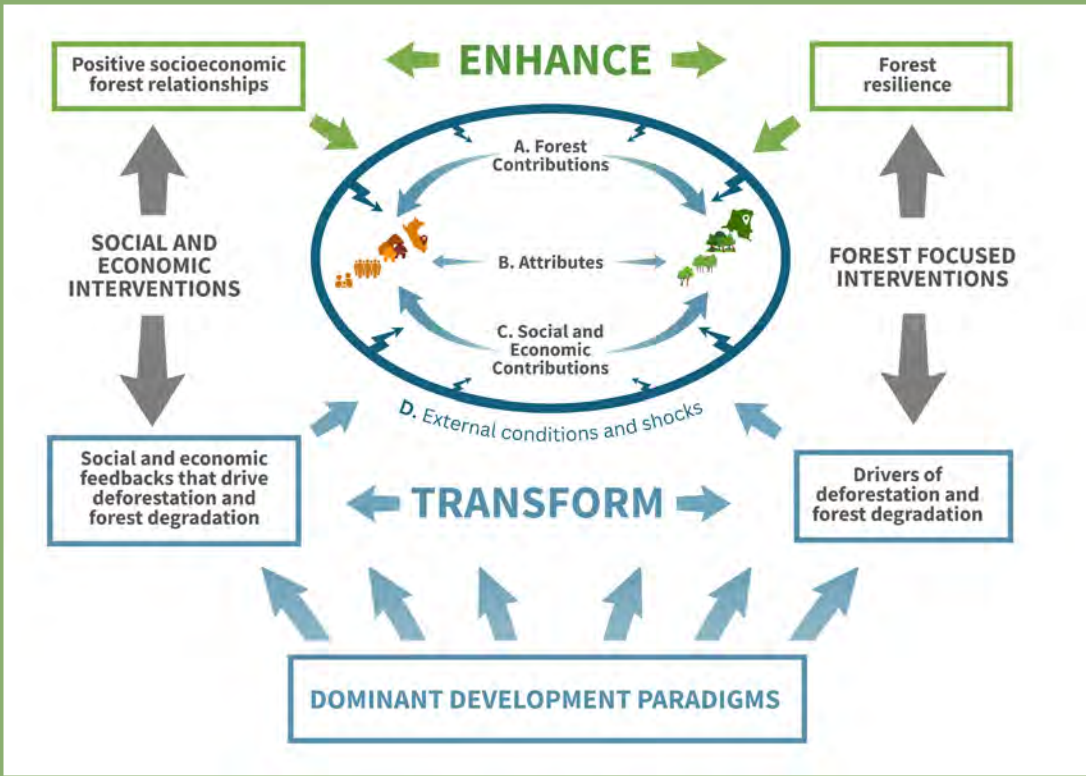
Figure 6.1 Example of a model highlighting response options to halt the conversion of forests into pasture



Source: Adapted from Nielsen et al. (2021)

Conversion of forests to pasture in the tropics threatens forest SES. Specific threats following from forest conversion to pasture in the Amazon are shown in colored boxes, and beneficial 'behavioural' response options are shown on the right. The response options lessen the impact of threats and enhance the resilience of the forests SES.

Figure 6.2 Conceptual model of a broad typology of entry-points for response options aimed at enhancing the role of forests in socio-economic resilience



Response options may be forest-focused (the emphasis of this Chapter), or socio-economic focused. Because of the interrelated nature of the components and the existence of feedbacks, response options in one domain will influence another. Further, because drivers are the result of actions across scales, interventions can, and must, also be multi-sited and operating at various points along the 'threat-chain'.

best orchestrated in broader scale approaches, like Connected Conservation approaches (Carmenta et al., 2023).

It is important to consider not only the various points along the 'threat-chain' where interventions may enter and influence the system or its components, but also the potential interactions and feedbacks between different threats, SES components, and interventions. We developed a conceptual model that builds from Chapter 3's model of relationships between forests and social and economic resilience. The conceptual model presented in Figure 6.2 shows major entry-points for response options across social-ecological dimensions and scales, and the interrelated nature of system components and feedbacks, demonstrating how response options targeting one domain or scale are likely to influence and be influenced by other options and their outcomes.

The conceptual model presented in Figure 6.2 shows major entry-points for response options across social-ecological dimensions and scales, and the interrelated nature of system components and feedbacks, demonstrating how response options targeting one domain or scale are likely to influence and be influenced by other options and their outcomes.

6.3 Developing and applying a 'filter' to assess response options for forest resilience

Taking into account the attributes of resilience (Chapters 2 and 5), the relationships that exist between forests and social and economic resilience (Chapter 3), and the governance approaches that can best deliver on forests and social and economic resilience (Chapter 4), we developed a resilience 'filter' to assess key attributes ascribable to a given intervention and its potential to enhance the contribution of forests to social and economic resilience. Resilience attributes may be considered the "individual and collective competencies and the enabling (or constraining) environment that enhance one or more resilience capacities (of robustness, adaptability, and transformability), and more broadly, general resilience" (Meuwissen et al., 2019, p. 5). As outlined in Chapter 2, a significant degree of agreement exists across various efforts to identify attributes, properties, and principles that may enhance social-ecological system resilience. Despite their different theoretical and empirical origins, the commonality allows us to identify a core set of resilience attributes (Chapter 2), which we reframe here to address an intervention's resilience-enhancing potential, and include additional key attributes that have been demonstrated to be critical for enhancing resilience in meaningful, measurable, de-colonial, and ethical ways (including equity and justice, plural voices and values, longevity and sustained support, locally-led and place-based, and collaborative and co-produced) (Box 6.2). In considering these ten attributes together, one can use them as a 'filter' to examine the resilience-enhancing potential of a given management or governance intervention in response to major forest threats, and its potential to support SES resilience.

Most efforts that aim to support forest resilience frequently focus on enhancing absorptive (for persistence and recovery) and adaptive capacities (for responding to change while maintaining essential functions and identity). Nevertheless, transformative capacities also appear increasingly necessary to navigate increasing complexity, reduce the vulnerabilities to unforeseen negative surprises and shocks, and shape future social-ecological system configurations when windows of opportunity open or are created (Kleinschmit et al., 2024; Reyers et al., 2022; Suiseeya, 2017). Governance and management interventions may support such transformative capacities through institutional flexibility, and continual and multi-loop learning that accounts not only for vulnerabilities and risks but also for their root causes, and supports the coproduction of a diversity of response options and pathways to resilience (Pascual et al., 2023).

6.4 Assessing response options for their resilience-enhancing potential

For our assessment of the resilience-enhancing potential of forest-focused and applicable response options, we developed a matrix that incorporates the ten resilience enhancing attributes (see Box 6.2 on the following page), along with measures of intervention, scale of influence, and potential to support a sustained system or its incremental or transformative change (online resource: www.iufro.org/programmes/scipol-forests-for-social-and-economic-resilience-2025). In the sections that follow, we discuss the resilience-enhancing potential of key management and governance interventions as examined through this filter, and associated assessment matrix of resilience-enhancing attributes. To serve as visual examples, we also generate for some of the interventions a radar plot demonstrating the degree (null-low-medium-high) to which the intervention may deliver on the ten resilience-enhancing attributes. This filter could be applied to other response options that we have not considered. As the analysis and discussion demonstrate, these tools are useful for considering the degree to which discrete forest-based interventions are likely to contribute to, overlook, or detract from forest contributions to social and economic resilience within broader SES resilience, and to the ability of people, communities, societies, and systems to live and thrive in the context of change and their capacity to absorb shocks, adapt to them, and transform when necessary or desirable.

Response options that are likely to result in more resilient forest SES are likely to require adaptive approaches that prioritise learning as a means for reducing vulnerability and for building resilience in social-ecological systems (e.g., Guignabert et al., 2024; Messier et al., 2019). Adaptive forest management typically incorporates experimentation and management options, monitoring and assessment, and adjustments to plans and practices in response to management outcomes and environmental and social changes through continuous learning. Adaptive management has been implemented predominantly in the Global North, and largely reported at forest management unit or localised levels. Widespread and largescale implementation of adaptive management is costly and requires clear and supportive legal and policy frameworks that promote and prioritise resilience, adequate budgets, capacity and public and political support, as well as institutional incentives and flexibility (Abrams, 2022).

Box 6.2 Ten key attributes of resilience-enhancing response options

1. **Maintain diversity and connectivity with feedbacks.** Diversity, including redundancy, underlies resilience and should be considered both within and across scales in social and ecological subsystems. With diversity, redundancy is also important and may be especially crucial when it occurs at different scales in a system, in which case, redundancy serves as a cross-scale reinforcement. Generally, more social-ecological diversity and cross-scale redundancy enhance resilience. Cross-scale feedbacks must be accounted for and affect the flows within and between SES. Modularity and connectivity are important to enable flows, and in general, a moderate degree of both, connectivity and modularity, enhance resilience.

2. **Support biophysical capital or assets.** Natural and biophysical capital or resources, in addition to socioeconomic assets and well-being, underpin a community's or system's ability to resist, absorb, cope, adapt, and transform in light of disturbances or disruptions.

3. **Support socio-economic capital or assets and well-being. Fi**nancial, social, and physical resources, along with subjective (e.g., happiness and contentment) and relational (e.g., institutional, and people-nature relationships) elements also underpin resilience, in addition to biophysical capital or assets.

4. **Promote well-functioning polycentricity.** Multiple centres of decision-making, decentralised capacities, and governing authorities at differing (yet connected) scales may best support resilience, for instance through polycentric and multilevel governance, which requires participation and connecting with multiple nodes of knowledge to enable collaborative networks that can maximise on windows of opportunity.

5. **Enhance adaptive capacity.** Systems with a high adaptive capacity change over time in response to changing conditions. Adaptive capacity is a latent property of systems, that may lead to incremental adjustments or changes over time and space, and although distinct from learning, it does build on learning (e.g., experimentation, innovation, creation of novelty).

6. **Foster transformative capacity.** Systems with transformative capacity have the potential to be intentionally shifted to a more desirable, self-organising state, characterised by new structures, processes, and feedbacks, and may involve a diversity of response options and pathways to resilience that depend on learning being fostered throughout.

7. **Enhance equity and justice.** SES resilience requires justice and fairness in decision-making, distribution of benefits and burdens, and outcomes of forest-based interventions. Enhancing equity helps to address the likelihood that what is desirable for one, may not be for another, and by engaging an equity lens, there is a better chance of deliberating a 'desirability' that is representative and causes the least harm.

8. **Provide for longevity and sustained support.** Resilience-enhancing potential is likely supported by long-term and sustained support and action. Long-term, sustained financial, technological, political, and other support can help to ensure ongoing monitoring, participation, learning, updates, and upgrades as deemed necessary or desirable to withstand, adapt, or transform in light of changing conditions and shocks.

9. **Support locally-led and place-based solutions.** Autonomous, bottom-up, place-based organisation ensures relevance and builds on the importance of particular places, their social-ecological context, and the lived experiences, agency, knowledge, and rights of their different inhabitants which are critical for pathways for sustainability. Requires strong forms of participation and power-shifts.

10. **Promote plural values.** The diversity and plurality of values that people hold for and associate with forest systems must be accounted for and supported in policies and practices to ensure adaptive and transformative capacities, social ecological resilience, and environmental and justice.

Prescribed fire in cedar forest, Great Plains, USA. Fire is a necessary component in some forest systems. Photo © Craig R. Allen

6.4.1 Forest, landscape, and tree management-based response options

Integrated fire management

Increasingly, flammability is a driver of forest degradation in many parts of the world, and climate-driven fire weather is inducing the conditions of flammability in multiple forest locations (Jones et al., 2024, 2022). For example, fire is a leading driver of degradation of Amazonian rainforests (Lapola et al., 2023), has been fundamental in system shifts in Indonesian peatland forests (Edwards et al., 2020), and is responsible for a global rise in emissions from forests throughout the tropics (Jones et al., 2024). In some systems, fire is a key driver of degradation, and is also associated with the deforestation process, as it is often used to clear the debris and residue of felled forest to make way for other forms of land management. As the global demand for products and land has increased, so too has the variety and scale of actors using fire in forest landscapes, and these actors have differing reasons for burning, or differing incentives for investing in fire management techniques. Therefore, their fires incur different sets of damage to the surrounding forest landscape (Barlow et al., 2020; Carmenta et al., 2021). There are also varying ecological relationships between forests and fire. For example, shorter fire-return intervals and shifts in fire intensity within fire-sensitive forests (such as tropical moist forests) can be contrasted with the removal of fire and longer fire-return intervals in fire-dependent systems. In one forest system, fire is highly destructive to resilience, whilst in another, it is a necessary component of it. Shifts in fire dynamics have, in part, been induced by policy; for example, through prohibitive fire policies (O'Connell, 2020; Ottolini et al., 2024).

Prohibitive fire policies are an approach applied in many parts of the world, in some cases implemented initially to protect timber stocks by colonial governments, and in other cases to remove and control fire within the system because of the multiple perceived negative effects (e.g., damages) of fire and the threat it can pose to resources, assets, and lives (Moura et al., 2019). However, fire suppression and prohibition has caused increased flammability, increased disease occurrence, and decline of biodiversity in fire-adapted forests, and therefore, it has impacted the flow of goods, services, and plural values from forests to social and economic systems (O'Connell, 2020; Ottolini et al., 2024). For example, in Oaxaca, Mexico, fire suppression within the oak and pine forests has led to a removal of natural fire levels from the system, generating an increase of pests, which in turn, are reducing the timber supply. Timber there is extracted under a sustainable management plan, and supports local communities through collective enterprise and collective re-investment of revenues. Communities are now working with government agencies and NGOs to reintroduce fire to their forests through prescribed burning in an integrated fire management approach.

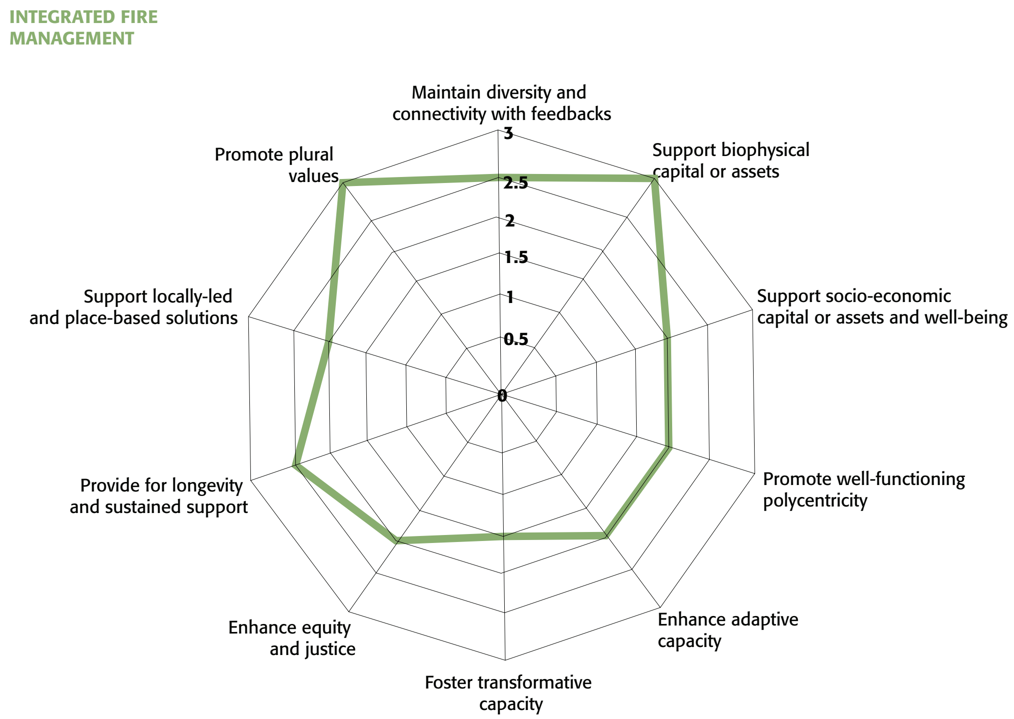
Distinct from fire-dependent forests, fire-sensitive forest landscapes do not require the reintroduction of fire to the system. However, its complete removal (e.g., through burn bans) also undermines forests' contributions to social and economic resilience because of the central role of fire-based traditional agriculture that is characteristic of many forest-based communities, particularly throughout the tropics (van Vliet et al., 2012). Fire-based swidden agriculture is an intergenerational practice that has been utilised over time alongside healthy forests and thriving biodiversity, contributing to local communities' production, autonomy, and culture (Garnett et al., 2018). Further, swidden agriculture generates a considerable contribution to regional food security in many contexts. In these systems, complete burn bans can negatively impact livelihoods and lifeways, and generate increased wildfire risk through more covert fire use, which reduces the possibility of hands-on management (Daeli et al., 2021). Burn-bans also create injustices by unduly placing the blame on forest-based communities when flammability has risen largely as a result of drivers operating across scales (including climate change).

Integrated Fire Management (IFM) moves beyond a focus on suppression to a more holistic response. Integrated fire management in general aims to enhance landscape resilience by encouraging the positive contributions of fire (e.g., in fire-adapted forests), whilst reducing the negative impacts of destructive fires through interventions focused on prevention, preparedness, and sometimes reintroducing fire to a fire-adapted, yet fire-deprived system (e.g., prescribed burnings, fire response, training, knowledge integration) (Wollstein et al., 2022). In this way, it seeks to replicate natural fire regimes and holds promise when tested against resilience-enhancing attributes. The approach is gaining traction in many parts of the world and across various forest types (e.g., RAMIF, the Global Fire Management Hub hosted by FAO in the Amazon region). It attempts to combine Indigenous and local knowledge with more technical and modern knowledge and approaches to fire management. It approaches adaptive capacity by constantly assessing the needs of the system and the landscape, and adapting prescribed burns and management approaches as necessary, often in mosaic approaches and across diverse groups of practitioners.

Further, IFM has been recently acknowledged as a promising approach for biodiversity conservation as well as for climate change mitigation and adaptation, and thus, has considerable co-benefits (Oliveras Menor et al., 2025; Puig-Gironès et al., 2025). IFM appears to have the capacity to deliver across multiple resilience-enhancing attributes (Figure 6.3). Yet, the implementation of IFM is surrounded by challenges, and countries are in various states of implementation progress and capacity (Oliveras Menor et al., 2025). Despite the resilience-enhancing potential, IFM appears to demonstrate, as discussed above, that site-level action and intervention can only go so far in addressing any degradation or deforestation driver, because multiple actions across scales combine.


Photo © INAB Guatemala

Fig 6.3 Degree to which Integrated Fire Management may deliver on the ten resilience-enhancing attributes (from low (0) to high (3))



Integrated Fire Management has potential to deliver across multiple resilience-enhancing attributes, though not all equally. For example, IFM has an especially beneficial impact on promoting plural values and supporting biophysical capital, and less impact on transformative capacity.

Community-based agroforestry systems

Agroforestry is no 'silver bullet' or magic solution to the challenges of global environmental change, but it can provide crucial ecosystem services and social co-benefits. Managing trees in agriculture and pastoralism can provide direct benefits such as crop and livestock productivity and diverse additional income. Tree-based systems also provide fodder for livestock that contributes to crop production and provision of milk and meat. Forests and trees sustain agriculture through the provision of ecosystem services that support crop production, including nutrient cycling, pollination, seed dispersal, soil formation, natural pest and disease control, and climate and water regulation. Nitrogen-fixing trees also maintain and enhance soil fertility by cycling atmospheric nitrogen, thereby increasing yields. Agroforestry systems, however, are complex to study considering the numerous interactions between species, the context-specific influence of social and cultural management, and the role of value chains and market tendencies. Today, there are still few value chains developed for agroforestry products.

Despite the potential benefits, agroforestry is not commonly promoted as a sustainable land management system. Since it is a combination of activities bringing together agriculture, livestock, and forestry, agroforestry tends to fall through the cracks of sectoral policies, and the impacts of agroforestry policies and interventions are poorly explored (Castle et al., 2021). Most countries have not included agroforestry in land management strategies, development plans, or extension services. The paradigm is instead to separate agriculture for food production, while forestry is focused on timber production and providing ecosystem services.

Agroforestry along a rice field in Indonesia. Photo © Viola Belohrad

Ecologically, agroforestry systems can enhance the ecological functions of a landscape, such as connectivity and biodiversity, especially when introduced as a way to restore degraded areas. They can increase carbon stocks in biomass (Chapman et al., 2020) and incorporate organic material into the soil (Muchane et al., 2020). When native species are employed, agroforestry systems can increase the diversity of natural predators that help control pests and diseases (Lamichhane, 2020). Agroforestry provides shade and increases humidity, buffering micro-climatic extremes.

Economically, agroforestry systems can contribute to local livelihoods by diversifying income sources from different crops and producing yields throughout the whole year (Cardozo et al., 2015). The additional income and food generated by tree products (e.g., fuelwood, fruits, nuts) strengthen coping capacities in times of need (Gergel et al., 2020). Further, agroforestry has the potential to increase farm productivity with more limited dependence on external inputs such as inorganic fertilisers and chemical inputs for pest management (Petersen-Rockney et al., 2021).

Socially, community-based agroforestry systems contribute to community-building, local mobilisation, and collective action, promoting different and innovative forms of polycentric governance through cooperatives, associations, networks or informal groups (Vasconcelos et al., 2016). Community-based agroforestry systems, thus, are a way to produce food while providing ecosystem services and promoting social and ecological resilience as well as adaptive capacity to climate change (Quandt, 2018).

Culturally, community-based agroforestry can also foster key transformations, particularly in areas of high deforestation pressures. It offers an alternative worldview and set of values that challenge the mainstream narrative of commodity production by replacing native vegetation as the most (or the only) efficient way to produce food (Russo Lopes, 2023). In the context of the Brazilian Amazon, many stakeholders highlight their relational values to the landscape, which includes, but goes beyond, short-term economic gains. This is visible when they describe decisions on how to choose species, distribute them in the farm plot, the order to plant, and the trees they are most fond of cultivating (Russo Lopes, 2023). As an illustration, some smallholders prefer banana trees because they grow faster, others prefer leguminous plants because they give a nutritional boost to the system, while others prefer fruit trees in general because they attract animals and birds to their home gardens. As anecdotal as these examples may seem, they show that alternative values in relation to nature can be fostered through agroforestry practices (Russo Lopes, 2023).

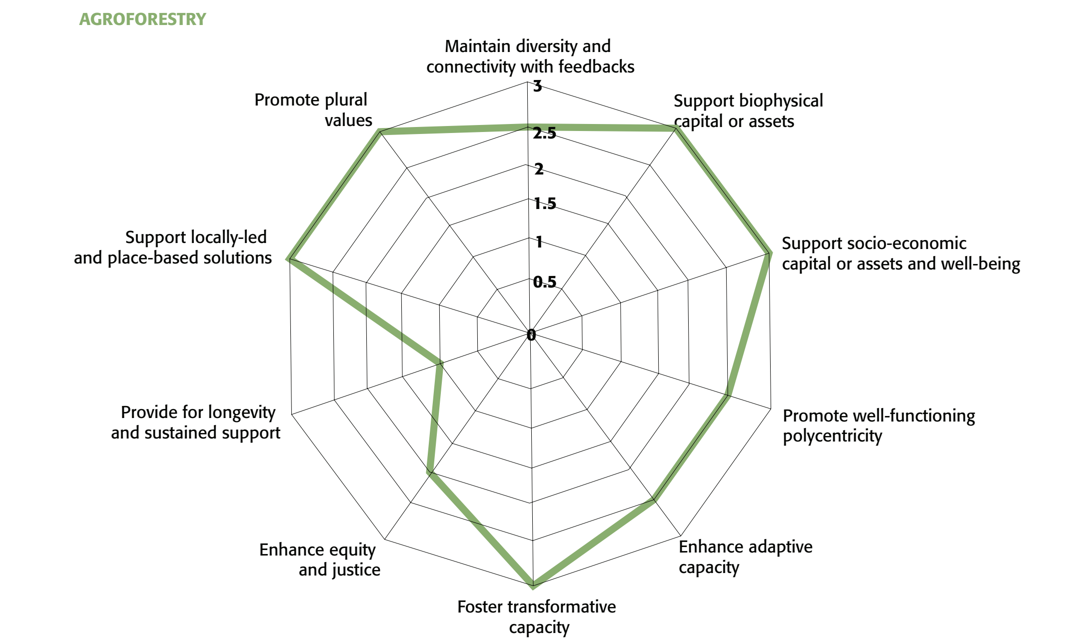
Community-based agroforestry is an important pathway toward sustainability, and a substantial resilience-enhancing response option (Figure 6.4). It can increase ecological connectivity, restore degraded ecosystems, enhance food production and food sovereignty, diversify local income streams, contribute to the livelihoods of smallholders in rural areas, and change the way nature is perceived. In this sense, community-based agroforestry is a local and context-specific system that relies on place-based actors, knowledge, and practices. In doing so, it promotes fundamental changes in land-use practices, public narratives, and relational values to nature (Quandt, 2018; Russo Lopes, 2023). As a result, community-based agroforestry has the potential to foster and enhance ecological, economic, social, and cultural transformations, paving the way for an ethics of care and attachment to the territory, as opposed to an ethics of resource extraction.

Forest and landscape restoration

Forest Landscape Restoration (FLR) and broader ecosystem restoration approaches are fostered as a key contemporary environmental policy strategy to mitigate climate change, slow biodiversity loss, and improve human well-being through enhanced supply of ecosystem goods and services to people (Djenontin et al., 2025, 2020). Restoring degraded forest SES has the potential to achieve many international environmental agreements within major global environmental governance frameworks (such as UNFCCC, UN Convention on Biological Diversity (UNCBD), UN Convention to Combat Desertification (UNCCD)), while offering co-benefits for the sustainable development goals (in particular, SDGs 1, 13, 15, and 17), and for forest resilience more broadly (Besseau and Christophersen, 2018; Chazdon and Brancalion, 2019).

While restoration targets demonstrate some political will, they can be challenging to achieve (Fagan et al., 2020), especially given non-stationarity and the contingency of assembled communities (Berger and Lambert, 2022), and

Fig 6.4 Degree to which agroforestry may deliver on the ten resilience-enhancing attributes (from low (0) to high (3))



given that different actors may value different restoration endpoints. Also, many restoration interventions face two problems that can undermine their resilience-enhancing potential (as elaborated in Chapter 4). On the ecological side, risks for undermining biodiversity and destabilising some ecosystems are high, given a too narrow focus on tree plantation (Bond et al., 2019; Di Sacco et al., 2021), despite evidence of the contribution of tree plantations to human well-being and poverty reduction (Choksi et al., 2025; den Braber et al., 2024; Mensah et al., 2024). On the social and economic side, a neglect of the human dimensions, particularly the institutional aspects (Djenontin and Zulu, 2021), associated with restoration interventions (from the conceptual design stage to implementation processes and outcomes), can jeopardise the expected social benefits, undermining their social sustainability (Elias et al., 2021).

Yet, how to mitigate such resilience-undermining potential is being increasingly emphasised. Attending to effective restoration governance and institutional arrangements is critical to addressing foreseen unfair implementation (Löfqvist et al., 2023; Osborne et al., 2021; Ramcilovic-Suominen et al., 2024), and to adequately balance scalar contentions and trade-offs in ecological and social outcomes. Well-designed FLR initiatives based on SES thinking (Tedesco et al., 2023), including appropriately articulated institutional arrangements, enhanced tenure rights, and participatory decision-making are needed to achieve cohesive, equitable, and adaptive implementation that reduces trade-offs and maximises synergies (e.g., Ahammad et al., 2023; Djenontin and Zulu, 2021; Rakotonarivo et al., 2023). Attention to monitoring, including what is monitored and (in)capacities to monitor (Elias et al., 2024), contributes to inform how FLR actions are or are not enhancing ecological, social, and economic resilience.

6.4.2 Economic and market-based response options

A broad range of economic and market-based interventions has been developed and implemented to address deforestation and forest degradation. These can include fiscal incentives for conservation and sound management, payments for ecosystem services from forests, certification of forest management, and chains of custody, among many others. Economic and market-based options are generally designed as voluntary instruments that may serve as alternative or complements to command-and-control based options. We examine two economic or market-based options with potential to support or enhance SES resilience: forest certification and forest bioeconomy and circular economy.

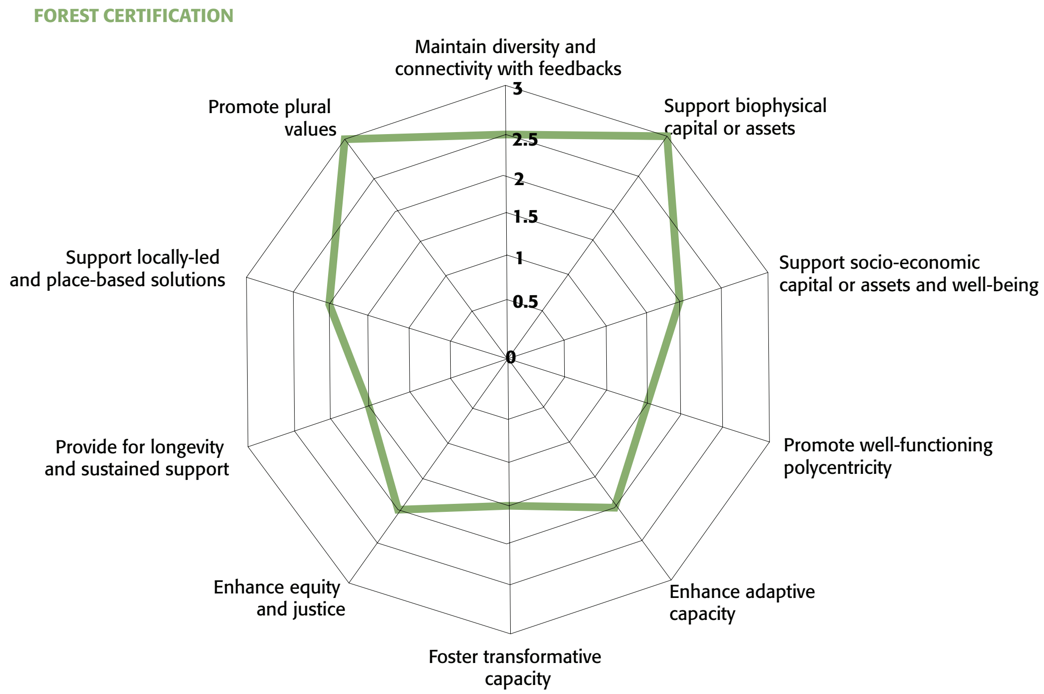
Forest certification

Forest certification is a non-state, market-driven governance intervention that emerged in the 1990s aimed at curbing illegal logging and unsustainable forest resource extraction-driven degradation and deforestation, while promoting environmental and socioeconomic benefits from sustainable forest management (Cashore et al., 2004; see additional information in Chapter 3). Today, there are two main certification schemes globally, the Forest Stewardship Council (FSC) established in 1993 that currently covers approximately 160 million hectares, and the Programme for the Endorsement of Forest Certification (PEFC), established in 1999 and currently covering approximately 297 million hectares. Additionally, about 95 million hectares of forests are certified through both standards. As noted by van der Ven and Cashore (2018), FSC and PEFC share key foundational aspects, including balanced (across ecological, economic, and social interests) and deliberative multi-stakeholder processes, but important distinctions remain, for instance, in standards setting, with FSC tending to favour global principles applied universally, whereas PEFC tends to favour national sovereignty.

Despite being initially devised to address deforestation and forest degradation in the tropics, the vast majority (approximately 90%) of certified forest area is in temperate and boreal biomes. Overall, the outcomes of forest certification have so far been mixed, with some evidence of reduced deforestation and forest degradation, and biodiversity and carbon benefits, as well as increased community participation and empowerment, greater market access, improved living and working conditions for forest workers, and other livelihood and well-being benefits in certain contexts or conditions. However, evidence of certification impacts beyond the local scale remains difficult to disentangle from other factors affecting forests (e.g., van der Ven and Cashore, 2018).

Forest certification is primarily an economic or market-based approach to enhance the sustainability of forest management that also draws on informational and institutional intervention logics. Certification is largely

Figure 6.5 Degree to which forest certification may deliver on the ten resilience-enhancing attributes (from low (0) to high (3))



designed and applied at the forest management unit level, but has expanded under some systems to include options for group certificates that may be applied at the local or landscape level. More recent efforts have also encompassed jurisdictional approaches to reducing deforestation and forest degradation (Schleifer, 2023). Forest certification has the potential (and in practice has been shown) to contribute to forest diversity through the application of management standards that encompass ecological, economic, social, and political dimensions of sustainability. However, this largely occurs at the forest management unit level, and is not likely to contribute explicitly to system redundancy, nor is it likely to contribute significantly to system connectivity or modularity.

Forest certification may contribute to feedbacks in part through system learning, which is promoted through monitoring and assessment across the ecological, economic, and social dimensions of the system, and it may result in adjustments or adaptations when sustainability thresholds are exceeded. Forest certification has also the potential to support adaptive capacity of forest SES at least at the forest management unit level, but does not appear to enhance or provide support for transformative capacities. Certification can also contribute to the maintenance and enhancement of a broad spectrum of forest capitals or assets. However, challenges such as high costs and limited market incentives, particularly in tropical regions and for smallholders and Indigenous Peoples and local communities, may compromise or produce trade-offs amongst assets. Forest certification systems appear to have potential to uphold and extend attributes of equity and justice (e.g., improved distribution of benefits) in their design and implementation. Certification standards are developed by decision bodies with representation across the different dimensions of sustainability and sectors of society, particularly for the FSC, which may serve to account for and support plural voices and values, co-production, and collaborativeness, and to support locally-led and place-based attributes when and where local standards exist (Figure 6.5).

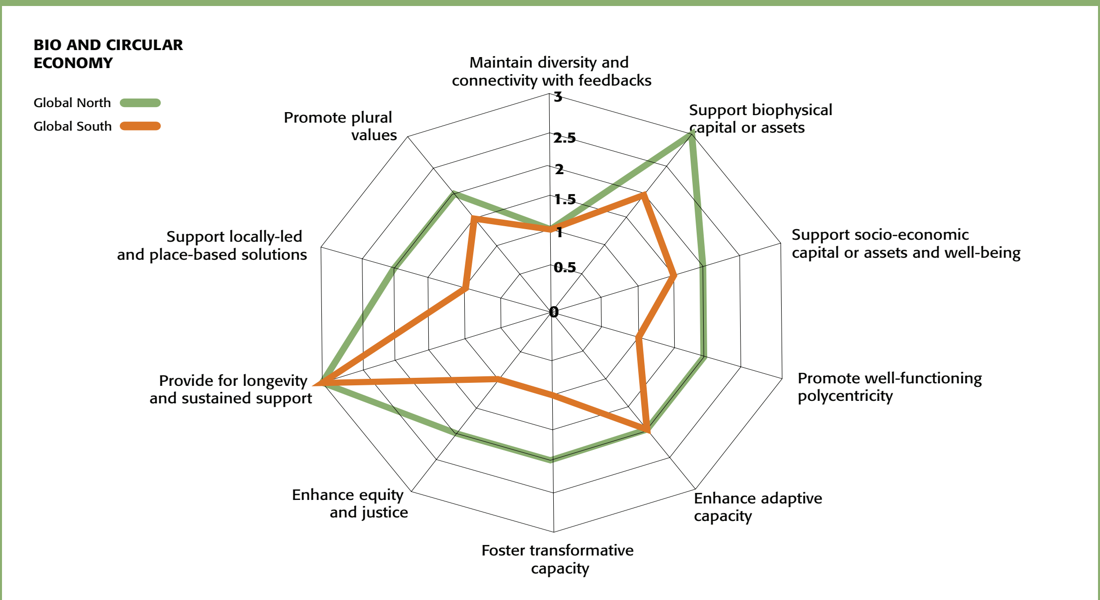
Bioeconomy and circular economy

The transition towards forest bioeconomy and forest circular economy approaches has the potential to significantly enhance the social and economic resilience of forest-dependent communities by shifting from extractive and linear models to regenerative and sustainable approaches (Cambero and Sowlati, 2016). New forest-based bioeconomic value chains, such as bioplastics, biofuels, pharmaceuticals, and engineered wood products diversify the economy, reduce economic vulnerabilities, improve environmental outcomes, and strengthen adaptive and transformation capacity in the face of climate change and global market fluctuations (e.g., Näyhä, 2019).

In parallel, the circular economy ensures that the utilisation of forest resources follows sustainability principles, minimising waste and maximising resource use. By reusing byproducts of forestry operations such as sawdust, lignin, and bark, and giving them new values, industries reduce inefficiencies and extend the lifecycle of forest materials, decreasing pressure on primary forest resources and reducing the environmental footprint of forest exploitation. These models promote responsible forestry practices, which enhance carbon sequestration, improve biodiversity, and increase forests' capacity to face extreme weather events. By maintaining forest cover and reducing waste, these approaches help regulate water cycles, prevent soil erosion, and protect against the negative impacts of increasing frequency of droughts, storms, and wildfires.

The convergence of bioeconomy and circular economy offers opportunities for forest-dependent regions to achieve social and economic resilience. These strategies are based on the diversification of forest-derived products, innovations, and sustainable management practices, which can enhance adaptive capacity and foster transformative capacity. Both strategies expand the range of forest-based outputs by fostering development opportunities, reducing dependency on any single commodity, and supporting socioeconomic assets and well-being. This diversification can stabilise incomes and generate new employment opportunities not characterised by physical labour and seasonal employment, but rather based on research,

Figure 6.6. Degree to which the bioeconomy and circular economy may deliver on the ten resilience-enhancing attributes (from low (0) to high (3))



The potential of the bioeconomy and circular economy is not uniform but differentiated depending on the context, as illustrated here through the broad examples of the Global North and the Global South.

technology development, and sustainable design. These jobs can be more attractive to a young and educated workforce, decreasing urban migration trends. All these factors provide for longevity and sustained support.

However, these response options demonstrate considerably different resilience-enhancing attributes in the Global North and in the Global South (Figure 6.6). Bioeconomy and circular economy strategies are being developed in many countries in the Global North. Finland and Canada are pioneers in promoting these strategies (Husgafvel et al., 2018; Jarre et al., 2020; Näyhä, 2019). The above-mentioned positive resilience attributes apply mainly to those countries and communities that can mobilise the capitals, assets, and financial means necessary to deploy them.

These strategies can be challenging for many forest-dependent economies in the Global South, and for less developed areas. The uptake of these models may face several barriers, particularly in the areas lacking appropriate resources and a suitable business environment to start radical innovation pathways. Bioeconomy and circular economy strategies require specialised knowledge in aspects such as biotechnology, materials science, and sustainable manufacturing. This knowledge is often difficult to find in many communities, which reduces the capacity to promote plural values and jeopardises its long-term viability. Furthermore, they can reinstall colonialism, making these communities more dependent on external outputs and skills, and consequently, discouraging locally-led and place-based solutions. Other challenges that emerge are the high costs of implementing these technologies (Cambero et al., 2015; van Kooten et al., 2019), which can be beyond the economic possibilities and capabilities of many forest-dependent communities, and can also boost competition for raw materials (Bryngemark, 2019), creating conflicts with the preservation of cultural heritage and traditional practices. These factors decrease the equity and justice options for these communities, discourage plural values, and decrease the transformative capacity of these strategies in the mentioned contexts.

On the other hand, the adoption of bioeconomy and circular economy strategies may strengthen governance structures and stakeholder collaboration. For instance, the shift from extractive to regenerative models requires cooperation between policymakers, industry leaders, researchers, and local communities, promoting polycentricity. In countries and communities with adaptive and inclusive governance systems, this multi-stakeholder engagement can foster participatory decision-making processes, ensuring that economic activities align with environmental conservation and social well-being. Governments and institutions can create long-term strategies that prevent overexploitation and safeguard the benefits of forest resources for future generations, providing for longevity and sustained support.

6.4.3 Rights and tenure-based response options

Land and resource rights, and more specifically, tenure security, are fundamental for local governance, while at the same time community organisation and good governance reinforce the security of rights (Blackman, 2015; Larson et al., 2021). But the situation on the ground is complex. Rights granted by law are not necessarily secure or defended by the state, and there is often substantial pushback or even rollbacks with political changes; rights granted are also likely to be partial, with many controls over decision-making regarding forests and forest resources, which interferes with local stewardship built on Indigenous knowledge and local institutions (Larson and Pulhin, 2012). Yet the potential is high. Secure tenure and local governance are important to laying the groundwork for SES resilience, fostering equity, plural values, place-based solutions, human well-being, and long-term sustainability (Carmenta et al., 2023).

Protected areas, land-sparing, and biocultural land sharing

A large debate in the forest conservation literature concerns whether a single sector style approach such as protecting land for conservation in protected areas or intensifying agriculture to increase yield per unit area, and thereby, 'spare' land for nature, is likely to be more effective than a land sharing style approach (Carmenta et al., 2023). Land sharing tends to be approached through mosaic landscapes of less intensive agriculture that incorporate people as part of the strategy in sustainable use of territories. The 'land sharing vs land sparing' debate has become considerably polarised, with land sparing proponents arguing the model is essential, particularly for the protection of species with high conservation value, whilst the land sharing community highlights how the omission of social or cultural attributes in the framework have created injustices or disparities in resource access, use, and other rights. Calls to move beyond the stalemate have been made by leading sustainability scholars, who suggest centring on human well-being would be a positive integrative framework (Bennett, 2017).

Nevertheless, protected areas remain a primary tool in conservation in general, and for forests in particular, and are a lead call for recent targets of the Global Biodiversity Framework (GBF) (e.g., 30x30 goal). Both forests and protected areas of all types are constructively considered social-ecological systems, and both are complex adaptive systems. Technically, protected areas can be of any size and for any purpose, ranging from protecting a sacred tree through norms to legislative protection of large areas. The degree of protection and the degree of allowed use also vary widely, ranging from being exclusionary for humans to allowing a wide set of multiple (and sometimes competing) uses. There are increasingly recognised extents of land held in customary rights outside of recognised protected area units (other effective area-based conservation measures (OECMs)). While protected areas may be effective in maintaining forest cover, the sustainable, multiple use, collaborative, and rights-based model appears to do so more ethically than strict protection. Strict protection may be an effective approach in the conservation toolkit where local populations are not residing within the forest, or dependent upon forest resources for their livelihood and well-being (e.g., Duffy et al., 2019).

To respond to the challenge of maintaining resilient forests, and providing services that enhance social and economic resilience, protected areas should be ecologically, economically, and politically sustainable. Yet, they also fundamentally need to be just (Martin, 2017). Historically, protected areas were often areas with high aesthetic appeal and/or with little economic value, but as a response to drivers of undesired change in remaining contemporary forests, protected areas should be managed to maintain the resilience and sustainability of the protected areas themselves, and of the landscapes in which they occur (see integrated landscape approaches in Section 6.5.2). This includes incorporating natural disturbance regimes and feedbacks as advocated within ecosystem management. Protected areas can also help provide key 'stepping stones' for functional connectivity, which is particularly important given the increasing changes in global, non-stationarity plant and animal distributions and movements (Brennan et al., 2022). Where the knowledge and values of local forest communities are an integral part of the system, their rights, governance, and management systems need to be respected, amplified, and foundational to the management of the territory. Clearly, spatial context should also be considered, because few protected areas and sustainable use reserves are being added that are large enough to encompass, within their boundaries, significant structuring and spatially contagious processes. This further endorses the need to manage landscapes at the system level, and to connect with the concept of distant drivers and the broader political economy (explored in following sections). Connected and networked protected areas and landscape approaches incorporating protected areas can meet broad goals of resilient systems of people and nature.

Community based forest management, co-management of forests and adaptive collaborative forest management

Throughout much of the 20th century, forest management relied heavily on a top-down approach to decision-making by government agencies with a focus on maximising the output of timber and other economically valuable forest products. The adverse social and ecological consequences associated with this sustained yield forest management paradigm of resource management, including rural poverty, social conflicts, neglect of local and traditional knowledge, and declining ecosystem health, have led to the turn towards participatory approaches such as community-based forest management and co-management of forest resources. Community-based forestry is a forest management approach that aims at enhancing community socioeconomic conditions and the health of forest ecosystems through the involvement of local communities in the management process. Community-based forestry seeks to promote sustainable forest management and sustainable community development through livelihood enhancement and local institutional capacity-building among others. Community-based forestry is often used interchangeably with the concept of community forestry, an approach that emphasises forest land ownership or some form of local property

Community forestry in Guatemala. Photo © INAB Guatemala

rights on forests and seeks to promote local ecological sustainability and community benefits (Charnley and Poe, 2007). Community forestry and community-based forestry offer several advantages that connect to resilience-enhancing attributes over centralised forest management. These include enhancing social equity, incorporating local and Indigenous knowledge, resolving conflicts among stakeholders, providing opportunities for learning and experimentation, providing opportunities for stakeholder engagement, and building capacities through the mobilisation of knowledge, resources and skills. However, like other forms of community-based conservation, community-based forest management systems are often confronted with several challenges, including capacity constraints, lack of incentives, and challenges in maintaining flexible institutional mechanisms for stakeholder engagement and conflict management over time.

Co-management of forest resources has also emerged in recent decades as a response to the shortfalls associated with centralised forest management approaches (Akamani and Hall, 2015). Co-management is an institutional mechanism that involves the sharing of rights, responsibilities, and power between local resource users, government representatives, and other non-state actors (Akamani, 2023), and thus, it can directly enhance multiple resilience attributes. As such, co-management has been posited as part of the broader transition from government to governance in the conservation and development arena (Berkes, 2010). Co-management promises several advantages over centralised forest management, including enhanced equity, effectiveness, and efficiency, as well as enhanced capacity, sustainability, and resilience (Akamani and Hall, 2019). In spite of its promise, available evidence on the outcomes of co-management suggests several limitations of the concept, including a poor record in poverty reduction, potential for widening pre-existing inequalities, lack of appropriate incentives to motivate stakeholders, lack of enabling legislation, and lack of capacity for effective implementation (Akamani et al., 2015).

Adaptive Collaborative Management (ACM) of forests largely evolved from adaptive management approaches. ACM aims to engage more actors, voices, and potentially more values, actively involving diverse stakeholders in forest decision-making and monitoring, and adjusting management practices to outcomes, new information, knowledges, and changes in social-ecological conditions. As opposed to development and conservation approaches assuming that forest management is predictable, ACM acknowledges that forests are complex and unpredictable, and therefore, it is important to develop joint solutions with the peoples and communities that will be most affected by the outcomes (Colfer, 2010). ACM can be designed as a flexible bottom-up approach that is inclusive of the broad range of stakeholders and fit to local contexts and capacities. It also can be designed to address multiple deforestation and degradation drivers at different scales from local communities to broader landscapes (Colfer et al., 2022). This response option draws on rights and tenure-based interventions and is examined in further detail in the corresponding section below (6.5.3).

Recognising and securing Indigenous Peoples' and local communities' land and resource rights

Support for Indigenous Peoples' (IP) and local communities' (LC) land rights, and now for afro-descendent (AD) peoples as a separate category has been growing. IP, LC, and AD organisations have been mobilising across the globe through their own alliances, such as the Global Alliance of Territorial Communities (GATC), and with support networks such as the Rights and Resources Initiative (RRI) and the International Land Coalition (ILC). Evidence of lower rates of deforestation in areas where these communities hold resource rights has proliferated, especially in Latin America (FAO and FILAC, 2021) but also globally (Garnett et al., 2018). Studies on carbon storage in these lands highlight their importance for climate and development ambitions (RRI, 2023). A group of donors at the COP 26 meeting of the United Nations Framework Convention on Climate Change pledged USD 1.7 billion to Indigenous Peoples to secure forest tenure rights from 2021 to 2025, which is under discussion for renewal in 2025. IP, LC, and AD organisations are demanding to be treated as full partners rather than beneficiaries, a common call from allies and researchers, and to receive direct funding given the very small percentage of climate finance that has reached them previously.

6.4.4 Other legal and regulatory response options

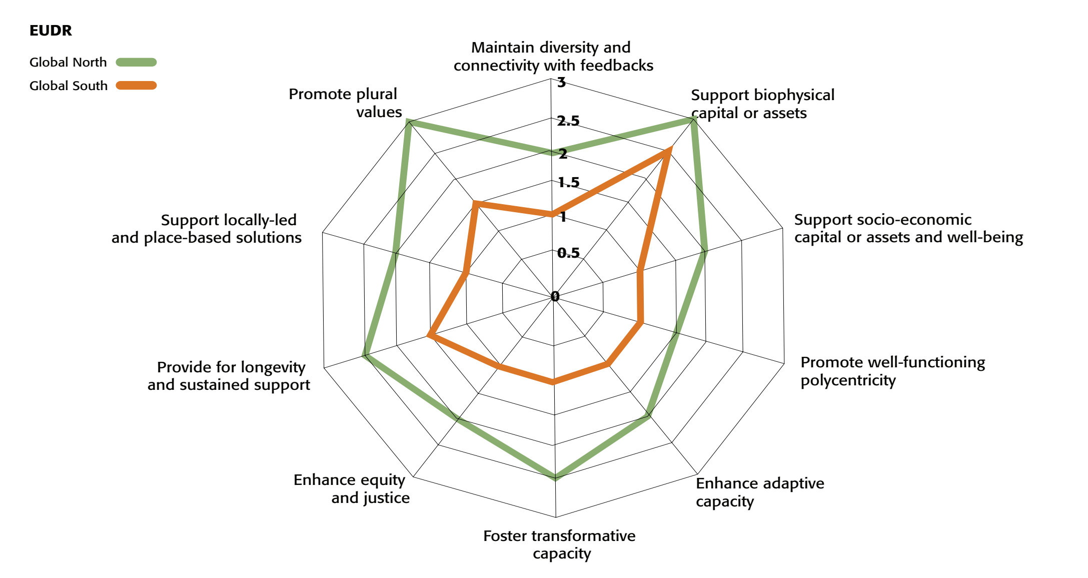
Demand-side policy and law: EU deforestation law

Forest policies have a great influence on social and economic resilience (Chapters 3 and 4). The recently approved Regulation (EU) No 2023/1115 on Deforestation Free Products (EUDR) aims to reduce global deforestation by ensuring that products entering the EU market that are derived from 'distant' forest landscapes, do not contribute to deforestation or forest degradation. We describe EUDR here because it provides an example of a legal response option directly addressing the loss of forests. The EUDR obliges EU companies to conduct due diligence on the supply chains of forest-derived commodities, such as soy, palm oil, beef, timber, coffee, cocoa, and rubber. Its overall aim is to enhance the ecological resilience of forests by reducing deforestation pressure, enhancing carbon sequestration, and protecting biodiversity. However, this regulation has been highly contested internally and externally due to its far-reaching implications for the social and economic resilience of forests, both in the Global North and Global South (Hedemann-Robinson, 2022; Kleinschmit et al., 2024), to the point that a one-year delay has been approved to habilitate all the necessary procedures to make possible its correct application.

The EUDR may strengthen sustainable forest supply chains, supporting biophysical and capital assets. It promotes market opportunities, especially for European and other timber producers and processors, who have already adopted deforestation-free and environmental standards under regulations such as the EU Timber Regulation (Regulation (EU) No 995/2010; this regulation was replaced by the EUDR in 2023). The growing demand for certified sustainable products is also likely to foster innovation in forest-based industries and boost economic advantages for these producers, hence supporting socioeconomic assets and well-being.

Compliance will be linked to digital technologies for forest monitoring. Companies will need to adopt digital traceability tools, such as satellite imagery, blockchain-based supply chain verification, and geospatial analytics to comply with the regulation. These technological advances are likely to encourage more efficient forest management, reduce illegal logging risks, and enhance forest health monitoring, providing longevity and sustained support, maintaining

Fig. 6.7 Degree to which the EUDR may deliver on the ten resilience-enhancing attributes, highlighting the differences between the effects on the Global North and the Global South (from low (0) to high (3))



connectivity and diversity with feedback, and fostering transformative adaptation. The EUDR aims to increase transparency, promote responsible corporate behaviour, and increase consumer trust in forest-derived products. Hence, it holds some capacity to increase resilience-enhancing attributes (Figure 6.7).

The scenario is more complex in the Global South. The EUDR can have a significant negative impact on many forest-dependent communities and export-oriented industries, especially in regions where deforestation has historically been driven by agricultural expansion, weak governance and social justice, and orientation to international markets. Countries whose economies are based on the export of palm oil, soy, beef, and cocoa to the EU may face market disruptions if they cannot demonstrate compliance with the EUDR requirements. The impacts on Vietnamese coffee (Mai, 2024) and Indonesian and Malaysian palm oil (Korniawan, 2024) have already been analysed, finding that smallholder foresters and small countries are likely to face significant difficulties in meeting these strict traceability and certification demands, largely owing to limited financial resources and technical knowledge for due diligence. That can create economic instability, job losses, and increased poverty in rural areas.

6.4.5 Information-based response options

Use of digital technologies

The application of digital technologies in forestry has significantly enhanced the contribution of forests to social and economic resilience by improving resource management, increasing efficiency, and enabling adaptive responses to environmental and market disruptions (Figure 6.8). Digital innovations such as remote sensing, artificial intelligence (AI), the Internet of Things (IoT), blockchain, and geospatial analytics have transformed how forests are managed, monitored, harvested, and protected, which may help to ensure their long-term sustainability while simultaneously strengthening socioeconomic assets and well-being (Cambero and Sowlati, 2016; Fardusi et al., 2017).

These technologies permit real-time monitoring and data-driven decision-making, and are mainly used to improve management in precision forestry systems and to monitor wildfires and forest health status (Barmpoutis et al., 2020; Pause et al., 2016). Remote sensing technologies, such as satellite imagery and drone-based LiDAR (Light Detection and Ranging), provide detailed information about forest conditions,

Fig. 6.8 Degree to which digital technologies may deliver on the ten resilience-enhancing attributes (from low (0) to high (3)). Digital technologies are currently more likely to have a larger resilience-enhancing effect in the Global North

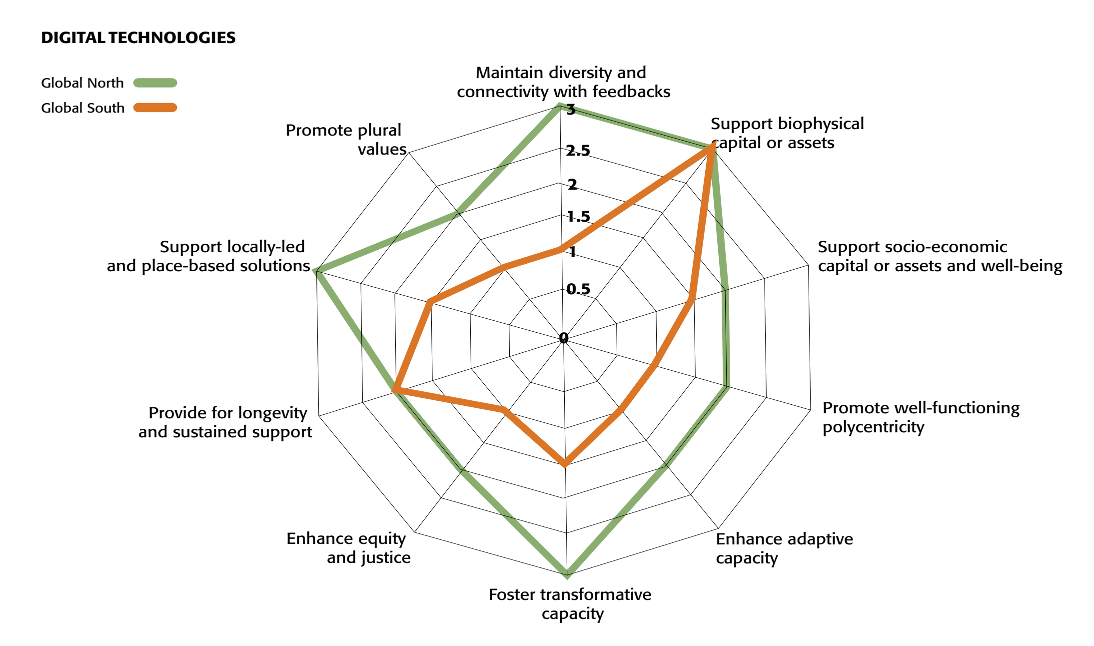


Fig. 6.9 Digital technology in forest monitoring

Photo and LiDAR processing images © R. Wack, Joanneum Research / AVT Airborne Sensing Austria /ANRICA

Digital technologies have significantly enhanced the contribution of forests to social and economic resilience by improving how forests are monitored. In Malaysia, a technical cooperation between Global North and Global South partners enabled the implementation of a cost-effective inventory method for tropical rainforests using LiDAR (on the left: preparation of flight campaign; on the right: LiDAR data processing to identify different vegetation types (top: forest; bottom: oil palm plantation).

including assessment of biomass, biodiversity, and signs of degradation (see example in Fig. 6.9). These tools enable forest managers to detect illegal logging, track the spread of pests and diseases, and assess damage following natural disasters such as wildfires or storms. Monitoring networks based on IoT technology provide continuous, real-time data collection that informs on forest health and tracks timber supply chains, improving transparency and ensuring compliance with sustainable forestry certifications, reducing the risk of illegal logging and market distortions. The use of digital tools in forest governance, harvesting, and conservation improves the response capacity to climate change, market fluctuations, and ecological threats, ensuring that forests continue to provide critical social, economic, and ecological benefits. By identifying early risks, interventions can be implemented before the damage becomes widespread, preventing economic losses and ensuring the continued productivity of forest ecosystems. AI-powered decision-support systems can assist policymakers and businesses in designing sustainable forest management plans. Digital technologies' predictive capacity has a very relevant role in supporting biophysical and capital assets and ensuring longevity and sustained support. These technologies also have a high transformative capacity.

However, as mentioned in the previous section, capacity to enhance forests contribution to social and economic resilience can have important variations depending on the context. In the Global North, mobile applications and online platforms provide forest-dependent communities with access to market information, training, and financial services, reducing barriers and isolation. Digital marketplaces for forest products enable small-scale producers to reach a broader consumer base, increasing the locally-led and place-based solutions. Different citizen science initiatives, where local communities contribute data through smartphone apps, are emerging (Hulbert et al., 2023) and may involve youth in the monitoring (Pitt and Schultz, 2018). These approaches increase society's awareness about forests and natural resources status, and enhance adaptive capacity. However, the adoption of digital solutions faces important constraints, particularly in the Global South forest-dependent communities and remote regions. These tools require digital connectivity, broadband internet, mobile networks, and digital devices to work. In the Global North, the expansion of digital technologies and the high investments in digital infrastructures are breaking the barriers of geographic isolation and opening many social and economic opportunities, supporting socio-economic assets and well-being and maintaining connectivity and diversity. These technologies can support locally-led and place-based solutions, enabling small-scale producers and companies to reach customers worldwide.

6.5 Responses to interconnected and cross-scale challenges

The analysis and discussion above underscore that no single intervention model will be sufficient to secure forests' role in social and economic resilience. Rather, bundles of options are likely necessary, and should be applicable and relevant at different scales. Further, each of the response options explored through our filter and associated matrix can be more or less top-down in its application (Chapter 4). Another pressing issue is organising and orchestrating responses, which can be a challenge, and some have termed governing leading environmental challenges (which include deforestation and degradation) as 'wicked' problems (van den Ende et al., 2023). These are problems that have multiple drivers, are contested, involve sets of benefits and burdens that accrue unevenly across stakeholders with divergent power, and thus, have no simple solution. A growing literature is documenting the importance and complexity of cross-scale interactions in hindering or enabling the resilience-enhancing, or transformative potential of interventions and the considerable relevance of bottom-up initiatives in those endeavours (Londres et al., 2023). These system-embracing and complexity-cognisant approaches pivot on the understanding that dynamics within a forest context are influenced by multiple interacting decisions, actions, and policies across scales (IPBES, 2024b). Countering these sets of influences necessarily entails multiple actions across sectors and scales.

Here we consider some available and overarching frameworks for addressing this complexity, and how they may be relevant to efforts that seek to enhance and secure the role of forests in SES resilience. Fundamental to all attempts at enhancing forest SES resilience must be justice and equity, and as such, here we also touch on the cross-cutting issue of securing the rights and territories of Indigenous Peoples and local communities and implementing response options in co-management designs. Below we outline some overarching approaches that may become useful frameworks.

6.5.1 Connected Conservation

Although many of the response options highlighted above demonstrate a range of resilience enhancing attributes to varying degrees, many also tend to focus on a specific scale, are siloed, fragmented, or disconnected, whilst the drivers, risks, and disablers of these responses are likely to be embedded in actions, norms, and values that accrue across multiple scales (Barlow et al., 2018; Nielsen et al., 2021). Ideally then, response options would be based on political economy, critical thinking, and be historically situated as well as organised to operate in concerted action across scales, engaging coalitions of actors (IPBES, 2024b). Connected Conservation (Carmenta et al., 2023) offers a model for a complex and multi-scalar approach that both addresses the 'distant' role of telecoupled drivers (namely the dominant development model and emphasis on material values, and the role of international trade and climate change), and champions and empowers local, sustainable, and resilient people-nature relationships. Connected Conservation seeks to maintain diversity, polycentricity, and place-based solutions, as well as building connectivity between coalitions of actors with different skill-sets and tools within the sphere of influence. It also recognises the insights of diverse knowledges, the strength of local-led governance, and the importance of plural values that are characteristic of many biocultural centres. Although the flows of biocultural centres to forests are positive, they are marginalised by the more dominant drivers of deforestation, degradation, and the broader political economy and development in pursuit of the growth-centred paradigms of modern times. Through the actions of levers (including governance and accountability, economy and finance, individual and collective action, and science and technology), Connected Conservation can be designed to bring together the coalitions of actors and their expertise and toolkits to enhance the positive flows of biocultural centres, while disrupting the dominant drivers undermining forest resilience. Indeed, other work has shown that whilst plural values, diverse knowledges, and local governance are central to sustainability, these actors and actions do best when supported by networks that extend across scales (Londres et al., 2023).

6.5.2 Integrated landscape approaches

Despite lacking a universally recognised definition, integrated landscape approaches (ILAs) can be generally thought of as inclusive and integrative approaches to governance at the landscape scale that aim to better balance competing land use interests, most typically related to production and conservation. Developed as a response to the traditionally sectoral approaches to governance, ILAs attempt to reconcile multiple sector groups across multiple decision-making scales to realise more equitable and sustainable multifunctional landscapes. Rooted in the conservation sciences, ILAs have evolved considerably in the last decade to better incorporate social, governance, and political-economic dimensions (Reed et al., 2021, 2016). Some interventions seeking to address interrelated policy issues, such as forest landscape restoration interventions, adopt ILAs approaches (Djenontin et al., 2020).

ILAs are gaining momentum, interest, traction, and funding, and multiple ILAs are now in place around the globe (Estrada-Carmona et al., 2024; Reed et al., 2020). Such forms of cross-sectoral landscape governance have been developed to address the uneven distribution of benefits and burdens associated with certain landscape management decisions, which impact different social groups in distinct ways, generating trade-offs from policy options. ILAs attempt to recognise these divergent priorities and power imbalances across stakeholders, and make visible the diverse views, values, and aspirations for landscape uses and their futures. By recognising the disparate needs, aims, goals, and values, the process of ILA aims to move towards deliberation and agreed compromises across groups, thus potentially enhancing the sustainability and the equity of landscape management decisions.

Relevant and impacted landscape stakeholders are typically convened in multi-stakeholder decision-making platforms that bring together actors that represent policy, practice, and research, and often do not have a history of working together. Through careful, often independent, facilitation, actors are encouraged to engage in deliberative democratic negotiation processes that reflect on historical and contemporary landscape challenges to collaboratively develop a vision and plan for the future trajectory of the landscape. Because of the emphasis on connectivity, modularity, diversity, and knowledge, ILAs offer potential for enhancing the resilience of forest-focused interventions. They can potentially address multiple drivers in combination, and indeed have been found to be most effective when they are most 'integrated' (Carmenta et al., 2021).

Despite the obvious potential for ILAs to contribute towards system resilience, several barriers to implementation have been identified. A recent review (Vermunt et al. 2020) categorised these as participation, interaction, resource, and institutional challenges. These challenges typically relate to the absence of relevant stakeholders and resources, and to weak connectivity and institutional arrangements, which are required to initiate ILAs. However, these challenges are not insurmountable, and evidence exists showing that ILAs can lead to community engagement in forest restoration while improving farmers' livelihoods (Acheampong et al. 2020), and that application of ILA principles has increased resident capacity, contributed to conflict resolution, and helped clarify mandates, roles, and responsibilities, ensuring greater landscape connectivity (Omoding et al. 2020).

6.5.3 Adaptive and transformative governance

Adaptive governance has emerged as an institutional mechanism that largely builds from the concepts of adaptive management. Adaptive governance relies on multi-level institutional mechanisms that connect actors across multiple scales to promote an ongoing process of dealing with conflicting values and managing uncertainties in ecosystem management processes (Olsson et al., 2007). One of the key features of adaptive governance regimes is a reliance on analytic deliberation processes, which refer to structured decision processes involving scientists, resource managers, and other stakeholders that allow for the integration of scientific analysis with public deliberation (Dietz et al., 2003). Another key feature of adaptive governance is its nested institutional structure. The nesting of institutions can be particularly effective in meeting management challenges posed by cross-scale interactions in social-ecological systems, as these complex systems have unique attributes at each level, as well as shared attributes across the system. Institutional nesting allows for the allocation of responsibilities at appropriate scales according to the principle of subsidiarity, while enabling coordination across the different levels. Finally, institutional variety is another important feature of adaptive governance regimes, involving the use of different types of institutional mechanisms (states, communities, and the private sector) as a way of overcoming the shortfalls associated with the reliance on a single type of institution as a panacea.

Transformative governance involves the formal and informal rules, rulemaking systems, and actor networks that enable transformative change through integrative, inclusive, adaptive, and pluralist approaches (Visseren-Hamakers et al., 2021). Transformative governance supports system capacity "to respond, manage, and trigger regime shifts in coupled socio-ecological systems at multiple scales" (Chaffin et al., 2016, p. 1). Transformation may be necessary in the drivers of forest degradation and deforestation, in the governance and management interventions designed to address forest threats, or in the social-ecological system itself (see Section 6.5.4). Yet, there are considerable challenges for shifting to new states, particularly for transformative governance that seeks to establish processes for abrupt, emergent, and systemic change in social-ecological systems, such as: institutional stickiness, path dependency, and established power dynamics, along with lack of financial resources, limited focus on underlying root causes of forest threats, and poorly targeted or misaligned resource allocation (Chaffin et al., 2016; Visseren-Hamakers et al., 2021). As described above, international to local level interventions aiming to address the climate or biodiversity crises, including those developed as part of the international forest regime, increasingly tout multiple aims or 'win-win' opportunities that include forests and people. However, most remain largely environmentally, technically, or legally focused in practice, with comparatively limited or less effective attention to the social factors and attributes necessary for sustainability or SES resilience. Furthermore, pathways for just transformation are largely absent, leading to calls for greater attention to values, interests, power, and other human dimensions of forest-focused interventions that may require significant reorganisation or transformation, particularly to support social-ecological resilience at multiple scales and across different contexts (e.g., Kleinschmit et al., 2024).

6.5.4 'Radical' alternatives to the dominant capitalist model

Some resilience-enhancing response options may represent relatively radical departures from current governance and management approaches, particularly as most governments tend to resist transformation in favour of business as usual, or incremental adaptation at most, and often to the disadvantage of already vulnerable or marginalised communities and systems. Transformation involving system-wide change is no panacea and may be 'messy', charged, or contested, for instance


Photo © Viola Belohrad

resulting in new or entrenched power dynamics that may shift the burden of response to already marginalised and vulnerable groups (e.g., Dudney et al., 2018). Just and desirable transformations may be fostered through multiple and multifunctional interventions that embed equitable approaches in their design, implementation, and outcomes, and in their integration and innovation across scales, requiring diverse and sustained coalitions of support (e.g., via social networks and movements), and building social tipping points for intentional or unexpected opportunities for transformation (Chaffin et al., 2016; Pascual et al., 2023).

Perhaps the most considerable challenge of all is the broader political economy that is emergent from the prevailing development paradigm and its pursuit of growth and material values. Changing this system will require difficult and transformative changes. Capitalism drives various significant negative people-nature relationships, and yet, response options to target capitalism itself appear untenable, out-of-reach, rogue, or radical. Despite the size of the challenge, scholars, environmental defenders, activists, philosophers, politicians, and economists have generated ideas for how to approach this issue, as well as documented sites where alternative people-nature relationships are thriving (Brondízio et al., 2021; Kothari et al., 2019; Levis et al., 2024; Stiglitz, 2019). Recent high-level reflections on these propositions for system-level transformations, such as the EU Parliamentary 'Beyond Growth' conference in 2023, are highlighting how the initial perception of the 'radical' nature of these ideas is potentially diluting, and offer promising signals that the present (lack-of) legitimacy in mainstream and common discourse may shift with time. For example, new models of well-being economies are being implemented in some countries around the world, championed by entities such as the Wellbeing Economy Alliance (Hayden and Dasilva, 2022). These early movers create a space where the performance of the economy is not measured by our 'addiction to wealth' (Costanza, 2022) and are signalling high-level recognition of the damages of the quest for accumulation (Cook et al., 2023). Ideas of post-growth, including degrowth (Kallis et al., 2025), doughnut economics (Raworth, 2018), and sufficiency (Jungell-Michelsson and Heikkurinen, 2022) are all based on a fundamental understanding that humanity is living on a planet with finite resources, and so they prioritise well-being and the plural values of nature over economic growth. Fundamentally, the prospects for forests' role in enhancing human well-being is likely to flourish under this type of system-wide backdrop, and indeed, transformations to the current economic model are deemed essential for just and sustainable futures (Díaz et al., 2019).

6.6 Research needs and evidence gaps

Through this analysis, we have identified multiple research needs and evidence gaps for better understanding response options with forest SES resilience-enhancing potential. These include:

- Enhanced understanding of the role of forests for social and economic resilience given the majority of the work has been on the ecological aspects of resilience.
- Enhanced understanding of how forests are changing under the influence of climatic shocks and stresses and non-climatic stressors, and how these changes affect the resilience-building attributes that forests and trees provide.
- Quantifying and modelling the feedbacks and trade-offs between social, ecological, and economic dimensions of forests SES resilience across scales.
- Effective measurement and recognition of the diverse and plural values embedded in people-nature relationships and what resilience is and means to different groups, including what is desirable and not desirable.
- Soliciting the desired visions of the future we want and connecting these to actionable pathways and to deep leverage points needed to achieve them.
- Considering potential overlaps and complementarity, the response options explored here could become a menu of adaptation measures to be applied to different contexts in response to climate risk and vulnerability assessments. In this sense, further research is required on context-specific planning, co-benefits between response options, the effectiveness of particular bundles of approaches, and trade-offs.
- How to enhance communication of forests values, including shifting the narratives to more powerful framings capable of catalysing positive change, including exploring the role of empathy.

- How to scale-out positive flows and approaches.

- The role of digital technologies in SES resilience: At the technological level, future research should focus on improving the integration of various monitoring methods, the interpretability of machine learning models, and the increasing use of open-source tools to facilitate widespread adoption. At the socioeconomic level, we need a better understanding of how to make these technologies inclusive, how to improve local communities' digital literacy, and how to ensure digital connectivity.

- Interdisciplinary work connecting forest resilience to alternative economic models and identifying the actor coalitions and pathways towards achieving those.

- Better understanding of how to build the coalitions of actors and actions across scales to culminate towards enhancing the role of forests in social and economic resilience.

6.7 Chapter conclusions

The key message of this Chapter is that no silver bullet or one-size-fits-all solution exists, but rather bundles of responses are likely necessary to successfully respond to, and counter, the drivers that compromise forest capacity to contribute to forest SES resilience. The contemporary context of climate change and other major environmental and anthropogenic global forces will require an adaptive mix of approaches fitted to and linked across different settings and scales (Carmenta et al., 2023; IPBES, 2024b). Resource managers are likely to be challenged to integrate adaptation strategies (actions that help ecosystems accommodate changes adaptively) and mitigation strategies (actions that enable ecosystems to reduce anthropogenic influences on global climate) into overall plans (Estrada-Carmona et al., 2024). Further, any response option will be operating within the broader political economy and under the dominant development paradigm that appears as a fundamental challenge to achieving sustainable people-nature relationships at scale (Díaz et al., 2019). The effectiveness of any response option aimed at enhancing the contribution of forests to SES resilience is both context dependent and interdependent with the ecological dimensions of the social-ecological system as a whole, and depends in large part upon the way in which it is implemented. The resilience-enhancing attributes developed in this Chapter can serve as a useful guide to steer effective and just responses.

Forest SES resilience (and thus, forests' contributions to social and economic resilience) is likely to be increasingly constrained, and it will be challenging to achieve within the dominant development model, which is based largely on growth and wealth accumulation often at the expense of nature and people-nature relations. As laid out in the IPBES Values Assessment, the collapse of our environment, including forests, represents a values crisis, and the "transformative change strategies [needed] include transforming dominant economic and financial paradigms so that they prioritise nature and social equity over private interests" (IPBES, 2024a, p. 8). Whilst the response options we outline surely fall short of steering towards a transformation of the status quo at the system level, they demonstrate the potential of at least incremental contributions to moving in this direction. The range of scales, sectors, and stakeholders involved in forest loss and degradation that also affect forest contributions to social and economic systems and their associated feedbacks means that the task of identifying effective response options risks being an unwieldly and unbounded venture (e.g., from interventions that reduce demand-driven consumption ideals in a capitalist system, to policies addressing rural exodus to urban areas, to empowering customary forest rights locally).

Most efforts that aim to support forest resilience frequently focus on enhancing absorptive (for persistence and recovery) and adaptive capacities (for responding to change while maintaining essential functions and identity), though transformative capacities will also be necessary to navigate increasing complexity, reduce the vulnerabilities to unforeseen negative surprises and shocks, and shape future social-ecological system configurations when windows of opportunity present themselves (Kleinschmit et al., 2024; Reyers et al., 2022; Suiseeya, 2017). Ultimately, transformation may be required. Systems with transformative capacities have the potential to be intentionally shifted to a more desirable, self-organising state, characterised by new structures, processes, and feedbacks. Governance and management interventions may support such transformative capacities through institutional flexibility and continual and multi-loop learning that accounts not only for vulnerabilities and risks, but also for their root causes, and that supports the coproduction of a diversity of response options and pathways to resilience (Pascual et al., 2023).

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7

Chapter 7

Forests for Social and Economic Resilience

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7.1 Overview

The assessment of the scientific evidence on the relationships between forests and social and economic resilience has focused both on social and economic resilience as bolstered by forests and on the resilience of forests themselves. Our assessment found strong evidence of the myriad ways in which forests are important. The resilience of social and economic systems is currently challenged by multiple and often interacting factors and rapid global change, including land use/land cover change, biodiversity loss, increasing disaster risk, and climate change, all of which are disproportionately driven by the pursuit of economic growth (Costanza, 2022). Resilient forests help adapt, mitigate and counter these global changes and provide key capacities and resources for adaptation and mitigation in the future. Resilient forests, social systems, and economic systems have less uncertainty than those with low resilience. Forests that are not resilient are at high risk of fundamental change that can adversely affect their contributions to social and economic resilience. Given this rapid global change, resilient forests and their contributions to social and economic resilience are significant.

We employ a social-ecological resilience lens to frame our assessment because forest systems are quintessential social-ecological systems (SES). The forest SES framing captures cascading and multiple stressors, and changes and responses to those stressors; responses that can range from resistance to rapid bounce-back and to deep fundamental and potentially irreversible change in key processes and functions. We also discuss transformation, the purposeful shift of the structural or institutional elements that maintain an undesired state of a system, in order to guide its renewal into a more desired (e.g., just and sustainable) state.

Our assessment substantiates that forests are globally important in providing social and economic resilience, as described in earlier chapters. Forests are a source of products and ecosystem services that provide livelihoods and resources not only for forest-dependent and other forest proximate peoples, but also for people distant from forests. In addition to the array of forest products, forests provide other key ecosystem services and benefits, including the cultural services and relational values that contribute to psychological benefits, human health, well-being, biocultural diversity, and resilience to a wide range of stressors and shocks. Some of these forest ecosystem services have an outsized influence on the future of humanity, for example, by providing clean water, soil conservation, and carbon sequestration, as well as through providing living loci for learning about the diverse social, economic, and governance systems that have proven consilient with forest resilience (Carmenta et al., 2023; Garnett et al., 2018). Forests can contribute to attaining SDGs, for all people regardless of wealth, forest proximity, or other factors.

At the global scale, planetary boundaries are being tested by anthropogenic changes connected to the Great Acceleration, the rapid increase in human activities and their global impacts that began in the mid-20th century driven by the pursuit of economic growth. Several planetary boundaries have already been crossed. Given the long lag times associated with slow global processes, the effects of boundary crossing are only beginning to manifest. Forests, and particularly resilient forest SES, have an important role in keeping humanity from crossing additional boundaries, and in mitigating the impacts of thresholds that have been exceeded. At meso-scales, multiple social and ecological processes have been altered, are changing, or may change in the near future, and are interconnected with processes at small and large scales, affecting forests and forest-human relationships across both spatial and temporal scales.

Clearly, forests are beneficial to humans and foster and maintain both social and economic resilience (Choksi et al., 2025). It is easier, and less risky by far, to maintain systems that are in desirable states and providing beneficial goods and services to humanity than to let them fundamentally change (undergo a regime shift resulting in the emergence of an alternative state), and then attempting to restore or rebuild them. The "Humpty Dumpty Effect" (Berger and Lambert, 2022) is real. Named after the British nursery rhyme, the Humpty Dumpty Effect refers to a situation where a complex system, once significantly disrupted, cannot be fully restored to its original state, even with considerable effort. Even if most of the components and relationships of a system are known, it is difficult if not impossible to put a collapsed system 'back together again', because it is impossible to know and restore all the contingent and temporary relationships that were important in shaping it (Lindenmayer et al., 2016). We know that regime shifts have historically happened at scales both small and large (e.g., the ancient abrupt shifts at a large scale between desert and vegetated states in the Sahel and Sahara desert systems; Scheffer et al., 2001), they are occurring now (grasslands globally are becoming woodlands and forests primarily of undesired species), and, in general, the scale of change is increasing as connectivity of the planet and synchrony of change has increased (Pratzer et al., 2024).

The assessment of forests for social and economic resilience is critical given the current policy context and the significant and increasing drivers of decline. The 2030 Agenda for Sustainable Development, which established 17 Sustainable Development Goals (SDGs) and 169 Targets was established in 2015 (UN, 2015), and humanity has only half a decade to meet these goals. Progress has been made, but enforcement and implementation of relevant actions is increasingly urgent (Cooper et al., 2023). Forests are important in meeting most of these goals, including alleviating poverty, ending hunger, ensuring well-being, ensuring clean water and affordable energy, making cities sustainable and resilient, combating climate change, protecting terrestrial systems, and more. Here we summarise key findings of the Expert Panel assessment and their implications for decision-makers, including policymakers and practitioners. We identify the primary knowledge gaps that became evident during our assessment and that require additional research (Table 7.1). We conclude by focusing on the future of forests in terms of resilience and their contributions to social and economic resilience. Our findings can help inform local, national, regional, and international policies relevant to forests and help foster several 2030 Sustainable Development Goals (SDGs), the Kunming-Montreal Global Biodiversity Framework targets, the 2015 Paris Agreement goals, and individual countries' net-zero targets. Our findings are also relevant to other stakeholders, including scientists, the private sector, and NGOs working with and within forests.

7.2 Key messages and implications for decision-makers

Key Message 1: Forests are complex social-ecological systems, and understanding their resilience and how to enhance it is key to ensuring their sustainability and the sustainability of their benefits to social and economic systems.

Resilient forests help keep humanity away from global tipping points. The idea of global tipping points is a resilience-derived concept and currently identifies nine planetary boundaries. Six of these may have been already surpassed (Richardson et al., 2023), specifically climate change, biosphere integrity, land system change, freshwater change, and biogeochemical flows. Forest SES have an important role in the control variables for all the identified planetary boundaries, and a strong direct role in seven of the nine. Exceeding the planetary boundaries could lead to a global state change to a "hothouse Earth" (Steffen et al., 2018), or to other alternative states. State changes are abrupt and difficult to navigate, and the consequences of a global state change could be catastrophic for much of humanity, including our social and economic systems (and for forests themselves).

Resilience-based assessment approaches are essential for gaining knowledge about the drivers of change that shape the resilience and vulnerability of forest SES and to inform adaptive responses. Currently, the assessment of resilience is largely done in a retrospective manner, with rare instances of resilience assessments being integrated into plan preparation and implementation processes in a forward-looking manner. There is a need for further refinement of the conceptual and methodological tools for resilience assessment and application of these tools to forest SES, as well as the development of more effective mechanisms for engaging stakeholders and feeding results into decision-making. Regardless, undesired regime changes are predicted to become more common under the trends of climate change, forest fragmentation and other degradation variables. Conversely, though, resilience dynamics can be used to transform systems from undesirable states to more desirable states when necessary.

Maintaining forests in desirable states is critical, and for forests in undesirable states there are tools for transformation. Determining what is desired is more difficult, and is inherently subjective and context dependent, involving multiple perspectives and attention to inclusiveness, justice, equitability, and trade-offs. Where the determination of a desired state is clear, **it is far simpler and safer to maintain forested SES in desirable states than to revert undesirable states, therefore consideration of forest resilience is a necessary policy and management goal into the future.**

Key Message 2: Forests provide key benefits for enhancing social and economic resilience through a myriad of relationships, and these benefits accrue both locally and globally.

Forests provide direct and indirect benefits at multiple scales to the resilience of both social and economic systems, ranging from individuals to societies. These services and processes often have reciprocal relationships with forests themselves, and feedback loops can help enhance the resilience of the forest itself. In contrast, forests in undesirable states produce fewer benefits for social and economic resilience and may have negative feedback loops that erode forest resilience.

The nature of relationships between forests and people, and therefore the resilience of social and economic systems, vary. Forest-dependent communities have livelihoods and lifeways that are strongly dependent and connected with the forests themselves, and their resilience is inextricably linked to the resilience of the forests as a very tightly coupled SES. Other forest proximate communities, including urban ones, are not as dependent upon direct forest contexts and their products, but their resilience is enhanced by forest proximity. Benefits they derive include access to places of meaning, products and services such as timber and non-timber forest products, clean water, recreation, carbon sequestration, and many others. Distant communities are even less directly affected by the status of forests, yet forests provide them with key benefits such as those described above, especially those related to global biogeochemical cycles, carbon sequestration, and the benefits of forest biodiversity.

Forests provide benefits that accrue to all of society, proximate and distant. It is easy to acknowledge the benefits of forests to forest-dependent peoples because they provide territory, home, place of cultural exchange, as well as economic products such as timber, food security, medicines, and much more. Some forest products (both timber and non-timber) enter the global supply chain. But strengthening the potential of forests as providers of economic support depends on broad structural changes through strong governance and resilience principles.

Resilient forests produce and 'export' goods and services that enable social and economic resilience. Forests are well-recognised as producers of timber and extractive resources, and as sources for biodiversity. But forests produce a large number of goods and services ranging from extractive to aesthetic. Many of these services are critical for humanity, for example the provision of clean water; services such as this have clear economic impacts, saving billions of USD annually that would otherwise be spent on water infrastructure and treatment (Lamsal et al., 2024). Economic benefits are derived from the production of timber, food, fodder, recreation, culture, heritage, water regulation, climate regulation, biodiversity, products such as pharmaceuticals, and more. Many of these forest ecosystem service benefits are difficult to value in financial terms, and thus, the estimated value of forests to the global economy has much uncertainty. The formal forest sector contributes approximately USD 1.5 trillion annually to the global economy (FAO, 2022), but forests also provide health and well-being options to proximate and distant communities. All of these benefits, through indirect means and processes such as telecoupling, accrue to people across the globe. Forests are fundamental to human survival.

The relationships between forests and people often reinforce the ability to cope with both disturbances and shocks. On the whole, **forests are highly beneficial locally and globally for mitigating the effects of shocks (and undesired change in general) on social and economic systems, and for providing sources of adaptation as humanity copes with a rapidly changing planet**. Relationships of people and their economic systems with resilient forests range from direct and easy to assess (for example for peoples whose livelihoods and lifeways in general are directly related to forests themselves), to indirect and complex, though they are just as important. Forest relationships occur between forests, social, and economic systems at all scales, and across diverse sectors.

Key Message 3: Forests remain vulnerable and at risk to undesired change, including those that may fundamentally alter forest contributions to social and economic resilience.

Although there is some partial and fragmented good news concerning forests, in general, forests are increasingly threatened via direct and indirect forces that remove biomass, alter structure, affect function, reduce their area and diminish their ecological resilience. Many forests remain vulnerable and are at risk of crossing critical thresholds and re-organising into less desirable states. The social and economic systems that are consilient with forest resilience are also under threat. Many forests, and therefore also the social and economic systems with which they interact, face multiple concurrent threats, and impacts may cascade and/or have impacts on distant systems. These threats are particularly pronounced for forest-dependent communities

Clear cut forest in Kalimantan, Indonesia. The world's forests face increasing pressures from growing demand for forest products and alternative land uses such as agriculture, driven by increasing human populations and consumption and the escalating throughput of economies. Photo © Viola Belohrad

across the tropics living in landscapes of frontier dynamics and rapid commodity expansion, land appropriation, and land use change. Further, the inequitable distribution of the benefits and burdens of declining forest resilience has proven difficult to address. The 'cost-shifting' inherent in the increasingly telecoupled reality of contemporary forest SES means that those experiencing most burdens are often not those driving the change for short-term benefits (Lapola et al., 2023).

Increasing biological invasion, anthropogenic forest loss, and unsustainable use are notable threats. Non-native and invasive species are prevalent in forest community composition and have impacts ranging from competition with native species to alteration of disturbance regimes. The latter impact can cause fundamental changes in forests, including altering composition, structure, and processes leading to the emergence of alternative forest states less desirable to humans. Expansion of human settlements and agriculture continue to erode forests, mostly from the edges. These and other activities can increase forest fragmentation and degradation which can increase invasion by non-native species leading to what has been termed "invasional meltdown" (Simberloff and Von Holle, 1999). Fragmentation can also halt important structuring processes that are spatially contagious, such as fire, and can favour species with certain dispersal characteristics over other species, altering forest composition and affecting their functions. Over-exploitation and unsustainable use of forest products, including timber, continue to be problematic in many locations. Attempts to maximise production at the cost of other ecosystem services can lead to trade-offs that undervalue services other than timber production, and can indirectly cause forest ecosystem collapse. For much of the 20th century, forest policy has emphasised a sustained yield management paradigm that focused on the continuous, and often maximised, supply of timber to manage forests that were assumed to be relatively stable and predictable, with predictability erroneously thought to be enhanced by fire bans (Putz et al., 2022). In many cases, this approach resulted in declining forest health, social conflicts, rural poverty, and in some cases, increased flammability.

The risk of tipping points emerging from the combined impact of various disturbances and climate change has been highlighted as a critical threat to global forest systems. Maintaining forest resilience can mean balancing short-term benefits versus long-term productivity. The general resilience of forests varies geographically, and the resilience of a single forest varies depending upon the stressor considered. Forests with larger extents and higher diversity are often more resilient. **Generally, forest resilience is declining, but there are numerous bright spots globally. Forests are threatened from many sources, and many of those threats, individually**

or in aggregate, threaten forest resilience, the contributions of forests to social and economic resilience, and the relationships between people and forests in general.

Key Message 4: Governance of forest social-ecological systems can enhance resilience with adaptive and transformative approaches, but is uneven and sometimes inequitable.

Many forests are already in less desirable alternative states, or have highly compromised resilience due to climate effects, land use change, biological invasions, and alteration of key structuring disturbance regimes such as fire. Governance and institutions fundamentally affect human-forest relationships, and therefore, the resilience of forests and forest contributions to social and economic resilience. In the context of forest SES resilience, formal and informal institutions (the rules, policies, and laws enacted to shape resource access, use, and management) affect the relationships between forests and people. This includes who benefits or loses from the current state of the forest and management policies, how they benefit, and why some groups benefit more or less than others. Both formal and informal governance and institutions, not only from the forest sector but also from the many other sectors that influence forests, steer forest system priorities, including what is considered the desired state of a forest social-ecological system, and how to respond to rapid changes. As the state of the forest has social and economic implications, this 'desired' state may vary according to different actors and scales, hence, the nature of governance institutions and processes for decision-making is crucial.

There is a need to understand and address the power relations and the resistant but undermining structural legacies in which forest governance has been and is embedded. Historically, the institutions of Indigenous and forest-dependent peoples have often been weakened, suppressed, or overlooked and dismissed in favour of global economic priorities and groups holding hegemonic power within and across scales. Human rights and justice needs should be addressed and rectified where injustices have occurred by engaging more inclusive, equitable, iterative, and adaptive governance approaches that adequately weave and bridge plural epistemologies (knowledge systems), ontologies, and practices.
These and a number of other institutional attributes of resilience have been identified (see Table 4.1), and **forest governance systems that appropriately integrate a combination of such institutional attributes are key to fostering and maintaining the resilience of forest-dependent social and economic systems**. Where they do not, there are risks for inequity and ineffectiveness. Governance of forest social-ecological systems that appropriately integrates multiple attributes is key to fostering and maintaining the resilience of forests and their positive contribution to social and economic resilience, as well as the capacity to transform for more sustainable and equitable outcomes.

Key Message 5: Forest-focused interventions are unlikely to be sufficient in building resilience independent of other complementary policy interventions.

A broad range of interventions are currently available, and multiple courses of action are possible to address threats and enhance forest resilience. However, a key issue is that the drivers of forest loss tend to arise outside of the forest sector or the conservation space, and are associated with disproportionately powerful agendas that drive decline. Management and governance options cover a range of activities, instruments, and strategies (e.g., sanctions, incentives) that can enhance forest SES resilience. A primary action is to reduce the drivers of forest degradation and forest loss, especially those linked to factors outside of the forest sector.

A key driver of loss is forest overexploitation and unsustainable extraction of resources. Certification schemes may help, but do not address the underlying demand. Agricultural intensification and expansion are key drivers of change that may require interventions that address land use and land cover change alongside others that shift diets in distant geographies. Addressing the proximate and ultimate drivers of forest system loss, such as urbanisation and commodity consumption, is needed. Integrated, interactive, inclusive, adaptive, and 'connected conservation' approaches (involving coalitions of diverse actors across sectors and scales) to conservation offer frameworks to address multiple challenges to forests, and to steer towards positive outcomes. Recognising the expanding evidence that wealth accumulation linked to the dominant capitalist development model can drive environmental collapse (IPBES, 2024, 2018; WWF and IUCN, 2000), there is a need for a cross-sectoral focus directed at a system-level transformation, which may require new, rare, or seemingly radical approaches.

Pursuing response options that build resilience-enhancing attributes may help maintain resilient forests under global change and ensure the continuation of forest contributions to social and economic resilience. These actions include:

- Maintaining diversity, connectivity, and feedbacks;
- Maintaining biophysical capital;
- Maintaining social and economic capital and well-being;
- Promoting polycentricity;
- Enhancing adaptive capacity;
- Fostering transformative capacity;
- Enhancing equity and justice;
- Supporting place-based solutions.

Maintaining these actions over time is critical for the future of resilient forest SES.

7.3 Knowledge gaps and research priorities

Based on knowledge gaps revealed by this assessment, we have identified a range of research priorities. These gaps range from questions that represent very basic science to those that are much applied. The logistics of answering the questions to fill these gaps ranges from relatively straight-forward to extremely difficult. However, tackling these unknowns will be important to ensuring that forest SES stay in, or shift to, desirable states that contribute to social and economic resilience.

Table 7.1 Research priorities for understanding the contribution of forests to social and economic resilience.

RESEARCH PRIORITY	KEY QUESTIONS
What are the key drivers of resilience in forest SES?	▪ What are the key drivers of forest SES resilience and at what scale do they operate? ▪ What are the most important relationships and feedbacks? ▪ What are the critical thresholds present in particular forest SES?
How can we quantify forest SES resilience?	▪ What methodological approach(es) are most appropriate for assessing resilience in forests? ▪ What attributes matter the most, and why? ▪ What early warning indicators might be appropriate for detecting the loss of resilience in forest SES? ▪ What is the relative resilience of different forest types and regions globally?
What adaptive approaches can best serve forest SES?	▪ What are the alternative states and futures possible for forests? ▪ How do we ensure positive outcomes of transformative change? ▪ How does science best inform learning and decision-making processes? ▪ How do we assure voice and agency for marginalised stakeholders?
How do we prioritise governance, management, and policy options to enhance forest SES?	▪ What untapped capacities exist within current legal frameworks to enhance resilience? ▪ What are the trade-offs associated with different management and policy options? ▪ What policies are most likely to enhance resilience? ▪ What are the appropriate scales of intervention?
How do we best communicate forest SES resilience benefits?	▪ How do we communicate better the importance of forests and their contributions to social and economic resilience? ▪ What modes of communication are better? ▪ How should communication vary with locations? ▪ How do we best communicate the consequences of low resilience?
How to equitably distribute benefits and burdens associated with forest SES?	▪ How can Indigenous Peoples' self-determination foster more equitable solutions? ▪ What are the trade-offs across benefits and across groups? ▪ What are the costs associated with trade-offs? ▪ How do we ensure transparency, legitimacy, and accountability?

Research Priority 1: What are the key drivers of resilience in forest SES?

There are two core meanings of resilience, the return time following disturbance and the amount of disturbance a system can withstand before it crosses a critical threshold and undergoes reorganisation, often into an alternative state. Understanding return time, both conceptually and mathematically, is relatively easy, and so resiliency and bounceback are often invoked and meant by laypersons when describing resilience. Resilience of forest SES and the existence of alternative stable states are conceptually more complex and reflect the nature of systems of forests and people as multi-scaled, complex adaptive systems. Resiliency is a common dynamic in forest SES, and although it is easy to measure return time, there is still much to learn about this aspect of resilience. Though we know the general dynamics, we are missing, in many cases, the details. How does management or policy influence return time for forest SES? What drivers should be addressed? How might compounding stressors, such as biological invasion and climate change affect return time following disturbance?

Alternative stable state dynamics and sources of resilience are less understood than return time. Literature focused on this understanding of resilience tends to be more basic and conceptual. Many details are uncertain, and research should focus on several fronts. In some of the theory underlying resilience, it is proposed that very few key processes are responsible for structure and function at a given scale. Some processes at some scales are obvious, such as the influence of fire regimes on forests. But collapse can scale up as well as down, and much more needs to be learnt regarding key drivers (processes) at multiple scales in SES and their relationship across scales, as well as resilience-enhancing relationships among social and ecological elements of forest SES.

Many contributions of forests to social and economic resilience are understood, but those with an ecological link, such as carbon sequestration, are better understood. Social and economic aspects are becoming better represented in recent literature but require a more explicit and direct focus. Forests are critical in maintaining carbon and water cycles, forests create livelihoods, forests buffer social and economic shocks, but many contributions are less understood, including distributional issues (who bears the costs and who benefits), and poorly documented because most work on resilience has focused on the ecological realm. Integrative work on SES resilience remains relatively minimal. Feedbacks are frequently integrative in that they reflect social-ecological interactions and are considered critical to understanding resilience and its sources. However, feedbacks remain under-studied, as are the trade-offs that are made when enhancing one or more attributes of resilience.

Research Priority 2: How can we quantify forest SES resilience?

Quantifying and assessing resilience is one area where there has been considerable academic effort, but proposed approaches still remain partial and contested (Quinlan et al., 2016). The development of early warning indicators (of an approaching regime shift) is an area of intense focus, but most metrics forwarded signal only after collapse is inevitable (Biggs et al., 2009). Some approaches show strong promise in that they may indicate causation (Sugihara et al., 2012), or in that they may provide decades of warning (Roberts et al., 2019).

Following from resilience theory is the idea of transformation, an agent-driven process of change. Transformation will continue to increase in importance as more thresholds are exceeded and systems become undesirable. However, transformation is an inherently risky process, and much more needs to be learnt to increase the possibility of desirable outcomes.

Precariousness, as presented by Walker et al. (2004), is a measure of how close to a tipping point a system is at a given point in time. This idea is related to quantifying resilience and understanding tipping points but is more an immediate measure of proximity to a potential tipping point. Notions of precariousness are still largely conceptual, though the idea has much overlap with vulnerability and risk, but for specific resilience outcomes. Many forest SES likely have low resilience and are precarious. Quantifying these measures will provide a better use of limited resources to address forest SES at risk of reorganisation.

Many have forwarded attributes that are core to resilience, but their application can be contextual, and we lack solid understanding of their role in many cases. The importance of a given attribute can vary with scale, including over time, and this shifting importance is poorly understood.

Research Priority 3: What adaptive approaches can best serve forest SES?

Ultimately, the desirability of the state of a forest, a social system, or economy is subjective, and depends upon stakeholder perspectives. Thus, we need to address even more thoughtfully the question of 'desired states'. In resilience, it is common to ask resilience of what, to what, and for whom, because the 'for whom' matters. Given that change is inevitable whether desired or not, it is important to address explicitly alternative states, whether they are expected to emerge from change beyond our immediate control (such as climate change), or if change is deliberate via transformation. Developing plausible future scenarios and potential alternative states for forested systems at risk of fundamental change is encouraged. Scenarios are useful as they force those involved to consider responses to current and future actions, consider unintended consequences, and consider actions that may change outcomes for the better, as well as explicitly communicate their assumptions and hypotheses underlying particular scenarios. Scenarios bring science into decision-making spaces and need to be developed in a way that involves all relevant stakeholders, including marginalised groups. As such, transparency and inclusiveness are necessary for outcomes that are considered just by all, even if this requires making hard decisions.

Scenarios force the expression of underlying, usually implicit assumptions of different user groups about the basic drivers of their SES system, which are then modelled. Different views of causality can be incorporated as alternative hypotheses within an adaptive management framework. Adaptive management is useful for complex systems where the loss of resilience is a potential, because it allows learning while continuing management. Management experiments under adaptive management are designed in a safe-to-fail manner, rather than in a fail-safe manner.

Other ways of learning and engaging people are encouraged. These could include developing mental models with different stakeholder groups, or engagement in forest SES resilience assessments (Resilience Alliance, 2010). How new technologies such as digitalisation and artificial intelligence may affect forest-dependent communities and how they might be beneficially adopted is an under-researched area that requires careful consideration and adaptive approaches.

Research Priority 4: How do we prioritise governance, management, and policy options to enhance forest SES?

Management and policy options exist within current legal and policy frameworks, and untapped capacities within legal and policy frameworks should be unlocked (Garmestani et al., 2019). Changing current environmental laws, especially, both locally and internationally, is difficult. In many countries, changing current environmental laws or enacting new laws is not feasible in a practical sense, or will take long periods. In addition, as global uncertainty increases, we have seen a rise of authoritarian governments and narrowing spaces for civil society. Laws and regulations, perhaps especially international laws that are meant to be one-size-fits-all, sometimes create externalities with unintended consequences, as happened with the deforestation-free law in the European Union, which created product certification challenges for many communities and countries (Zhunusova et al., 2022). Understanding such consequences is key to good decision-making.

The implementation of collaborative adaptive resource management, which engages and includes stakeholders in learning and better understanding the multiple values of forests, of forest resilience, and of forests to social, economic, and cultural resilience, for both forest-proximate and distant peoples can help reduce key uncertainties identified by stakeholders. The set of policy options that are readily available are partial, but even without new policy approaches, we need to better understand which available levers to pull, and when and how. There is a need to better understand the obstacles to changing governance when changes are appropriate, and how to overcome barriers where there is resistance. There are differential impacts of management and policy with various costs and benefits, which should be assessed and quantified. Different worldviews should be incorporated and engaged on equal terms. Trade-offs exist across scales, across sectors, across human groups, across suites of ecosystem services, but are poorly understood. We also need to develop better ways to account for and to demonstrate the success of various actions and returns on investments focused on improving forest SES, and in general, to better include the role and contribution of forests into economic assessments.

Resilient forest SES enable resilient social and economic systems. Photo © Viola Belohrad

Research Priority 5: How do we best communicate forest SES resilience benefits?

Communication of forest values and the reasons behind current or future forest management is critical; not all people value forests, though all people benefit from forests. The benefits from forests in terms of global biogeochemical cycles, genetic diversity, resilience from shocks, hazard prevention, contribution to the resilience of social and economic systems, production of ecosystem services in general, and much more, have been described in the chapters of this assessment. But much of the public at large is unaware of these contributions and how important they are for well-being and economic prosperity. Despite the enormous economic benefits of forests, the realised potential remains below what it could be, due, in part, to a limited recognition of the value of forests.

Research efforts to enhance communication should focus on three key areas. First, how to communicate the importance of forests in carbon sequestration and carbon mitigation strategies. Second, how to communicate the consequences of forest loss through land use change, and due to the loss of resilience and emergence of less desirable alternative system states. Third, forests are dynamic and management creates trade-offs, across scales, across sectors, across peoples, and across ecosystem services. Communicating those complex trade-offs will make enacting policy interventions more transparent and more likely to succeed. The role of forests in improving human health and well-being needs to be emphasised, and ways to communicate this most effectively are critical because the importance of forests is widely under-recognised.

Research Priority 6: How to equitably distribute benefits and burdens associated with forest SES?

Forest benefits are not distributed evenly, across space, individuals, groups, or governments. This can mean that the distribution of benefits and costs lacks legitimacy or accountability. Indigenous groups and those with poor representation within their governments are often marginalised, sometimes from their ancestral lands and forests. Indigenous groups are particularly key to forest health and resilience but have had little compensation for their stewardship. Equitable ways to distribute forest benefits are needed. This is especially true where benefits accrue at large scales, for example in the sequestration of carbon, but is also true across scales and economies; for example, pharmaceutical discoveries from forest genomes rarely benefit local communities.

To meet these goals, governance institutions and processes need to be grounded in principles of rights and justice, requiring transparency, legitimacy, and accountability, which also helps assure participation and legitimacy. Decision-making requires trade-offs, and just as goals, trade-offs should be approached with the same principles of justice and transparency. Much is left to be learnt regarding how to equitably navigate these trade-offs, and how to equitably distribute the benefits derived from forests. Collaborative research efforts that provide voice to marginalised groups should be encouraged and prioritised. In part, this can be achieved with more equitable distribution of funding in a way that marginalised groups are included.

7.4 Fostering resilience in forest systems

Resilient forest SES have a myriad of benefits, including enabling resilient social and economic systems. However, the world is highly non-stationary, and now, fully connected at large scales, creating the potential for even more rapid change. If that change is synchronous, effects will be global. Interventions are needed to foster resilience of forest SES in desirable conditions.

Not all forest SES are in desirable states, and some currently in desirable states are likely to reorganise into less desirable states. Transformation of those systems is possible to create desired futures from an undesirable present. Transformation involves eroding the resilience of the undesirable state and fostering reorganisation to a more desirable state. Transformation requires changes to the biophysical, social and economic aspects of forest SES. As such, it is a risky endeavour, but one with potentially high returns.

We have documented the value of forest SES to social and economic resilience. On the whole, the contributions are highly beneficial and valuable, economically and for human well-being. Forest systems are perhaps **the** critical land cover to help humanity navigate a turbulent near-term future.

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Appendix I: Glossary

Adaptive capacity	The potential within social-ecological systems to provide a flexible and effective response to changing circumstances or shocks. This capacity is necessary in order to effect adaptive responses to change (Angeler et al., 2019).
Adaptive governance	A flexible, inclusive, and iterative approach to managing social-ecological systems amid uncertainty and change. It emphasises learning, collaboration, and the capacity to adjust policies and institutions over time based on new knowledge and evolving conditions (Adger, 2003). Among others, adaptive governance involves connecting actors and institutions at multiple levels to enable the effective stewardship of ecosystems in the face of shocks or disturbances, along with fostering flexibility, self-organisation, collaboration, learning, and experimentation (Stockholm Resilience Centre, 2016).
Afforestation	Establishment of forest through planting and/or deliberate seeding on land that, until then, was not classified as forest (FAO, 2020).
Agroforestry	A collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence (World Agroforestry Centre, 2017).
Capital assets	For the purpose of this report, defined as the means mobilised at different scales (household, community) to shape, transform, and maintain socioeconomic development. Capital assets also encompass social capital, the formal and informal social relations and networks that can be critical in fostering resilience. See also '*network diversity*'.
Complex Adaptive System (CAS)	A type of system characterised by the absence of global control and by many constituent entities interacting with each other and the environment in dispersed, non-linear fashion, exhibiting behaviours of self-organisation, learning, adaptation, and creation of novelty (Gupta and Anish, 2010). Concepts of SES resilience are built upon the idea that the systems we attempt to manage, such as forests, operate as Complex Adaptive Systems of both people and nature.
Connected Conservation	A new, dual-branched conservation model focusing on (i) tackling distant wealth-related drivers of biodiversity decline, and (ii) enhancing site-level conservation to empower biodiversity stewards (Carmenta et al., 2023).
Deforestation	The conversion of forest to other land use independently whether human-induced or not (FAO, 2023, 2010). Explanatory notes: • Includes permanent reduction of the tree canopy cover below the minimum 10% threshold. • Includes areas of forest converted to agriculture, pasture, water reservoirs, and urban areas. • Includes areas where, for example, the impact of disturbance, overutilisation, or changing environmental conditions affects the forest to an extent that it cannot sustain a tree cover above the 10% threshold. • Specifically excludes areas where the trees have been removed as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvicultural measures.

Unless logging is followed by the clearing of the remaining forest (for the introduction of alternative land uses, or the maintenance of the clearings through continued disturbance), forests commonly regenerate, although often to a different, secondary condition. In areas of shifting agriculture, forest, forest fallow, and agricultural lands appear in a dynamic pattern where deforestation and the return of forest occur frequently in small patches. To simplify reporting of such areas, the net change over a larger area is typically used.

Distal communities	For the purpose of this report, defined as the broader societal groups that, despite being geographically distant from forests, still derive significant benefits from their ecosystem services, including climate regulation, carbon sequestration, and biodiversity conservation. See also 'forest-proximate communities'.
Economic resilience	The ability of an economic system to cope, recover, and reconstruct with equity after a shock minimising the welfare losses. Minimising aggregate welfare is macroeconomic resilience, whereas distributional issues such as vulnerable households suffering more is microeconomic resilience (European Commission, 2018; Hallegatte, 2014).
Ecosystem	A dynamic complex of plant, animal, micro-organism communities, and their non-living environment interacting as a functional unit (CBD, 1992).
Ecosystem services	The results of ecological processes or functions that benefit people, either as goods or as services, and that may have monetary or non-monetary value to individuals or society at large. These include: i) provisioning services such as food, water, timber, and fibres; (ii) regulating services that affect climate, floods, disease, wastes, and water quality; (iii) cultural services that provide recreational, aesthetic, and spiritual benefits; and (iv) supporting services such as soil formation and nutrient cycling (MEA, 2005).
Forest	Land with trees under a specified management. Common definitions combine biophysical aspects of tree cover ("Land spanning more than 0.5 ha, with trees higher than 5 m, and a canopy cover of more than 10%, or trees able to reach these thresholds in situ") with institutional aspects ("excluding trees that are considered to be agricultural, and/or land that is predominantly under agricultural or urban land use"). It also includes areas temporarily unstocked (e.g., after clear cut or disturbance) but that are expected (without time limit) to revert back to tree cover above the stated thresholds (FAO, 2018).
Forest degradation	Changes within a forest that negatively affect the structure or function of the stand or site, lowering the capacity to supply products and/or services (FAO, 2010).
Forest-dependent communities/people	For the purpose of this report, defined as communities that have a direct relationship with forests and trees, live within or adjacent to forested areas, and rely on them for their subsistence and/or income. See also 'forest-proximate communities'.
Forest Landscape Restoration (FLR)	A planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes (Mansourian and Parrotta, 2018).

Forest management	The processes of planning and implementing practices for the stewardship and use of forests and other wooded land, aimed at achieving specific environmental, economic, social, and/or cultural objectives. Includes management at all scales such as normative, strategic, tactical, and operational level management (FAO, 2004).
Forest-proximate communities/people	People who live in and around forests. The term captures the spatial relationship between people and forests without additional assumptions about the nature of the relationship between them, as implied by the related term 'forest-dependent' people (Newton et al., 2020). See also 'distal communities' and 'forest-dependent communities'.
Forest social-ecological system (SES)	For the purpose of this report, defined as a complex system of people and nature where the natural elements are dominated by forests. In this characterisation, the ecological and social aspects are inextricably connected through feedbacks and reciprocal relationships.
General resilience	How resilient a system is to change, without specifying that change. There are common properties of systems that are known or believed to contribute to resilience in general, but it is often the case that a system that is resilient to one type of change (e.g., increased drought), is not resilient to a different type of change (e.g., dramatic increases in timber prices). Therefore, considering specific resilience is often preferred (Carpenter et al. 2001). See also 'specific resilience'.
Global North (or North)	According to the UN Conference on Trade and Development (UNCTAD, 2022), the Global North broadly comprises Australia, Canada, Europe, Israel, Japan, New Zealand, South Korea, and USA. See also 'Global South'.
Global South (or South)	According to the UN Conference on Trade and Development (UNCTAD, 2022), the Global South broadly comprises Africa, Asia (excluding Israel, Japan, and South Korea), Latin America and the Caribbean, and Oceania (excluding Australia and New Zealand). Most of the countries included are commonly identified as lacking in their standard of living. See also 'Global North'.
Governance	For the purpose of this report, defined as the sets of formal and informal institutions, regulatory processes, and mechanisms through which individuals and/or groups of actors exercise their rights and obligations, interrelate at multiple scales and levels, and mediate their needs and interests over time (Colfer and Pfund, 2011; Lemos and Agrawal, 2006).
Integrated Landscape Approaches (ILA)	For the purpose of this report, defined as inclusive and integrative approaches to governance at the landscape level that aim to better balance competing land use interests, most typically related to production and conservation. Developed as a response to the traditionally sectoral approaches to governance, ILAs attempt to reconcile multiple sector groups across multiple decision-making scales to realise more equitable and sustainable, multifunctional landscapes.
Low-Income Countries	A group of countries classified according to their gross national income per capita estimates using the World Bank Atlas method. Low-Income Countries are currently defined as those with a GNI per capita of USD 1,145 or less in 2023 (World Bank, 2024). See also 'Middle-Income Countries'.

Middle-Income Countries	A group of countries classified according to their gross national income per capita estimates using the World Bank Atlas method. Middle-Income Countries consist of two groups: Lower Middle-Income Countries with a GNI per capita between USD 1,146 and USD 4,515, and Upper Middle-Income Countries with a GNI per capita between USD 4,516 and USD 14,005 in 2023 (World Bank, 2024). See also 'Low-Income Countries'.
Multidimensional well-being	A positive physical, social, and mental state (Summers et al., 2012) comprising the objective material circumstances of people's lives such as health, housing, and income; relational aspects such as community relations and trust, and people-nature relations; and a subjective dimension relating to how individuals view their own circumstances (OECD, 2017).
Multi-level governance (MLG)	Governance approach that considers the intricate relationships between governmental, corporate, and civil society players at different levels, as well as the institutions that connect higher echelons of social and political organisation. MLG approaches focus on better integrating both the horizontal (at the same level) and the vertical (from local to global) linkages that exist in human-environment interactions while also better considering conflicts related to the management and use of environmental resources. See also 'nestedness/nested governance' and 'polycentric governance'.
Nestedness/nested governance	An institutional design principle focusing on the importance of nesting of local and larger institutional arrangements to accommodate the goals and interests of groups organised at different levels (Brondizio et al., 2009). See also 'multi-level governance (MLG)' and 'polycentric governance'.
Network diversity	For the purpose of this report, defined as the different types of social capital, such as bonding ties (close relationships) for coping with challenges, and bridging ties (connections to diverse groups) for accessing new knowledge and opportunities (García-Amado et al., 2012). See also 'capital assets'.
Panarchy	Concept in resilience theory explaining observed patterns and dynamics within and across scales (Gunderson and Holling, 2002). A panarchy is a set of nested adaptive cycles, with each adaptive cycle occurring at a specific domain of spatio-temporal scale.
Paris Agreement	The Paris Agreement is a legally binding international treaty on climate change adopted by 196 Parties at the UNFCCC COP21 on 12 December 2015 and entering into force on 4 November 2016. Its goal is to limit global warming to well below 2°C, preferably 1.5°C, compared to pre-industrial levels. The Paris Agreement provides a framework for financial, technical, and capacity building support to those countries who need it. (UNFCCC, n.d.).
Payments for ecosystem (or environmental) services (PES)	A type of economic compensation (monetary or otherwise) offered to ecosystem managers as an incentive to apply practices that increase or maintain the flow of goods and services provided by the land they manage (Grima et al., 2018). These incentives are typically provided by those who benefit from the services, including local, regional, and global stakeholders, but can also come from other sources such as tax revenues.

Polycentric governance	A governance model with multiple and/or nested actors or centres of (semi-)autonomous decision-making. A fundamental characteristic of polycentric governance is the overlapping of jurisdictions between these decision-making centres. These overlaps may refer to physical boundaries (e.g., forest landscapes that straddle multiple administrative jurisdictions), the interdependence of policy issues (e.g., deforestation, land degradation, biodiversity loss), or the functions of decision-making authorities (Skelcher, 2005; Thiel, 2023). See also 'multi-level governance (MLG)' and 'nestedness / nested governance'.
REDD+ (Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries)	REDD+ can be understood as a global PES scheme. Launched in 2008 as a climate change mitigation option in the forest and land use sector and later institutionalised in the 2013 Warsaw Framework and in Article 5.2 of the 2015 Paris Agreement, REDD+ policy mechanisms promote the idea of protecting and increasing forest and tree cover to leverage their carbon sequestration and sink potential (Brockhaus et al., 2012). To date, more than 60 countries have created REDD+ plans, carried out pilots, and/or established forest monitoring and reporting systems, safeguard systems, and benefit-sharing mechanisms (UNFCCC, 2025; Wong et al., 2019). See also 'Paris Agreement' and 'Payments for ecosystem services (PES)'.
Reforestation	Re-establishment of forest through planting and/or deliberate seeding on land classified as forest after a temporary period (<10 years) during which there was less than 10% canopy cover due to human-induced or natural perturbations (FAO, 2010). According to UNFCCC, reforestation can occur on land that was forested but that has been converted to non-forested land.
Regime (in resilience literature)	For the purpose of this report, defined as the characteristic set of processes that maintain a system in a particular 'state'. In forests, for example, the specific fire regime in place fundamentally affects the state of the forest. See also 'state'.
Regime shifts (in resilience literature)	Changes in processes that lead to the emergence of alternative, stable states in complex systems of people and nature that fundamentally alter the social-ecological systems on which humans depend for survival. Often, these shifts are abrupt, surprising, and undesirable for humans (Scheffer et al., 2001).
Resilience	For the purpose of this report, defined as a measure of a system's ability to cope with disturbance and change, both of which are increasing with increasing human dominance of the biosphere (Allen et al., 2019). Simply defined, resilience is the amount of disturbance a system can withstand without 'collapsing'.
Resilience attributes	The social-ecological characteristics, capacities, and principles that determine a system's capacity to anticipate, respond to, and recover from shocks and stressors. They encompass both individual and collective competences, as well as the enabling (or constraining) environment influencing a system's robustness, adaptability, or transformability (Meuwissen et al., 2019).
SES resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganising in ways that maintain their essential function, identity, structure, and capacity for self-organisation. Resilience is a positive attribute when it maintains capacity for adaptation, learning, and/or transformation (Arctic Council, 2016), while the system is in a desirable state.

Social resilience	The ability of households, communities, and cultures to cope, respond, and maintain (or enhance) their multidimensional well-being in response to external stresses and disturbances as a result of social, political, economic, and environmental change (Adger, 2000).
Specific resilience	Specific resilience looks at the resilience of what, to what (Carpenter et al., 2001), and for whom (Cutter, 2016; Le Dé et al., 2021). This approach identifies the system or attribute being considered, the disturbance in question, and who is affected. A specific resilience approach might ask "How resilient is tropical dry forest to fire in a changing climate, and how does this affect Indigenous livelihoods?" Adding the 'for whom' into assessments recognises that what is valued in systems depends on and varies amongst different stakeholder groups. See also 'general resilience'.
State; alternative state	The structure, function, and identity of a system reflecting the process regime. Alternative states emerge when the process regime changes. For example, exclusion of fire from a fire-dependent forest leads to the emergence of a different forest state over time (Beisner et al., 2003).
Sustainable forest management	A dynamic and evolving concept that aims to maintain and enhance the economic, social, and environmental values of all types of forests, for the benefit of present and future generations (FAO, 2018).
Telecoupling	The potential of social-ecological systems (SES) separated by geography and/or scale to interact with one another, laterally and/or vertically (between scales) (Liu, 2017). For example, conversion of the forest in the Amazon Basin to soybean production simultaneously has: global-scale influences on climate and commodity markets (affects near-to-distant SES); meso-scale influences on biodiversity, health, and employment (affects near-to-midrange SES); and local-scale influences on soil nutrients, cultures, and animal movements (affects near SES). The strength of these effects across scales is likely to depend on the scale at which the (for example) rainforest-to-cropland regime shift is occurring.
Transformation/ transformative capacity (in resilience literature)	The purposeful (with agency) weakening of the resilience of a system in an undesirable state to then collapse the system and guide its renewal into a desired state. Because outcomes cannot be assured, transformation is a high-risk proposition. Transformative capacity is the potential of a system to be intentionally shifted to a more desirable, self-organising state, characterised by new structures, processes, and feedbacks (Michaels et al., 2025).
Vulnerability	Concept rooted in the field of risks and hazards research, often posited as the opposite (or inverse) of resilience (Adger et al., 2005). Vulnerability has three key components: the exposure of a system to a given threat (i.e., the extent to which the system experiences the threat); the sensitivity of the system (i.e., the degree to which the system is likely to be affected by the threat); and the resilience of the system (i.e., the capacity of the system to absorb disturbances while maintaining its essential structures, functions, and feedbacks).

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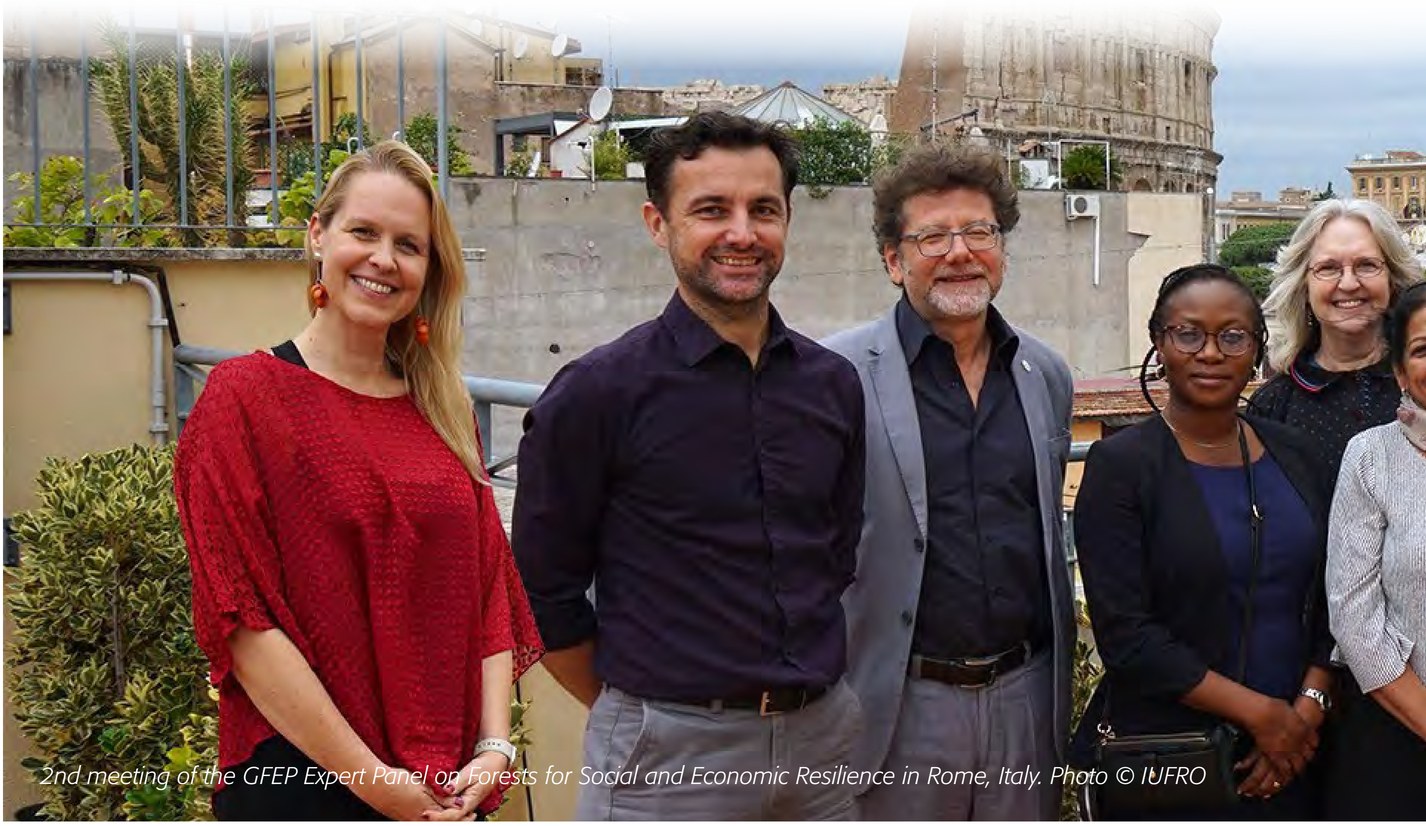

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