Chapter 11
Sustainable Forest Management (SFM) for C Footprint and Climate Change Mitigation

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11.1 Introduction

Nowadays government, stakeholders, and other common people are shifting from conventional forest management to sustainable forest management (SFM) to improve the productivity without affecting the environment. To implement the principles of sustainability, Sustainable Forest Management (SFM) requires adaptive measures, scrutiny of knowledge insights, and continuous monitoring of social, economical, and environmental factors. SFM is characterized by some identifiable features like trans-disciplinary, pluralistic, integrative nature, and heterogeneity that make it different from the conventional forest management approach. According to

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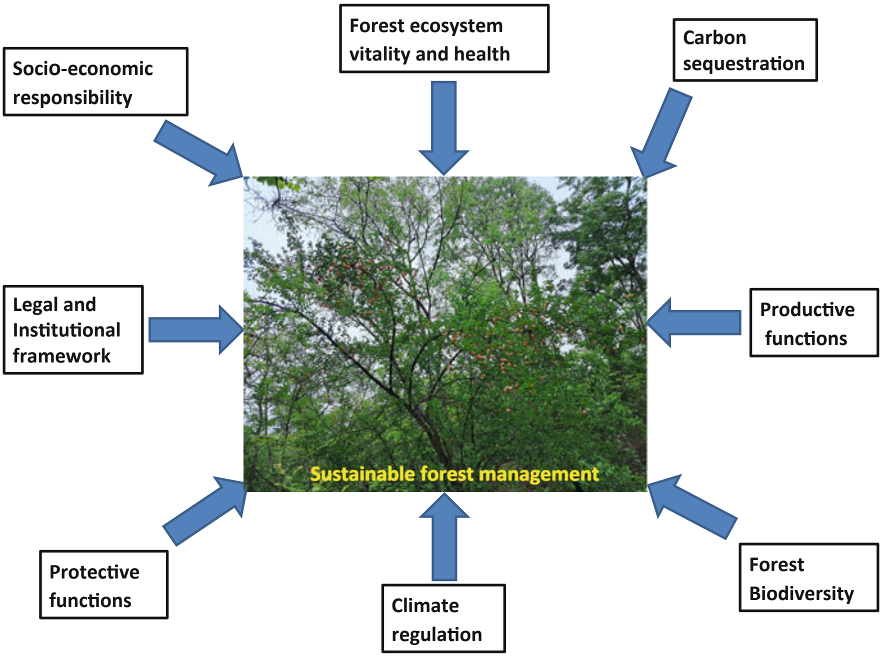

Fig. 11.1 Global-level thematic elements of SFM

Keenan (2015), approximately 30% of the Earth's land area is covered by forests, making it difficult to imagine a person who does not rely on forest products and services in their daily life (Köthke 2014). The economic contribution of forests is significant, providing various amenities that sustain livelihoods and safeguard our environment (MacDicken et al. 2015).

Managing the regenerative capacity of forests sustainably to ensure future benefits is a significant challenge, as emphasized by Nasi and Frost (2009) and Chow et al. (2013). This challenge gave rise to the concept of SFM, which recognizes the importance of sound management practices for both forest production and protection (Keeton and Crow 2009; Putz and Thompson 2020). The potential of SFM lies in two key aspects: the inherent ability of ecosystems to regenerate themselves and the adaptability of economic activities and social perceptions that influence human interaction with the ecosystem, ultimately safeguarding its long-term productivity and health, as stated by MacDicken et al. (2015). However, the planning of SFM must be tailored to climate change scenarios since climate plays a crucial role in adopting SFM strategies. Tropical, temperate, and boreal forests collectively provide diverse habitats for plants, animals, and micro-organisms, serving as homes to the majority of terrestrial species worldwide, according to the CBD (2009). Forests provide both productive and protective functions, supplying valuable resources and services while safeguarding the environment (Fig. 11.1). Sustainable management and conservation of forest resources are essential for ensuring their continued contribution to economic development, biodiversity conservation, climate regulation, and the well-being of present and future generations. The health of forests and the provision of various ecosystem services depend on species diversity, genetic diversity within species, and the diversity of forest types. The global-level thematic elements of SFM encompass key principles and components that are essential for the effective and holistic management of forests worldwide. These elements provide a framework for guiding policies, practices, and decision-making processes aimed at achieving sustainable outcomes for forests and the communities that depend on them. These elements include the productive and protective functions of forests, climate regulation, biodiversity conservation, forest health, socioeconomic considerations, and policy and institutional frameworks (Fig. 11.1).

11.2 Sustainable Forest Management (SFM) for C Footprint

SFM scheme assisted by forest certification with the green economy reduces the carbon footprint by C sequestration and also balances the economic, social responsibility, and environment to sustain the livelihood. SFM plays a key role in combating climate-related risk or climate variability and also ensures the environmental safety. SFM increases the carbon sequestration in both soil and plants which reduce the greenhouse gas emission to the atmosphere and lower the C footprint. SFM ensures the renewable carbon-neutral energy source from forest biomass and acts as a substitute for materials which are carbon intensive including cement and steel, thereby reducing C footprints and improving greenery economy.

11.3 Sustainable Forest Management (SFM) for Climate Change Mitigation in Tropical and Sub-tropical Regions

The implementation of SFM in tropical landscapes presents a unique challenge that necessitates disaggregated approaches for assessment, as highlighted by Köthke (2014). The definition of SFM in relation to tropical forests encompasses various categories, including managed, exploited, and unmanaged forests across landscapes, as well as protected areas, selectively logged natural forests, and logged forests subjected to additional silvicultural treatments (Putz and Thompson 2020). Many tropical forested areas face challenges such as weak administration, disputed land ownership, poverty, a high dependence on forests by local communities, intensified exploitation and deforestation, modest-to-high opportunity costs for forest conservation, and political conflicts.

The effectiveness of tropical protected areas within the framework of SFM relies heavily on governance, stakeholder consensus, adequate staff training and commitment, and sufficient funding (Bruner et al. 2001). In tropical and sub-tropical forests, SFM requires consideration of large enough landscapes that can sustain all values, including sustainable wood production and ecosystem services for people, without causing species losses. Individual protected areas often lack the size necessary to protect wide-ranging or rare species. However, proper management of buffer areas surrounding protected areas can establish connectivity, which is crucial for the persistence of certain species on a larger scale, as highlighted by Hodgson et al. (2011). Unmanaged or primary forests, which show no visible signs of human intrusion according to FAO (2018), are rapidly declining.

A recent article by Potapov et al. (2017) reported a global decline of 7.2% in the area of intact forests, defined as areas larger than 500 km^2 without roads, between 2000 and 2013. Intact forests are already absent in many tropical countries. Several large-bodied and heavily exploited animal species in tropical regions, such as the Asian elephant (*Elephas maximus*), African forest elephant (*Loxodonta cyclotis*), tiger (*Panthera tigris*), and harpy eagle (*Harpiaharpyja*), depend on intact forests for their survival (Kinnaird et al. 2003; Barlow et al. 2011; Birdlife International 2017; Roopsind et al. 2017). Furthermore, intact forests have high conservation value, as research shows that up to 94% of designated blocks of selectively logged forest remain intact due to factors such as absence of commercial timber, unfavourable conditions, poor planning, and insufficient supervision, as stated by Putz et al. (2019). The rate of intact forest loss has generally been higher compared to areas outside designated protected forests, although intact forest areas within parks also experience degradation.

In most tropical countries, timber stocks fail to recover to primary-forest levels within the officially designated minimum cutting cycle as per current regulations. For instance, in Amazonian Brazil, it takes over 60 years for timber volumes to recover after conventional timber harvest, as reported by Vidal et al. (2020). A meta-analysis based on numerous studies of yield recovery (over 100 publications) indicates significant variability in timber yield, with a decline of approximately 46% from the first to the second harvest (Putz et al. 2012). It is worth noting that while many tropical forests are logged multiple times, most of the reviewed studies focused on timber harvests from primary forests. Overall, the review suggests that despite the conservation potential of selective logging on a large scale, SFM is currently compromised in many tropical regions due to poor logging practices and premature re-entry logging after previous harvests (Sasaki et al. 2016; Ellis et al. 2019).

11.4 Sustainable Forest Management (SFM) for Climate Change Mitigation in Temperate Region

At the global level, policies and regulations pertaining to SFM have been reported to cover 97% of the world's forested areas. However, despite these efforts, sustainable forest operations and other factors such as fuelwood collection can contribute to forest degradation and negatively impact biodiversity within ecosystems. Disturbingly, more than 50% of the temperate broadleaf and mixed forest biome, as well as nearly 25% of the tropical rainforest biome, have experienced fragmentation or destruction due to various human activities, as documented by Secretariat of the Convention on Biological Diversity (SCBD) (2006).

To ensure the sustainable management of temperate forests, it is crucial to develop and implement appropriate and region-specific Forest Management Planning (FMP). MacDicken et al. (2015) conducted a global meta-analysis and observed that the proportion of land area under FMP was relatively high in temperate domains (63%), compared to tropical and subtropical domains, which had approximately 28% coverage (Table 11.1). However, the mere presence of an FMP does not guarantee its effective execution. Nevertheless, having an FMP in place is a positive step toward establishing conditions favourable for SFM. It is worth noting that successful long-term SFM can also be achieved without a written management plan, as evidenced by multi-generational family management of private forests. Monitoring of FMP implementation by governments plays a vital role in improving compliance with pre-determined strategies. The meta-analysis revealed that 40% of FMPs in tropical climates were monitored annually, followed by 38% in the boreal domain and 32% in the temperate domain (Fig. 11.2). In contrast, the subtropical domain showed a lower frequency of monitoring events, with only 22% of FMPs being monitored annually. On average, FMPs in the tropics were monitored and evaluated once every 2.5 years to ensure their smooth functioning (MacDicken et al. 2015). Globally, the adoption of forest management planning and the monitoring of plans has significantly increased, covering over 430 million hectares by 2014. However, it is worth noting that internationally verified certification is predominantly concentrated in the boreal and temperate climatic domains, accounting for

Table 11.1 Forest area with FMP by climatic domain. (Source: MacDicken et al. 2015)

Domain	Forest under FMP		FMP for conservation	
	Area (000 ha)	% of domain forest area	Area (000 ha)	% of domain forest area
Tropical	5,09,761	28.2	2,03,787	11.3
Temperate	4,24,971	63.1	2,09,428	31.1
Boreal	10,73,801	87.7	4,01,497	32.8
Boreal without Russia	2,58,656	63.1	7852	1.9
Sub-tropical	91,131	28.5	28,678	8.9
Total	20,99,664		8,43,391	

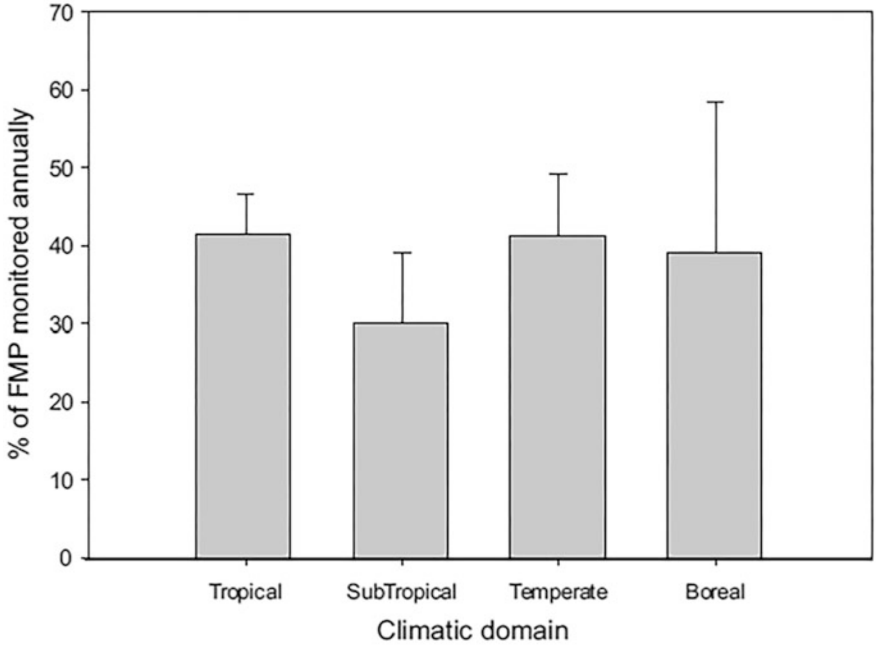

Fig. 11.2 Average proportion of forest management plans monitored annually by climatic domain (bars are the standard error of the mean) (Source: MacDicken et al. 2015)

90% of the total certifications. In contrast, only 6% of permanent forests in the tropical domain have been certified (MacDicken et al. 2015).

Over the next 30 years, it is projected that the consumption of primary timber products will increase, and the utilization of solid biofuels for electricity generation could be three times higher by 2030 compared to the present level (FAO 2018). Furthermore, it is anticipated that the demand for industrial round wood will rise by 50–75% by 2050, reflecting the overall growth in demand (Sedjo 2001). As a consequence of this escalating demand, the area of tropical forest plantations more than doubled between 1995 and 2005, reaching 67 million hectares, primarily concentrated in Asia. Plantations in boreal and temperate regions have also experienced some level of expansion, and this upward trend is expected to persist (ITTO 2006). However, the use of a limited number of tree species in these plantations and modified natural forests raises concerns regarding ecosystem resilience (Hagar 2007).

11.5 Forest Certification and REDD+ as New Approach for Healthy Forestry

Forest plays a very crucial role in fulfilling the material needs of humans as well as adding the aesthetic value to the society, protecting the environment from natural calamities, and also maintaining the quality of natural resources like soil, water, and environment by the process of waste water processing, ground water recharge, reducing effects of noise, erosion control, binding, and inactivation of toxic substances present in soil and water. Thus, along with the regeneration of new forests, it is of utmost importance to maintain the existing forests and to assess and monitor their functions through some scientific criteria. Forest certification is one such method which can promote better management of forests by providing environmental and financial assistance through forest and forest products.

11.5.1 What Is Forest Certification?

Forest certification is a program of judging the forest management practices by comparing with a series of pre-set standards based on environmental, social and economic perspectives for monitoring, and tracing and labelling the forest products, for example, timber and non-timber forest products and pulp, etc.

11.5.2 Aim of Forest Certification

1. Achieving SFM through market forces
2. Reducing greenhouse gas (GHG) emissions through healthy forests' sequestration potential for carbons

The government regulations are very unlikely to be imposed successfully at every corner of the world, improving the economic value of forest produce could be used as a way to motivate people for better forest management.

- Certification ensures better protection to the existing forests and adequate financial returns from sustainably managed forests.
- Secondly, a healthy forest can absorb a tremendous amount of carbon dioxide which can potentially reduce the carbon load in the environment.
- Along with climate change mitigation, the huge carbon sequestrating capacity of the forest trees offers a generation of carbon credits which can generate another source of income for the forest landowners.

11.5.3 Forest Certification Process

The two separate processes of forest certification deal with monitoring the forest management practices as well as movement of certified forest products from its origin to the point of sale (Fig. 11.3) (awsassets.wwfindia.org/). For example, the Forest Stewardship Council (FSC) is one of the globally established reliable certification schemes.

11.5.4 Forest Management Certification

In the forest certification method, the forestry operations are analysed to assess whether the operations are up to a predetermined set of standards or not. On meeting the desired standards, the landowner is issued with a certificate with the potential to market the products as certified products brought from the certified forests. Forest certification addresses the quality of forest management.

In order to attend SFM, some of the national and international criteria are being set. The indicators for forest management which are being set by the Montreal Process are as follows:

- Biodiversity conservation, maintenance of forest ecosystem and productivity of forests
- Conservation and maintenance of soil and water resources
- Observing the contribution of forest entities to carbon cycles
- Enhancement and maintenance of long-term socioeconomic benefits
- Construction of legal, institutional, and economic frameworks for sustainable management and conservation of forest (The Montreal Process 2015)

Broadly forest certification is done to identify and promote well-managed forest lands and to recognize the products of sustainably managed forests (Bettinger et al. 2016). Forest certification has certain benefits on the marketability of products obtained from such forests. For example, these products are eventually recognized as premium products and demand high price from the buyers. Also, the certified

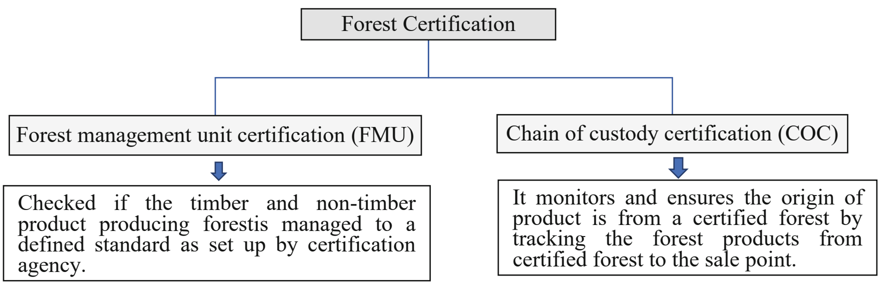

Fig. 11.3 Types of forest certification processes

products get access to certain high-quality markets, have new market penetration potential, and show increased sales too (Paluš et al. 2018; Yamamoto et al. 2014; Aguilar and Vlosky 2007). The forest certification scheme owing to its monetary benefit to the managers and land owners can better act as a way for healthy forest and for ensuring forest ecosystem services.

11.5.5 REDD+

Globally around 11% of global greenhouse gas emission is accounted to forest degradation and deforestation. The forest ecosystem can successfully uptake a huge amount of atmospheric CO_2 and store it in huge tree biomass and soils thereby carrying out an important role in climate change mitigation. Like forest certification, REDD+ also promotes SFM activities to reduce forest degradation by providing financial assistance to the countries promoting forest preservation and conservation activities.

REDD+ (also recognized in Article 5 of the Paris Agreement) is a framework to guide activities to reduce forest degradation and deforestation (Fig. 11.4). This aims to implement REDD+ activities at both the national and sub-national levels of government to reduce anthropogenic pressure on forests. The developing countries will receive payments in exchange for proof that they have reduced deforestation or for demonstrating their forest preservation activities.

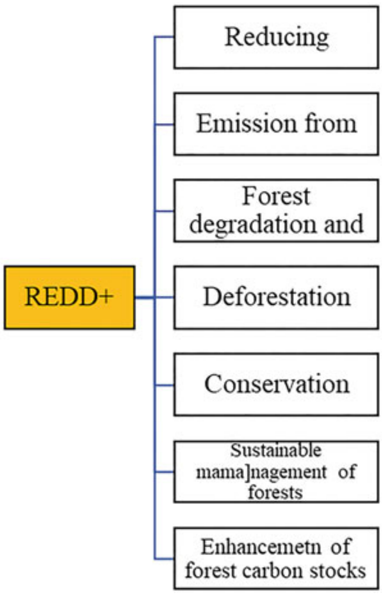

Fig. 11.4 Components of REDD+ (Cosslett 2013)

11.5.6 Phases of Working of REDD+

1. **Readiness phase**: Development of national strategies or action plans, policies and measures, and capacity-building.
2. **Implementation**: Implementation of the set policies and action plans. The results of such policy implementation are used as case studies for public demonstration. Also, the outcomes can be used as feedback for further capacity-building.
3. **Results-based report**: The results of the implemented actions are fully verified and reported and the countries are allowed to seek results-based payments (FAO.org).

11.6 Challenges for Sustainable Forest Management (SFM) to Mitigate Climate Change

Implementing SFM in a diverse country like India poses significant challenges. SFM, being aligned with sustainable development, carries crucial implications for the global economic landscape. The foremost challenge of the coming decades is climate change, which poses a threat to surpass the safe planetary boundaries for humanity (Rockstrom et al. 2009). Consequently, climate change has garnered considerable attention from the scientific community and policymakers, with a primary focus on mitigating human-induced interference with the climate system (IPCC 2007). Scientific research has provided irrefutable evidence that global warming is already occurring (IPCC 2007). The previously stable average global temperature is now rising at a rate of 0.2 °C per decade (Hansen et al. 2010), and the continued increase in greenhouse gas (GHG) concentrations will further elevate the temperature. The causes of this global climate change include the escalated release of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Human activities, including land-use changes, deforestation, and the burning of fossil fuels, have been the primary contributors to increased carbon dioxide emissions. Without effective policies to restrict human-induced emissions, the global average temperature is projected to increase by 1.1–6.4 °C by 2100 (IPCC 2007).

Forests play a crucial role in the global carbon cycle. Forest ecosystems contain a substantial amount of carbon, estimated to be around 1200 gigatonnes (Gt), which represents a significant portion of terrestrial carbon and surpasses the amount of carbon (550 Gt) stored in the atmosphere (IPCC 2001). Climate, with its variability and changing patterns, exerts a significant influence on forest growth, development, migration, succession, and regeneration. While climate information has traditionally been incorporated into local or regional forest management decisions, the global impact of climate has often received limited attention. However, the projected changes in global climate pose threats to SFM. Therefore, it is imperative to develop

Table 11.2 Top ten countries in terms of forest area (2020)

Sl. No	Country	Forest Area (000 ha)	% of world forest area	% of country area
1	Russian federation	8,15,312	20	49.8
2	Brazil	4,96,620	12	59.4
3	Canada	3,46,928	9	38.7
4	USA	3,09,795	8	33.9
5	China	2,19,978	5	23.3
6	Australia	1,34,005	3	17.4
7	Democratic Republic of Congo	1,26,155	3	55.6
8	Indonesia	92,133	2	49.1
9	Peru	72,330	2	56.5
10	India	72,160	2	24.3
	Total	**4,85,438**	**66**	

Source: ISFR (2021)

a climate plan as an integral part of SFM, encompassing improved strategies for regeneration and protection to adapt to these changes.

Human-induced climate change presents potential risks to forests and poses future challenges for forest managers. Addressing climate change, through both mitigation and adaptation measures, necessitates transformative changes in forest management and research. Climate change is leading to increasing temperatures and alterations in precipitation patterns, including changes in snowfall and the timing, quantity, and variability of rainfall (IPCC 2013). Forests are long-lived ecosystems that are inherently complex to manage, both internally and externally. They are also susceptible to the impacts of long-term climatic changes, as are the societies and economies reliant on them. Climate change amplifies the significance of numerous existing challenges related to environmental, social, and economic changes.

In India, the total forest and tree cover spans 80.9 million hectares, accounting for 24.62% of the country's geographical area (ISFR 2021). Climate change hotspots within Indian forests, as identified by India State of Forest Report (ISFR) (2021), indicate that approximately 45–64% of forests in the country will experience adverse effects from climate change and rising temperatures by 2030. Among the states, except for Nagaland, Tripura, Meghalaya, and Assam, most forested regions in India are highly vulnerable to climate change. The Union Territory of Ladakh is expected to be particularly impacted by climate change and rising temperatures. The total forest cover in India spans 72,160 ha, equivalent to 24.3% of the country's geographical area, while the tree cover represents 2.91% of the geographical area (Table 11.2). According to ISFR (2021), the latest assessment indicates a combined increase of 0.38% in forest and tree cover at the national level, with forest cover increasing by 0.22% and tree cover by 0.76% (Table 11.3).

To achieve these goals, information, innovation, and implementation are the three essential factors that rely on human resources to make them a reality.

Table 11.3 Top ten countries for average net gain in forest area (2010–2020)

Sl. No	Country		Annual forest area gain
		Area (000 ha)	% 2010 forest area
1	China	1937	0.93
2	Australia	446	0.34
3	India	266	0.38
4	Chile	149	0.85
5	Vietnam	126	0.90
6	Turkey	114	0.53
7	USA	108	0.03
8	France	83	0.50
9	Italy	54	0.58
10	Romania	41	0.62

Source: IFSR (2021)

11.7 Challenges of SFM for Government, Research Scientists, and Institutions

Forests are a global resource, and effectively dealing with important issues related to their use and maintenance requires global participation. To fully understand and address the challenges in forest science, it is essential to establish an appropriate framework and enhance our capacity to generate knowledge for a sustainable future. A balanced approach is crucial for the successful management and development of forests, ensuring their existence at acceptable levels for the benefit of present and future generations.

1. Addressing the drivers of forest degradation and deforestation, and enabling SFM, requires greater innovation and better coordination in global forestry dialogue, national sector planning, and technical analysis. Demonstrating the potential of forests to reduce poverty, support economic growth, and provide environmental services at local and global levels necessitates close collaboration between donors and governments, linking forest sector activities with national strategies. Promoting forest ownership and access rights, as well as emphasizing stakeholder participation in policy formulation and implementation, are essential for poverty reduction and effective forest governance.
2. One of the main challenges with sustainability is its multidimensionality. Achieving a state of sustainable development requires progress in one dimension without compromising progress in other dimensions. Climate change, although initially perceived as an environmental issue, is closely interconnected with various sectors in society, such as energy. Climate policy cannot be confined solely to environmental policy as it encompasses multiple fields. National governments often struggle to determine how they will precisely achieve their goals, leading to a significant gap between expected emission reductions and global commitments.

3. The gap in forestry research capacity and the translation of practical results between developing and developed countries remains unacceptably wide. However, highly efficient and locally adapted low-cost technologies often contain a substantial amount of research-based knowledge. Unfortunately, the state of forestry research in many developing countries is characterized by a lack of political commitments, a shortage of scientists with diverse expertise, limited methodological and technological innovation, and inadequate funding for research programs. Consequently, forestry research in these places has not significantly evolved to address current and future global, national, or local issues, hindering the development of sustainable forest.
4. The implementation of climate policy administration patterns is not always clear-cut. In Italy, a significant number of responsibilities have been transferred to lower levels of government, while environmental issues remain predominantly centralized. In France, a central government policy is supplemented by the expectation that regions will develop their own plans incorporating climate change considerations, although only a few countries or regions have done so.
5. Challenges lie ahead for governments in the process of redefining the sharing of authority between different entities with regards to climate change. National governments grapple with the complexities of climate change and face difficulties in finding effective solutions within existing monitoring frameworks. Relations with lower levels of government are being revisited to foster greater unity in policymaking and explore new opportunities. Local governments play a crucial role in spatial planning, transportation, housing, and energy. SFM is a highly complex task that requires a comprehensive approach, including policy frameworks, strengthened governance, removal of market distortions, and engagement of market actors, full valuation and sharing of forest benefits through market mechanisms, capacity building, and mobilization of adequate financial resources.

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