Chapter 2
Defining Climate-Smart Forestry

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Abstract Climate-Smart Forestry (CSF) is a developing concept to help policy-makers and practitioners develop focused forestry governance and management to adapt to and mitigate climate change. Within the EU COST Action CA15226, CLIMO (Climate-Smart Forestry in Mountain Regions), a CSF definition was developed considering three main pillars: (1) adaptation to climate change, (2) mitigation of climate change, and (3) the social dimension. Climate mitigation occurs through carbon (C) sequestration by trees, C storage in vegetation and soils, and C substitution by wood. However, present and future climate mitigation depends on

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R. Tognetti et al. (eds.), *Climate-Smart Forestry in Mountain Regions*, Managing Forest Ecosystems 40, https://doi.org/10.1007/978-3-030-80767-2_2

the adaptation of trees, woods, and forests to adapt to climate change, which is also driven by societal change.

Criteria and Indicators (C & I) can be used to assess the climate smartness of forestry in different conditions, and over time. A suite of C & I that quantify the climate smartness of forestry practices has been developed by experts as guidelines for CSF. This chapter charts the development of this definition, presents initial feedback from forest managers across Europe, and discusses other gaps and uncertainties, as well as potential future perspectives for the further evolution of this concept.

2.1 Introduction

Anthropogenic climate change has been described as the "*defining issue of our time*" (United Nations 2020). This chapter and the whole book will focus on one potential solution of how to manage our trees, woods, and forests to enable them to adapt to and mitigate climate change for the benefit of human society and wider biodiversity. This is Climate-Smart Forestry (CSF).

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2.1.1 Why Do we Need Climate Smart Forestry?

Like all specialist disciplines, forest management is replete with jargon, a language that is helpful to the subject expert, but alienating to policymakers, the public, and even practitioners (who may not always keep up with the latest scientific developments in their field). Recent examples of jargon to describe land management approaches, including forestry, are "ecosystem services" and "natural capital." Some jargon such as "nature-based solutions" seem accessible and obvious to the user, as to a certain extent the phrase describes the purpose, but others such as "rewilding" clearly mean many different things to many people. Even more established apparently descriptive phrases can be deceptive in their complexity. For example, although "sustainable forest management" is a term that forestry academics and researchers understand and are able to expand as a definition 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 2020).

Most ordinary forest workers and users (stakeholders) are more likely to describe it as a way of managing trees so that when some of them are harvested, the forest survives. This is in fact closer to the first published definition of sustainability itself, which derives from "Sylvicultura Oeconomica," (von Carlowitz 1713) which described "*the sustainable management of forest resources*."

It could be argued that sustainable forest management (SFM) already addresses climate change by maintaining and enhancing environmental values for the benefit of present and future generations. However, a challenge of SFM, and also of an ecosystem services approach, is that managers aim to fulfill many objectives simultaneously. Inevitably there are trade-offs, which means that some attempt to value, or rank, objectives in terms of priorities is necessary. For those who believe that climate change is the greatest challenge of our times, CSF is an approach that identifies the adaptation of trees, woods, and forests to climate change and the use of forestry to mitigate climate change as the priority for SFM, so that other ecosystem services can be provided now and in the future.

2.1.2 Definition and Approaches to Climate Smart Forestry

This chapter derives from the work of Working Group 1 in an EU Co-operation in Science and Technology (COST) Action, CA15226, Climate Smart Forestry in Mountain Regions (CLIMO). It comprises a brief review of the literature concerning the novel concept of CSF, a definition developed in a participatory approach led by the working group, an introduction to using criteria and indicators familiar from SFM approaches for CSF, an analysis of gaps and uncertainties in the definition and approaches, a consideration of the perspective of forest management and finally, an indication of how the CSF process should develop to become more than just another piece of jargon, but a tool to enable policymakers and practitioners to protect, improve, and enhance the management of our trees woods and forests in our climate changed world.

2.2 A Brief History of Climate Smart Forestry

To be able to put CSF in context, it is important to know the evolution of our understanding of the role of forests in the global climate. Keeling (1960) suggested that the observed seasonal trend in CO_2 in the atmosphere (i.e., the zigzag of the Keeling Curve) was the result of net photosynthesis in the northern hemisphere. Tans et al. (1990) improved our understanding of the role that global and especially northern hemisphere forests were playing in the global carbon cycle.

Forests gained a lot of attention because of their large C pools in biomass and soil (Dixon et al. 1994), especially as C turnover time in forest ecosystems is much longer than agricultural and grassland areas (Harmon 1992). Thus, it became an urgent issue to determine the amount of C sequestration and fluxes in biomass and soil pools after large areas of deforestation in tropical forests in the 1980s (Kimmins 1997).

The early and mid-1990s became the time of negotiations working toward the Kyoto Protocol, the first worldwide legally binding agreement aimed at reducing global greenhouse gas emissions. With information about the role of forests being incomplete and scarce at the time, debates in Kyoto swung between encompassing global forests in a binding agreement to completely omitting their role due to the lack of insight and genuine concerns that forests might be used for greenwashing (i.e., the role of forests was confined to strictly human-induced activities). It was believed that these activities would be clearly discernible (well monitored) and their role limited. Article 3.3 (and 3.4) stated:

> *.. direct human induced land use change and forestry activities limited to afforestation, reforestation, and deforestation since 1990…* (UNFCC 1997).

Article 3.4. specified additional measures in forest management. However, since the overall reduction target was very small, there were fears that forests would be used for obscuring this small target, rather than actually reducing emissions from other sectors. Therefore, a long period of uncertainty about rules and the role of forests began. An IPCC special report on Land Use, Land Use Change and Forestry (LULUCF; Watson et al. 2000) only increased the controversy, partly because of its complexity and partly because of the very large potentials identified. For example, under Article 3.4 alone, a potential reduction of 9 Gt CO_2/y in 2040 was identified. For comparison: in the mid-1990s, the total global greenhouse gas (GHG) emissions from fossil fuels were around 26 Gt CO_2/y. However, because of the complexity of rules and guidelines and the low overall reduction targets, not much happened in the land use sector as a result of the Kyoto Protocol until forests were specifically included in Article 5 of the Paris Agreement (UNFCC 2015) and subsequently, the accounting rules for the inclusion of LULUCF in climate targets (Korosuo et al. 2020) were published.

The scope for activities in the land use sector widened, in part because of a narrow focus on mitigation and also because of controversy over large-scale monoculture plantations for afforestation. Nature-based solution was the term that attempted to capture biodiversity and social issues at the same time, defined by the International Union for Conservation of Nature as follows:

> *Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits* (Cohen-Shacham et al. 2016).

According to the definition of the Institute of Development Studies:

> *being "climate smart'" describes an organization's ability to manage existing and future climate change risks while taking advantage of opportunities associated with climate change* (IDS 2007).

In agricultural sciences, this term was firstly adopted as Climate Smart Agriculture (CSA) by the FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010 (FAO 2013) and refined by Lipper et al. (2014), but can be traced back to the 1990s when the growing awareness of farmers needing to adapt to new constraints due to climate change was first recognized (Easterling et al. 1992). The CSA definition integrates three main elements: (1) productivity, which refers to the sustainable increase of agricultural productivity and incomes from crops, livestock, and fish, without negative impact on the environment; (2) adaptation to climate change refers to make production systems more resilient and better able to withstand extreme weather events; and (3) mitigation – referring the reduction and/or removal of the greenhouse gases released by agriculture (The World Bank 2016).

The term "climate smart forestry" was first launched in 2008 (Nitschke and Innes 2008) and the CSF concept was first used in 2015 (Nabuurs et al. 2015) and since then has been modified through interactions with multiple stakeholders providing input to develop the concept (Bowditch et al. 2020; Kauppi et al. 2018; Nabuurs et al. 2017; Nabuurs et al. 2018; Verkerk et al. 2020; Yousefpour et al. 2018). CSF can arguably be seen as a category of Nature-Based Solutions with a focus on forests and forestry, which increasingly provides evidence on the effects of climate change (Schelhaas et al. 2003).

In summary, CSF initially developed as a similar concept to the CSA concept of FAO (FAO 2013) with a focus on using forestry to mitigate climate change (rather than adapting forest to climate change), while considering regional differences (Nabuurs et al. 2018).

2.3 A Definition from the EU COST Action Climate Smart Forestry in Mountain Regions

In 2016, an EU Co-Operation in Science and Technology (COST) Action was established to develop a concept of CSF with a particular focus on European mountain forests (Tognetti 2017). The aim of Working Group 1 within this COST Action Climate Smart Forestry in Mountain Regions (CLIMO) was to translate the CSA concept to forestry developing a definition and selecting Criteria and Indicators C&I) for CSF (COST Action CA15226 2016).

The new CSF definition was developed on three main thematic areas: 1) mitigation, 2) adaptation, and 3) social dimension and integrates the three-dimensions of sustainable development (economic, social, and environmental) (COST Action CA15226 2016; Bowditch et al. 2020) (Fig. 2.1).

Within the framework of the COST Action CLIMO, a wide range of experts with different expertise contributed to the development of a new CSF definition through interactive discussions during and between three separate meetings of Working Group 1 and cross-Working Group engagement (Bowditch et al. 2020), involving representatives from 28 countries (http://climo.unimol.it/). It was specifically intended that this definition should be no longer than one page for ease of sharing (Fig. 2.2).

Some of the aspects underlying the definition have been studied experimentally. Jandl et al. (2018) focusing on climate smart management strategies for Austrian forests, examined and evaluated carbon dynamics in the stem biomass and soils. The authors concluded that the production of long-living wood products is the preferred implementation of CSF, and the production of bioenergy is suitable as a by-product of high-value forest products (Jandl et al. 2018). However, CSF measures can vary from country to country and region to region depending on different circumstances (e.g. socioecological and technological framework, climate change impacts, and cultural aspects), and the success of CSF requires the balance between them (Verkerk et al. 2020). Indeed, case studies in three European regions (Spain, Czech Republic, and Republic of Ireland) differ in the composition and history of their forests and forest sectors, clearly demonstrating that CSF mitigation measures need to consider local- or country-specific conditions (Nabuurs et al. 2018).

Fig. 2.1 The main pillars of Climate-Smart Forestry

***Climate-smart forestry** is sustainable adaptive forest management and governance to protect and enhance the potential of forests to adapt to, and mitigate climate change. The aim is to sustain ecosystem integrity and functions and to ensure the continuous delivery of ecosystem goods and services, while minimising the impact of climate-induced changes on forests on well-being and nature's contribution to people.*

Adaptation measures forests that maintain or improve their ability to grow under current and projected climatic conditions and increase their resistance and resilience. The adaptive capacity to changes in climate and to the timing and size of climate-induced disturbances (e.g., fire, extreme storm events, pests and diseases) can be enhanced by promoting genetic, compositional, structural, and functional diversity at both stand and landscape scales. This includes facilitating natural regeneration and planting of native as well as non-native tree species, genetic variants and individuals that are considered to be adapted to future conditions. Increased connectivity assists the migration of forest species.

Mitigation of climate change by forests is a combination of carbon sequestration by trees, carbon storage by forest ecosystems, especially soils, and forest derived products, such as structural timber, and by carbon substitution -directly by replacing fossil fuels with bioenergy and indirectly through use of wood to substitute for higher carbon footprint materials.

The ***social dimension*** of forestry holds many aspects, from the involvement of stakeholders from local communities, and their conflicts over land use or for the access to skills and technology, to global forest governance challenges. Climate change may jeopardize forest ecosystem functioning and brings social and economic consequences for people, which may modify priorities of ecosystem services at various scales. Assessment for ecosystem services could be a tool making this process more efficient with respect to indicators relevant for governance regime and actors involved.

In summary, **climate-smart forestry** should enable both forests and society to transform, adapt to and mitigate climate-induced changes.

Fig. 2.2 Climate smart forestry (CSF) definition from the EU COST CA15226, Climate Smart Forestry in Mountain Regions (Bowditch et al. 2020)

2.4 Criteria and Indicators for the Assessment of Climate-Smart Forestry

2.4.1 Assessing Climate Smart Forestry

Recent advances on the concept of CSF in Europe have encouraged the development of tools and approaches to measure its effects on forest health, function, and productivity.

Concepts such as CSF are only meaningful if they are developed with suitable C&I to monitor whether the principles outlined in the definition are being adopted over time. Indicators need to balance ease of collection against being as detailed as possible, but general enough to be widely applicable. For CSF, an indicator is a variable, generally quantitative, that enables one to describe the status of forests and forestry as well as trends in forest development. It needs to be applicable in as many forest ecosystems and methods of forest management as possible allowing comparisons across temporal and spatial scales.

2.4.2 Criteria and Indicators for Sustainable Forest Management

Rather than reinventing the wheel, the COST Action participants first evaluated the existing pan-European C&I for SFM (Santopuoli et al. 2016; Wolfslehner and Baycheva-Merger 2016). In the past 30 years, as a result of several initiatives about sustainable development, numerous sets of C&I for SFM have been proposed worldwide (Castañeda 2000; Linser et al. 2018). In Europe, the main driving force involved in the implementation of C&I for SFM is FOREST EUROPE, a multi-stakeholder participatory process currently involving 46 European countries and the European Union (EU) as signatory bodies. Since the 1990s, seven Ministerial Conferences have taken place (Fig. 2.3), within which C&I for SFM were defined and adopted.

The first set of C&I for SFM was approved at the Lisbon pan-European conference of 1998 (MCPFE 2001), as were the "Pan-European Operational Level Guidelines for SFM" that became the basis for the development of the forest certification scheme Programme for the Endorsement of Forest Certification (PEFC) (Rametsteiner and Simula 2003).

The first set of C&I was improved at the Vienna Ministerial Conference (MCPFE 2003), and subsequently updated in Madrid 2015 (Forest Europe 2015). This robust process has currently led to 6 criteria, 34 quantitative indicators (Table 2.1), and 11 qualitative indicators covering all aspects of SFM.

Although their implementation is not legally binding, the Pan-European C&I for SFM generated a broad variety of responses among FOREST EUROPE signatory bodies and were formally adopted by the signatory bodies as a policy framework for

Fig. 2.3 Forest Europe Ministerial Conference on the Protection of forests in Europe (Former MCPFE) timeframe. The eighth Ministerial Conference will take place in April 2021 in Bratislava (Slovakia)

forest management concerns. The Pan-European C&I for SFM are collected in a harmonized way, are broadly accepted by policy makers, cover the most important forest ecosystem services, and are publicly available. This makes them a suitable basis for further development toward an indicator set for the assessment of CSF at a European scale.

2.4.3 From Sustainable Forest Management to Climate-Smart Forestry Indicators

The COST Action participants assessed these SFM C&I and judged twenty-five indicators to be highly relevant to CSF, four new indicators were also identified by the CLIMO participants. As a result, a total of 29 indicators were selected as suitable to assess climate adaptation and mitigation by CSF (Bowditch et al. 2020).

Some challenges for C&I implementation across signatory countries are still evident (Santopuoli et al. 2016; Wolfslehner and Baycheva-Merger 2016), even if they provide great support to assess many aspects of SFM, and most of them are useful to support the assessment of CSF (Bowditch et al. 2020; Santopuoli et al. 2020).

Selecting or developing new indicators to assess CSF requires a multidisciplinary approach that covers all the aspects of SFM, which are related to climate change. Beyond modelling approaches (Mäkelä et al. 2012; Pretzsch et al. 2014; Zeller and Pretzsch 2019) that provide useful information on long-term forest growth to promote adaptive forest management, CSF should support forest decision-makers and managers to help adapt to and mitigate climate change while maintaining long-term ecosystem service provision. For example, focusing on C storage by prioritizing soil sustainability and extending the life cycle of timber products through the circular bioeconomy.

Focusing on the climate smart vision, 10 out of 34 quantitative indicators are the most recurrent indicators used for monitoring the effects of climate change on forest resources (Santopuoli et al. 2020). Particularly important were the indicators 1.4

Table 2.1 Criteria and Indicators for Sustainable Forest Management. Sources: Updated Pan-European Indicators for Sustainable Forest Management, as adopted by the FOREST EUROPE Expert Level Meeting 30 June – 2 July 2015, Madrid, Spain. Accessed (https://foresteurope.org), June 2020. Accessed 25 Jan 2021. Five qualitative indicators for forest policy are followed by the 6 criteria each with a qualitative indicator and one or more quantitative indicators (34 in all)

	No.	Indicator	
Forest policy and governance	1	National Forest Programmes or equivalent	
	2	Institutional frameworks	
	3	Legal/regulatory framework: National (and/or subnational) and international commitments	
	4	Financial and economic instruments	
	5	Information and communication	
Criteria	No.	Indicator	Full text
Criterion 1: Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles	C.1	Policies, institutions, and instruments to maintain and appropriately enhance forest resources and their contribution to global carbon cycles	
	1.1	Forest area	Area of forest and other wooded land, classified by forest type and by availability for wood supply, and share of forest and other wooded land in total land area
	1.2	Growing stock	Growing stock on forest and other wooded land, classified by forest type and by availability for wood supply
	1.3	Age structure and/or diameter distribution	Age structure and/or diameter distribution of forest and other wooded land, classified by availability for wood supply
	1.4	Forest carbon	Carbon stock and carbon stock changes in forest biomass, forest soils, and in harvested wood products
Criterion 2: Maintenance of forest ecosystem, health, and vitality	C.2	Policies, institutions, and instruments to maintain forest ecosystems health and vitality	
	2.1	Deposition and concentration of air pollutants	Deposition and concentration of air pollutants on forest and other wooded land
	2.2	Soil condition	Chemical soil properties (pH, CEC, C/N, organic C, base saturation) on forest and other wooded land related to soil acidity and eutrophication, classified by main soil types
	2.3	Defoliation	Defoliation of one or more main tree species on forest and other wooded land in each of the defoliation classes
	2.4	Forest damage	Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic, and human induced)
	2.5	Forest land degradation	Trends in forest land degradation

(continued)

Table 2.1 (continued)

	No.	Indicator	
Criterion 3: Maintenance and encouragement of productive functions of forests (wood and nonwood)	C.3	Policies, institutions, and instruments to maintain and encourage the productive functions of forests	
	3.1	Increment and fellings	Balance between net annual increment and annual fellings of wood on forest available for wood supply
	3.2	Roundwood	Quantity and market value of roundwood
	3.3	Nonwood goods	Quantity and market value of nonwood goods from forest and other wooded land
	3.4	Services	Value of marketed services on forest and other wooded land
Criterion 4: Maintenance, conservation, and appropriate enhancement of biological diversity in forest ecosystems	C.4	Policies, institutions, and instruments to maintain, conserve, and appropriately enhance the biological diversity in forest ecosystems	
	4.1	Diversity of tree species	Area of forest and other wooded land, classified by number of tree species occurring
	4.2	Regeneration	Total forest area by stand origin and area of annual forest regeneration and expansion
	4.3	Naturalness	Area of forest and other wooded land by class of naturalness
	4.4	Introduced tree species	Area of forest and other wooded land dominated by introduced tree species
	4.5	Deadwood	Volume of standing deadwood and of lying deadwood on forest and other wooded land
	4.6	Genetic resources	Area managed for conservation and utilization of forest tree genetic resources (in situ and ex situ genetic conservation) and area managed for seed production
	4.7	Forest fragmentation	Area of continuous forest and of patches of forest separated by nonforest lands
	4.8	Threatened forest species	Number of threatened forest species, classified according to IUCN red list categories in relation to total number of forest species
	4.9	Protected forests	Area of forest and other wooded land protected to conserve biodiversity, landscapes, and specific natural elements, according to MCPFE categories
	4.10	Common forest bird species	Occurrence of common breeding bird species related to forest ecosystems
Criterion 5: Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water)	C.5	Policies, institutions, and instruments to maintain and appropriately enhance the protective functions in forest management	
	5.1	Protective forests – Soil, water, and other ecosystem functions – infrastructure and managed natural resources	Area of forest and other wooded land designated to prevent soil erosion, preserve water resources, maintain other protective functions, protect infrastructure, and manage natural resources against natural hazards

(continued)

Table 2.1 (continued)

	No.	Indicator	
Criterion 6: Maintenance of other socioeconomic functions and conditions	C.6	Policies, institutions, and instruments to maintain other socioeconomic functions and conditions	
	6.1	Forest holdings	Number of forest holdings, classified by ownership categories and size classes
	6.2	Contribution of forest sector to GDP	Contribution of forestry and manufacturing of wood and paper products to gross domestic product
	6.3	Net revenue	Net revenue of forest enterprises
	6.4	Investments in forests and forestry	Total public and private investments in forests and forestry
	6.5	Forest sector workforce	Number of persons employed and labor input in the forest sector, classified by gender and age group, education, and job characteristics
	6.6	Occupational safety and health	Frequency of occupational accidents and occupational diseases in forestry
	6.7	Wood consumption	Consumption per head of wood and products derived from wood
	6.8	Trade in wood	Imports and exports of wood and products derived from wood
	6.9	Wood energy	Share of wood energy in total primary energy supply, classified by origin of wood
	6.10	Recreation in forests	The use of forests and other wooded land for recreation in terms of right of access, provision of facilities, and intensity of use

"Carbon stock," 4.1 "Tree species composition," 2.4 "Forest damages," and 6.9 "Energy from wood resources." The number of indicators that resulted useful to support CSF increased significantly when all aspects of SFM, particularly the socio-economic aspects, are considered (Bowditch et al. 2020). Overall, indicators belonging to the criteria "Forest Biological Diversity" and "Forests Health and Vitality" are considered particularly important to manage forests according to a climate smart approach (Fig. 2.4).

Finally, four new indicators, concerning the forest structure, were suggested by CLIMO participants during the CLIMO meetings (Bowditch et al. 2020). Monitoring these indicators (management system, slenderness coefficient, and tree crown distribution both vertical and horizontal) allows to observe the impacts of forest management on the forest productivity and growth, as well as the delivery of ecosystem services, supporting CSF evaluation (Fig. 2.4). These indicators can be evaluated through remote sensing and thus are particularly important, because they can be monitored frequently providing timely forest inventory data (e.g., Giannetti et al. 2020).

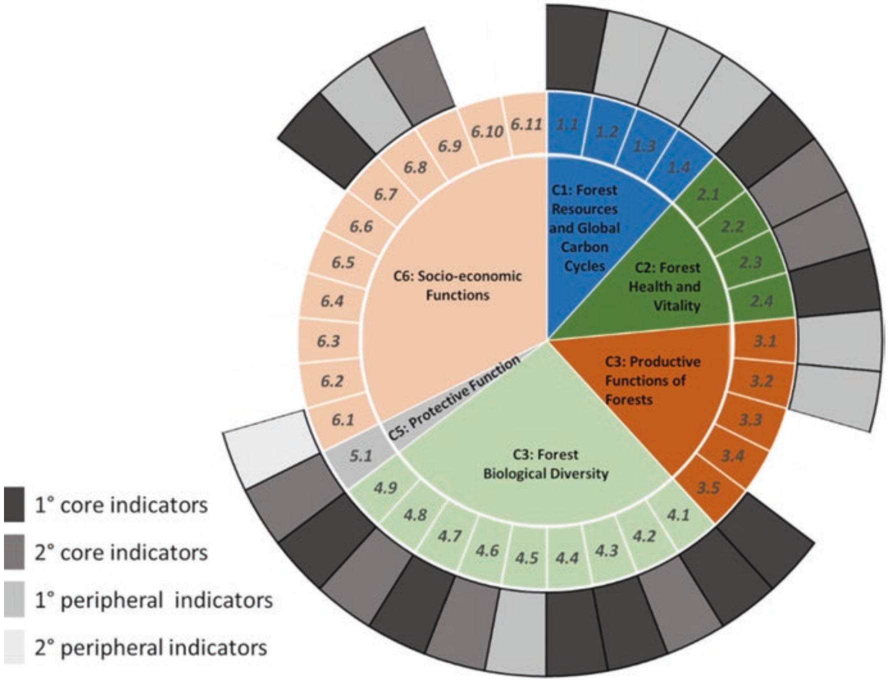

Fig. 2.4 Indicators relevant for assessing Climate-Smart Forestry. The set of indicators refers to Vienna 2003, since some of the indicators from the updated set (Madrid 2015) require further development and testing for consideration (Bowditch et al. 2020)

2.5 A Critical Analysis of the Definition, Gaps, and Uncertainties

The definition of the CSF concept derived from the COST Action (Fig. 2.1, Bowditch et al. 2020) was an important development in reasserting that the climate adaption of forests is a vital component, in part because this is necessary to secure future climate mitigation by forestry. This definition also recognized the importance of the social dimension. However, CSF is an evolving concept and this definition marks the current stage in its development, not an end point. In particular, it is important to recognize that the definition is derived by a group working from a European perspective on climate smart forestry in mountain regions.

2.5.1 Gaps and Uncertainties

When scaling-up to global level and beyond mountain environments, several issues need to be reconsidered. For example, a future definition of CSF should cover a more global climate change context, reducing emissions from forest degradation and deforestation is one of the most important ways of combatting climate change.

It has been suggested that in areas more likely to maintain optimal growth conditions for forests in the long term, forest management should make use of their mitigation capacity (Jandl et al. 2015). The definition does not emphasize that SFM already provides climate mitigation and that the role of CSF in enhancing this may benefit from some positive feedbacks. For example, the growth rate of some European forests has accelerated and total stand volume prior to final cutting is reached now much earlier than 100 years ago, thus increasing the C sequestration and substitution (Mäkinen et al. 2017; Pretzsch et al. 2014; Pretzsch et al. 2019; Socha et al. 2017; Socha and Staniaszek 2015). However, the potential for further mitigation of climate change is uncertain, since there is a lack of sufficient knowledge of how elevated CO_2 and temperature and changing weather pattern will affect tree growth, nor are there historical parallels (Yousefpour et al. 2012). Furthermore, the impacts of pests, diseases, and abiotic threats are uncertain. For example, European countries have recently experienced a series of noticeable forest disturbances, such as several storms in the fall/winter 2017–2018, extended drought in 2018 and 2019 with subsequent bark beetle outbreaks, and disastrous wild forest fires. Cumulative evidence proves that CC is contributing to the increased frequency and intensity of these forest disturbances (Forest Europe 2019). Thus, while individual trees may grow faster, forest resilience may decline, so that the overall level of C sequestration is reduced. This is why trade-offs and conflicts between adaptation and mitigation measures should be considered (Böttcher et al. 2009) and why adaptation appears before mitigation in the COST Action definition (Bowditch et al. 2020).

It is important to have a definition of climate smart forestry, just as there is one for CSA; however, for adaptation and mitigation measures to be truly successful, an approach that considers the entire land use system is required. It is therefore necessary to harmonize forest management under climate change with respective measures in agriculture, wildlife conservation, and any other objectives with implications for land management and the bioeconomy. This does not mean that the concept of CSF is wrong, but a gap exists in defining how it fits within a wider climate smart landscapes approach.

The focus in the definition on social dimension is a new look at the problem, but it deserves more attention (Scheffers et al. 2017). In particular, indicators and analysis methods to measure and depict potential trade-offs between fostering adaptation and mitigation and ecosystem service provision need to be further developed. For example, the economic costs for adaptation and mitigation treatments need to be quantified in order to device CSF scenarios that are economically feasible in the long term. For example, in many mountain areas, the protection efficiency against rockfall, avalanches, and landslides must be ensured when currently nonautochthonous tree species or provenances are introduced to adapt forests to the future climate. Another example is the potential trade-off between adaptation or mitigation and the provision of the forests recreational, cultural, and tourism services. The role of professionals (scientists and forest managers) involved in education and clarification of climate change processes can be important not only for forest owners but also for the society as the whole and therefore for public acceptance of climate smart forestry (Laakkonen et al. 2018).

2.6 Developing a Forest Manager Vision of CSF

An important step for implementing CSF on any type of forest policy is ensuring that concepts are accessible and translatable into practice for forest managers (Groot et al. 2010; Sousa-Silva et al. 2018; Bowditch et al. 2019). They play a key role in adopting the mechanisms of policy and turning them into common and best practice, representing a broad behavioral change that can have wide-ranging benefits (Nichiforel 2010; Carmon-Torresa et al. 2011; Raymond et al. 2016). However, the science-policy-practice interface has been difficult to navigate with many still emphasizing a large disconnect in communication (Nijnik et al. 2016). The CSF definition and indicators are a first step in introducing forest management specifically focused on climate change response. Although these were developed by a range of forest professionals, only a small number of managers were involved; therefore, engaging managers was viewed as a crucial stage of the process of refining and testing the accessibility and relevance of the work (Bowditch et al. 2020).

In an online survey, forest managers from 14 European and neighboring countries were asked to critique the CSF definition and indicators from a management perspective. Representatives from each country involved in the CLIMO project disseminated the survey to public, private, community, or other relevant forest management entities within the country to capture the range of perspectives and challenges.

2.6.1 Forest manager's Response

Forty-seven percent of all managers viewed climate change as a critical or high risk to management aims and objectives; however, 42% viewed it as a medium risk and 11% considered it to be a low or nonexistent risk. Around 41% of managers believed that they were equipped with the tools and knowledge to respond to climate change, 40% were unsure, and the remainder did not believe they were equipped. Examples of contrasting options included:

> "*we have knowledge but constraints outside our control prevents us from effective delivery*"

> "*there are more threats than ever before but as professionals would rise to the challenge through constant pursuit of knowledge*"

A main challenge identified by forest managers is the ability to turn knowledge into action and management approaches with constraints ranging from systemic national forestry policy and management, to capacity to deliver on aims at stand level due to available time, resources, and bureaucratic barriers.

The CSF definition presented to managers was generally well-received with 62% saying it was accessible, clear, and relevant, but 38% either saying it was too complex or that they did not understand the definition. The majority of the negative responses were in countries where the definition had to be translated into the native language with a possibility of some meanings and phrases being lost in translation.

Although 37% of managers found the definition either very useful or useful with 54% finding it moderately or marginally useful, 9% found the definition not useful. Examples of contrasting responses are:

> "*it is succinct and clear and brings together useful aims*"

> "*A definition should also include the economic dimension, long-term profitability*"

> "*would become lost in the busy job of a manager but would be good as reference during design and operational phases*".

> "*distant from the realities of management in the field*".

The CSF list of indicators based on the pan-European Criteria and Indicators for Sustainable Forest Management was well received by the forest managers, who all acknowledged it represented a comprehensive set of management concerns. Despite the positive attitude toward the indicators, most managers highlighted the limited scope of using indicators in management plans, as the current systems (national, regulatory, and company) were not compatible to integrate into plans. Managers further highlighted that there were too many indicators, which would be time consuming to measure, additionally managers pointed out that they did not have the knowledge or resources to measure most indicators. "*Tree species composition*" and "*natural regeneration*" were identified as the most important Sustainable Forest Management (SFM) indicators, whereas the "*slenderness coefficient*" and "*roundwood*" were ranked as the least important. "*Erosion prevention and maintenance of soil health*" were the top ranked ecosystem services indicators followed by "*water and air purification.*" Ranked least important were "*pharmaceuticals and biochemicals*" followed by "*food.*" Managers suggested that the indicators could be streamlined or modified for different forest types or objectives. The current list was unrealistic to implement but considered appropriate as a checklist and a broader list that could be classified into different areas of management.

2.6.2 Refinement of Definition and Indicators

The main suggestions to improve the definition and indicators focused around economic and social factors. Most notably profitability or revenue from management and transport, and the relationship with GHG emissions. Further clarification on the C cost of producing different forest products and bringing them to market was highlighted by a cross-section of managers, emphasizing the importance of integrating life cycle knowledge into management decisions (Karvonen et al. 2017). It was also suggested that measurement of the benefits of direct fossil fuel substitution from forestry could explicitly translate another element of the definition into an indicator (Münnich Vass 2017). The use of technology was also mentioned as a potential indicator to track integration and use, which either benefits or hinders CSF adaptation (Biggs et al. 2010; Ghaffariyan et al. 2017).

Support of communities and rural areas was mentioned widely by respondents as an indicator that could evaluate the importance of a forest to the local area and wider rural economy. Greater recognition of small landowners and their management needs, as well as recognizing contributions to climate change was viewed as important locally and landscape wide to encourage investment in CSF. The level of public awareness of forest management and services was identified as a potentially powerful social indicator, which demonstrates the current disconnect between forestry sector and society about the role of forests and forestry including their benefit to the wider environment (Upton et al. 2015; Seidl et al. 2016).

A key theme emerged that addressed wider issues of communication among policy, science, and practice, which highlighted the need to integrate explicit climate change adaptation and mitigation goals into grants and incentives (Opdam et al. 2013; Fischer et al. 2015; Blades et al. 2016). This was further supported by a range of forest managers expressing the need to challenge traditional silviculture and approaches to forest management, as well as considering other land uses such as agriculture in joined-up approaches:

> "*We cannot be afraid of having healthy discussion that challenges traditional management's compatibility with current goals*"

Training and education also emerged as a common theme:

> "*there needs to be a commitment to training those future professionals and current professionals in climate and resilience thinking and practice*".

Other managers identified that scenario planning within management plans and at higher levels would be crucial to climate change responses (Jandl et al. 2018):

> "*Local climate change scenarios that address fine scale change will be really important for managers and provide guidance for planning and redundancies*".

Scenario-driven analyses would give managers response pathways to follow in case of unexpected or unprecedented events affecting the productivity and integrity of their forests.

In general, the definition was viewed as a positive start by the majority of forest managers who saw it as a vision statement to reference broad aims and only lacked wording on economic implications. The indicators were identified by managers as a set of tools that could potentially have practical relevance for their work. However, the indicators required clear instructions and tools for them to be implemented into management plans. The next step would be to trial a set of indicators with forest managers to assess the ease of use and interpretation to inform current data and/or create new baselines.

2.7 Future Perspectives for CSF

With the definition of CSF in this chapter and in Bowditch et al. (2020) and numerous previous applications (e.g., Nabuurs et al. 2017; Yousefpour et al. 2018; Jandl et al. 2018), the concept of CSF is established in forest science. The next step will be to implement CSF in practice. This encompasses balancing adaptation, mitigation, and ES provision from the stand to the European scale, and working with international partners to expand the definition to suit a global understanding of the concept. While in some cases, all three aspects of CSF may be considered in management decisions at the stand scale, other circumstances may require prioritizing for one or the other at the landscape scale. Decisions on such sparing versus sharing strategies may depend on topography, structure of the forest landscape, forest industry and administration, and other circumstances in different countries and regions. CSF needs to link global priorities with specific local conditions. A clear definition of CSF and its implementation in practical forest management can contribute to this link.

The implementation of climate smart management decisions should be embedded within the cyclical adaptive management process of planning, implementing, monitoring, evaluating, and revising CSF management (Walters 1986). A forward-looking rather than reactive approach should be adopted for planning (Yousefpour et al. 2017). This involves considering climate and other environmental and socio-economic conditions expected for the future as well as their uncertainties in decision making. Results from species distribution models may provide a basis for the selection of candidate tree species to grow under future conditions (e.g., Hanewinkel et al. 2012), whereas dynamic forest development models may deliver understanding on successional dynamics and management and disturbance impacts under climate change scenarios (Temperli et al. 2020; Reyer et al. 2015; Seidl et al. 2017; Gutsch et al. 2018). Specifically, these models can be used to evaluate potential CSF scenarios, including schemes for natural regeneration and planting (assisted migration), and generally deliver management targets for forward looking adaptive managers at a broad range of spatial and temporal scales (Pretzsch et al. 2008; Yousefpour et al. 2018; Jandl et al. 2018). In addition, a database of "best practices" from individual forest management agencies, regions, and countries may serve as useful decision tools to promote CSF management.

Indicator system to measure mitigation, adaptation, and ES provision, such as the one suggested in this chapter based on C& I for sustainable forest management by Forest Europe (Forest Europe 2015), need to be constantly updated to tackle upcoming challenges. With C sinks in European forests being limited (Nabuurs et al. 2013), mitigation strategies need to also focus on storing C in wood products and buildings and thereby substituting fossil fuel–intensive energy sources. Hence, indicators to quantify mitigation need to go beyond the C sequestered in the tree biomass and the soil, but also include the wood value chain (Verkerk et al. 2020). Challenging questions on system boundaries need to be resolved in that regard (Sandin et al. 2016). The CSF aspect of adaptation is often captured indirectly as the so-called adaptive capacity of forests and the forestry industry (Lindner et al. 2010; Irauschek et al. 2017). Indicators on provenances, tree species and stand and forest type diversity, as well as on the density of forest road networks and the regulatory and economic boundaries of forest enterprises are inter alia used for this purpose. A step forward would be to assess adaptation directly by quantifying the difference between the current and a targeted state of the forest. This may include measuring the progress of assisted migration of climate change-adapted provenances and (native and nonnative) tree species (Bolte et al. 2009). Indicators could be the percentage of a drought-adapted provenance or tree species, or forest structural parameters that measure disturbance resistance and resilience (Bryant et al. 2019; Temperli et al. 2020). These difference-indicators could be advantageous for a more targeted adaptation process, but may also create challenges with regard to comparability across stands, landscapes, or countries, because management targets need to be defined specifically for each spatial entity. Efforts to further harmonize indicators internationally are pivotal for climate smart policy making at European levels (Alberdi et al. 2016).

Evaluating and revising CSF strategies completes the adaptive management cycle. Evaluation needs to assess whether targeted ES can be provided sustainably (also considering social and economic aspects) as forests adapt to climate change and novel tree species compositions emerge. Thereby climate change may also create opportunities. Expanding deciduous trees in subalpine conifer forests may offer a broader spectrum of site-adapted tree species that can be promoted following timber harvesting or natural disturbances. This may benefit management toward heterogeneous stand structures and thus the long-term maintenance of the forest's protective function against rockfall and landslides (Bebi et al. 2016), as well as positive effects on soil water availability and water cycling at the landscape scale. Moreover, forest stands with high levels of genetic diversity and species richness may improve ecosystem service provision including the production of raw materials, medical resources, tourism, recreation, and aesthetic, cultural, and spiritual experiences. The CSF concept offers the opportunity to connect agriculture and forestry in submountain regions to create an effective (integrated) climate smart management system of whole areas. CSF decisions must consider uncertainties (i.e., by promoting a range of candidate tree species) as CSF paradigms of today may shift in the next decades as we learn from the effects of past management. Further developments of the CSF concept need to ensure that it remains flexible and dynamic such that it can be applied to a broad range of environmental and socioeconomic conditions in an uncertain future.

In summary, CSF is a continuously evolving concept; the definition presented here from COST Action CA15226 Climate Smart Forestry in Mountain Regions and use throughout this book aims to help policymakers and practitioners develop focused governance and management through which forests can adapt and mitigate climate change, while continuing to deliver wide benefits to society (Bowditch et al. 2020).

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