HLPE REPORT 11

Sustainable forestry for food security and nutrition

A report by

The High Level Panel of Experts on Food Security and Nutrition

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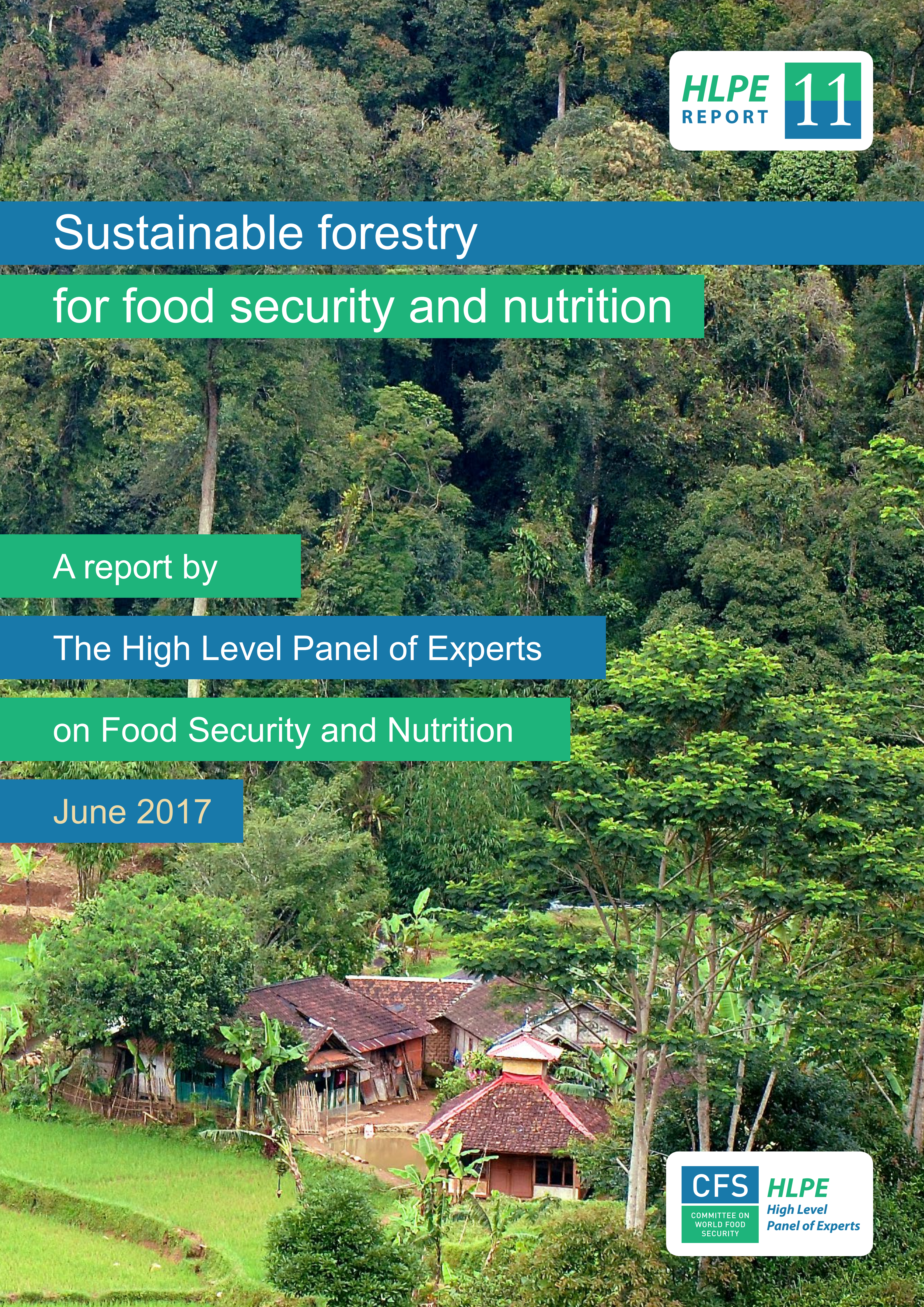

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Contents

List of Figures

List of Tables

List of Boxes

FOREWORD

The High Level Panel of Experts for Food Security and Nutrition (HLPE) is the science–policy interface of the Committee on World Food Security (CFS), which is, at global level, the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition (FSN).

HLPE reports serve as a common, comprehensive, evidence-based starting point for intergovernmental and international multistakeholder policy debates in CFS. The HLPE draws its studies based on existing research and knowledge. The HLPE strives to clarify contradictory information and knowledge, elicit the backgrounds and rationales of controversies and identify emerging issues. To do so, it organizes a scientific dialogue, built upon the diversity of disciplines, backgrounds and knowledge systems among Steering Committee and Project Teams members, and of the knowledge community involved in the open electronic consultations.

HLPE reports are widely used as reference documents within and beyond CFS and the UN System, by the scientific community as well as by political decision-makers and stakeholders, at international, regional and national levels.

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In October 2014, at its 41st session, the CFS requested the HLPE to prepare a study on *sustainable forestry for food security and nutrition* to inform the debates at the 44th CFS Plenary Session of October 2017. The key issue here is how to optimize the multiple, direct and indirect, contributions of forests and trees to FSN in its four dimensions (availability, access, utilization and stability), in a context of increasing and competing demands on land, forests and trees (including for wood, food, energy and ecosystem services), as well as of climate change.

Recognition of the importance of forests within debates about FSN has come out recently. Discussions on FSN often remained somewhat production-centric, focused on improving yields from agriculture, and finding ways to disseminate new technologies and practices to enhance outputs from the productive landscape. Forests were rarely featured in such discussions, other than being perceived as a space for further agricultural expansion or a threatened resource to be protected because of such expansion. The changing perception of the role of forests for FSN has actually been influenced by the Millennium Ecosystem Assessment (2005), which, while focusing on environmental concerns, has demonstrated the links between human health and nutrition and the health of ecosystems, including forests. Addressing the CFS request, this report deliberately reverses the perspective, adopting a focus on FSN.

The report identifies four main channels through which forests and trees contribute to FSN: direct provision of food; provision of energy, especially for cooking; income generation and employment; and provision of ecosystem services essential for food production in the long term, including water regulation, soil protection, biodiversity conservation and climate change adaptation and mitigation. These contributions vary across forest and tree systems, and depend on the way they are managed.

When looking at the various contributions of forests and trees to FSN, there is no clear-cut point at which trees stop providing these contributions. Trees in non-forested areas also play a major role to improve FSN. The HLPE thus adopted a broad scope for this report, covering not only forests, but also trees outside forests, and moving beyond a mere focus on deforestation, with the view to enable the decision-makers to elaborate a comprehensive vision and strategy at different spatial and temporal scales.

This report calls for sustainable forest management (SFM) that takes fully into account and integrates the multiple and competing uses of forests and trees as well as the diverging and sometimes conflicting interests, needs and rights of different stakeholders. SFM requires the establishment of intersectorial governance mechanisms at different scales that: enable the full and effective participation of concerned stakeholders, particularly of forest-dependent indigenous peoples and local communities; articulate different functions of forests and trees (including wood and food production, biodiversity conservation and socio-cultural benefits); consider short- and long-term objectives; and that recognize and reduce conflicts between stakeholders.

With its 11 reports published since its creation, the HLPE is progressively building a global narrative, a comprehensive analysis of FSN and its underlying causes. This report on sustainable forestry, coming after the reports on fisheries and aquaculture (2014) and on sustainable agriculture (2016), completes the HLPE analysis of FSN from a sectoral perspective. These three sectors share some commonalities in their multiple contributions to FSN: they directly provide food; they generate income and employment for many people; they manage and impact natural resources; and they generate social and environment concerns. These HLPE reports also show the interdependencies between those three sectors that compete for natural resources, particularly land and water. They call for an integrated approach, in particular at the landscape level, to improve the way human activities contribute to the realization of the right to adequate food and of the 2030 Agenda. This report, like the report on water, highlights trade-offs, which sometimes turn into conflicts, between stakeholders with diverging rights, needs and interests. It demonstrates the need to integrate different spatial and temporal scales to address local and global challenges with effective positive impacts on FSN.

This report builds upon the important research programmes undertaken by the International Union of Forest Research Organizations (IUFRO) and its many international and national members, the Center for International Forestry Research (CIFOR) and the World Agroforestry Centre (ICRAF), as well as on the CGIAR Research Program on Forests, Trees and Agroforestry. The HLPE commends the work coordinated by FAO, supported by international and national organizations and by a network of national correspondents, to produce the Global Forest Resources Assessment and encourages them to pursue their effort for the integration of FSN concerns, in particular by improving the quality of data on forest-related informal activities, including non-wood forest products collection. The HLPE considers that there is still much to be done by the whole science and knowledge community to raise awareness and to develop policy-relevant knowledge on the direct and indirect contributions of forests, trees and agroforestry to sustainable development and FSN.

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On behalf of the Steering Committee, I would like to acknowledge the engagement and commitment of all the experts who worked for the elaboration of this report, and especially the Project Team Leader, Terence Sunderland (United Kingdom) and Project Team Members: Fernande Abanda (Cameroon), Ronnie de Camino Velozo (Chile), Patrick Matakala (Zambia), Peter May (Brazil), Anatoly Petrov (Russian Federation), Bronwen Powell (Canada), Bhaskar Vira (India), Camilla Widmark (Sweden).

This report also benefited greatly from the suggestions of the external peer reviewers and from the comments provided by a large number of experts and institutions, both on the scope and on the first draft of the report.

I would like to commend and thank the HLPE Secretariat for its precious support to our work.

Last but not least, I would like to thank the resource partners who support the work of the HLPE in a totally independent way.

Patrick Caron

Chairperson, Steering Committee of the HLPE, 15 June 2017

SUMMARY AND RECOMMENDATIONS

In October 2014, at its 41st session, the Committee on World Food Security (CFS) requested the High Level Panel of Experts (HLPE) to prepare a study on sustainable forestry for food security and nutrition (FSN) to inform the debates at the 44th CFS Plenary Session of October 2017. The key issue here is the multiple contributions of forests and trees to FSN[1] in its four dimensions and how they can be optimized, at different spatial and temporal scales, in a context of increasing and competing demands on land, forests and trees (including for wood, food, energy and ecosystem services), as well as of climate change.

This report is an evidence-based, comprehensive analysis of the diverse, direct and indirect, contributions of forests and trees to FSN. Chapter 1 examines the linkages between forests and FSN and proposes, for the purpose of this report, a conceptual framework and a forest typology grounded on management criteria. Chapter 2 provides an in-depth analysis of the channels through which forests and trees contribute to FSN. Chapter 3 reviews the state of the world's forests and identifies challenges and opportunities for forestry in relation to FSN. Chapter 4 is solution-oriented and discusses how to optimize the contributions of forests and trees to FSN in a sustainable manner.

Summary

Forests, trees and FSN: scope and conceptual framework

1. There are numerous definitions of forests reflecting both the diversity of forest ecosystems in the world and the diversity of human perceptions and uses of forests. The term "forest" is used to describe a broad range of ecosystems from scattered trees in dry landscapes to dense, close canopy old-growth forests in high rainfall areas. A forest can be an administrative unit, a type of land cover or a type of land use. Land cover refers to the physical appearance of land, while land use refers to its utilization by humans for different purposes (including production, conservation, cultural or religious value). The FAO Global Forest Resources Assessment (FRA) has contributed to harmonize, for statistical purposes at the global level, the approaches used to define and categorize forests. The FRA uses a definition of forests that includes minimum thresholds for the height of trees (5 m), the canopy cover (10 percent) and the area (0.5 ha).
2. The FRA definition covers very different types of forests. In addition, there are various types of landscapes incorporating trees. Given this diversity and the purpose of this report, a typology of forests and landscapes with trees, building on the FRA statistical categories, is proposed. This typology uses FRA data and is grounded on the degree of management, as this is the criterion that most influences the various contributions of forests to FSN and that can be more easily influenced by policies. This typology distinguishes three broad categories that are considered as forests according to the FRA definition (primary [or old-growth] forests, secondary forests, plantation forests); a fourth one gathering other wooded lands that are not classified as agricultural land and with a canopy cover of 5 to 10 percent; and a fifth one called "trees outside forests". Delimitations among these types are not always clear cut as they exist on a continuum of management intensity along the forest transition curve.[2]
3. The category "trees outside forests" gathers the considerable diversity of agriculture systems with trees. It includes in particular agricultural tree plantations such as palm

[1] Food security exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. In 2009, the World Summit on Food Security stated that the "four pillars of food security are availability, access, utilization, and stability". *Availability* is the supply of food through production, distribution and exchange; *access* is the affordability and allocation of food, as well as the preferences of individuals and households requirements of each member of the household; *utilization* is the metabolism of food by individuals; and *stability* is the ability to obtain food over time.

[2] The forest transition curve, from natural forests to agriculture and reforestation, illustrates the evolution of forests, through a continuum of management intensity across the different forest types. This curve can not only illustrate the evolution of forests in time but also describes spatial variations across contemporary landscapes.

oil, olive trees and orchards (fruit and nut trees), as well as very diverse agroforestry systems and mosaic landscapes where forest patches are too small to be considered as forests for statistical purposes. The term “agroforestry” refers to systems and technologies where trees are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In spite of their diversity, all these systems share the common characteristic of trees being closely linked to agriculture and food production activities.

4. Any people who rely to some extent on forests and trees for their livelihood can be considered forest-dependent. When including: indigenous peoples that mainly depend on forests for their subsistence, rural dwellers living in or at the margins of forests, smallholder farmers who grow trees or manage forest patches and employees in formal or informal forest-based enterprises, from 1 to 1.7 billion people can be considered as forest-dependent.

5. In this report, forestry is considered in a very broad sense, encompassing all decisions related to forest management, in any type of system or landscape that includes trees, including three broad types of decisions: those related to the presence or absence of trees in a certain area, to the types of forests and trees, to the way they are managed. The purpose of sustainable forest management (SFM), as defined by the United Nations General Assembly, is to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations. SFM is rooted in two main premises: first that ecosystems have the potential to renew themselves, and second that economic activities and social perceptions or values that define human interaction with the environment are choices that can be changed or modified to ensure the long-term productivity and health of the ecosystem.

Contributions of forests and trees to FSN

6. Forests and trees contribute to FSN through four main channels: direct provision of food; provision of energy, especially for cooking; income generation and employment; and provision of ecosystem services that are essential for FSN, human health and well-being.

7. *Direct provision of food:* Although forest foods have been estimated to represent only 0.6 percent of global food energy supply, they make a considerable contribution to dietary quality and diversity and play a critical role for the FSN of forest-dependent communities. Forest foods, by reaching local, national and even international markets, also contribute to diverse and balanced diets for people living far from forests. Forests and trees are also used as a source of fodder by farmers and pastoralists in traditional extensive systems and in more intensive silvopastoral systems.

8. *Provision of energy:* Woodfuel[3] contributes globally to 6 percent of the total primary energy supply and 27 percent in Africa. Some 2.4 billion people, one-third of the global population (including two-thirds of the households in Africa), rely on wood as their main source of energy for cooking. Moreover, 764 million people use woodfuel to boil and sterilize water, of which 644 million are in Asia.

9. *Income and employment:* The formal and informal forestry sectors are also important sources of employment and income, often underestimated given the importance of the informal sector. In 2011, the formal forest sector employed an estimated 13.2 million people worldwide and represented 0.9 percent of the world gross domestic product. Such figures hide a huge diversity across countries and generally underestimate the real contribution of forests to national income as they do not integrate the value added of wood products accounted for in the industrial sector, nor, for instance, their contribution to tourism and recreation. Moreover those figures only cover the formal forest sector and data are still lacking to properly reflect the importance of informal forest-related activities for income generation and employment, including through woodfuel and collection of non-wood forest products (NWFPs).

[3] Woodfuel designates the total of fuelwood plus charcoal, as per FAO terminology.

10. Forest products collected either for sale or for auto-subsistence can, in both cases, make a crucial contribution to the FSN of women and of their entire household. In spite of a lack of gender-disaggregated data, studies suggest that women play a lesser role in the formal sector and in income generating activities, but are central in fuelwood collection as well as in the collection of many forest products, with important regional differences.

11. _Provision of ecosystem services:_ Forests and trees directly support food production at farm, landscape and broader levels by delivering numerous non-provisioning ecosystem services that are essential for FSN and sustainable development in the long term (such as water regulation, soil protection, nutrient circulation, pest control and pollination). Forests host the major part of terrestrial biodiversity and play a critical role for climate change mitigation at the global level and for adaptation to climate change at farm, household, landscape and broader levels. Production systems that integrate forests, trees and crops need to explicitly take into account potential competition for nutrients, water and light.

12. _Human health and well-being:_ Forests, tree-based agricultural systems and forestry impact human health in a diversity of ways, including: provisioning of food, medicinal plants, fuelwood, clean water and income. Empirical evidence suggests that forest environments can improve peoples' mental health and reduce depression and stress. However, forests can also provide habitat for parasites and diseases that can affect human and domestic animals. The critical linkages between human, animal, and ecosystem health are encompassed in the concept of "One Health", which highlights the need for collaboration across sectors.

13. _Resilience and safety net:_ Forests and trees can play a crucial role to improve resilience, defined as the capacity to prevent, mitigate or cope with risk, and recover from shocks, at landscape, community and household levels. They thus make a significant contribution to stability, the fourth dimension of FSN, by playing a major role as a safety net during drought or lean seasons as well as during periods of crises and conflicts. Forests and trees can provide a complement or a substitute to other sources of food, income and employment, in periods of scarcity. This role of safety net is often important for the most vulnerable groups.

14. Importantly, contributions of forests and trees to FSN depend upon numerous interactions inside complex environmental, economic and social systems that are often built and sustained with a considerable amount of traditional and indigenous knowledge.

Forestry trends: challenges and opportunities for FSN

15. Changes in forest cover, forest types and management have considerable impacts on the contributions of forests and trees to FSN at different spatial and temporal scales. These changes, as well as their drivers, enable the identification of some of the challenges and opportunities for sustainable forestry to contribute to FSN.

16. In 2015, almost 4 billion ha worldwide (30.6 percent of the world's land area) were covered by forests. Despite relatively high rates of ongoing deforestation, particularly in the tropics, the global net forest loss has slowed over the past two decades. The FRA 2015 (FAO, 2015) has also provided for the first time global figures on forest degradation based on partial canopy cover loss (PCCL)[4] and estimated that, in the tropics, the area subject to PCCL is 6.5 times the area deforested since 1990.

17. The overall decrease in total forest area is the result of contrasted trends across forest types and across regions. Between 1990 and 2015, most regions showed a steady decrease in natural forest area, including primary and secondary forests, and a sharp increase in planted forests. The loss of primary forests is of particular concern as they are irreplaceable reserves of biodiversity. Planted forests are increasingly important, not only in terms of area, increasing from 4 to 7 percent between 1990 and 2015, but also in terms of production, with 46.3 percent of industrial roundwood coming from planted forests in 2012. Planted forests are also a way to restore degraded land and to provide ecosystem services such as reduced erosion and protection from floods. Considering the

[4] Defined as the loss of more than 20 percent of tree cover between 2000 and 2012.

increasing demand for wood, planted forests could help to reduce the pressure on natural forests.

18. Deforestation and forest degradation threaten income, livelihoods and ways of life of forest-dependent populations, and compromise the provision of ecosystem services that are essential to FSN and sustainable development in the long term. Deforestation for agricultural expansion is sometimes considered to offer greater opportunities for welfare improvement. However, those immediate benefits can result in depletion of natural resources, simplified diets and compromised livelihoods and ways of life in the long term. Finally, deforestation and forest degradation, leading to habitat fragmentation, can also impact human health by increasing the risk of transmission of pests and diseases.

19. Changes in forest cover, forest types and uses are driven by the interaction of numerous factors, at local and global levels: growing demand for food, feed, wood and energy, driven by population and income growth; and increased importance given to the protection of biodiversity, to carbon stocks, water and soil protection. They also depend on the governance systems that address and manage these demands.

20. Given the global population and economic growth, the increase in demand for food, feed, wood and bioenergy is expected to continue in the future. Wood and fibre demand is in particular expected to double between 2005 and 2030.

21. In addition, forests need now to adapt to climate change and are called upon to contribute to its mitigation. Land degradation fuels additional demand for land for agriculture, creating additional pressure on forests, but also opportunities for reforestation and afforestation. There is at the same time increased awareness of the role of forests to protect soil, water and biodiversity and to contribute to climate change mitigation. These trends intensify the competition for land. They also intensify the competition between forest uses, for environmental preservation, for timber and wood production, and for food and other NWFPs, each of which impacts FSN. Addressing the issue of competition for land while taking into account agricultural and forests demands on the one hand, environmental and climate concerns on the other hand, calls for tackling consistently the trade-offs at and between different scales, from local to global. This requires moving beyond the controversy materialized by the two opposite narratives “land sharing – land sparing” to design and implement appropriate arrangements and mechanisms.

22. These increasing demands on land, forests and trees create new challenges and opportunities for their contributions to FSN. They can threaten some of the contributions of forests to FSN, particularly when such contributions are less visible or concern marginalized and most vulnerable groups. On the other hand, they can create additional reasons to protect and invest in forests and generate new jobs and opportunities for sustainable development. This calls for a better understanding of the drivers of change, and of the dynamics at play in evolving landscapes such as secondary forests, landscape mosaics, agroforestry systems and their impact for FSN and sustainable development, and for a better support for the forest restoration of areas that qualify as other wooded land.

How to optimize the contributions of forests and trees to FSN in a sustainable way?

23. There are potential synergies and trade-offs between the benefits provided by forests and trees for FSN, at different scales, from local and global, from short to long term. SFM for FSN has thus to take fully into account and integrate the multiple uses of forests and trees, as well as the diverging and sometimes conflicting interests, needs and rights of different stakeholders, paying specific attention to the more vulnerable and marginalized groups. It requires governance mechanisms at different spatial and temporal scales, through international instruments, national policies and local arrangements.

24. The FRA identifies a set of enabling conditions for SFM: permanent forestlands, legal frameworks, management plans, stakeholder involvement, as well as information, monitoring and reporting systems. According to the FRA, only half of the 2.2 billion ha of permanent forest land met all those conditions in 2015. However, areas under forest

management plans have sharply increased during the last decades. In 2015, 167 countries reported to have such forest management plans and these plans cover more than half of their forest area (around 2.1 billion ha). The main objective of a forest management plan (whether forest conservation in primary forests and protected areas or wood production in plantation forests) may conflict with rights of access to and use of forest resources and therefore with the FSN of local forest-dependent people and communities, including indigenous peoples. Legal frameworks regulating these rights vary hugely across countries.

25. There are numerous international treaties and standards that have an influence on the way forests are managed. Among them some focus on the environmental dimensions of forest management, such as the three Rio Conventions, the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Diversification (UNCCD). Other treaties relate to international human rights, in particular to the right to adequate food and nutrition. A third group of international instruments is directly linked to forest management, such as the 1992 United Nations Forest Principles[5] and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security.

26. There is increasing interest in market-based instruments to recognize and valorize the different contributions of forests, especially related to environmental issues. Examples include carbon credits and other payments for environmental services, certification and green procurement. Forest certification plays an important role in assessing and monitoring the sustainable management of forests in an independent way. The two main international certification schemes (the Forest Stewardship Council [FSC] and the Programme for the Endorsement of Forest Certification [PEFC], introduced in the late 1990s) covered 438 million ha in 2014 (90 percent of which are situated in boreal and temperate climatic domains). Also, voluntary green building programmes, codes and standards promote the use of legally and sustainably harvested wood products. While such instruments can link forestry management to people who consume forest products from a distance by enabling them to pay for environmental impacts, they do not always fully integrate FSN concerns and the needs of local forest-dependent people and communities.

27. SFM for FSN thus requires integrated, innovative and inclusive governance systems across sectors at different spatial and temporal scales, ensuring the full and effective participation of all concerned stakeholders and affected groups, particularly of women, as well as vulnerable and marginalized groups, including indigenous peoples and forest-dependent communities. In particular, appropriate arrangements must be designed at the landscape level where the challenges are to optimize the concrete cohabitation among cities, agriculture, forests and other natural areas, and to better integrate FSN concerns in forest management.

28. The realization of the right to adequate food of local communities, forest-dependent communities and indigenous peoples requires ensuring their land and forest use rights. Forest-based goods and services are also crucial for the realization of social, economic and cultural rights of people around the world. In this context, laws, policies and interventions related to forests should not only avoid infringing rights but advance human rights outcomes, prioritizing the most disadvantaged groups in order to achieve substantive rather than formal equality. Such processes should respect the human rights principles of non-discrimination and equality, transparency and access to information, participation, empowerment, legality and accountability.

[5] Annex III – Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests – Report of the United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 1992.

Recommendations

Forests and trees contribute directly and indirectly to FSN in numerous ways. They are a source of energy, foods and other products. They provide livelihoods for an important part of the worldwide population, often the most vulnerable. Forests perform vital ecosystem services, including the regulation of the water and carbon cycles and protection of biodiversity, that are essential to agriculture. These contributions vary according to types of forests and the way they are managed. They are of course particularly important for forest dependent people but have also impacts on a very large scale. Sustainable forest management aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations, leaving no one behind.

1. DEVELOP AND USE POLICY-RELEVANT KNOWLEDGE ON THE DIRECT AND INDIRECT CONTRIBUTIONS OF FORESTS AND TREES TO FSN

States and academic institutions should take measures to inform and train FSN policy-makers and practitioners about the importance of sustainable forests for FSN. This should be done using participatory methodologies that enable the co-construction of knowledge about the contributions of forests and trees to FSN, at different spatial and temporal scales.

In particular, they should:

a. build the necessary capacities, professional training and organizational changes needed for participatory expertise and research;
b. design metrics and collect data that are disaggregated by gender, ethnicity, social class, age and other social parameters, to measure the multiple, direct and indirect, contributions that forests and trees make to FSN through production, ecological processes, income and livelihoods, cultures and well-being, with a particular focus on the FSN status of forest-dependent people;
c. gather data on nutritional trade-offs between increased income and changing diets on the one hand, and socio-cultural, economic, environmental and health impacts of deforestation and forest degradation on FSN on the other hand;
d. improve trans-sectoral, systemic data collection in FSN and forestry monitoring systems, on the use of wild foods (animals, plants, mushrooms) and forest products, including for dietary quality and diversity, poverty alleviation, health and medicinal purposes, as well as harvest impacts, to ensure long-term availability of wild foods and forest products;
e. strengthen FAO INFOODS studies on the nutrient composition of wild foods.

2. ENHANCE THE ROLE OF FORESTS IN ENVIRONMENTAL PROCESSES AT ALL SCALES WITHOUT COMPROMISING THE RIGHT TO ADEQUATE FOOD OF FOREST-DEPENDENT PEOPLE

All stakeholders should use an ecosystem approach to promote the sustainable management of forests and trees, from local to global levels, in order to preserve ecosystem functions of forests and trees, as well as their contributions to FSN.

In particular, **states, intergovernmental organizations (IGOs), non-governmental organizations (NGOs) and other stakeholders should:**

a. recognize and enhance the role of forests and trees in regulating climate, water cycle and water quality, as well as in biodiversity conservation;
b. promote the role of forests and trees to limit soil erosion and land degradation, and to restore land;
c. consider how the implementation of initiatives designed to address environmental issues will affect local communities' and indigenous peoples' access to forest foods, and how this might impact dietary diversity and quality.

3. SUPPORT THE CONTRIBUTIONS OF FORESTS TO IMPROVE LIVELIHOODS AND ECONOMIES FOR FSN

States and the private sector should:

a. develop and promote participatory forest planning and management policies and measures that enable access to nutritionally important forest foods, in particular for forest dependent communities and indigenous peoples;
b. promote and enable income generation and livelihoods opportunities in local communities, through the sustainable management and use of forest resources, particularly for those living in mountains and other remote areas;
c. integrate low-carbon, renewable energy schemes in forest management plans to achieve multiple benefits, including adequate access to fuel for food preparation;
d. increase public investments to support community-driven, forest-based enterprises for sustainable livelihoods, culture and well-being;
e. invest in social and technical innovations to minimize health risks associated with the use of fuelwood and wood stoves;
f. develop transformative, transparent and understandable marketing information systems for non-wood forest products.

4. PROMOTE MULTIFUNCTIONAL LANDSCAPES FOR FSN THAT INTEGRATE FORESTS AND TREES AS KEY COMPONENTS

States, IGOs, local authorities, conservations agencies, NGOs and other stakeholders should:

a. strengthen the contribution of forests and trees, within landscape mosaics, in the provision of fundamental ecosystem services to support agricultural production, including pollination and water and nutrient cycling;
b. promote integrated planning and local adaptive management of landscapes with strong acknowledgement of the multiple functions and uses of forests and trees;
c. promote a nutrition-sensitive landscape approach to integrate the multiple goals of FSN, sustainable forestry, land use and biodiversity conservation for human, animal and ecosystems health;
d. promote and invest in research and technologies aiming at developing and up-scaling diverse suitable agroforestry systems within integrated landscape mosaics;
e. ensure that governance mechanisms at different scales enable sustainable integrated landscape approaches that: articulate different functions of forests and trees (including wood and food production, biodiversity conservation and sociocultural benefits); consider short- and long-term objectives; recognize and reduce conflicts between stakeholders.

5. ACKNOWLEDGE THE IMPORTANCE AND STRENGTHEN THE ROLE OF FORESTS AND TREES IN ENHANCING RESILIENCE AT LANDSCAPE, COMMUNITY AND HOUSEHOLD LEVELS FOR FSN

States, IGOs, local authorities, conservations agencies, NGOs and other stakeholders should:

a. identify and strengthen the ways in which forests and trees contribute to build resilience at landscape, community and household levels;
b. develop integrated food-forestry systems building on local knowledge that contribute to enhance resilience of landscapes, communities and livelihoods;
c. strengthen the capacity of forest-dependent and indigenous peoples, local communities, local organizations and national institutions to mainstream and enhance

the concept of resilience of landscapes, communities and households in policies, plans and projects that address the forest-FSN nexus;

d. determine and provide the institutional and financial requirements to integrate and implement resilience-enhancing dimensions of forests and trees into policies and programmes.

6. RECOGNIZE AND RESPECT LAND AND NATURAL RESOURCE TENURE AND USE RIGHTS OVER FORESTS AND TREES FOR FSN

States should:

a. ensure local communities', forest dependent communities' and indigenous peoples' access to and use of forest resources for the realization of their right to adequate food;
b. ensure that policies, legislation and programmes that affect forests and trees respect and ensure the rights of indigenous peoples, smallholders and marginalized communities, including the rights of indigenous peoples over their genetic resources and associated traditional knowledge;
c. legally protect customary land and natural resource tenure and use rights of food-insecure people over forests and trees for FSN through formal instruments consistent with legal frameworks;[6]
d. ensure and enforce access, use and tenure rights of vulnerable and marginalized groups to forests and trees, especially in the face of large-scale infrastructure development as well as land grabbing and the establishment or expansion of protected areas;
e. collaboratively develop rights-based initiatives with indigenous peoples to enhance the productivity and resilience of forests and tree-based systems, and incorporate these initiatives into policies, programmes and practices.

7. STRENGTHEN INCLUSIVE FOREST GOVERNANCE SYSTEMS ACROSS SECTORS AND SCALES FOR FSN

States and other stakeholders should:

a. strengthen policy coherence across forestry, agriculture, education and other sectors at different scales, in order to ensure sustainable forest management strategies for improved FSN;
b. promote effective incentives for the sustainable production and consumption of forest products for FSN;
c. promote a rights-based approach to the governance of forests and trees for FSN, ensuring compliance with international human rights law and standards,[7] including standards of transparency and accountability;
d. ensure that laws, policies and programmes affecting forests and trees avoid or minimize negative impacts on FSN, create forest governance regimes that incorporate FSN concerns, clearly define the roles, rights and obligations of various stakeholders, and are effectively enforced;
e. ensure the full and effective participation of all relevant stakeholders in forest policy development, governance and management at all scales, particularly of women as well as vulnerable and marginalized groups, including indigenous peoples, and forest-

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6 For example: UN Declaration on the Rights of Indigenous Peoples; CFS Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT), Convention on the Elimination of All Forms of Discrimination against Women (CEDAW).

7 Including the International Covenant on Civil and Political Rights and the International Covenant on Economic, Social and Cultural Rights, the CEDAW, the UN Declaration on the Rights of Indigenous Peoples, and the CFS VGGT.

dependent communities, by providing them with adequate support and capacity building;

f. ensure the full and effective participation of concerned stakeholders, including indigenous peoples and forest-dependent communities, in order to integrate FSN concerns in the creation and management of protected areas;

g. facilitate the implementation of processes that take into account the impacts of forestry management on FSN at different spatial and temporal scales;

h. ensure that forest certification schemes include FSN concerns of all stakeholders by facilitating their full and effective participation;

i. promote inclusive co-management and co-production initiatives that are co-developed with relevant stakeholders, including through concessions, and corporate and social responsibility schemes.

INTRODUCTION

Forests and trees contribute directly and indirectly to food security and nutrition (FSN) in numerous ways. They are a source of wood, energy, food and other products. They provide livelihoods for an important part of the worldwide population, often the most vulnerable. Forests perform vital ecosystem services, including the regulation of the water and carbon cycles and protection of biodiversity, that are essential to food production and FSN in the long term. These contributions vary according to types of forests and the ways they are managed and governance is exerted. They are of course particularly important for forest-dependent people but also have impacts on a very large scale.

Recognition of the importance of forests within debates about FSN has, arguably, been slow to materialize. Discussions on FSN often remained somewhat production-centric, focused on improving yields from agriculture, and finding ways to disseminate new technologies and practices to enhance outputs from agricultural production. Forests were rarely featured in such discussions, other than being perceived as a space for further agricultural expansion or a threatened resource to be protected because of such expansion. The changing perception of the role of forests for FSN has actually been influenced by the Millennium Ecosystem Assessment (MA, 2005), which has demonstrated decisively that human health and nutrition are “inextricably linked” with the health of natural ecosystems, including forests (Whitmee *et al*., 2015). This invites a better integration of FSN issues and concerns in forestry-related research and policies as well as a better integration of the contributions of forests to FSN in agriculture and FSN research and policies.

The Collaborative Partnership on Forests convened a Global Forest Expert Panel (GFEP) in November 2013, and produced a report on the role of forests in FSN (Vira *et al.,* 2015), which was released at the United Nations Forum on Forests in May 2015. This has resonated with the forestry community. Forests and trees matter for FSN, both because of their direct roles (provision of food – including fruits, nuts, seeds, mushrooms, etc. – and as a safety net in times of food scarcity) and the indirect contributions that they make to the production systems that underpin agriculture and nutrition strategies (provision of ecosystem services and source of income from the sale of fuelwood and non-wood forest products [NWFPs]). This requires forest sector decision-makers to re-imagine forests, not just as spaces for conservation, protection or production (whether that be for wood, NWFPs and other forest products or ecosystem services – all of which have been well recognized), but also as key to the world’s food systems and diets.

It is also increasingly recognized that forests and trees can play an important role in contributing to environmentally sustainable agricultural systems capable of meeting the global food security requirements and be a principal driver of human and natural well-being (Ickowitz *et al.,* 2014, 2016; Vira *et al.,* 2015). This resonates well with a contemporary discourse around agriculture and nutrition that increasingly focuses on how best to create a food system that is productive, equitable and sustainable in the long term (Pinstrup-Andersen, 2013; Ruel and Alderman, 2013; Carletto *et al.,* 2015). Today, the “grand challenge” is to feed a growing population with adequately nutritious diets in an environmentally sustainable manner in the context of climate change and natural resource scarcity (Frison *et al.*, 2006; FAO, 2010a; Fanzo *et al.,* 2013; Powell *et al.*, 2015). It calls for landscape configurations that allow for the increase in agricultural production without undermining the capacity of natural ecosystems to support agriculture (Sayer *et al.,* 2013; Baudron and Giller, 2014).

Forests face increasing and competing demands for land, wood, food, feed, energy and ecosystem services. Agriculture expansion is often at the expense of forests (Gibbs *et al.,* 2010) and is considered the largest cause of deforestation, responsible for approximately 80 percent of forest loss (Kissinger *et al*., 2012). Demand for renewable energy and materials is also expected to increase (IEA, 2010), putting further pressure on forest resources. This has immediate direct effects on the livelihoods and FSN of forest-dependent men and women. It also impacts, at local and global levels, the delivery of ecosystems services on which agricultural production systems depend, raising concerns about their capacity to meet global future food demand. Policy responses to protect forests in turn influence the way they contribute to FSN, particularly of forest-dependent people.

In this context, in October 2014, at its 41st session, the Committee on World Food Security (CFS) requested the High Level Panel of Experts (HLPE) to prepare a study on sustainable forestry for FSN to inform the debates at the 44th CFS Plenary Session of October 2017. The key issue here is the multiple contributions of forests and trees to FSN[8] in its four dimensions and how they can be optimized, at different spatial and temporal scales, in a context of increasing and competing demands on land, forests and trees (including for wood, food, energy and ecosystem services), as well as of climate change.

This report aims at providing an evidence-based, comprehensive analysis of the relationships between forestry and FSN. It clarifies the links between sustainable forestry and FSN. It considers how sustainable forestry can address competing demands and contribute to FSN in the long term. It is organized as follows. Chapter 1 examines the linkages between forests and FSN and proposes, for the purpose of this report, a conceptual framework and a forest typology grounded on their level of human modification, i.e. the extent to which they have been modified by humans. Chapter 2 provides an in-depth analysis of the channels through which forests affect FSN. It describes the various contributions of forests and trees to FSN, given the specificities of the time scales of forestry-related activities. It considers the different roles of forests and forestry to support food systems in the long term (including forest ecosystem services at different scales: biodiversity, water cycle, biogeochemical cycles). Chapter 3 reviews the state of the world's forests and examines the current pressures and challenges for forestry in their contributions to the FSN of people living in the forests, at the forests' margins and outside forests, from local to global levels. To do so, the report addresses relevant issues of land use and relationships between forests and agriculture. It considers threats to and opportunities for the social, economic and environmental functions of forests and forestry, including biodiversity, the role of forests in the climate system and the impacts of climate change. Chapter 4 is oriented towards solutions, to highlight how sustainable forestry can contribute to FSN, focusing on the enabling environment for it and thus on policy instruments and governance issues.

[8] Food security exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. In 2009, the World Summit on Food Security stated that the "four pillars of food security are availability, access, utilization, and stability". *Availability* is the supply of food through production, distribution and exchange; *access* is the affordability and allocation of food, as well as the preferences of individuals and households requirements of each member of the household; *utilization* is the metabolism of food by individuals; and *stability* is the ability to obtain food over time.

1 FORESTS, TREES AND FSN: SCOPE AND CONCEPTUAL FRAMEWORK

Defining the scope of this report is in itself a challenge. Forests and landscapes with trees are extremely diverse around the world. Definitions of forests vary. There is also a need to choose between a restricted approach, considering forests in a narrow sense, and a broader perspective, encompassing trees in agricultural landscapes, such as orchards or agroforestry systems.

When looking at the various contributions of forests and trees to FSN, there is no clear-cut point at which trees stop providing these contributions. Trees in non-forested areas can often play a major role to improve FSN. Also, as emphasized by the Forests, Trees and Agroforestry (FTA) programme of the CGIAR,[9] forested areas experience changes in both type and amount of tree cover in landscapes. Too narrow a scope would not enable the discussion of some of the landscapes where these dynamics are at play, nor of their consequences for FSN. This report thus adopts a broad perspective, covering both forests in their diversity and trees outside forests.

Box 1 presents the main sources of data on forests and forest products used in this report and some of the related challenges.

Box 1 Forests and forest products: data availability and quality

At the global level, the most comprehensive source of data on forests and forest products is provided by the Food and Agriculture Organization of the United Nations (FAO), which has been monitoring the world's forests at five- to ten-year intervals since 1946.[10] The Global Forest Resources Assessments (FRA) are now produced every five years, based on data provided by a growing number of countries. At the global level, the FRA is the only database that allows analysis of the relationships between forest management and forest functions (Miura *et al.,* 2015).

The latest FRA (FAO, 2015) is the result of contributions of a network of national correspondents from 155 countries, who prepared country reports that present government forest statistics in a common format, using common definitions. The quality (precision, reliability, validity) of data about forest area has improved in recent years. As of 2014, 112 countries, representing about 83 percent of the global forest area, had carried out or were carrying out a national forest assessment, based on either a field inventory, remote sensing or a combination of the two, for which most information had been collected or updated during the last five years.

The recent production of several independent global satellite-based estimates of forest area and forest change can renew and enrich the debate around the quality of the FRA data and improve the precise monitoring of forest change at global level: the convergence between the FRA 2015 (FAO, 2015) and remotely-sensed studies has already improved when compared with previous FRAs (Sloan and Sayer, 2015). However, while the FRA defines forest as a combination of tree cover and land use, remote sensing datasets, using satellite imagery, can only monitor tree cover. For instance, they cannot differentiate between tree cover in forests and tree cover outside forests (e.g. tree crops in agricultural systems, oil palm plantations, coffee plantations, etc.). Moreover, they cannot differentiate between a permanent forest loss and a tree cover temporarily removed as part of a forest management plan.

This report also relies heavily on the FAO's *State of the World's Forests* (SOFO) (FAO, 2014a), which analyses data on the socio-economic benefits of forests for sustainable development and FSN using data from national censuses, national accounts' statistics and international surveys implemented by agencies such as the World Bank, the United Nations

[9] The CGIAR Research Program on Forests, Trees and Agroforestry (FTA), launched in 2011 and gathering multiple institutional research, development partners and donors to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. FTA works from the piloting to the scaling-up of solutions from technical options, management, governance and policies to unlock the potential and maximize the benefits that trees can bring. It has entered, in 2017, a six-year second phase up to 2022 and operates currently 118 projects in 41 countries, for a budget of USD80 million in 2017. See http://www.foreststreesagroforestry.org/

[10] See http://www.fao.org/forest-resources-assessment/en/

Children’s Fund (UNICEF), the World Health Organization (WHO), FAO and the United States Agency for International Development (USAID).

Information on gross value added (GVA) from and employment in the formal forest sector is taken from international statistical data as well as from international statistical databases, from the UN Statistics Division, the International Labour Organization (ILO) and the United Nations Industrial Development Organization (UNIDO), and is considered to be quite precise and reliable. However, it does not integrate indirect contributions of forests to formal income and employment in transportation and processing, since these activities are included in other industrial or services sectors.

Estimates of the number of households using woodfuel for cooking seem quite accurate as they cover 134 countries, accounting for 83 percent of the global population. Most of the countries where data were unavailable were in developed regions (where this information is probably not collected due to the small numbers of people using woodfuel for cooking), whereas for the few less developed countries where data were not available, regional averages were used as estimates (FAO, 2014a).

Conversely, the available information on the production, trade and consumption of non-wood forest products (NWFPs) appears to be far from complete, and not comparable across countries and over time (May *et al.*, 2001). Available estimations probably largely underestimate the informal contributions of forests to FSN for the following reasons: first, there is no agreed international definition of NWFP; second, there are a wide variety of NWFPs to be covered; third, NWFPs are often classified under agricultural products without distinction between wild and farmed products; and fourth, NWFPs are often produced or collected for auto-consumption or trade on informal markets and thus not captured through formal statistics.

In order to address this gap, the FAO Forestry Statistics programme undertook a first systematic review of NWFPs in the existing international classification systems used for collection and dissemination of data (Sorrenti, 2017). It identifies “major” NWFPs (including: edible mushrooms and truffles; forest berries; maple products; edible nuts; bamboo and rattan; cork; bark; latexes; gums and resins; hides; skins and trophies; game meat and edible insects) and calls for clarification and harmonization of terminology and classification in order to improve data collection. It finally notes the need for targeted household surveys to complement statistical databases and to capture the full value of NWFPs, including the informal sector.

We use here, when available, global figures from FAO, which is generally the most comprehensive source at global level. We complement these global figures with other data, from the IUFRO assessment (Vira *et al.*, 2015) and selected case studies.

Sources: FAO (2014a); FAO (2015); Sorrenti (2017*).*

This first chapter clarifies some of the concepts and definitions used in this report, and proposes a typology of forests and other tree systems, based mainly on their degree of human modification, that will be used in the report to help understand their contributions to FSN and guide policies to improve them. This analysis enables clarification of the notion of forest-dependent people. The chapter then considers briefly, building upon the notion of ecosystems services, the relationships between forests and trees and the four dimensions of FSN, showing the need to integrate both direct and indirect links, at different spatial and temporal scales. It proposes a conceptual framework aimed at facilitating their analysis for different systems and at clarifying the notion of sustainable forestry for FSN in light of the definition of sustainable food systems (HLPE, 2014a).

1.1 Forests, trees and agroforestry: definitions and scope

Forests are extremely diverse, resulting from the diversity of environmental conditions with which interact a diversity of cultures, economic conditions, institutions and management systems/human activities. As forests play multiple roles, they can be defined from numerous perspectives, by different actors: as a specific type of ecosystem; as an area producing wood; a hunting area; a recreational space; a conservation area; etc. These two elements explain the number and diversity of definitions used at local, national and international levels, often for different purposes.

1.1.1 An extreme diversity

Forests and trees occur under varying geographic, edaphic and climate regimes ranging from the boreal regions to the tropics. According to some estimates,[3] out of the 867 terrestrial ecoregions identified in the world (Olson *et al.,* 2001), more than 60 percent could be classified as forests or woodlands. In addition, trees are an important element in many agricultural landscapes, grasslands and rangelands.

Forest types differ widely, determined by factors including latitude, temperature, rainfall patterns, soil composition and human activity. They can be classified according to numerous characteristics. Major types of forests are generally distinguished by climatic domains (see a description of tropical, temperate and boreal forests in Box 2), with important variations in each type.

Box 2 The forest biomes

Tropical forest

Tropical forests are characterized by the greatest diversity of species. They occur near the equator, within the area bounded by latitudes 23.5 °N and 23.5 °S. One of the major characteristics of tropical forests is their distinct seasonality: winter is absent, and only two seasons are present (rainy and dry). The length of daylight is 12 hours and varies little.

- Temperature is on average 20–25 °C and varies little throughout the year: the average temperatures of the three warmest and three coldest months do not differ by more than 5 °C.
- Precipitation is evenly distributed throughout the year, with annual rainfall exceeding 200 cm.
- Soil is nutrient-poor and acidic. Decomposition is rapid and soils are subject to heavy leaching.
- Canopy in tropical forests is multilayered and continuous, allowing little light penetration.
- Flora is highly diverse: one square kilometre may contain as many as 100 different tree species. Trees are 25–35 m tall, with buttressed trunks and shallow roots, mostly evergreen, with large dark green leaves. Plants such as orchids, bromeliads, vines (lianas), ferns, mosses and palms are present in tropical forests.
- Fauna include numerous birds, bats, small mammals and insects.

Further subdivisions of this group are determined by seasonal distribution of rainfall:

- Evergreen rainforest: no dry season.
- Seasonal rainforest: short dry period in a very wet tropical region (the forest exhibits definite seasonal changes as trees undergo developmental changes simultaneously, but the general character of vegetation remains the same as in evergreen rainforests).
- Semi-evergreen forest: longer dry season (the upper tree story consists of deciduous trees, while the lower story is still evergreen).
- Moist/dry deciduous forest (monsoon): the length of the dry season increases further as rainfall decreases (most trees are deciduous).

Temperate forest

Temperate forests occur in eastern North America, northeastern Asia, and western and central Europe. Well-defined seasons with a distinct winter characterize this forest biome. A moderate climate and a growing season of 140–200 days during 4–6 frost-free months distinguish temperate forests.

- Temperature varies from –30 °C to 30 °C.
- Precipitation (75–150 cm) is distributed evenly throughout the year.
- Soil is fertile, enriched with decaying litter.
- Canopy is moderately dense and allows light to penetrate, resulting in well-developed and richly diversified understory vegetation and stratification of animals.
- Flora is characterized by 3–4 tree species per square kilometre. Trees are distinguished by broad leaves that are lost annually and include such species as oak, hickory, beech, hemlock, maple, basswood, cottonwood, elm, willow and spring-flowering herbs.
- Fauna is represented by squirrels, rabbits, skunks, birds, deer, mountain lion, bobcat, timber wolf, fox and black bear.

[3] https://library.cgiar.org/bitstream/handle/10947/2564/fc4_crp6_report.pdf?sequence=1

Further subdivisions of this group are determined by seasonal distribution of rainfall:

- Moist conifer and evergreen broad-leaved forests: wet winters and dry summers (rainfall is concentrated in the winter months and winters are relatively mild).
- Dry conifer forests: dominate higher elevation zones; low precipitation.
- Mediterranean forests: precipitation is concentrated in winter, less than 100 cm per year.
- Temperate coniferous: mild winters, high annual precipitation (greater than 200 cm).
- Temperate broad-leaved rainforests: mild, frost-free winters, high precipitation (more than 150 cm) evenly distributed throughout the year.

Boreal forests

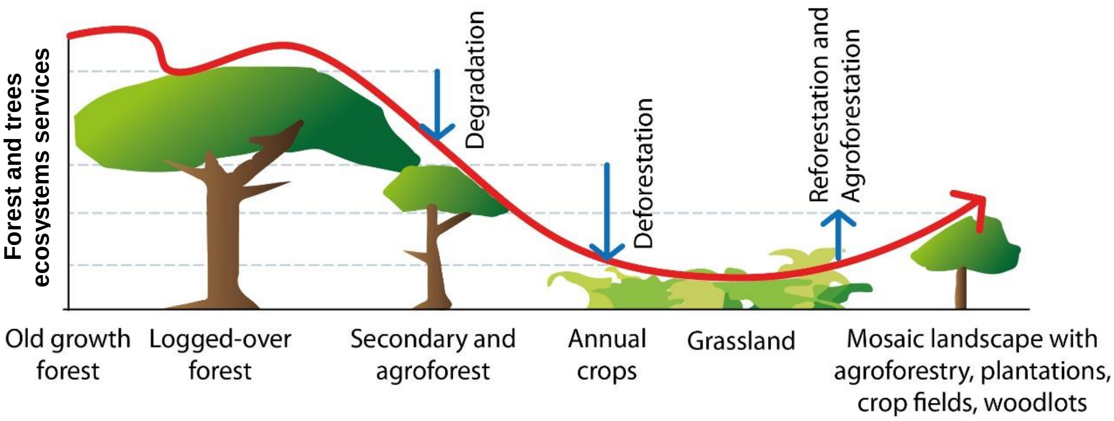
Boreal forests, or taiga, represent the largest terrestrial biome. Occurring between 50 and 60 °N latitudes, boreal forests can be found in the broad belt of Eurasia and North America: two-thirds in Siberia with the rest in Scandinavia, Alaska and Canada. Seasons are divided into short, moist and moderately warm summers and long, cold and dry winters. The length of the growing season in boreal forests is 130 days.

- Temperatures are very low.
- Precipitation is primarily in the form of snow, 40–100 cm annually.
- Soil is thin, nutrient-poor and acidic.
- Canopy permits low light penetration and, as a result, understory is limited.
- Flora consists mostly of cold-tolerant evergreen conifers with needle-like leaves, such as pine, fir and spruce.
- Fauna includes woodpeckers, hawks, moose, bear, weasel, lynx, fox, wolf, deer, hares, chipmunks, shrews and bats.

See: http://www.ucmp.berkeley.edu/exhibits/biomes/forests.php

Another important way to distinguish different types of forests is according to the degree of human influence, which can be presented along a "transition curve" from natural forests to agriculture and reforestation. Historically, forested countries have experienced phases of decreasing and then increasing forest area, with changes in both type and amount of tree cover in landscapes. The forest transition curve (see Figure 1) illustrates clearly how a continuum of management intensity, from low to high intensity, cuts across the "evolution" of forest and tree cover loss and recovery (Mather and Needle, 1998). The movement of a country or region along this forest and land-use transition curve has tended to follow demographic change and economic development. However, this curve is also useful for describing spatial variation across contemporary landscapes.

Figure 1 Forest and land-use transition curve



Source: Adapted from CIFOR (2011).

1.1.2 Forest definitions

There are numerous definitions of forests. Lund (2017) found 1 660 different definitions for forests and wooded areas in use around the world – with some countries using several definitions at the same time. This reflects both the diversity of forests and forest ecosystems in the world and the diversity of human perceptions and uses of forests. The term “forest” can be used to describe a broad range of ecosystems from scattered trees in dry landscapes to dense, close-canopy, old-growth forests in high rainfall areas (Sloan and Sayer, 2015). Because of their wide geographic distribution within many diverse biomes, forests are extremely diverse, from dry and sparse to moist and dense, driving a diversity of national definitions. The diversity of definitions is also linked to differences in culture and forest use (Helms, 2002). A forest may be an administrative unit, a type of land use or a type of land cover (Lund, 2002). Some areas can be designated as forests as an administrative unit, even if not totally forested.

Most definitions of forests are based on land cover or land use. Land cover refers to the actual physical appearance of the land. Land use refers to its use by humans. From a land-use perspective, an area temporarily devoid of trees because they have been cleared is still a forest if it will be reforested in a foreseeable future. Most definitions combine criteria of crown cover (canopy density determined by estimating the area of ground shaded by the crown of the trees), tree height and minimum area size, often adding land-use considerations to include areas currently devoid of trees but to be reforested and/or to exclude some areas used for agricultural purposes.

The definition used, including such criteria and thresholds, can have a decisive influence on the area considered as forest. Lund, taking the example of Turkey (Lund, 2014) notes that the area considered as forest according to the national definition is almost double that which Turkey declares to FAO using the FAO definition (see below). He shows that the difference is mainly due to the inclusion in the Turkish definition of forest of areas with a crown cover between 1 and 10 percent, named as “degraded forest”. He also notes that, within the United States of America, the definitions of tree and forestland vary by federal agency (Lund, 2002), each of them having a specific interest and perspective. As shown by these examples, most definitions are adapted to national situations and often to a specific purpose.

The FRA has contributed to harmonize, at the global level, the approaches used to define and categorize forests, even if a total uniformity across national approaches is likely to be elusive (Sloan and Sayer, 2015). The FRA (see Box 3), uses an agreed global definition of forest that includes a minimum threshold for the height of trees (5 m), at least 10 percent canopy cover and a minimum forest area size (0.5 ha). Urban parks, orchards, palm oil plantations, agroforestry and other agricultural tree crops are excluded from this definition (but rubber, cork oak and plantations of Christmas trees are included) (FAO, 2012a).

From this definition of forest, one can deduce the following definitions (FAO, 2012a):

- **Deforestation:** the conversion of forest to other land use or the permanent reduction of the tree canopy cover below the minimum 10 percent threshold.
- **Afforestation:** establishment of forest through planting and/or deliberate seeding on land that, until then, was not classified as forest.
- **Reforestation:** re-establishment of forest through planting and/or deliberate seeding on land classified as forest.

With those definitions, in 2015, forests covered almost 4 billion ha globally, around 30 percent of global land area (FAO, 2015). A further 1.2 billion ha are covered by other wooded land (FAO, 2015; Keenan *et al.,* 2015) that is mainly, as defined in Box 3, land with a canopy cover between 5 and 10 percent.

Box 3 Definitions used for FAO's forest resources assessments

In the FRA, FAO distinguishes three categories of land (FAO, 2012a).

1. **Forest**

"Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use."

Among forests, FAO distinguishes again three categories:

- **Primary forest:** "Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed."
- **Other naturally regenerated forest:** "Naturally regenerated forest where there are clearly visible indications of human activities."
- **Planted forest:** "Forest predominantly composed of trees established through planting and/or deliberate seeding."

2. **Other wooded land**

"Land not defined as "Forest", spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5–10 percent, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use."

3. **Other land**

*"*All land that is not classified as forest or other wooded land."

This last category includes land that is predominantly under agricultural or urban land use.

It includes in particular a subcategory named "other land with tree cover" defined as: "Land considered as "Other land", that is predominantly agricultural or urban land use and has patches of tree cover that span more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 metres at maturity. It includes both forest and non-forest tree species."*

This subcategory includes groups of trees and scattered trees (e.g. "trees outside forest") in agricultural landscapes and urban areas, respecting the three criteria described above. It includes in particular fruit tree plantations and agroforestry systems, as well as tree plantations established mainly for other purposes than wood production, such as oil palm plantations.

** More details/explanations on the definitions can be found in FAO (2012a).*

Other regional and global maps and assessments of forests have been produced – often with differing results, reflecting the various forest definitions and methodologies used and also the differing interpretations made. For example, the use of satellite imagery might produce very different results with regard to ground-based surveys as explained in Box 1. Using large databases of satellite imagery at very high spatial and temporal resolution, made available for scientists through the Google Earth platform, building on a new FAO photo-interpretation tool, and on the participatory expertise of more than 200 local operators, Bastin *et al.* (2017) identified 467 million ha of "hidden" forests in dryland biomes that had not been reported before. This estimation of dryland forest area increases previous estimates by 40 to 50 percent. These "hidden" forests represent at least 9 percent of the actual global forest area. The differences are particularly significant in Africa where dryland forest area doubled. Such tools could improve sensibly the evaluation and monitoring of forests areas and their evolution in the future and help to improve the quality of the data collected in future FRAs.

Even at international level different definitions are used, resulting in data that are not totally comparable. For instance, for the greenhouse gas (GHG) inventories communicated to the United Nations Framework Convention on Climate Change (UNFCCC), each country documents and uses its own national definitions.

Forest definitions have been criticized (see Chazdon *et al*., 2016a) as not capturing such characteristics as natural or planted, composed of native or non-native species, continuous or fragmented, healthy or degraded, thus hiding some very significant changes in the composition and health of forests. The inclusion of homogeneous plantations in the forest definition has been particularly criticized for their lower level of biodiversity. Another critique is that the minimum threshold used leaves out small patches and areas with sparse tree densities, both of which can play important roles for ecosystems and local FSN and livelihoods.

Such critiques are generally grounded on the recognition of the specificity and relative importance of certain types of forests. They call for a nuanced approach to the notion of forest, recognizing the need for definitions for statistical purposes while capturing differences. In other words, even if there is a need for a single definition of forest for global statistical purposes, there is also a need to distinguish inside this definition different types and categories, for different purposes. In this report, figures related to "forests" refer, most of the time and unless otherwise specified, to the FAO definition that is used for most global numbers. The report uses, however, a more nuanced and broader typology, described in section 1.2.

1.2 A typology of forests and trees outside forests

Historically, earth's ecosystems and the human cultures associated with them have produced a wide range of forests and tree-based systems, often connected to the traditional knowledge and practices of indigenous peoples and local communities worldwide (Vira *et al.,* 2015). A typology of forests could use biotic criteria (climatic domains or types of ecosystems, density of canopy cover) or management criteria (position in a historical continuum of forest and land-use transition curve; degree of human modification; or main recognized role from a human activity perspective).

For the purposes of this report, the typology used here is grounded on management criteria, broadly the degree of human modification and the position on the transition curve, as these are the criteria that most influence the various contributions to FSN and can be more easily influenced by policies. It aims to facilitate the analysis of land-use management challenges across a broad range of situations.

This typology thus distinguishes five broad categories:

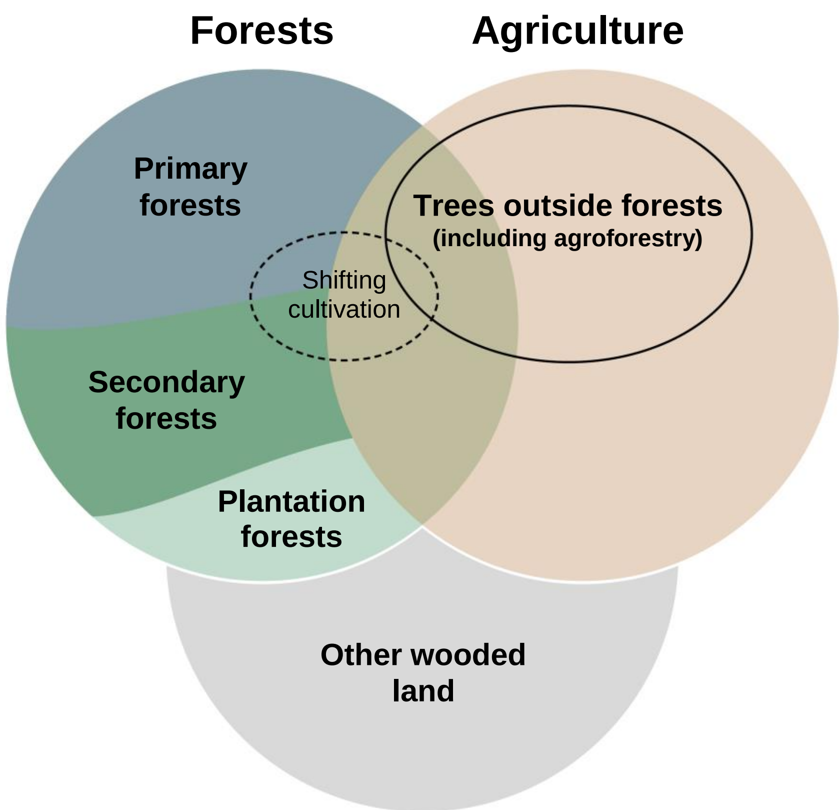
1. **primary (or old-growth) forests** with little human-induced perturbation (although shifting cultivation and selective logging can alter the forest structure);
2. **secondary forests** that have been profoundly modified at one stage by human intervention and are the result of natural regeneration and/or active human management;
3. **plantation forests,** including monospecific timber plantations;
4. **other wooded land** with scattered tree cover, not considered as forest by FAO;
5. **trees outside forests,** including trees in agricultural landscapes and agroforestry systems, as well as small patches of forests in mosaic landscapes.

There is generally no clear delineation among these types, because they exist on a continuum of management intensity along the forest transition curve, from relatively undisturbed forest to intensively farmed agricultural land (see Figure 2). There is also a considerable diversity within each type. It is, however, very useful to recognize the differences between these types, as a means to approach diversity and to facilitate the design of concrete and context-specific management. The first three types are comprised of what FAO considers as forests, and are identified in FAO statistics, which gives the possibility to consider their respective importance as well as their evolution in terms of surface (see Chapter 3). The last two categories gather systems that are generally not classified as forests, although based on, or incorporating, trees.

The denominations proposed here take into account previous classifications as well as the concerns expressed about the definition of forests (see above). It is, however, important to recognize that whatever the terminology adopted, it can be misleading because it tends to emphasize one aspect above others.

Figure 2 shows schematically how the various types of forests and tree systems are related to each other and linked with forest and agriculture activities. There is an increasing human modification and management intensity from primary forests, secondary forests to plantations and agriculture. To a certain extent, monospecific intensively managed plantation forests share many characteristics with monocropping farming systems. Shifting cultivation (see Box 5) is an agricultural activity practised inside forests.

Figure 2 Five types of forests and tree systems



1.2.1 Primary (or old-growth) forests

Most forest practitioners and academics do not recognize the term "primary forest" as it appears in the FAO terminology (see FAO, 2012a) and prefer "mature" or "old-growth" forest to recognize the limited extent of truly untouched forests

Primary or old-growth forests are characterized by limited management (Pimbert and Pretty, 1997) and low level of human disturbance. Even in forests classified as primary, plant distribution may have been influenced by humans. For instance, Levis *et al.* (2017) show that plants domesticated by pre-Columbian peoples are much more likely to be dominant in Amazonian forests than other species. These forests are considered as being close to their original composition. Many primary forests have been and/or are being modified by the people living in or close to them to increase the supply of plant-based food and/or change the supply of favoured animal species (Jamnadass *et al.,* 2015).

Primary forests account for almost one-third of the total forest area (Morales-Hidalgo *et al.*, 2015). In 2015, they still covered 1 277 million ha globally, half of which are located in the tropics (FAO, 2015). Primary forests are distributed among all the climatic domains all over the world with 400 million ha reported in South America (of which 203 million in Brazil), 320 million in North and Central America (of which 206 million in Canada), 277 million in Europe (of which 273 million in the Russian Federation), 135 million in Africa (of which 103 million in the Democratic Republic of the Congo), 117 million in Asia (of which 46 million in Indonesia), and 27 million in Oceania (FAO, 2015).

Primary or old-growth forests, including mangroves (see Box 4) contribute to FSN through the direct collection of products for immediate consumption and derivation of income through the sale of NWFPs and a broad suite of forest resources (Angelsen and Wunder, 2003). They also provide ecosystem services such as: air quality, water quality, climate regulation and pollination; and nutrient cycling, water cycling, soil formation and photosynthesis. They often provide religious, spiritual and cultural values and in some cases are used for recreation and tourism.

Box 4 Mangroves: a key contribution to FSN

Mangroves are defined as assemblages of salt-tolerant trees and shrubs that grow in the intertidal regions of the tropical and subtropical coastlines. They harbour a unique assemblage of aquatic and terrestrial biodiversity. Their net primary production is among the highest compared with any terrestrial ecosystem, providing wood and food as well as supporting (nutrient cycling and land building) and regulating (pollution, salinity, carbon storage, wave, storm surges and tsunami) services. They enhance fisheries productivity of the adjacent coastal waters by acting as a nursery ground for commercially important fish, prawn and crabs and supplying organic and inorganic nutrients. They play a critical role in reducing the impact of cyclonic storms, hurricanes and tsunami on human lives and properties. Thanks to their high productivity and carbon burial rates, the carbon stocks in the mangrove ecosystem can be as much as four times higher compared with other terrestrial ecosystems (Alongi *et al.*, 2016).

They are, however, facing considerable pressure, with deforestation rates estimated to be five to six times higher than average rates (Spalding *et al.*, 2011).

Source: Alongi *et al.* (2016); Spalding *et al.* (2011); FAO (2007a).

1.2.2 Secondary forests

For the purposes of this report, secondary forests are defined as “forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites” (Chokkalingum and de Jong, 2001). This change in structure and species follows a successional process, and the time elapsed since the human or natural disturbance plays an important role.

This category “secondary forests” includes what FAO calls “other naturally regenerated forests”, which cover globally around 2.4 billion ha (FAO, 2015). Secondary forests can be managed to various degrees and for various purposes. Such forests can contribute significantly to FSN through the provision of income from timber, cash crops and the direct provision of food. In addition, they contribute to FSN through the provision of ecosystem services. Most of the secondary forests in Europe and North America are actively managed to enhance wood production as well as other functions, through practices combining natural regeneration, plantation and selective logging. Secondary forests are also the main providers of fuelwood in the rural areas in most of the tropics, especially in the dryer areas (Henao-Bravo *et al.*, 2015). In some countries, the communities (*mestizo* or indigenous peoples) have access to the forests through concessions (Guatemala) (Orjuela Vásquez, 2015), communal property (Nicaragua) (Henao-Bravo *et al.*, 2015) or forest use rights (Honduras) (Forest Trends, 2013), and they produce wood, food, fodder and NWFPs.

As Wadsworth (1997) states: “if managed sustainably, secondary forests can contribute to the generation of income, can provide, through wood production, other forest products for the markets, and other environmental services”. Since many of them are regenerated in former cattle and agricultural areas that have been degraded, secondary forests are normally easily accessible through the rural road network.

Finally, shifting cultivation, which to a great extent could be considered as an agroforestry system (see section 1.2.5), is practised inside forests, both secondary and primary (see Box 5).

Box 5 Shifting cultivation, or swidden agriculture

Shifting cultivation involves the intermittent clearing and burning of small patches of forest for subsistence food crop production, followed by longer periods of fallow in which the forest restores the productivity of the land (Cramb *et al*., 2009). Also known as swidden agriculture, it covers a wide diversity of traditional practices in very different landscapes and ecosystems. In many rural upland tropical areas, it remains the dominant form of agriculture, contributing to the creation of complex landscapes. The forest clearings made for shifting cultivation, often in secondary forests, may range from a few square metres to several hectares. Useful tree species (frequently fruit trees) are spared and protected from fire. Intensive cropping of annual species usually lasts one or two years and is then replaced by less intensive management allowing natural vegetation to gradually dominate the site. Selective weeding spares natural plants valuable for food, medicine or other purposes. These practices may lead to an agrobiodiversity that can be very high in some of these systems (Rerkasem *et al.,* 2009).

The extent and impacts of shifting cultivation are debated (van Vliet *et al.,* 2012) and accurate estimates of land and number of people involved are lacking. Swidden agriculture is still practised in over 40 countries of Africa, Asia and Latin America. Regional estimates for Southeast Asia suggest that swidden agriculture is still common, with between 14 and 34 million people engaged in nine countries (Mertz *et al.,* 2009). Similarly, it can be assumed that swidden agriculture concerns a significant proportion of the 850 million ha of tropical secondary forests in Africa, Latin America and Asia (Mertz *et al.,* 2008).

A growing body of research indicates that shifting cultivation, particularly where traditional knowledge is well-developed and applied, can be managed sustainably, without undermining soil fertility and productivity, while preserving biodiversity and various ecosystem services provided by forests. However, the introduction of more intensive practices, such as new crops and technologies unadapted to local agroecological conditions or shorter cropping cycles, while increasing agricultural production in the short term could endanger the whole ecosystem and contribute to soil fertility and productivity declines in the long term.

While suitable when there is an abundance of land and low human population, shifting cultivation could lead to forest degradation with a denser population. This in turn compromises FSN due to lost biodiversity upon which many rural poor households depend for their livelihoods. However, the impact of policies promoting the abandonment of shifting cultivation must also carefully consider alternatives for local communities and the impacts of such transitions on diet quality and food security (Parrotta *et al*., 2015).

Sources: Peng *et al.* (2014); Vira *et al.* (2015).

1.2.3 Plantation forests

For the purpose of this report, “plantation forests” are defined as those forests planted with a reduced number of tree species, sometimes a single one, often on large areas, mainly to produce wood. Taking into account the critiques of forest definitions (see section 1.1.2), this category is close to the FAO category called “planted forests”, which covers globally 291 million ha (FAO, 2015). It includes the “industrial fast-growing forest plantations” reported by INDUFOR to cover 54 million ha worldwide (INDUFOR, 2012).

A large, increasing proportion of the timber products used in the world today, especially pulpwood, comes from plantations. Plantation forests are often established for the purpose of production and/or protection of soil and water.

Plantation forests generally contribute to FSN through providing a source of income, employment and economic growth. They can be very efficiently managed, as wood-producing systems, using improved, sometimes introduced species, and in some cases fertilizers and weed control. Well-managed planted forests generally have higher yields of wood than natural forests. In the tropics, commercial plantations have a yield of 10–30 m^3 per ha, compared with 1–5 for natural forests (Evans and Turnbull, 2004). There are examples of significant yield gains, often linked to genetic improvements. For instance, in Brazil, the average yield in the 1970s was 13 m^3 per ha and it now currently exceeds 40 m^3 per ha (IBA, 2015).

Plantation forests are sometimes perceived as being composed of exotic species. However, only between 18 and 19 percent of planted forests comprise exotic species. This proportion is particularly low in North America, West and Central Asia and Europe; it is much higher in South America (88 percent), Oceania (75 percent) and Southern Africa (65 percent) (Payn *et al.*, 2015).

Plantations forests generallly barely contribute to direct food provision. Provision of other ecosystem services depends greatly on the way they are managed. Well-managed planted forests can provide various forest goods and services and help to reduce the pressure on natural forests (WWF/IIASA, 2012; FAO, 2015).

There are also systems in which the main purpose is the harvest of trees, while at the same time producing agricultural crops and/or cattle. These systems accrue from large-scale to small-scale initiatives and from companies to individual farmers and communities. The non-forest crop provides food, cattle or a permanent crop in order to keep a positive cash flow in the system. They include mixes such as teak/cattle, mahogany/cocoa/cattle, eucalyptus/coffee, eucalyptus/rice/soybeans/sunflower/cattle, etc. (de Camino *et al.,* 2012). Such systems, while integrating wood production as a main component, are in fact part of agroforestry systems described below.

1.2.4 Other wooded land

As explained above, this category includes the wooded areas that are not considered as forests by FAO because, while meeting the criteria of size and height, they do not meet the criteria of canopy cover (see Box 3). This category also excludes all agricultural land with trees (see below).

The area classified as “other wooded land” is equivalent to the primary forest area and represented 1 204 million ha in 2015 globally, with over three-quarters situated in the tropical and subtropical domains (FAO, 2015). There is a lack of data and analysis on these “other wooded lands” that include a significant part of degraded forests.

1.2.5 Trees outside forests: agroforestry and other systems

This last category includes a considerable variety of systems that provide, in many countries, a critical source of wood, fruits and other NWFPs. It encompasses diverse agroforestry systems, mosaic landscapes where forest patches are too small to be considered as forest for statistical purposes, as well as agriculture tree plantations like palm oil, olive trees and orchards (fruit and nuts trees). In spite of their diversity, these systems share the common characteristic of trees being closely linked to agriculture and food production activities.

“Trees outside forests” are more difficult and costly to characterize, as they do not give way to accurate and harmonized statistics and as they are in some cases exceptionally dynamic and are evolving rapidly. This category includes areas characterized in FRA as “other land with tree cover” (see Box 3). Only 84 countries, representing 51 percent of the global forest area reported on tree cover in agricultural and other landscapes in the FRA 2015 (FAO, 2015), mainly because of lack of data. Some 284 million ha globally are reported in the FRA 2015 (FAO, 2015) as “other lands with tree cover”, of which 75 percent (214 million ha) are in the tropics. This area has increased by 0.52 percent per year from 1990 to 2015 (FAO, 2015; Sloan and Sayer, 2015).

In tropical Asia and subhumid Africa, vast areas considered as agriculture have substantial tree cover (Sloan and Sayer, 2015). The growth of such systems can coincide with ongoing deforestation. For instance, El Salvador reported net forest loss for the period 1990–2015, resulting from deforestation of dense forest, while not accounting as forest the growth of trees in agropastoral mosaics that results, in fact, in a net gain according to satellite observation (Sloan and Sayer, 2015).

Agroforestry systems

"*Agroforestry* is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components" (Lundgren and Raintree, 1982). Agroforestry systems range from scattered *Faidherbia albida* trees in Sahelian millet fields to the high-density multistoried home gardens of the humid tropics, such as the rubber gardens of Indonesia (Rahman *et al.,* 2016), and from systems in which trees play a predominantly service role (e.g. windbreaks) to those in which they provide the main commercial product (e.g. intercropping with plantation crops).

Agroforestry and tree-based agricultural systems provide a wide array of benefits for local communities and the environment. These include the provision of shade in parklands and agricultural landscapes, important for shade-tolerant agricultural crops, especially vegetable crops. For instance, under optimal soil and climate conditions, cocoa grown under tree shade can produce significant yields for 60–100 years, instead of less than 20 years for cocoa grown without shade (Ruf and Schroth 2004; Obiri *et al.,* 2007, 2011). Agroforestry can also provide: improved soil fertility resulting in increased crop yields, fodder for livestock, fuelwood, and improved household resilience through the provision of additional products for sale or home consumption (Rahman *et al*., 2016). Some communities, such as the Bribri of Costa Rica, plant or maintain fruit trees in their agricultural landscape to attract wild animals for hunting (Sylvester and Segura, 2016).

Agroforestry systems can be classified according to their structure, i.e. the spatial and temporal arrangements between tree and non-tree components. Three broad classes of agroforestry systems can be distinguished (Nair, 1993; Vira *et al.,* 2015):

- agrisilvicultural systems, combining agricultural crops and trees or shrubs;
- silvopastoral systems, combining trees and pasture for grazing livestock;
- agrosilvopastoral systems, combining crops, pastures and trees.

There are no reliable statistics on agroforestry systems at the global level, but Zomer *et al.* (2009, 2014, 2016) made a first attempt to quantify the place of trees in agricultural landscapes using available remote sensing datasets. They showed that, at the global level, 40 percent of agricultural land had more than 10 percent of tree cover.

Mosaic landscapes with trees

In addition to agroforestry, forests often constitute patches inside small- and medium-size farms. They also provide food for auto-consumption and for the local markets, to complement agricultural production, especially when food crops are grown under the canopy of the forest. Forest fragments in diverse landscapes also support local livelihoods, both directly and indirectly through the provision of diverse ecosystem services, including pollination and pest control services (Ricketts, 2004; Rickets *et al.,* 2008; Holzschuch *et al.,* 2010). Fragmentation may affect the health of the forest and induce biodiversity loss, increase of invasive species or pests and reduced water quality (Bogaert *et al*., 2011). Fragmentation and lower connectivity of forest patches also affect the ability of pollinators, pest predators, water and nutrients to move across a landscape (Vira *et al.,* 2015).

Agricultural tree crop plantations

Agricultural tree crops (such as palm oil, coffee, cocoa or olive tree plantations, as well as orchards) provide food directly, most of which is often sold, providing income and employment. They share, especially when of large dimensions, many of the characteristics of plantation forests and their contribution to other ecosystem services depends both on their size and the way they are managed. Small and/or mixed orchards are close to or part of agroforestry systems.

FAOSTAT[11] provides statistical data for those tree plantations that are considered as agricultural crops. For instance, palm oil plantations were reported to cover almost 19 million ha in 2014 at the global level, while cocoa, coffee and olive trees covered around 10 million ha each.

1.3 Forest-dependent people

Evaluating the number of "forest-dependent people" is challenging and has given way to very diverse estimates for two major reasons: first, uncertainty of data (Chao, 2012) and second the ambiguity of the concept itself.

Although it is possible to refer to any people who rely on forest products for their livelihood as being to some extent "forest-dependent", this generic concept obscures fundamental distinctions between different types of relationships. Byron and Arnold (1997) have presented a fundamental critique of the use of the term "forest dependence", arguing that it is more useful to present a typology of different types of users. They make a crucial distinction between those who rely on forest use and have no alternative, and those who use forest products or engage in economic activities involving forests, but do so as a matter of choice.

Fisher *et al.* (1997) propose distinguishing three types of forest-dependent people:

(a) People who live in and around natural forests, or on the forest frontier, often living as hunter–gatherers or shifting cultivators, and who are heavily dependent on forest resources for their livelihoods primarily, but not always, on a subsistence basis. Shifting cultivation is a major contributor to their food security. People in this category are often indigenous peoples or people from minority ethnic groups. They are, thus, usually outside both the political and economic mainstream.

(b) People who live in proximity to forests, are usually involved in agricultural practices either within or outside the forest, and regularly use forest products (timber, fuelwood, bush foods, medicinal plants, etc.) partly for their own subsistence purposes and partly for income generation. For those more involved in agriculture, dietary supplements from forests are often of critical importance to FSN.

(c) People engaged in such commercial activities as hunting, collecting minerals or forest industries such as forest management and logging. Such people may be part of a mixed subsistence and cash economy. These people depend on forest mainly as a source of cash income. Howver, it is important to note that this type of people–forest interaction can exist even in a highly monetized context: for example, small rural communities in highly industrialized countries such as Australia can be almost totally dependent on wages from commercial logging.

The assumption is that forest dependence type (a) is found most commonly within primary forests systems, forest dependence type (b) in both primary and secondary forests, as well as in some agroforestry systems, while forest dependence type (c) is predominantly found within some secondary and plantation forests, which are more intensively managed. Communities in remote areas may have fewer opportunities to find off-village employment and fewer resources to purchase foods (Narain *et al.,* 2008). They thus may show higher forest dependence of types (a) or (b). For instance, in the more remote areas in Pando (Bolivia), forest income may represent up to 64 percent of total household income, against 12 percent in Acre (Brazil), a region better connected to cities and markets, infrastructures and services, with more off-village job opportunities (Duchelle *et al.,* 2014).

[11] See http://www.fao.org/faostat/en/#data (accessed March 2017).

Aside from economic dependence on forests, people may also be socially or culturally dependent on the forest, regardless of which of the above-mentioned groups they belong to. It may be for religious reasons, or for recreational reasons (Glück, 2000). Spiritual or religious values of forest have also contributed to protect forests through religious rules (Stara *et al*., 2016). Further, for many people around the world, forests have important recreational and/or aesthetic values. Forests are also providing health-related treatments and may contribute to mental health status (Gibson *et al*., 1979). Especially for indigenous peoples, forests typically play an important role not only in their livelihoods, but are also in their cultures, traditions, religions, spiritual beliefs and practices (e.g. Widmark, 2009).

Various attempts to quantify the number of forest-dependent people have been made, although relying on different methodologies and definitions of what forest dependence actually means. As such, various estimates have placed the number of people considered forest-dependent at between 250 million (Pimentel *et al.,* 1997), 500 million (Lynch and Talbott, 1995), “over one billion” (WCFSD, 1999; Agrawal *et al.*, 2013) to 1.6 billion (Chao, 2012). This latter figure includes indigenous peoples, rural communities, smallholder farmers and employees of forest-based enterprises (see Table 1).

In terms of direct forest income, the pantropical Poverty and Environment Network (PEN),[12] covering 58 sites across the world, showed the importance of the income derived from forests, calculating that on average over one-fifth (22.2 percent) of rural income is derived from forest and environmental resources, often equivalent to, or even outstripping, direct income from agriculture (Angelsen *et al.,* 2014). This shows how the contributions of forests and agriculture to FSN and livelihood security can be complementary.

Importantly, all these figures rely on estimations of dependence mainly for food or income. They do not reflect the fact that most agricultural activities depend to some extent on ecosystems services provided by forests. Nor do they account for the people, often remote, that depend on forests, for instance for water management (quality, protection against floods).

Table 1 Forest peoples’ number by type of dependence

Type of forest dependence	Estimated population
Indigenous peoples who depend primarily on natural (usually closed canopy) forests for their livelihoods (hunting, gathering, shifting cultivation)	200 million
Rural people who live in or at the margin of natural forests or woodlands, who rely on the forest as a safety net or for supplemental income	350 million
Smallholder farmers who grow farm trees or manage remnant forests for subsistence and income	500 million–1 billion
Artisans or employees in formal or informal forest-based enterprises	45 million
Estimated total	**1.095–1.745 billion**

Source: Chao (2012).

[12] The PEN is a collaborative effort led by the Center for International Forestry Research (CIFOR). Launched in 2004, PEN is the largest and most comprehensive global analysis of tropical forests and poverty. It involves more than 50 research partners, covers the major tropical forested regions in Africa, Asia and Latin America, and analyses data gathered from more than 8 000 households in 25 developing countries (http://www.cifor.org/pen).

1.4 Forests, trees and FSN: a conceptual framework

Starting from the notion of ecosystem services, this section aims to show the links between forests and trees and FSN in its multiple dimensions, in order to better understand the contributions that sustainable forestry can make to sustainable food systems and FSN.

1.4.1 Ecosystem services

The term “ecosystem services” is borrowed from biodiversity conservation science, and can be defined in multiple ways, which illustrates the complexity of the concept (Danley and Widmark, 2016). For the purpose of this report, ecosystem services can broadly be defined as the structures and functional attributes of ecosystems that result in the provisioning of goods and services that contribute to human well-being (Daily, 1997; Boyd and Banzhaf, 2007).

Ecosystems services are all linked to human well-being either directly or indirectly (MA, 2005). Ecosystem services can be classified into those provided directly and those obtained indirectly. Direct services from forests and trees are represented by the provisioning of a wide range of products (wood and NWFPs) collected for food, feed, energy, construction and other uses. Indirect services are largely biophysical environmental processes that support the production of food in the long term, including access to clean water and nutrients, and enhanced quality of life (MA, 2005).

Ecosystem services are divided by the Millennium Ecosystem Assessment (MA) into four groups: regulatory, supporting, provisioning and cultural ecosystem services, as shown in Figure 3.

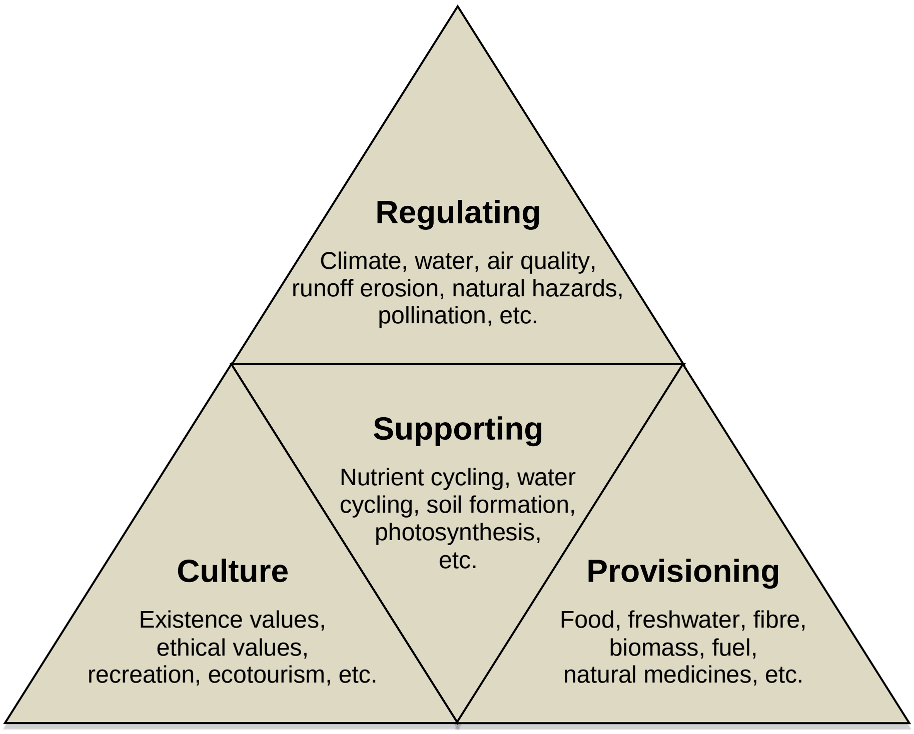
Regulatory services represent those ecosystem functions that provide environments conducive to human well-being and that ensure protection against natural disasters. They are realized over a global scale encompassing substantial marine and terrestrial ecosystems. Such services include clean air supply, groundwater purification, protection against runoff and erosion, and the global mobility of pollinators (both wind and animal pollinators).

Supporting services are the crucial functions of soil and the atmospheric stabilization that enable the production of crops and livestock. Such supporting services include photosynthesis, precipitation and the bioavailability of soil nutrients for plant growth. Long-term processes of soil formation and cycling of nutrients mediated by soil organisms as well as atmospheric interactions of nitrogen and phosphorous deposition also fall under this category.

Provisioning services, sometimes called “ecosystem goods”, include the directly available food, medicines, building material and fuel that can be harvested from marine and terrestrial ecosystems.

Cultural ecosystem services are described as the intangible values that society derives from the environment.

Figure 3 Concept pyramid of ecosystem services



Source: adapted from conceptdraw.com based on the Millennium Ecosystem Assessment (MA, 2005).

1.4.2 Linking ecosystem services provided by forest and trees to FSN

The World Food Summit provided an extensive understanding of food security: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). This widely accepted definition points to four dimensions of food security:

- Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports.
- Food access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet.
- Utilization: Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met.
- Stability: To be food secure, a population, household or individual must have access to adequate food at all times.

Building upon the MA (2005) and the International Union of Forest Research Organization's (IUFRO) assessment (Vira *et al.,* 2015), Figure 4 shows how the economic, social and environmental roles of forests and trees can contribute to and support FSN in its four dimensions.

Figure 4 Forest functions and their links to FSN

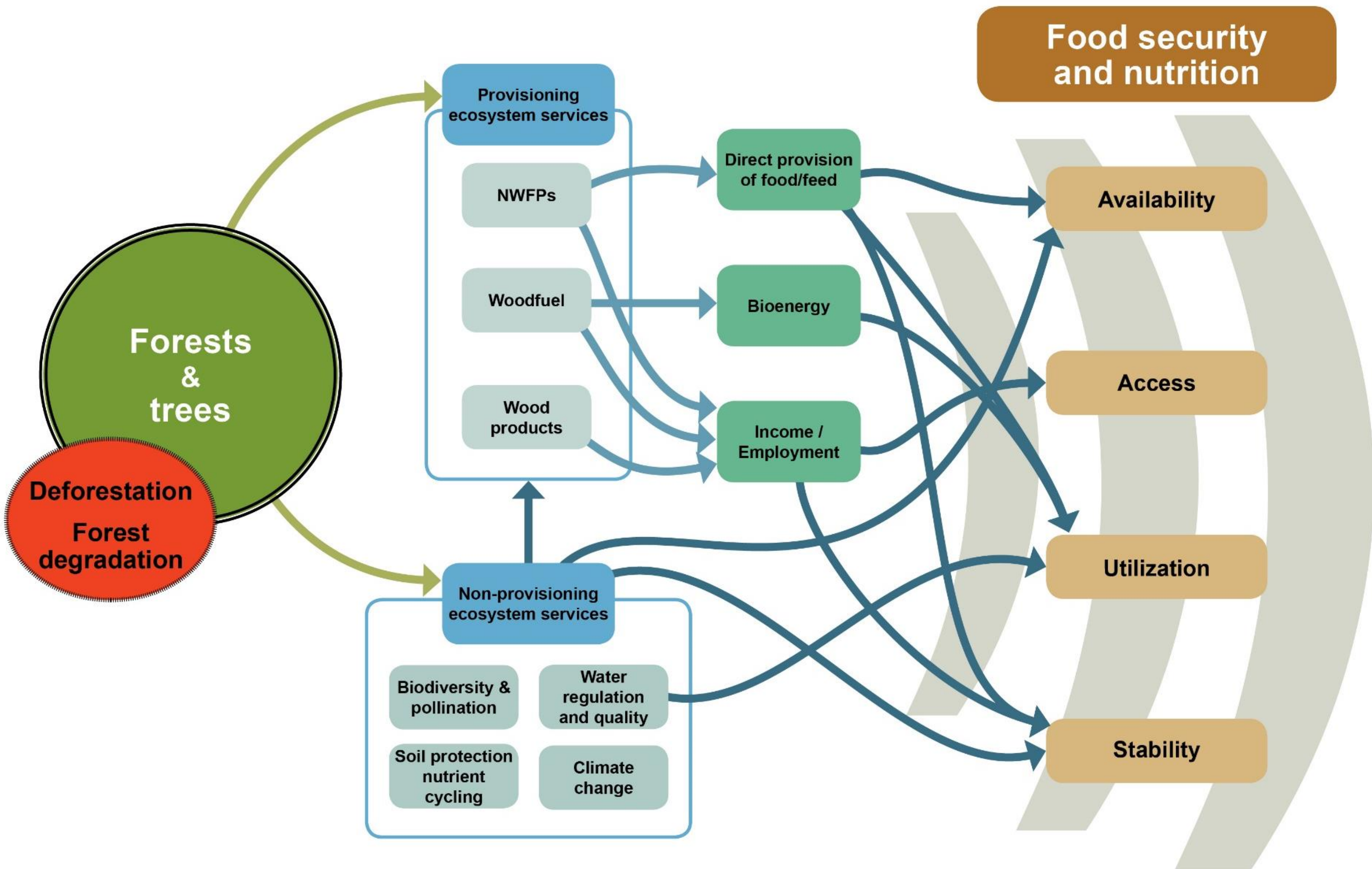


Figure 4 shows the different channels (provision of food; provision of energy, especially for cooking; income generation and employment; and provision of ecosystems services for agricultural production) through which forests and trees can contribute, directly or indirectly, in the short, medium or long term, to FSN in its four dimensions. Forests and trees also contribute to human health and well-being, including through the provision of medicinal plants. The relative importance of these contributions varies across the types of forests or tree systems considered, and also depends on the way they are managed.

On the right of Figure 4, the three portions of circle indicate that these contributions impact differently the FSN of the various categories of forest-dependent people identified in section 1.3 (people living in or near forests, as well as people engaged in forest-related activities all over the world). They also represent the different scales, from local and landscape, national and regional, to global, that should be considered in forest governance mechanisms (Vira *et al.,* 2015).

1.4.3 Sustainable forestry for FSN

For the purpose of this report, forestry is considered in a very broad sense, as encompassing all decisions related to forest and tree management (including three broad types of decisions: those related to the presence or absence of trees in a certain area, to the types of forests and trees, to the way they are managed), and applying to any type of system or landscape that includes trees.

The United Nations General Assembly (UNGA, 2008) recognizes “that sustainable forest management (SFM), as a dynamic and evolving concept, is intended to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations”. It aims to restore and reverse the effects of deforestation and degradation and provides multiple benefits for people and society (FAO, 2011a).

SFM is rooted in two main premises: first, that ecosystems have the potential to renew themselves, and second that economic activities and social perceptions or values that define human interaction with the environment are choices that can be changed or modified to ensure the long-term productivity and health of the ecosystem (MacDicken *et al.,* 2015). It encompasses all forests, both natural and planted, in all geographic regions and climatic zones, managed for conservation, production or multiple purposes, to provide a range of forest ecosystem goods and services at the local, national, regional and global levels (Brandt *et al.,* 2016). This is in line with the five strategic goals on biodiversity conservation of the Convention on Biological Diversity (CBD) [13] and with Sustainable Development Goal #15 – “to manage natural resource assets sustainably” of which forests are a key component (Reed *et al.,* 2015).

As such, sustainable forestry is an essential part of sustainable food systems, which are defined as “food systems that ensure FSN for all in such a way that the economic, social and environmental bases to generate FSN of future generations are not compromised” (HLPE, 2014a).

1.5 Concluding remarks

This opening chapter has provided an introduction to some basic forestry definitions, concepts and approaches. It provides a typology of forests and trees that will be used throughout the report to facilitate analysis of specific situations. It also clarifies the notion of forest-dependent people. It finally proposes a conceptual framework of the relationships among forests, trees and FSN that organizes the reflection in the report.

[13] See https://www.cbd.int/

The contributions of forests and trees to FSN, further developed in Chapter 2, are to be considered taking into account the following parameters:

- Their importance varies across the types of forests or tree systems considered, and according to the way they are managed.
- Their effects can be medium or long term.
- Their geographical impact depends on the type of contribution, and obviously on the size of forests.
- They also contribute to resilience at landscape, community and household levels.

Those parameters are key to understand how changes in the management of forests and trees (size, place, type, practices) can impact their contributions to FSN and the role that governance can play to improve them.

Chapter 2 now takes on the discussion and provides an in-depth analysis of the channels through which forests and trees affect, and are linked to, FSN.

2 CONTRIBUTIONS OF FORESTS AND TREES TO FSN

This chapter presents more detailed insights on the various contributions of forests and trees to FSN in its four dimensions.

It is important to underline here the gaps in data and their uncertainties, as many forest products, including food but also fuelwood, are, in large part, either auto-consumed or traded informally. As a consequence, their contribution to food availability and to adequate nutrition, as well as to access to food through the income they generate, are often underestimated. Since statistics are generally calculated on an annual basis, seasonal variations are masked, and this impedes the ability to highlight the critical contribution that forests and trees often provide to the stability of livelihoods, to access to food and good nutrition. Also, the lack of disaggregated figures, both at local level as well as by gender, prevents the formation of a complete picture of their social effects, in particular on the FSN of the most vulnerable. Finally, as ecosystem services are usually not ascribed with an economic value, their contribution is both underestimated and undervalued.

The chapter is structured as follows. The first section describes the importance of forest- and tree-derived foods. The second section recalls the importance of woodfuel particularly for cooking in developing countries. The third section attempts to quantify the importance of forestry as an economic activity and details the role of forests in providing employment and income, thus improving food access. The fourth section highlights the importance of the ecosystem services that forests and trees provide to agriculture. The chapter concludes with a synthesis of the links with the four dimensions of FSN and a descriptive matrix summarizing the relationship between forest types and FSN dimensions.

2.1 Direct provision of food

Evidence reviewed in Jamnadass *et al.* (2015) shows the variety of forest foods that are consumed on a regular or occasional basis. These foods are particularly important for forest-dependent people living in or near forests, including indigenous peoples, who depend on them for an important part of their diet, often most of it. They provide essential nutrients, often lacking in poor diets that are mainly based on staple foods. Forest foods are an important source of income through trade in local, regional or even global markets. Finally, they also play a key role in periods when food is scarce, during the “hungry season” (Powell *et al.,* 2015).

Hunting and gathering of forest foods still provide an important contribution to FSN and to the cultural identity[14] of many forest-dependent communities, including indigenous peoples, not only in the tropics but also in boreal forests of North America (Canada and Alaska) and northern Europe (Sweden, Finland, Norway and parts of the Russian Federation). Indigenous peoples are often highly attached to their traditional forest food resources (Kuhnlein *et al*., 2009).

2.1.1 Contribution to dietary diversity and quality

Animal- and plant-based forest foods have been estimated to represent 0.6 percent of global food energy supply (FAO, 2014a). However, this global figure, which needs to be considered with caution, does not give an adequate picture of the contribution of forest foods to FSN.

Firstly, it is probably an underestimate, due to the lack of available data.

Second, such a global figure underestimates in particular the contribution of nutrient-rich wild forest foods to dietary quality and diversity (Vinceti *et al.,* 2008; Powell *et al.*, 2013a, 2015). For example, despite low to moderate contribution to energy intake, wild foods are considered to represent 36 percent of total vitamin A and 20 percent of iron in the diet in a study from Gabon (Blaney *et al.,* 2009); 31 percent of retinol activity equivalents (vitamin A) and 19 percent of iron in the diet in a study from the United Republic of Tanzania (Powell *et al.,*

[14] Forests and forests products (e.g. copal) can also play a significant role in the community health systems and spiritual/religious practices of the Maya and other indigenous peoples.

2013b); 42 percent of calcium, 17 percent of vitamin A and 13 percent of iron in a traditional swidden agricultural community in the Philippines (Schlegel and Guthrie, 1973). In forests and tree-based systems, particular nutrients such as vitamins can often be made available all year round since different species in the landscape have different fruiting phenologies (Vira *et al.,* 2015). Edible leaves of wild African trees, such as baobab (*Adansonia digitata)* and tamarind *(Tamarindus indica)* are important sources of protein, iron and calcium (Kehlenbeck and Jamnadass, 2014). Consumption of only 10 to 20 g of baobab fruit pulp (or a glass of its juice) can cover a child's daily vitamin C requirement (Vira *et al.,* 2015).

Finally, this global figure hides the importance of wild foods for specific populations, in particular for forest-dependent communities. Even if the proportion of supply of food from the forests is small at the national level, it can vary drastically from one site to another and can be fundamental for specific communities (Food Secure Canada, 2008; Powell *et al.,* 2015).

Rowland *et al.* (2016) investigated the dietary contributions of wild forest foods for smallholder households in forested landscapes in 24 tropical countries, using household level data derived from the PEN project; the study estimated the contributions of micronutrient-rich forest foods to meeting dietary recommendations. They found high variability in forest food use and created a forest food use site typology made of four types to characterize the variation: forest food-dependent, limited forest food use, forest food supplementation and specialist forest food consumer sites. The results suggest that, in some sites where large quantities of forest foods are consumed, their contribution towards dietary adequacy is substantial.

Studies pairing satellite-based information on tree cover and dietary intake information yield emerging evidence of a positive link between tree cover and dietary diversity, as well as fruit and vegetable consumption (Ickowitz *et al.,* 2014, 2016; Johnson *et al.,* 2013, Powell *et al.*, 2011). Ickowitz *et al.* (2016) also found that, in Indonesia, swidden agriculture or agroforestry systems were associated with higher quality diets. Parrotta *et al*. (2015) provide a summary of the potential impacts of different livelihood strategies and their associated land-use patterns on FSN.

In parts of West Africa, shea butter (made from the fruits of *Vitellaria* paradoxa) is one of the main sources of cooking fat. Baobab and other tree leaves are some of the most commonly used vegetables and the nutrient-rich fermented seeds of the *Parkia* tree are an almost ubiquitous seasoning in stew (Rowland *et al.,* 2015).

In southern Chile and Argentina, the Pehuenche people in pre-modern times used the seed of *Araucaria araucana* as their main staple food. It remains part of their diet despite the fact that they now have access to urban markets to buy food. Furthermore, members of the Pehuenche communities have been introducing the seeds into national markets and are utilizing them for ethnic cuisine in local restaurants for consumption by tourists visiting the Araucarias de Alto Malleco and Panguipulli Model Forests in Chile (Conforti and Lupano, 2011).

At least 138 crops had been domesticated and used by native Amazonians in various types of production systems at the time of European conquest, including 83 crops native from Amazonia and immediately adjacent areas in northern South America, and 55 exotic ones, i.e*,* from other regions, such as northeastern Brazil, the Caribbean and Mesoamerica (Clement, 1999). Since then, products that were once restricted to forests such as peanuts (*Arachis hypogea*), various species of beans (*Phaseolus* spp.), cassava (*Manihot esculenta*), pineapple (*Ananas comosus*), cashew (*Anacardium occidentale*), maracujá (*Passiflora edulis*), achiote (*Bixa orellana*) and peach-palm (*Bactris gasipaes*) have all become domesticated and traded commodities.

NWFPs are also still collected in developed countries. For instance, in Sweden and Finland, even if the collection of plant-based NWFPs has decreased over the years, there is still a large share of individuals that state in different surveys that they pick berries and mushrooms, typically found in forestlands. In Sweden, around two-thirds of the population pick berries and mushrooms. The younger generations are underrepresented among the berry- and mushroom-picking population (Fredman *et al.*, 2013). The shares of berries and mushrooms left in the forest are still very high (see figures for the Russian Federation in Box 6). In general, researchers estimate that 95 percent of berries are left unharvested. In

Finland, estimates show that no more than 10 percent of berry species and 1–3 percent of mushrooms are collected each year (Salo *et al.*, 2014).

Domestication of indigenous trees could bring large production gains (Vira *et al.,* 2015). More efforts and research are needed to fully realize their potential in terms of production, marketing and trade (Jamnadass *et al.,* 2011; Gyau *et al.,* 2012). These efforts could build upon the traditional knowledge systems of indigenous forest-dependent communities.

Box 6 Assortment, potential and actual procurement of forest food products, Russian Federation

Forest food products	Annual biological resources (million tonnes)	Actual production* (million tonnes)
Wild berries (cowberry, cranberry, bilberry, etc.)	8.8	0.14
Wild mushrooms	4.3	0.43
Nuts (total)	3.5	**
Siberian pine nut (as part of total)	0.991	0.0346
Wild fruits	1.632	**
Honey	0.35	0.06
Wild animal meat (hunting)	**	**

** Does not include subsistence production. ** Data unavailable.*

Source: A. Petrov (personal communication)

2.1.2 Provision of animal-sourced foods

Animal-sourced foods (ASFs) are important for FSN not only as source of protein but also of highly bio-available[15] micronutrients. In regions with high rates of micronutrient deficiency, modest amounts of ASFs can result in substantial improvements in nutritional status and cognitive development in children (Neumann *et al.,* 2007).

The nutritional potential of bushmeat, fish and insects as important forms of ASFs should not be underestimated.

Bushmeat

Meat from wild terrestrial or semi-terrestrial animals, termed “bushmeat”, is a significant source of animal protein extracted from the forest. Nasi *et al.* (2011) estimated that nearly 4.6 million tonnes of bushmeat are extracted annually from the Congo Basin and 1.3 million tonnes from Amazonia.

In tropical areas, where livestock production is limited due to tsetse fly and other environmental constraints, bushmeat is a particularly important source of micronutrients and may be the main source of animal protein available, cheaper than any source of domesticated meat. For example, data from Madagascar have shown that the loss of access to wild bushmeat would result in a 29 percent increase in the number of children with anaemia (Golden *et al.,* 2011).

At the same time, this resource needs to be managed in a sustainable way (van Vliet *et al.*, 2015). The depletion of wildlife is intimately linked to the food and livelihood security of numerous inhabitants of the Congo Basin, as many forest-dwelling or forest-dependent people have few alternative sources of protein and income. Estimates of per capita consumption of illegally harvested bushmeat (driven largely by low dietary standards and poverty) from the Congo Basin, for instance, range from 180 g/person/day in Gabon, to 89 g/person/day in the Democratic Republic of the Congo and 26 g/person/day in Cameroon (Fa *et al.*, 2002). Similar information is only available from case studies in a few specific locations in the United Republic of Tanzania. In five districts in Western Serengeti National Park, per

[15] Indicating they are easily absorbed and utilized by the body.

capita bushmeat consumption ranged from 3 to 89 g/person/day, depending on the distance from the national park boundary (Ceppi and Nielsen, 2014).

Primary forests are not the only source of bushmeat. Secondary forests and plantation forests, as well as fallows and agroforestry systems, which attract wild animals, also play a critical function in the FSN of millions of rural families, particularly in Amazonia and Central America (Smith, 2005; Parry *et al.*, 2009).

Hunting and food gathering in boreal forests among diverse indigenous peoples include important food and nutrient sources such as: elk/moose, mountain goats, Dall sheep, musk ox, beaver, ducks and other fowl species; freshwater and migratory fish such as wild salmon, trout, pike and char; and plant-derived vitamin C sources that include many types of berries, angelica, and the inner bark of pine trees (Kuhnlein and Turner, 1991; Baer, 1996; Vors and Boyce, 2009; Kivinen *et al.*, 2010; Roturier and Roué, 2009; Nuttall *et al.*, 2009).

While in North America (Canada and Alaska) the Inuit and other indigenous peoples hunt wild reindeer (Ford, 2009), in Northern Europe[16] (more specifically in Sweden, Finland,[17] Norway and parts of the Russian Federation) the Sami actively herd reindeer. The reindeer is also an important cultural symbol for those indigenous peoples (Vors and Boyce, 2009).

In Canadian Inuit societies, the combination of hunting and fishing is of importance not only economically but also culturally. In a survey, about 40 percent of the respondents stated that about half of their meat and fish were sourced from the wild (Ford, 2009).

Apart from being vital for survival, hunting plays an important role in societies, fulfilling a social function through its historical, religious, symbolic and culture-bearing values (Konijnendijk, 2010; Fischer *et al*., 2013). Hunting is also important economically, providing livelihood and income from recreational hunting; socially (hunting being an important cultural and social determinant); and environmentally when management of game is integrated in land use management (for instance in policies both regarding population control and regeneration of forests for conservation or commercial purposes) (Fischer *et al.*, 2013).

Box 7 The role of bushmeat in the livelihoods and food security of rural people in Equatorial Guinea

Bushmeat is an important resource for rural people in the Congo Basin, as either a regular source of protein or income, or a safety net in times of hardship. However, it is important to understand the extent to which rural communities depend on bushmeat, and would therefore suffer with its demise. An evaluation of wildlife use and dependence within the context of other available livelihoods and foods was carried out in continental Equatorial Guinea, a country currently undergoing a dramatic economic boom. Household surveys and hunter interviews over 12 months in three villages with differing combinations of market and forest access enabled comparisons between communities, households and individuals.

At community-level, bushmeat was an important source of income (with nearly 90 percent of men hunting), while wild plants were more important for consumption, particularly where limited market access increased prices of imported alternatives. Within a village, the poorest and most vulnerable households gained a significantly greater proportion of income and production from bushmeat, largely because of a lack of other livelihoods, and this increased in the lean season. Poorer households were least food-secure (having higher “food insecurity” scores) and least livelihood-secure (having fewer sources of income). At individual-level, hunting income benefited men more, and was less likely to flow back to the household. Median monthly income from hunting was, however, less than half that of preferred paid employment.

Bushmeat contributed significantly to income in all communities studied, suggesting it is an important component of the rural economy across the country. Forest and particularly market access were important factors in determining livelihood strategies. Critically, bushmeat was important for the poorest households, particularly as a safety net at vulnerable times. To ensure the sustainability of bushmeat hunting, policy needs to account for the true value of forests to people, control trade, manage forest access and off-takes, and also promote alternative livelihoods for potential commercial hunters.

Source: adapted from Kümpel (2006).

[16] Reindeer husbandry in Greenland is very limited and most reindeer are wild and hunted accordingly.

[17] In Finland, reindeer husbandry is not an exclusive right of the Sami, but rather based on a long tradition of carrying out reindeer husbandry.

Fish and aquaculture

Inland fisheries are often overlooked as an important source of low-cost protein and income, particularly where alternatives are scarce (HLPE, 2014b). In many tropical forests, wild fish represent the main source of animal protein in the diet. In the Amazon Basin, fish consumption by local people is in many cases the most important source of protein. For instance, in the Rio Negro region of the Brazilian Amazon, da Silva and Begossi (2009) found that fish caught in flooded forests and in forest rivers accounted for 70 percent of animal protein in the diet, excluding other aquatic species such as turtles. In the Congo Basin, fish is often the major source of protein for both urban and rural dwellers, as well as an important source of income (Oishi and Hagiwara, 2015). McIntyre *et al.* (2016) estimate that freshwater fisheries provide enough animal protein to cover the dietary needs of 158 million people.

However, catches increase with both river discharge and human populations and it is estimated that 90 percent of global freshwater catch comes from river basins with above-average stress levels. In addition, fish richness and catches are positively correlated, so that fishing pressure is most intense in rivers where the potential impacts on biodiversity are greatest (McIntyre *et al.*, 2016).

Insects

The global importance of insects as a source of protein is difficult to evaluate, as statistics are mostly restricted to specific studies. However, insects have recently regained attention (FAO, 2013a) as a potential cheap and available source of nutrients, protein and fat, and to a lesser degree carbohydrates. Some species provide vitamins and minerals (Dunkel, 1996; FAO, 2013a; Schabel, 2010). Many forests and tree-based systems are managed to enhance edible insect supply (Johnson, 2010). For example, sago palms (*Metroxylon* spp.) are managed in forest-agriculture landscape mosaics in Papua New Guinea and eastern Indonesia to support grub production (Mercer, 1997).

2.1.3 Provision of feed

Forests and trees are also a source of feed for livestock.

Fodder trees have been traditionally used by farmers and pastoralists on extensive systems but fodder shrubs such as *Calliandra* and *Leucaena* are now being used in more intensive systems, increasing production and reducing the need for external feeds (Franzel *et al.,* 2003). Agroforestry systems for fodder are also profitable in developed countries. For example, in the northern agricultural region of western Australia, using tagasaste (*Chamaecytisus proliferus*) has increased returns to farmers whose cattle formerly grazed only on grasses and legumes (Abadi *et al.*, 2003). In the western Mediterranean, silvopastoral systems (called in Spanish *dehesa* or Portuguese *montado*) are characterized by the presence of trees, mainly oak (*Quercus* spp.) and annual grasses (Diaz-Ambrona, 1998), with pigs eating acorns, and cows, sheep or goats grazing on over five million ha (about 30 percent of forest land) in the Iberian Peninsula (Joffre *et al.,* 1999).

Semi-domesticated reindeer grazing in the forest are the main source of meat in some indigenous peoples' communities in several boreal areas,[18] but also as a source of material for handicrafts (derived from antlers and hides). In winter, semi-domesticated and wild reindeer rely for feeding on a number of species of lichen called "reindeer lichen" (including *Cladina stellaris*) growing in boreal forests.

2.1.4 Traded forest food products

A recent report on biodiversity for human health highlights the importance of the trade of wild/forest foods in local and regional markets (WHO/CBD, 2015), providing those not only to populations living in or near forests (types (a) and (b) of forest-dependent people, see section 1.3) but also to a much wider population.

Bushmeat markets in some regions are highly developed and can be physically sited hundreds of miles from the hunting source. There is such a great difference between the supply and the national and regional demand for bushmeat that supply crises for bushmeat

[18] In Norway, Finland, Sweden, the Russian Federation, Greenland, Alaska, Mongolia, China and Canada.

have developed in some areas such as Central and West Africa (Bennett *et al.,* 2007; Nasi *et al.,* 2008). As a result of such crises, scarcity of bushmeat has in turn led to price increases, and bushmeat can in such situations become more expensive than conventional protein sources (eggs, beef, chicken, etc.). Recent studies of the consumption of bushmeat comparing rural and urban children from Kisangani in the Democratic Republic of the Congo (van Vliet *et al.,* 2015) show evidence that despite the tendency towards urbanization and increased livelihood opportunities in urban areas, wildlife harvest remains a critical component of dietary quality and diversity in both rural and urban areas. Bushmeat consumption in urban areas is rapidly increasing and appears to be income-elastic, suggesting that bushmeat is socially and culturally viewed as a “high status food”. Nasi *et al.* (2011) estimated that in central Africa 289 000 tonnes per year (or around 6 percent of the total bushmeat extracted in the Congo Basin) were consumed primarily in urban areas, whereas almost all the bushmeat extracted from the Amazon Basin was consumed in rural areas. In Colombia, bushmeat consumption was found to be lower in urban than in rural areas, and in urban areas wealthier families consumed bushmeat more frequently than did the poorer ones (van Vliet *et al.,* 2015).

Numerous species are being introduced to local, regional, national and international markets (Lescano, 1996). Although the scarcity and fragility of some useful species have been overcome in part through domestication, those that continue to be utilized primarily from wild sources are subject to overharvesting, which can threaten their production in the long term and the income they provide.

Together with the increasing commercialization of berries, a market has developed in Sweden and Finland. Today, most of the production of berries is exported. Berries from northern Sweden are in especially high demand due to the midnight sun and its effect on berries, increasing anti-oxidant properties (for the medical industry), as well as pigmentation (for the cosmetic industry) (Salo *et al.,* 2014).

2.1.5 A critical role to buffer food scarcity

For some communities, forest foods play an important function as a safety net during times of agricultural crop failure or seasonal downturns in agricultural production (Blackie *et al.*, 2014; Keller *et al.,* 2006; Shackleton and Shackleton, 2004; Sunderland *et al.,* 2013; Karjalainen *et al.,* 2010).

In Sahel ecosystems with dry spells lasting up to seven months a year, trees and shrubs are vital sources of food to supplement cereal staples (Nyong *et al.*, 2007) as well as fodder for livestock (Franzel *et al.,* 2014). For example, in the Niger 83 percent of informants reported increased reliance on wild foods during drought (Humphry *et al.,* 1993) and in the United Republic of Tanzania a greater portion of the diet came from wild foods during periods of food insecurity (Powell *et al.,* 2013b). A recent review reported that for studies on the role of wild foods for diet and nutrition that included an assessment across seasons, six out of the nine cases reviewed showed higher dependence on wild foods in the lean or food-insecure season, while the other three showed higher wild food use in periods of higher availability (Powell *et al.,* 2015). A greater diversity of fruit tree species in agroforestry systems has been shown to help fill seasonal gaps in fruit supply (Jamnadass *et al.,* 2011; Vinceti *et al.,* 2013).

A recent study based on the PEN survey conducted in forest-dependent or forest-adjacent communities found that an average of 4 percent of household income was derived from the sale of wild foods, despite the fact that 77 percent of households reported having sold wild foods. The study did, however, also report that poorer households and households experiencing shocks derived higher income shares from wild foods. As with many comparative studies, the authors of this study also caution that there is a large amount of variation across sites (Hickey *et al*., 2016).

2.2 Provision of bio-energy, especially for cooking

At the global level, wood energy contributes 6 percent of the total primary energy supply (FAO, 2014a). Wood energy is often the only source of energy available and accessible in rural areas and is especially important for poor people in developing countries, particularly in Africa where it accounts for 27 percent of the total primary energy supply (FAO, 2014a).

Cooking is essential to food safety and to the bio-availability of micronutrients. Opportunities associated with woodfuel[19] use are evident (it is available in rural areas, cheap, renewable, can be sustainable and produces fewer emissions compared with fossil fuel), but challenges persist (lack of secure tenure, unsustainable harvesting practices, health impacts).

Therefore, a major contribution of forests to FSN and health is the provision of woodfuel to cook and sterilize water. At the global level, 2.4 billion people, one-third of the global population, relies on woodfuel for cooking, particularly in Africa where two-thirds of the households are reported to use woodfuel as their main fuel for cooking. Moreover, 764 million people are reported to use woodfuel for boiling and sterilizing water, of which 644 million in Asia (FAO, 2014a).

Yet over-harvesting is reducing the availability of fuelwood. In Central Africa, fuelwood extraction is an important component of human impacts on forests. This is for instance well observed around Kinshasa, the capital of the Democratic Republic of the Congo, where 90 percent of the 10 million inhabitants rely largely on charcoal for cooking (Gond *et al.,* 2016). In rural areas of developing countries, where people have no alternative energy sources, the lack of fuelwood can reduce the quality and variety of food consumed. Fuelwood availability can also impact cooking and dietary decisions, with scarcity leading to omission of meals, or exclusion of foods that require longer cooking times (Brouwer *et al.*, 1996,1997; Wan *et al.*, 2011). Remedial efforts like village woodlot planting near communities have been successful in combating the increased effort associated with dwindling fuelwood supplies (Kumar *et al.*, 2015).

Table 2 Proportion of households cooking with woodfuel in 2011, by region and fuel type

Region*	Share of households where wood is the main fuel used for cooking (%)			Estimated population using woodfuel for cooking (x1000)		
	Fuelwood	Charcoal	Woodfuel	Fuelwood	Charcoal	Woodfuel
Africa	53	10	63	555 098	104 535	659 632
Asia and Oceania	37	1	38	1 571 223	59 034	1 630 257
Europe	3	-	3	19 001	156	19 157
North America	–	–	–	–	–	–
Latin America and Caribbean	15	1	16	89 569	5 383	94 952
World	***32***	***2***	***34***	***2 234 890***	***169 108***	***2 403 998***

**This table, as well as all the other tables with regional breakdowns in this report, being built mainly on data from the SOFO and the FRA reproduces the regional breakdowns used in those documents, which are different from FAO regions.*

Sources: FAO (2014a), based on national census data and the results of WHO and UNICEF surveys.

The impacts of woodfuel on human health are complex. Access to woodfuel ensures proper cooking of foods and sterilization of water, and thus prevention of food-borne illness. However, the links between the use of woodfuel and respiratory illness (which impacts nutritional status) in women and children are well established (Kiraz *et al.,* 2003; Wan *et al.*, 2011; WHO, 2015). According to WHO,[20] 3 billion people cook and heat their homes using solid fuels (i.e. fuelwood, charcoal, coal, dung, crop wastes) on open fires or traditional stoves. FAO (2014a), using data from WHO, estimates that, globally, 2.5 million people die

[19] "Fuelwood" designates "wood in the rough (from trunks, and branches of trees) to be used as fuel for purposes such as cooking, heating or power production". "Charcoal" designates "wood carbonized by partial combustion or application of heat from an external source to be used as a fuel or for other uses". "Woodfuel" designates the total of "fuelwood" plus "charcoal". See http://www.fao.org/waicent/faostat/forestry/products.htm , accessed May 2017).

[20] See WHO estimates on the impacts of indoor air pollution (http://www.who.int/indoorair/en/).

each year due to the effects of long-term smoke inhalation as a result of using woodfuel for cooking and heating, representing 12 percent of child mortality (under five years) and 3 percent of adult deaths. Almost all of these reported deaths occurred in Africa, Asia and Oceania. The introduction of more efficient cooking stoves can make a significant improvement in the amount of fuel required and on health effects. Culturally sensitive efforts to introduce improved cooking stoves have been successful. A set of examples and principles for successful project design are provided in Soini and Coe (2014), as are numerous interventions in both indoor cooking technology and forest restoration for fuelwood accomplished through the Safe Access to Fuel and Energy (SAFE) programme of the World Food Programme (WFP).[21] With the support of NGO partners, WFP's SAFE programme provided 540 000 internally displaced women and their families in Darfur with an alternative to collecting firewood and safer methods of preparing meals, contributing to improved livelihoods and reduction of forest depletion.

Because women are the primary cooks in most cultures, the burden of illness affects them much more significantly than men. One systematic review and meta-analysis from 2011, reporting on over 2 700 studies, showed much higher risks of acute respiratory infection in children and chronic bronchitis in women with exposure to solid biomass fuel smoke (Po *et al.*, 2011).

Fuelwood collection is physically demanding, leading to illness from excessive workloads in contexts where wood sources are distant from the home (FAO, 2014a; MA, 2005; Wan *et al.,* 2011). It can also be very time-consuming and affect time available for agricultural or other forest-related income-generating activities, as well as for cooking and caring for children or in achieving full educational potential (Sunderland *et al.*, 2013; Wan *et al.*, 2011). The time needed to gather fuelwood, chiefly by women and children, tends to increase, because of scarcity and increasing distance to the resource. However, very little research has examined the drivers of woodfuel demand or the possible adaptations to reduced availability. A review of the literature conducted by FAO suggests that the average time needed to collect one cubic metre of fuelwood varies from about 106 hours in Latin America and the Caribbean to 139 hours in Asia and Oceania (FAO, 2014a). Similarly, responsibility for fuelwood collection varies significantly among regions: women are responsible for 55.8 percent of fuelwood collection in Latin America, 39 percent in Asia and 77 percent in Africa (Sunderland *et al.*, 2014, using household level data from the PEN). Even in countries with moderate fuelwood scarcity, women have been reported to walk up to 10 km to gather wood (Wan *et al.*, 2011).

2.3 Contributions to economy and livelihoods

Forests and trees do not only contribute to FSN through direct provision of food or energy for cooking, but also indirectly through income generation from sale of wood and NWFPs in local, national and international markets, and from forest-related employment.

2.3.1 Income generation

It is estimated that global industrial roundwood production is around 1.8 billion m^3/year (FAOSTAT), the majority coming from forests in the northern hemisphere. The United States of America, China, the Russian Federation, Canada and Brazil are among the world´s largest wood producers. Wood is used for building, furniture manufacture, tools and crafts, pulp and paper, as well as charcoal and pellets for biomass energy.

According to FAO (2014a), the global gross value added (GVA) in the formal forest sector represented, in 2011, USD606 billion, i.e. 0.9 percent of the world GDP.

[21] See http://www.wfp.org/climate-change/initiatives/safe

Table 3 Gross value added in the forest sector and contribution to GDP in 2011, by region and subsector

Region	Gross value added in the forest sector (in billion USD at 2011 prices)				Forest sector GVA in total GDP (%)
	Forest	SWP	PP	Total	Total
Africa	11	3	3	17	**0.9**
Asia and Oceania	84	66	111	260	**1.1**
Europe	35	61	68	164	**0.9**
North America	26	29	61	115	**0.7**
Latin America and Caribbean	14	12	24	49	**0.9**
World	***169***	***170***	***266***	***606***	***0.9***

Forest = Forestry and logging activities; SWP = sawnwood and wood-based panel production; PP = pulp and paper production.

Source: FAO (2014a), based on UN national account main aggregates database (available at http://unstats.un.org/unsd/snaama) supplemented with national income account data from country sources.

These global and regional figures hide a huge diversity across countries. The highest proportionate contribution of forestry to GDP is in Liberia (15 percent of total GDP) (FAO, 2014a). At a national level, the GVA forest sector is not correlated with forest area but depends mainly on the types of forests and management systems present in the country. For instance, on 19 million ha of forests in Cameroon, 16 million ha are reported as production forests and the GVA in the formal forest sector amounts to USD695 million. Conversely, in the Democratic Republic of the Congo, only 12 million out of 153 million ha of forests are reported as production forests and the GVA in the formal forest sector amounts to USD85 million (FAO, 2014a, 2015a). In Europe, the GVA produced in the formal forest sector is highest in Italy (USD15 billion), France (USD14.5 billion), Sweden (USD13.8 billion) and the Russian Federation (USD13 billion) (FAO, 2014a). Such figures generally underestimate the real contribution of forests to national income as they do not include the value added on wood products that is accounted for in the industrial sector or, for instance, in tourism.

Specific studies show that values of NWFPs can be important in some countries as shown, for instance, in Box 8 on hunting in boreal areas. In the Maya forest in the north of Guatemala, Belize and Southern Mexico, the forests provide many NWFPs that are commonly used by the local people, but also reach export markets. Some of them are edible and others have other uses such as: xáte (*Chamaedorea ernestii-agustii*), which is an ornamental palm for export; bayal (*Desmoncus orthocantos*), a fibre for handicrafts; guano (*Sabal* sp.*),* a palm leaf for roofing or local consumption; ramón tree seeds (*Brosimum alicastrum*) for biscuits and bread that is moving from local consumption to rural and town markets; allspice (*Pimenta dioica*) as a spice; latex (*Manilkara zapota*) for chewing gum; and copal resin (*Protium copal*) for perfumes and cosmetics (Godoy, 2010). In Canada in 2015, maple products represented 53 528 tonnes and USD279.9 million (Sorrenti, 2017). The Sudan, Nigeria and Chad produce 95 percent of the gum arabic exported to the world market. The Sudan is the main producer with 76 000 tonnes in 2013 (data from Central Bank of Sudan in Sorrenti, 2017).

Moreover, official figures only cover the formal forest sector. FAO (2014a) estimates that, when including the contribution of the informal sector, GVA from the forest sector increases to almost USD730 billion, of which USD88 billion from NWFPs (animal- and plant-based, including medicinal plants) and USD33 billion from informal production for construction and fuel (see Table 4).

Table 4 Estimated income from the informal forest sector in 2011 (in billion USD at 2011 prices)

Region	Woodfuel and construction	NWFPs	Total
Africa	14.4	5.3	**19.7**
Asia and Oceania	9.9	67.4	**77.3**
Europe	–	8	**8**
North America	-	3.6	**3.6**
Latin America and Caribbean	9	3.6	**12.6**
World	***33.3***	***88***	***121.3***

Source: FAO (2014a), based on various sources.

Most non-provisioning environmental services are not accounted for in global economic figures. According to FAO (2014a) USD2.4 billion of payments for environmental services (PES) can be added to the GVA from forests. This represents a very small part of the environmental services that are provided. Only recently has the UN Statistical Office determined the need to include ecosystem services in the System of National Accounts, but this inclusion is still voluntary and how this approach may be applied more broadly in both developed and developing countries should still be assessed.

Box 8 Value of wild meat and hunting in the boreal area

In the boreal area, aside from its practice by indigenous peoples, hunting has mostly recreational and/or social functions. Hunting has historically been an important provider of food, but also helped in developing symbolic and social capital. At the present time, the symbolic and social values of hunting are still important in many societies (e.g. locals being part of stalking moose in Sweden during hunting seasons) (Fischer *et al*., 2013). In some parts of the boreal zone, hunting is mostly a leisure activity among locals and hunting tourism is limited, although currently growing. In other parts, hunting tourism is a mature market, contributing extensively to local societies' economies (Fischer *et al*., 2013; MacKay and Campbell, 2004; Willebrand, 2009).

Several attempts have been made to value the economic benefits of hunting in the boreal area. For instance, in Norway, hunting of moose is valued at USD70 to USD90 million (Storaas *et al*., 2001). In Sweden, the moose is considered to be the most valuable game (Mattsson, 1990). In Finland, Norway and Sweden, non-market valuation studies show that the value of hunting can be divided into one recreation-based part, and one meat-based part (Fredman *et al*., 2008). However, other game species such as fowl, deer or bear are not included in these studies.

Hence, an overall view of the economic value of hunting and hunting's contribution to the livelihood of societies in the boreal area is difficult to grasp. One of the reasons is the challenge of valuing complex goods with both market and non-market values, as hunting is strongly rooted in social and cultural functions as well as being a recreational activity. Some of the meat, but probably only a small portion, ends up in the marketplace. Further, there are extensive statistics on harvest per year, but little on how much is sold on the market and how much is individually consumed.

2.3.2 Employment

The formal and informal forestry sector is an important source of employment, particularly for some groups. According to FAO (2014a), in 2011 the formal forest sector employed some 13.2 million people around the world representing 0.4 percent of the total workforce. It does not include, for instance, work in furniture manufacture, most of which is wood-based, nor work in building that uses wood.

Official statistics on employment are often weak, largely due to the importance of informal and part-time activities that play a crucial role in the livelihoods of people in rural areas especially in developing countries (Whiteman *et al.,* 2015). According to FAO (2014a), the three countries with the highest formal and informal employment in the forestry sector are Brazil (7.6 million), China (6 million) and India (4 million). Forest-related activities in Zambia represent more than one million jobs in the formal and informal sectors (total population is about 13 million), supporting over 80 percent of rural Zambian households that are heavily dependent upon the use of natural resources to supplement or sustain their livelihoods (Turpie *et al.,* 2015). Agrawal *et al.* (2013) mention that an estimated 40–60 million people are employed in the informal forestry sector, while FAO (2014a) suggests that at least 41 million people are engaged full time in fuelwood and charcoal production.

Box 1 highlights the gaps in data employment in NWFP gathering and utilization. However, comparable estimates at the global level exist for certain forest products such as fuelwood and charcoal (see Table 6).

Table 5 Total employment in the formal forestry sector in 2011, by region and subsector

Region	Employment in the forest sector (in millions)				Share of the total workforce employed in the sector (%)			
	Forest	SWP	PP	**Total**	Forest	SWP	PP	**Total**
Africa	0.3	0.2	0.1	**0.6**	0.1	0.1	0.0	**0.2**
Asia and Oceania	1.8	2.6	2.5	**6.9**	0.1	0.1	0.1	**0.3**
Europe	0.8	1.5	0.9	**3.2**	0.2	0.4	0.2	**0.9**
North America	0.2	0.4	0.5	**1.1**	0.1	0.2	0.3	**0.6**
Latin Am. and Caribbean	0.4	0.6	0.4	**1.3**	0.1	0.2	0.1	**0.5**
World	***3.5***	***5.4***	***4.3***	***13.2***	***0.1***	***0.2***	***0.1***	***0.4***

Forest = forestry and logging activities; SWP = sawnwood and wood-based panel production; PP = pulp and paper production.

Source: FAO (2014a), based on International Labour Organization database on labour statistics. (www.ilo.org/ilostat), supplemented with employment statistics from country sources.

Table 6 Estimated number of people engaged in fuelwood and charcoal production in 2011

Region	Gross number of people (in millions)				Proportion of total population (%)
	Full time number	Part time		Total number	
		Number	Allocation of time (%)		
Africa	19	176	8	195	19
Asia and Oceania	11	631	4	642	15
Latin America and Caribbean	10	35	9	45	8
World	***41***	***841***	***5***	***882***	***13***

Source: FAO (2014a), based on data from FAOSTAT and International Labour Organization database on labour statistics (www.ilo.org/ilostat).

Forestry continues to be one of the most hazardous sectors in most countries for occupational safety and health (ILO, 1998). Personal protective equipment may not be available. Most workers (including children and migrant workers) are informally engaged and wages are low. Working hours are long, and the work locations are often in far off locations, making it difficult for labour inspection to check compliance with labour standards. These conditions could have negative implications on the income, health and other socio-economic conditions for FSN.

Production of tree crops for major global markets provides income and employment locally and internationally and involves a number of smallholders. It is estimated that, at the global level, smallholders produce over 67 percent of the coffee and 90 percent of the cocoa.[22]. For instance, it is also estimated that the cultivation, processing, trading, transportation and marketing of coffee provide employment for 15 million people in Ethiopia and over 5 million in Uganda (Vira *et al.,* 2015).

Forests also provide employment for migrant workers, creating potential tensions with local communities. A well-documented example is berry picking in Sweden and Finland. Thousands of migrating workers, typically from Eastern Europe or East Asia, come to pick berries for approximately three months. Problems occur each year between berry companies and local people who consider the berries their property. Also, in recent years there were some cases of labour exploitation, but that has decreased since the adoption of regulations to protect migrant berry pickers (Vanaspong, 2012). It is hard work but most workers earn a decent amount of money to support themselves over the next year. Together with local sellers, migrating workers help ensure berries on the marketplace all over the world (Salo *et al.,* 2014).

2.3.3 Gender roles

Social processes are key to forest-dependent livelihood, resource management decisions, governance processes, and to the distribution of the benefits, with strongly differentiated gender roles and impact. A challenge to fully document this at national, regional and global levels, is the limited availability of gender disaggregated data, except for some employment data. This underscores the importance of developing gender research in forests, trees and agroforestry systems, an issue already raised about fisheries and aquaculture and about water (HLPE, 2014b, 2015).

The data collected for the FAO SOFO (2014a), suggest that women play a lower role in the formal forest sector and in informal activities that generate income and are largely confined to the collection of forest products for subsistence use.
According to FAO (2014a), women represented only 24 percent of total employment in the formal forestry sector in 2011, whereas, according to ILOSTAT,[23] they represent in 2017 around 40 percent of the total labour force (15 years-old and more) when considering all economic sectors.

Concerning informal activities, FAO (2014a) analysed the gender dimension of only woodfuel collection, due to a lack of data for other activities. Out of the 41 million people engaged full time in fuelwood and charcoal production, only 4 million are women. Out of the 841 million people that devote part of their time to collecting fuelwood or producing charcoal, 706 million are women (FAO, 2014a). Thus, women appear to bear the greatest responsibility for fuelwood collection. In some areas with fuelwood scarcity, women have been reported to carry up to 70 kg of wood (Wan *et al.,* 2011).

Very few gender-disaggregated data on consumption of forest products are available at the global level. Although women tend to commercialize forest products less than men, the sale of forest products can be an essential source of cash income for women, who lack many of the opportunities commonly available to men (Sunderland *et al*., 2014). In West Africa, over four million women earn about 80 percent of their income from the collection, processing and marketing of oil-rich nuts from shea trees that occur naturally in the forests (UNEP, 2014).

[22] See International Coffee Organization (www.ico.org) and International Cacao Organization (www.icco.org) (accessed 15 January 2015).

[23] See https://www.ilo.org/ilostat/ (accessed March 2017).

The different roles of women and men in forest management and the different benefits they receive from forests are documented at the local level. A recent study (Sunderland *et al.*, 2014), using household level data from the PEN project, shows that both men and women collect forest products, whether for subsistence or for market. This study shows regional differences in the respective contributions of men and women to the value of household income from unprocessed forest products such as timber, poles, fruits and mushrooms. In Latin America, for example, men bring about seven times more income from unprocessed forest products to the household than women. The opposite trend occurs in Africa, whereas men and women contribute more equally in Asian sites. In Latin America, the data show that men are very involved in the commercial production of non-timber forest products such as Brazil nuts. In Africa, women play a stronger subsistence role, while in Southeast Asia men and women tend to share more responsibilities in forest management and agricultural production. In Africa, where the markets tend to be more subsistence-oriented, women tend to dominate. In Latin America, which has more specialized markets, men dominate. In Asia, it is a combination of the two.

2.4 Provision of ecosystem services, essential for agricultural production

Forests and trees deliver numerous non-provisioning ecosystem services that are essential to agriculture (Richardson, 2010; Foli *et al.,* 2014) and to food production as a whole, including inland fisheries, as well as to human health and well-being. They host the major part of terrestrial biodiversity and play a critical role for climate change mitigation at global level as well as for adaptation to climate change at farm, landscape and regional scales (see Chapter 3). This section focuses on some of the ecosystem services that provide direct support to agricultural activities: water regulation, soil protection and nutrient circulation, pest control and pollination. It also examines some trade-offs for the provision of these services.

2.4.1 Water regulation

Forests and trees play a considerable role in the hydrological cycle at local and global levels, by regulating surface and groundwater flows while contributing to water quality (Miura *et al.,* 2015; Ellison *et al*., 2017). They contribute to rainfall, locally and remotely, through evapotranspiration.[24] They facilitate infiltration and can improve groundwater recharge. Forests and trees can also offer important protection against flooding, which may threaten water supply, both in terms of quantity and quality as well as infrastructure, dwellings and other buildings, including shelter for displaced communities. A study conducted in 56 African, Asian and Latin American countries shows that a 10 percent increase in deforestation would result in a 4–28 percent increase in flood frequency (Bradshaw *et al.,* 2007),

A review of scientific papers on the Amazon Basin and its relationships to climate and rainfall in Brazil (Nobre, 2014) concluded that deforestation in this region influences water shortages in other parts of the country. The removal of vegetation cover interrupts the soil moisture flux to the atmosphere. The decrease in the number of trees in the biome prevents the flow of moisture between the north and the south. A “flying river”[25] greater than the Amazon River and responsible for freshwater supply in Southeast Latin America is seriously threatened by deforestation (HLPE, 2015). This suggests that forest loss to expand pasture and soybean cultivation could have negative feedback effects on the productivity of the expanded crops and pasture grasses, so that the net effect of deforestation may be a decline in output (Oliveira *et al*., 2013). A recent review (Ellison *et al.*, 2017) highlights the considerable role that forests play at national, regional and continental levels in determining rainfall and water circulation.

An adequate water supply is clearly essential to FSN in all its dimensions. The regulation and provision of an adequate volume of water of appropriate quality for human and animal

[24] Evapotranspiration, a critical element of the water cycle, is the overlap/sum of evaporation and plant transpiration from the earth's surface (land and ocean) to the atmosphere.

[25] The term “flying rivers” (Marengo *et al.*, 2004) refers to low-level jets of water (water vapour flux) driven by the winds that move from the Amazon region towards the east of the Andes and, barred by the mountain range, reach the southeast and southern regions of Brazil and the north of Argentina.

consumption are also strongly associated with forest cover in watersheds, hillsides and streambanks. FAO (2013b) estimates that at least one-third of the world's largest cities draw a significant proportion of their drinking water from forested areas. The water supply benefits from the maintenance of forest cover depend on the overall water balance of the system that depends on water availability and on evapotranspiration (FAO, 2013b). Water quality is strongly enhanced by forest protection of streams and vegetative coverage of hillsides subject to erosion. Thus, forest coverage also plays a critical role in ensuring stability and quality of water provision to lakes and rivers on which inland fisheries depend (Carignan and Steedman, 2011).

Forest protection of watershed services may be enhanced if native species are retained or restored, but agroforestry systems and plantation forests may provide similar water production functions if they ensure sufficient forest cover to assure groundwater recharge and spring flow and do not themselves exceed water demands (Gerten *et al.*, 2004). Evidently, there can be trade-offs between forest cover and agricultural land use in watersheds that can only be resolved within each specific context.

According to the FRA (FAO, 2015), almost 40 percent of forests in the United Nations Economic Commission for Europe (UNECE) region, home to 20 percent of the world's population, are designated for soil and water protection – and a significant 54 million ha of them are managed and protected exclusively for water purification.

Indirectly, forests also contribute to the provisioning of fish resources, both for the local communities and for the local, regional and national markets. Sport fishing is often an important contributor to income generation. In the United States of America there are over 150 000 miles (241 499 km) of streams and 2.5 million acres (approximately 1 million ha) of lakes found in the national forests and grasslands.[26] But the impacts that this and other income-generating activities have on subsistence fishing and FSN should be considered.

Importantly, most water regulation also has a remote effect, at landscape, watershed or even regional levels. However, much of it is not fully understood, nor appropriately taken into account and valued.

2.4.2 Soil formation, protection and nutrient circulation

Along with their role in water regulation, forests and trees also contribute to soil formation, protection and to nutrient circulation. Forests and trees contribute directly to organic matter accumulation on the soil (Kimble *et al*., 2007) that is directly exploited by swidden agriculture and various forms of agroforestry. Organic matter can also, particularly in dry areas, be transported by humans and animals, including as green manure and manure of domestic animals fed in the forest, from forest to fields. Nutrients circulate, above and underground, from trees to crops.

Forests and trees, through their root systems, also contribute to nutrient circulation and water cycling, bringing deeper water resources and nutrients closer to the surface for other crops (Bradshaw *et al.,* 2007). Annual or seasonal capture of plant nutrients in the root zones of trees and in the subsoils can be particularly important for bio-availability of plant nutrients in tree-based crop production systems (Jose, 2009). Cropping systems with nitrogen-fixing tree species enhance nitrogen availability to crops, increasing yield (see Box 9). In Malawi, more than 180 000 farmers, encouraged to plant fertilizer trees, obtained increased maize yields, a greater period of food security per year as well as an improved dietary diversity (CIE, 2011). Green forest leaves can be used as a source of compost to enhance productivity of agricultural crops, such as for instance in the areca nut plantations in India (Sinu *et al.,* 2012).

Forests and trees protect the soil from erosion by water and wind, through above ground protection as well as their root system. This action is particularly important in sloping areas and where precipitation is intense and violent, such as in Mediterranean climates or where wind erosion is important (see Box 10). For instance, windbreaks of two rows of *Casuarina* sp. used in West Nubariah, a reclaimed desert area in Egypt, to protect wheat and barley fields, increased the yields by 10 to 15 percent (Khalil, 1983).

[26] USDA Forest Service: http://www.fs.fed.us/fishing/ (accessed May 2017).

Box 9 *Faidherbia albida* agroforestry/agrosilvipastoral system

Faidherbia albida is a tree commonly found in agroforestry systems throughout sub-Saharan Africa, in a range of soils and ecosystems, from deserts to wet tropical climates.

Faidherbia albida is a nitrogen-fixing tree that contributes to increase significantly, from 6 to more than 100 percent, the yield of agricutural crops grown at proximity. It has a “reversed leaf phenology”, meaning it is dormant and sheds its leaves during the early rainy season and leafs out when the dry season begins. This feature makes it compatible with foodcrop production, because it does not compete for light, nutrients and water. Like many other agroforestry species, *Faidherbia* tends to increase carbon stocks both above ground and in the soil and improves soil water retention and nutrient status. *Faidherbia* trees are currently found on less than 2 percent of Africa’s maize area and less than 13 percent of the area grown with sorghum and millet. With maize being the most widely cropped staple in Africa, the potential for adopting this agroforestry system is tremendous.

Further research is needed to better explore the potential benefits *Faidherbia* can provide, including for crop productivity in different agro-ecosystems – wood and non-wood products for household use or sale on the market.

Source: FAO (2010b).

Box 10 Environmental services from forests to agriculture: the role of forest shelterbelts in the Russian Federation

The role of forest shelterbelts in Russian agriculture has a long history, dating back to the nineteenth century, when it became clear that this would help to secure the grain harvest against losses due to drought and natural disasters. Forests are thus perceived to represent a crucial environmental service to food productivity. The development of field protective forest plantations received particular political attention during the Soviet period. From 1949 to 1953, forest belts were established on a total of 5.2 million ha. Later, the established forest belts were maintained by forest authorities in order to protect agricultural lands. At present, however, forest belts have lost their perception of ecological protective value. Federal and regional authorities have not continued to maintain the forest belts for economic reasons.

According to Petrov and Lobovikov (2012), currently 126 million ha, or 75 percent of all agricultural land, are exposed to different types of erosion. One of the main causes of erosion is the shortage of forests in the main agricultural regions. Over recent years, about 5 million ha of protective stand have been planted, of which no more than 3 million ha have been preserved. Petrov and Lobovikov (2012) estimate that, in order to ensure the forestry protection of agricultural land, the Russian Federation should plant 11 million ha of various types of protective forest belts and stands

Source: Petrov and Lobovikov (2012).

2.4.3 Agroecosystem stability, biodiversity protection and downstream resources

Forests contain 80 percent of terrestrial biomass and provide habitat for over half of the world’s known terrestrial plant and animal species (Shvidenko *et al.,* 2005; Aerts and Honnay, 2011). Not all forests are equal in terms of the biodiversity they support and primary forests are irreplaceable for biodiversity conservation. For instance, Barlow *et al.* (2007) found that 25 percent of species in the Brazilian Amazon, and almost 60 percent of tree and liana genera, were unique to primary forests. Biodiversity in North American primary forests often includes a wide range of lichens, fungi, insects, bats, spiders and other organisms found only in structurally complex mature forests (Spies, 2003).

At the global scale, forests are also stores of genetic diversity and conserve endemic species. Products derived from genetic resources (including agricultural crops, pharmaceuticals, etc.) have been estimated to be worth USD500 billion per year (ten Kate and Laird, 1999; TEEB, 2010). Although many point at hotspots such as the Amazon and the forests of central Africa as important stocks of biodiversity of global relevance, the critical presence of diverse species and ecosystem variability across all biomes and scales are important as contributors to food availability.

Trees provide shelter and habitat for a number of species that provide beneficial services at various spatial scales, including pollinators and natural enemies to pests. The biodiversity maintained by forests has been shown to mitigate the effects of disease and crop damage, for example through the regulation of pest species and disease vectors (Foli *et al.*, 2014), then contributing to food production and FSN. This particularly benefits low-input smallholder systems that apply little to no agro-chemicals (Bale *et al.,* 2008; Karp *et al*., 2013). Such processes occur at a local scale but they inevitably have an effect at landscape and regional scales, affecting adjacent agricultural systems. Examples of forest- and tree-based ecosystem services provided at different scales are shown by Foli *et al.* (2014) and Reed *et al.* (2017).

2.4.4 Pollination

Besides water provision, pollination is certainly the most widely studied ecosystem service, largely due to its tangible significance for global food production. Klein *et al.* (2007) found that fruit, vegetable or seed production from 87 of the world's leading food crops depends upon animal pollination, representing 35 percent of global food production. FAO (1995) provided a detailed list of 1 330 tropical plant species, showing that, for approximately 70 percent of tropical crops, at least one variety is improved by animal pollination. A recent study (Garibaldi *et al.,* 2016) has shown that on small farms that provide food for the most vulnerable populations globally, pollinator diversity can significantly increase pollination intensity. They found that yield gaps could be closed by a median of 24 percent for fields of less than 2 ha.

Bees and especially the honey bee (*Apis melifera*) are the backbone of agricultural pollination. Managed honey bees provide pollination services in intensive systems. Globally, as commercial agriculture has trended toward large-scale land conversion and monoculture production systems, there has been an associated loss of essential pollinating species (Klein *et al.,* 2014). As such, managed honey bee populations are declining, as a result of colony collapse disorder (CCD) and disease die-offs, as well as excessive pesticide application. There is increasing consideration for native wild bees that have been found to enhance fruit set in crops complementing the role of the honey bee (Garibaldi *et al.,* 2011, 2013). Moreover, with die-offs in honey-bee colonies, native species of bees can make up the pollination deficit where forests provide the natural habitat needed to maintain diverse assemblages of wild species as well as additional pollen sources (IPBES, 2016).

Forests provide a habitat for wild pollinators that are crucial to sustain crop yield in animal pollinated crops (Aizen *et al.,* 2009). Forests also provide a habitat for diverse assemblages of pollinating species needed to ensure crop outputs and guarantee food security (Garibaldi *et al.,* 2011). Some studies indicate that forest strips can serve as corridors to restore animal-mediated pollination in fragmented tropical forest landscapes (Kormann *et al.*, 2016). There is also evidence suggesting that the abundance of coffee pollinators is directly proportional to the proximity to forest fragments (Ricketts, 2004). Freitas *et al.* (2014) highlighted the importance of forest fragments on cashew productivity in Northeast Brazil, through their provision of pollinator habitat. Rapeseed productivity is likewise enhanced by edge effects of forestlands in France, which provide habitat for native bee species (Bailey *et al.*, 2014). Studies have demonstrated a negative relationship between the distance from forests and pollination rates, bee abundance and richness both in tropical ecosystems (De Marco and Coelho, 2004; Blanche *et al.*, 2006; Chacoff and Aizen, 2006) and temperate ecosystems (Hawkins, 1965; Taki *et al.,* 2007; Arthur *et al.,* 2010; Watson *et al.,* 2011).

Garibaldi *et al.* (2016) note that flower-visitor assemblages are increasingly threatened, posing risks of yield declines, and propose various measures to increase yields by increasing flower-visitor density through the furnishing of diverse flower and nesting resources, for which trees and forest patches can play a considerable role.

2.4.5 Synergies and trade-offs

There are synergies but also trade-offs between ecosystem services and even when they are correlated they can have different spatial distributions (Locatelli *et al.,* 2013). Proximate tree cover can be beneficial to crop yield in agroforestry systems but can also have unintended negative outcomes for crop yield. This includes the harbouring of pests within adjacent forests or acting as incubation zones for plant diseases that can be transferred to growing plants. Trees also directly compete for water, nutrient and light resources, especially where their niches overlap with food crops. Such interactions have been established in agroforestry systems in which tree roots often cover a larger soil surface area and are more capable of accessing water and nutrients than the associated crop species. Responding to these factors that may depress agricultural output, Zhang *et al.* (2007) coined the term “ecosystem disservices”. This is why, when developing agroforestry systems, it is essential to understand which tree options work in which agro-pedo-climatological, livelihood and institutional contexts, to enable the full realization of agroforestry’s important potential for improved agricultural yields and food security (FTA, 2016).

Wildlife animal populations encroach onto human-claimed land, including (but not limited to) agricultural production areas (Distefano, 2005). For instance, in Kenyan rangelands, problems associated with wildlife include crop damage, competition for water and grazing, livestock predation, increased risk of some livestock diseases, inconveniences when protecting crops and even human fatalities (Makindi *et al.,* 2014). Human wildlife conflicts are exacerbated by many factors such as: human and livestock population growth; land-use transformation and wildlife habitat loss, degradation and fragmentation; or climate change (Distefano, 2005).

Examples from Europe include wild boars, deer and badgers, as well as large predators such as bears, wolves or lynx that attack sheep and even cattle (FAO, 2009a). In France, the total amount paid to the farmers in compensation for the damage caused by wild boars and deer, negligible in 1970, increased to between EUR 20 and 25 million per year between 2000 and 2007, wild boars representing 83 percent of the total and deer 17 percent (Carnis and Facchini, 2012). In the United Kingdom, badgers have been known to spread bovine tuberculosis to dairy cattle. In the Amazon Province of Tambopata in Peru, the principal wild herbivore responsible for damage is the Brazilian tapir (Distefano, 2005).

Yet there is sufficient evidence to show that the benefits of forests and trees to agriculture are far superior to their purported costs. A recent review (Reed *et al.,* 2017) suggests that incorporating trees in an appropriate manner can maintain or increase crop yields and also bring additional benefits in terms of additional income sources and increased resilience. It highlights the need for larger-scale and longer-term research to better understand and improve the contribution of forests and trees within a broader landscape and food production system approach. The design of agroforestry systems takes explicitly into account the shade and root architecture of the companion species so as to limit competition. Additionally, the forests at the borders with cattle and agricultural fields can be managed, controlling density of trees, wind circulation, etc.

2.5 Forests, health and well-being

Forests, tree-based agricultural systems and forestry impact human health in a diversity of ways, including provisioning of food, medicinal plants, fuelwood, clean water and income, as well as mediation of disease transmission and mental health improvements associated with time spent in nature-based recreation (Arnold *et al.,* 2011; Colfer, 2008; Colfer *et al.*, 2006; Karjalainen *et al.*, 2010; MA, 2005; WHO/CBD, 2015). Colfer *et al.* (2006) report on the relationship between forests and health, including the importance of medicines gathered from the wild, and the role of culture. Further, forests help mitigate air pollutions and improve air quality (Nowak *et al.*, 2014).

Several studies have examined forest effects on mental health and stress reduction. Results indicate that forests not only have a restorative effect on a person's mind and thus contribute to recovery from stress-related exhaustion, but also that the participants felt more harmonious and in a better mood after regularly visiting the forests (Sonntag-Öström *et al.*, 2011). Park *et al.* (2010) demonstrate, from field experiments conducted in 24 forests across Japan, the positive physiological effects of *Shinrin-yoku* (i.e. taking in the forest atmosphere or forest bathing). They show that forest environments promote lower concentrations of cortisol, lower pulse rate, lower blood pressure, greater parasympathetic nerve activity and lower sympathetic nerve activity than do city environments. Another study concludes that the forest itself cannot heal a person with an exhaustive disorder, but visiting the forest contributes to a person's mental state and attention capacity, improving the condition for rehabilitation (Sonntag-Öström *et al.* 2015). Yet another study shows that the well-being of young girls is enhanced by activities in the forest (Wiens *et al.*, 2016). In sum, forests have three main health effects on people: short-term recovery, faster physical recovery and long-term overall improvement of health (Randrup *et al.*, 2005).

Exposure to the natural environment, including forests, has been shown to correlate with numerous mental health outcomes including reduced depression, anxiety and hostility – especially if combined with physical activity (Sonntag-Öström *et al.*, 2015). Empirical evidence suggests that forest environments can improve peoples' cognitive and emotional health (Shin *et al.,* 2010). Research shows that urban forests, in comparison with urban build environments, offer an important contribution to peoples' recovery from mental fatigue (Konijnendijk, 2010; Randrup *et al.*, 2005). Other research has shown that the environments surrounding hospitals and clinics that have a high component of vegetation (trees, gardens) reduce the post-operation recovery period of patients. Houses or schools with wooded environments have been shown to influence heart rhythm and lower blood pressure.

On the other hand, forests also act as reservoirs for parasites and diseases that can affect domestic animals and humans. The majority of emerging and re-emerging human diseases are zoonotic – they come from animals and are transmitted to humans (HLPE, 2016). Most emerging zoonoses have a wildlife component, and the study of disease emergence has a strong focus on wildlife. Drivers of zoonotic disease emergence include land-use change, encroachment of agriculture on natural ecosystems (see also section 3.4.1), urbanization, conflict, travel, migration, global trade, trade in wildlife and changing dietary preferences (IOM/NRC, 2009). The critical linkages between human health, animal health and ecosystems are encompassed in the concept of "One Health", which highlights the need for collaboration across sectors (FAO/OIE/WHO/UN System Influenza Coordination/UNICEF/World Bank*,* 2008).

2.6 Contributions to resilience of food systems

Forests and trees can play a crucial role to improve resilience of food systems (Vira *et al.,* 2015), defined as the capacity to prevent, mitigate or cope with risk, and recover from shocks, at household, community and landscape level (Gitz and Meybeck, 2012).

At landscape level, forests and trees play an important role in reducing the impacts of climate variability and weather-related shocks, including floods, droughts, winds and heatwaves. They can also act as barriers in the propagation of some pests and diseases. As climate change increases the potential volatility of food supply and markets, developing more resilient production systems and integrating forests, trees and agriculture at the landscape level are becoming essential to ensure FSN of the most vulnerable groups (Vira *et al.,* 2015). In agroforestry systems, trees can contribute to microclimate regulation and thus increase the productivity and resilience of the food production system (Pramova *et al.,* 2012). In the Sahel, for instance, trees can facilitate the cultivation of nutritious vegetables and pulses despite the long dry seasons (Sendzimir *et al.,* 2011)

Moreover, they contribute to a diversification of sources of food and income that can help buffer economic shocks whatever their origin. These sources of food and income can play a particularly important role for the most vulnerable groups.

Forests and trees play, for the people that have access to them, a major role as a safety net in lean seasons, or in periods of conflicts, natural disaster or economic crisis, particularly for the more vulnerable members of a community, providing an additional source of food as well as an additional source of income and employment, through woodfuel and NWFP collection and sale, thus improving FSN of forest-dependent households and communities (Angelsen and Wunder, 2003; Shackleton and Shackleton, 2004; Mulenga *et al.,* 2012). Many people depend on wildlife resources as a buffer to see them through times of hardship (e.g. unemployment, illness of relatives, crop failure), or to gain additional income for special needs (e.g. school fees, festivals, funerals), and this "safety net" is often more important for the more vulnerable members of a community.

The PEN data also showed that lower income classes were proportionally more dependent on NWFP collection (Angelsen *et al.,* 2014; Wunder *et al.,* 2014). Barriers to access to wildlife resources mean that in some cases it is the middle-income or wealthier households in a community that benefit most from hunting, with implications for development policies that depend on absolute poverty and wealth distribution within the community (van Vliet *et al.,* 2012).

2.7 Synthesis and conclusions

Based on the studies summarized in this chapter, it is clear that forests provide a range of benefits important to FSN in different contexts. These benefits are not all well characterized and quantified, and thus often not fully taken into account. They also benefit different categories of forest-dependent people (see Chapter 1), generally to a more pronounced degree among communities that reside within or in close proximity to forests; they can also have far reaching local, regional and global effects. Indirect benefits of forests at a landscape scale also affect agricultural productivity and resilience at a much broader, even global scale, given forests' ability to sequester carbon and enhance water flow and quality for human consumption, irrigation and energy. Forests and trees also provide important sources of income and employment in many countries, as well as fuelwood and charcoal, essential to food preparation and water sterilization among most rural communities in developing countries. These benefits depend on the presence, extent and localization of forests and trees, as well as on the type of forest and the manner in which they are managed. Table 7 summarizes the principal contributions to FSN dimensions of different types of forests and trees.

As shown above, many of the benefits provided by forests and trees, especially at local scale, result from delicate balances that are likely to be disturbed by any modification. Changes in the extent, localization, type of forest, management practices and governance will thus have an impact on the contribution of forests and trees to FSN (see Chapters 3 and 4).

Table 7 Summary of interactions between forest types and FSN functions

Forest types	Availability	Access	Stability	Utilization
Primary forests	Forest fruits, mushrooms/leaves (low intensity harvesting in native forests worldwide) Bushmeat/wild insects (Asia, Africa, Amazonia) Regulating ecosystem services essential for sustainable agricultural production	Incomes from sustainable use or protection, ecotourism Income transfers for forest protective services (REDD+, PES and food security schemes in protected areas)	Essential for global and local climate mitigation and regulation. Significant risk-reduction mechanism, providing food and income in times of crisis	Important for supply of clean water for cooking and consumption Important for recreation and psychological health Sustainable gathering of fallen branches for fuelwood
Secondary forests	Forest foods (fruits, leaves, nuts) as well as bushmeat (moderate intensity harvesting) Grazing in woodland pastures for domesticated animals (meat, milk) Can provide regulating ecosystem services essential for sustainable agricultural production	Income from timber and NWFPs where management systems and property rights permit access by forest-dependent peoples	Can be maintained by farmers and communities to provide income in times of crisis Contribute to global and local climate mitigation and regulation	An excellent source of sustainable fuelwood and charcoal for regional markets and local consumption A source of medicinal plants Can also be used for recreation
Plantations	Can provide regulating ecosystem services essential for sustainable agricultural production	Income from sale of produce or timber, employment in forest product industries	Timber can be sold by farmers and communities to provide income in times of crisis Contribute to global and local climate mitigation and regulation	Can provide fuelwood Sawmills may provide residues for fuel for local energy production and use
Trees on farms: agroforestry	Tree foods, fruits, nuts, leaves (intensive harvesting) Also used for hunting animals attracted to fruit and crops An excellent source of grazing and fodder for domesticated animals (meat/milk) in silvopastoral systems Often provide regulating ecosystem services essential for sustainable agricultural production Increased crop/agricultural yields.	Income from sale of produce	May be an important source of food and feed in seasonal shortage Evidence of the importance for fruit in periods of low fruit supply A source of income in time of crisis Modest contributions to global and local climate mitigation and regulation	A good source of sustainable fuelwood Home gardens are a source of medicinal plants and cultural pride and well-being

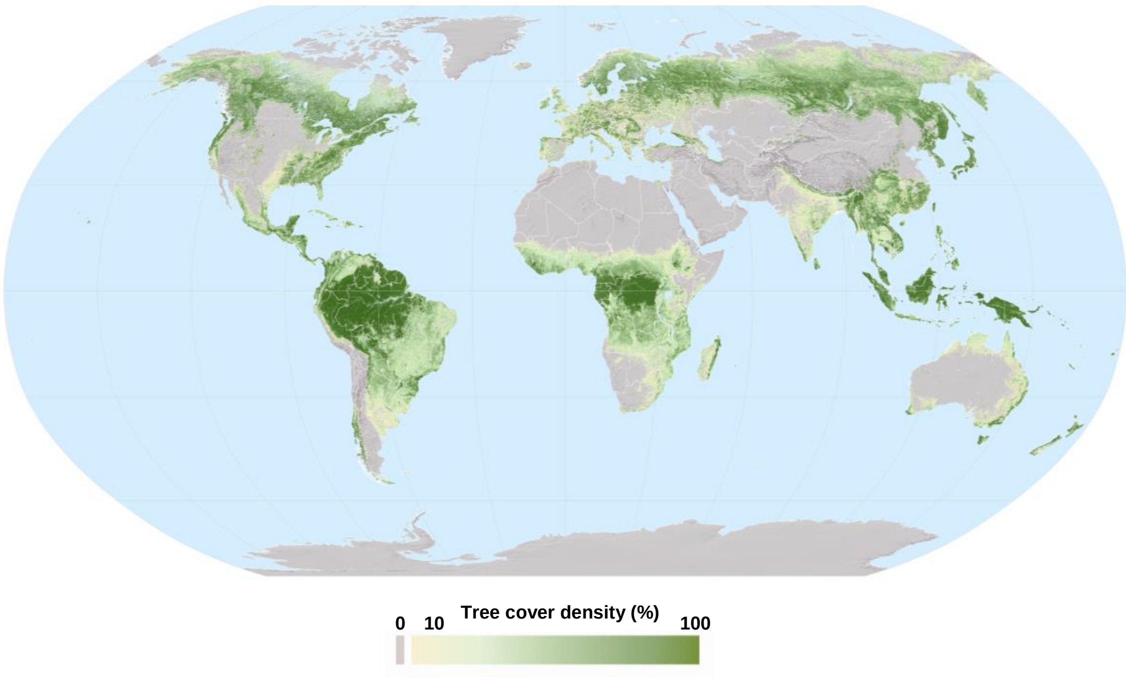
3 FORESTRY TRENDS: CHALLENGES AND OPPORTUNITIES FOR FSN

This chapter describes the state of forests worldwide and the main trends affecting it, considering the various types distinguished in Chapter 1. Changes in forest cover, forest types and uses are driven by the interaction of numerous factors, at local and global levels: growing demand for food, feed, wood and energy, driven by population and income growth; and increased importance given to carbon stocks, and to biodiversity, water and soil protection. Climate change and the policies to strengthen the contribution of forests and trees to mitigation are also having a growing influence on forest management. All these changes affect forests and forest management and impact FSN.

3.1 Forests at a glance: global area and main trends

In 2015, 30.6 percent of the world's land area was covered by forests (FAO, 2015). 44 percent of the global forest area is found in countries classified as tropical, 8 percent as subtropical, 26 percent as temperate and 22 percent as boreal. Europe (including the Russian Federation) represents 25 percent of global forest area, followed by South America (21 percent) and North America (16 percent). Figure 5 gives a global idea of this regional distribution. Three-quarters of all forests are in high- and upper-middle-income countries (Keenan *et al*., 2015).

Figure 5 Map of the world's forests and tree cover



Source: FAO (http://foris.fao.org/static/data/fra2010/forest2010mapwithleg.jpg)[27]

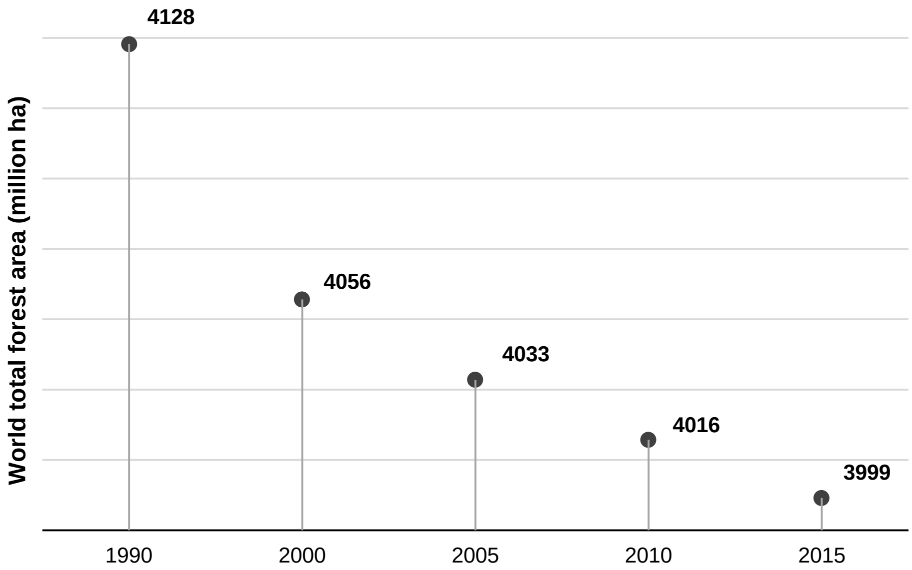
At the global level, data available show a continuous, although decelerating, net forest loss, particularly in the tropics, with some contrasted evolutions between forest types identified in Chapter 1.

[27] This map was published for the FRA 2010 (FAO, 2010c) and relies on older data from different sources (including Carroll *et al.,* 2009; Hansen *et al.,* 2013; Iremonger and Gerrand, 2011) as well as from www.fao.org/geonetwork).

3.1.1 Global net forest loss is slowing down

The evolution of the global forest area is a net balance between forest loss and forest gain. According to FAO (2015), from 1990 to 2015, the global forest area fell by 129 million ha, with a loss of 195 million ha in tropical forest and a gain of 67 million ha for temperate forest. Despite relatively high rates of ongoing deforestation, particularly in the tropics, the overall rate of global forest loss has slowed over the past two decades: the rate of annual net loss of forest decreased from 7.3 million ha per year (0.18 percent) in the 1990s to 3.3 million ha per year (0.08 percent) between 2010 and 2015 (FAO, 2015; Keenan *et al*., 2015). Between 2010 and 2015, the tropical forest area decreased at a rate of 5.5 million ha per year, only 58 percent of the rate in the 1990s, while temperate forest area increased at a rate of 2.2 million ha per year (Keenan *et al.,* 2015). In Brazil, the net loss rate between 2010 and 2015 was only 40 percent of the rate experienced in the 1990s, while Indonesia's net loss rate has also dropped by two-thirds over the same period (Keenan *et al.,* 2015).

Figure 6 Global forest area (1990–2015)



Source: FAO (2015).

Asia and Europe are the only regions where the total forested area has increased over the period. The positive trends of forest cover in Asia are primarily driven by reforestation programmes in countries such as China, the Republic of Korea and Viet Nam, which are primarily comprised of plantation forests characterized by a focus on a small number of tree species. China has substantially increased its forest area since the early 1990s because of its important afforestation and reforestation programmes that have benefited from sustained and substantial allocation of fiscal and other resources by central and local governments (Antweiler *et al.,* 2012). Forest area in Viet Nam increased from a minimum of 28 percent in the 1990s to nearly 40 percent in 2013 despite a decrease in primary forest and a continuing trend of deforestation and forest degradation (FAO, 2016a).

D'Annunzio *et al.* (2015) conclude that global forest area will continue to decrease over the next 15 years, although at a lower rate, slowing down from 0.13 percent per year at the beginning of the century to 0.06 percent per year by 2030. This global trend is the result of a decrease in the area of natural forests (0.19 per year by 2030) combined with an increase in planted forests (2 percent per year by 2030). According to their model, forest area will continue to increase in Asia, Europe and North America and to decrease in Africa and South America. Future policy measures related to forest management, climate change and land-use planning have not been integrated in this model, and can have a strong impact on forest area trajectories. For instance, Arima *et al.* (2014) showed that the decline in deforestation in the Brazilian Amazon after 2008 is likely due in large part to political efforts.

There is a clear dichotomy between regions where the forest area is stable or increasing and regions experiencing net forest loss, almost exclusively in the tropics. This dichotomy is apparently correlated to national wealth. Since 1990, richer countries have experienced forest gains, while poorer ones experience overall forest loss and many middle-income countries are transitioning from net loss to net gain (Keenan *et al.*, 2015). However, Sloan and Sayer (2015) note that other factors are playing a major role, including changes in forest management and land use. In particular, the expansion of planted forests represents an important part of the gains in forest area since 1990 in many of the tropical countries experiencing a more advanced forest transition. Countries with expanding economies in the global south are rapidly establishing forests in response to market opportunities (Sloan and Sayer, 2015).

There are also some countries in which natural regeneration of degraded pastures and agricultural areas has recovered important forest areas. In Costa Rica, a period of important deforestation between 1960 and 1986 when the forest cover decreased from 59.5 to 40.8 percent of total land area was followed by a period of reforestation and afforestation, when the forest increased from 40.8 percent in 1986 to 51.4 percent in 2010 (Sanchez, 2015).

Forest degradation

FRA 2015 (FAO, 2015) has provided, for the first time, global figures on partial canopy cover loss (PCCL), or degradation, defined as the loss of more than 20 percent of tree cover between 2000 and 2012. The total area of PCCL over this period was 185 million ha, unevenly spread across climatic domains, with 9 percent of the tropical forest affected (156 million ha), and respectively 2.1 percent and 1.3 percent of subtropical and boreal forests. According to Van Lierop and Lindquist (2015), the area subject to PCCL in the tropical domain is 6.5 times that deforested since 1990. With 18 percent of its forest area, Central America is the region most affected by PCCL. In absolute terms, the largest amounts of PCCL are identified in South and Southeast Asia with more than 50 million ha affected (FAO, 2015).

Such figures raise concerns. They show the need to take into account not only the extent of forests but also their state of conservation. First, because degraded forests generally provide less environmental services than intact forests, and also because degraded forests may be more prone to deforestation. This may be even accentuated by the fact that several prominent NGOs, and some of the schemes with the private sector that they have influenced, recommend to assess forests according to their carbon stock and to orient forest conversion in priority towards degraded forests (Dinerstein *et al.,* 2014). This may lead to the conversion of forests that have a reduced canopy cover because of selective logging or shifting agriculture while retaining important value for conservation and the services they provide to local populations and that could still be maintained and restored.

3.1.2 Contrasted evolutions across forest types: the “forest transition”

As shown in Tables 8 and 9, the overall decrease in forest area hides contrasted trends across forest types, regions and climatic domains. Even with no net loss of forest area, the composition and structure of forest, and its value in terms of ecosystem services provided, can change (Keenan *et al.,* 2015). Such changes will profoundly modify forests contributions to FSN.

Most regions showed a steady decrease in natural forest area during this period, including “primary” and “secondary” forests (“other naturally regenerated forests” in the FRA classification), and a sharp increase in “planted forests” (+57.9 percent at the global level, see Table 8). Africa experienced the greatest decrease in natural forest area (in absolute and relative terms) and South America the greatest increase in planted forest area.

At the same time, there have been increasing efforts to reforest degraded lands, as well as to protect natural forest regeneration. Such trends – if they continue – offer the potential of a forest transition from net forest loss to net gain – a transition that has already occurred in a number of countries, including middle-income countries (Sloan and Sayer, 2015). The analysis of Keenan *et al.* (2015) suggests that, between 1990 and 2015, 13 tropical countries or territories[28] have already passed through this forest transition from net forest loss to net forest gain.

Table 8 State and trends of the world's forests and changes from 1990 to 2015 by region

Forest area* (million ha)	Total			Primary forests**			Other naturally regenerated forests			Planted forests			Other wooded land		
	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)
World	4128	3999	-3.1	1203	1172	-2.6	2313	2163	-6.5	182	287	57.9	978	954	-3
Africa	706	624	-11.6	151	135	-10.7	511	446	-12.7	12	16	39.5	398	367	-8
Asia	568	593	4.4	67	68	0.8	303	304	0.1	75	129	71.0	231	235	2
Europe	994	1015	2.1	246	277	12.7	677	646	-4.5	61	80	31.7	104	100	-3
North and Central America	752	751	-0.2	321	318	-0.9	395	381	-3.5	23	43	85.7	84	89	7
Oceania	177	174	-1.9	33	20	-41.3	4	18	318.1	3	4	56.9	7	6	-5
South America	931	842	-9.5	384	355	-7.7	422	368	-12.9	8	14	80.1	155	156	1

** The trends provided in this table for each forest type cover only those countries that reported data for this forest type over the whole period. At the global level, 234 countries reported their total forest area, 189 their primary forest area, 184 their area of "other naturally regenerated forests" and 196 their planted forest area. In particular, figures given for Oceania exclude Australia, which did not provide a complete time series (except for planted forests).*

*** Many countries rely on proxies, such as the extent of forest within national parks and conservation areas, to estimate the extent of primary forests. Reported increases are generally a result of reclassifications at the national level – such as the designation of new protected or conservation areas – rather than a real increase (FAO, 2015).*

Source: FAO (2015).

Table 9 State and trends of the world's forests and changes from 1990 to 2015 by climatic domain

Forest area (million ha)	Total			Primary forests			Other naturally regenerated forests			Planted forests			Other wooded land		
	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)	1990	2015	(%)
Boreal	1219	1224	0.4	451	481	6.7	738	685	-7.2	30	58	91.6	121	121	0
Temperate	618	684	10.8	102	108	5.4	395	406	2.7	99	148	49.8	158	167	6
Sub tropical	325	320	-1.6	47	42	-11.0	127	125	-0.9	19	25	30.7	150	148	-1
Tropical	1966	1770	-9.9	603	541	-10.2	1053	947	-10.1	34	56	67.0	550	517	-6

Note: The trends provided in this table for each forest type cover only those countries that reported data for this forest type over the whole period.

Source: FAO (2015), Keenan *et al.* (2015).

[28] Burundi, Gambia, Ghana, Rwanda, Bhutan, India, Lao People's Democratic Republic, Philippines, Viet Nam, Cuba, Costa Rica, Dominican Republic, Puerto Rico (United States of America).

Decrease in primary forests

While some progress has been made in the protection of primary forests at a global scale, including in the tropics, primary forests are still declining in the tropics, albeit more slowly. Loss of primary forest in the tropics (62 million ha) and subtropics (6 million ha) mirrors total forest loss in these biomes (Morales-Hidalgo *et al.*, 2015). This is of particular concern as primary forests are irreplaceable reserves of tropical biodiversity (Gibson *et al.*, 2011).

Growing importance of planted forests

Planted forests are increasingly important, in terms of surface and even more in terms of production.

Global planted forest areas have increased between 1990 and 2015 from 4 to 7 percent of total forest area (i.e. from 182 to 287 million ha), the increase varying by region and climate domain (FAO, 2015). In 2015, more than half of the planted forest was in the temperate area. East Asia and Europe have the largest area, followed by North America and Southern and Southeast Asia, China showing by far the biggest absolute increase with 30.7 million ha (Payn *et al.*, 2015). The increase in planted forests, peaking at 2.7 percent per year between 2000 and 2005, slowed down to 1.2 percent per year between 2010 and 2015 (Payn *et al.*, 2015).

The contribution of planted forests to pulp and timber production plays a major role to answer the increasing demand for wood. In 2012, 46.3 percent of industrial roundwood came from planted forests, ranging from 14 percent in boreal forests, 45 percent in temperate forests, to almost 65 percent in the tropics and subtropics (Payn *et al.,* 2015). A study by Buongiorno and Zhu (2014) applying a general equilibrium model, the Global Forest Products Model (GFPM), to 2009 data of roundwood concluded that the utilization of planted forests reduced roundwood harvesting from natural forests in 2009 by 26 percent. In South America, 90 percent of industrial roundwood production is already sourced from planted forests (Payn *et al.,* 2015).

To realize the productivity benefit of plantation forests, while preserving natural ecosystems, further expansion of tree plantations should be focused on degraded land (WWF/IIASA, 2012). Planted forests are in fact increasingly a means to restore degraded land and to provide some ecosystem services such as reduced erosion or protection from floods. In China, the Natural Forest Protection Program and the Conversion of Cropland to Forest Program, following the floods of 1998, have afforested an estimated 32.5 million ha (Payn *et al.,* 2015).

Certification schemes such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) (see Chapter 4) do not allow conversion of natural forests to plantations. Schemes such as the WWF's new generation plantation platform encourage better managed, more profitable and inclusive plantations (Payn *et al.*, 2015). Sustainable plantation systems often incorporate or set aside areas of high conservation value (HCV) – areas of forest assessed to be of high importance for local communities' FSN and livelihoods, and for biodiversity conservation. Such HCV areas can provide sources of NWFPs and wild foods as well as ecosystem services for agriculture. However, integrating HCV areas of forest into the broader landscape as well as connecting them with wildlife corridors and buffer zones remain a challenge. Community access to commercial plantation areas for such use is also contentious in many contexts.

Planted forests may be affected by pest and disease outbreaks as well as by droughts and fires – all of which risk being increased by climate change (Payn *et al.,* 2015). Plantations of introduced species such as *Eucalyptus, Acacia* and *Pinus* have been relatively free of pests and diseases during their early years as a result of separation from their natural enemies (Wingfield *et al*., 2008), but over time this has been changing, with pests and diseases being accidently introduced and native pests becoming adapted to these alien species. Overall, pests and diseases are likely to be an increasing cause of loss for planted forests in the future, requiring important research efforts[29] (Payn *et al.,* 2015).

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[29] See IUFRO www.iufro.org

Planted forests constitute an increasing resource for future wood and energy supplies, as well as, depending on their location and management, for the provision of environmental benefits.

This invites more in depth consideration of the potential contribution of planted forests to sustainable development and FSN. Planted forests have been criticized, in particular when replacing natural forests – some even proposing to exclude planted forests from the definition of forests. Planted forests generally provide fewer ecosystem services than natural forests; they are less biodiverse, often monospecific. However, from a global perspective, and especially considering the increasing demand for wood, they could play a crucial role to reduce the pressure on natural forests (Sloan and Sayer, 2015).

Important potential for forest restoration

There are considerable dynamics at play, involving large surfaces, often not well-known, that can offer space for future development of forests and trees systems.

Chazdon (2014) qualifies secondary forests as “the promise of tropical forest regeneration in an age of deforestation”. Secondary forests are a great opportunity for initiatives such as the Bonn Challenge[30] since they represent restoration in action, and an alternative way to restore soils and forests. In Latin America, important areas of abandoned agricultural land experience spontaneous forest regrowth: according to Aide *et al.* (2013), 22 to 36 million ha of net forest gain occurred on abandoned agricultural land between 2000 and 2010.

Box 11 Forest restoration and food security in Burkina Faso

In Burkina Faso, although the country does not have a substantial forest, the population is highly dependent on forest for income, energy and food security. Natural resources are the main source of employment; fuelwood and charcoal are the main sources of energy for cooking, and tree foods provide a significant portion of income (especially for women). Shea (*Vitellaria paradoxa*), nere (*Parkia biglobosa*) and baobab (*Adansonia digitata*) leaves supplement local diets and income. These and other non-timber forest products contribute 16–27 percent of women’s income, which is then used to supplement diets with purchased foods in seasons of resource scarcity (Lamien and Vognan, 2001, Djenontin and Djoudi 2015).

The drivers of land degradation and deforestation in Burkina Faso include the expansion of agriculture, cash cropping (that requires large areas), agro-business and bushfires. Joining international efforts, forest restoration began in Burkina Faso in the early 2000s and has been led by an NGO, NewTree/Tiipaalga, primarily in the central and northern parts of the country. Restoration activities have involved assisted natural regeneration of tree resources as well as increasing biodiversity. Involved households fence about 3 ha of degraded land (mostly land that used to be cultivated) and protect it from fire. By December 2014, 247 such enclosures in 109 villages in eight provinces in Burkina Faso had been recorded, accounting for a total of 722 ha of reforested lands under Tiipaalga’s leadership. A recent assessment of the impact of forest restoration on FSN conducted interviews with 38 households in three provinces of central Burkina Faso: Kadiogo, Kourweogo and Oubritenga. The assessment examined the diversity of products procured from reforested lands, the share of the different products in the total production and the role of the reforested lands as a safety net during the lean seasons. The results indicated that informants harvested on average six different types of products from restoration areas, ranging from non-wood forest products used for food to non-edible forest products, fodder for livestock, small wildlife and crops including cereals and legumes. More than 26 percent of fruits, nuts, leafy vegetables and spices produced by the households were obtained from restoration areas and 40 percent of households reported obtaining small species of bushmeat (squirrels, partridges, rats, hedgehogs, hares and foxes) from restoration areas. These foods are micronutrient-dense and therefore important for micronutrient intake in a country where rates of malnutrition remain high. Restored forests further contributed to most of the food supply when other sources of foods were most limited.

Sources: Djenontin and Djoudi **(**2015).

[30] The Bonn Challenge is a global effort aiming at restoring 150 million ha of deforested and degraded land by 2020 and 350 million ha by 2030 (see http://www.bonnchallenge.org/content/challenge).

Secondary forests play an important role in contributing to carbon sequestration and thus to REDD+ (see Box 18 in section 4.2.1), but only if well managed (Avitabile *et al.*, 2016; Chazdon *et al.*, 2016b). In recent decades, forest conversion to cattle pasture or agricultural fields, followed by land abandonment, has led to large areas of second-growth forest in the Amazon. These forests grow rapidly and sequester large amounts of carbon in their biomass, but they tend to be ignored, as most of the debate on the carbon balance of the Amazon basin tends to revolve around old-growth forests.

“Other wooded lands”, which represent almost one-third of the total forest area at the global level, as well as degraded lands and abandoned agricultural lands, provide significant areas globally where forests could be developed or strengthened in order to meet the increasing demands described in the following section. WWF/IIASA (2012) identify 2 155 million ha worldwide, currently non-forested (mainly croplands, grasslands and degraded land), with biophysical characteristics capable of supporting forests. In such areas, forest restoration could take many forms, from ecological restoration of secondary forests to agroforestry systems or intensively managed plantations.

This calls for a better understanding of the drivers of change, and of the dynamics at play in evolving landscapes such as secondary forests, other wooded land and degraded land in order to support forest and landscape restoration (FLR).[31]

Increased recognition of the role of trees outside forests

There is an increasing recognition of the critical role played by “trees outside forests” in a variety of complex landscapes including agroforestry systems, mosaic landscapes with forest fragments and agricultural tree crops plantations. Specific policies and programmes are developed in some countries to support the conservation and improvement of traditional systems and encourage the development of adapted systems.

FAOSTAT provides statistical data for those tree plantations that are considered as agricultural crops. At the global level, in 2014, the four main agricultural tree crops, in terms of area, are palm oil plantations, cocoa, coffee and olive trees. Table 10 presents the evolution of these areas between 1990 and 2014. FAOSTAT also provides statistical data on many fruit tree species, including: mangoes, mangosteens and guavas (5.6 million ha in 2014), apples (5.1 million ha), and oranges (4 million ha).

Table 10 Evolution of main agricultural tree crops at global level

Area (million ha)	1990	1995	2000	2005	2010	2014
Cocoa	5.7	6.6	7.6	8.7	9.6	10.4
Coffee	11.2	9.7	10.8	10.7	10.5	10.5
Palm oil	6.1	8.0	10.0	12.9	16.1	18.7
Olive trees	7.4	7.7	8.4	9.2	9.9	10.3

Source: FAOSTAT (see http://www.fao.org/faostat/en/#data, accessed March 2017).

In Africa, many agroforestry systems, such as the 800 year-old “Kihamba” system in the United Republic of Tanzania (see Box 12), rely on the traditional knowledge systems of indigenous peoples and local communities. As an example of the successful application of traditional knowledge on a massive scale, Reij (2014) presents the re-greening of the Sahel in Burkina Faso, Mali and the Niger where, since the 1980s, hundreds of thousands of poor farmers have been involved in the transformation of millions of acres of semi-desert degraded land into more productive land.

[31] In June 2014, FAO established a forest and landscape restoration (FLR) mechanism, working in full collaboration with the Global Partnership on Forest and Landscape Restoration (GPFLR), and aiming at scaling-up, monitoring and reporting on FLR activities in order to meet the Bonn Challenge and the CBD Aichi Biodiversity Targets related to ecosystem conservation and restoration (see http://www.fao.org/in-action/forest-landscape-restoration-mechanism/en/ and http://www.forestlandscaperestoration.org/).

Box 12 The "Kihamba" agroforestry system

The "Kihamba" agroforestry system covers 120 000 hectares of Mount Kilimanjaro's southern slopes. Without undermining sustainability, it supports one of the highest rural population densities in Africa, providing livelihoods for an estimated one million people.

This system has a multilayered vegetation structure similar to a tropical mountain forest, which maximizes the use of limited land, provides a large variety of foods all year round, income through wood and cash-crops production, as well as substantive ecosystem services beyond the areas where it is practised. For instance, through its dense vegetation, the "Kihamba" system contributes significantly to carbon storage and helps considerably to ensure that Mount Kilimanjaro remains a "water tower" for the whole region.

Under FAO's Globally Important Agricultural Heritage Systems Initiative (GIAHS), activities were piloted in 660 households to enhance farmers' cash income while preserving the ecological and social integrity of the "Kihamba" system. An action plan was formulated and implemented together with the community, through a free, prior and informed consent (FPIC) process, with the following key activities:

- Rethinking sources of cash income. Three interventions were agreed upon: (a) conversion to certified organic coffee farming; (b) introduction of vanilla as a high-value additional cash crop; and (c) introduction of trout aquaculture along the canals of the irrigation system.
- Rehabilitation of the irrigation system to reduce water loss and expansion of the capacity of storage ponds to cope with longer dry seasons due to climate change.
- Training in sustainable land management.

The interventions in coffee management alone are expected to increase farm cash income by 25 percent in three years.

See: http://www.fao.org/giahs/giahsaroundtheworld/designated-sites/africa/shimbwe-juu-kihamba-agro-forestry-heritage-site/en/; http://www.fao.org/3/a-i3817e.pdf; http://www.fao.org/climate-change/news/detail/en/c/881113/

In Europe, the classification of land either as agricultural or forested land does not facilitate the recognition and development of agroforestry systems (McAdam *et al.*, 2009). However, in some Mediterranean countries, traditional agroforestry systems produce for instance cork, fruit, nuts, olive and olive oil (Rigueiro-Rodróguez *et al.*, 2009). In Central Europe, hedgerows and windbreaks are still very common (Herzog, 1998). The *dehesas*[32] system, covering 3.1 million ha, mainly in Spain and Portugal, integrates natural forests, livestock, crops, cork and firewood harvesting and hunting, under specific management treatment systems (von Maydell, 1994; Brownlow, 1992; Moreno and Pulido, 2009). A more widespread agroforestry system throughout Western, Central and Eastern Europe is the *streuobst,*[33] which is a combination of plantations of trees and pastures.

Agroforestry systems provide a wide array of benefits that are increasingly being recognized. For instance, silvo-arable systems have been shown to reduce environmental degradation and loss of fertility of arable land by reducing the leaching of nitrates and maintaining soil integrity. Studies have shown that silvopastoral systems reduce environmental degradation and improve agricultural productivity through increased retention of soil phosphorous and carbon (Nair *et al.*, 2007). It has been suggested that around one-fifth of European arable land could be protected from nitrate leaching by intercropping trees (Reisner *et al.*, 2007).

With the perspective to promote and develop those agroforestry systems, some countries are developing national agroforestry policies. For instance, in 2014, India was the first country to adopt a comprehensive national agroforestry policy in 2014, to overcome the historical segregation between forestry and agriculture policy domains (see Box 13). In December 2015, France launched a national plan for the development of agroforestry with the view to better understand agroforestry systems and to support their development at national and international levels.[34]

[32] An agrosilvopastoral system, in which land is partially cleared, combining trees, native grasses, crops and livestock under a specific management treatment systems (Moreno and Pulido, 2009).

[33] *Streuobst* is defined as "tall trees of different types and varieties of fruit, belonging to different age groups, which are dispersed on cropland, meadows and pastures in a rather irregular pattern" (Herzog, 1998).

[34] See http://agriculture.gouv.fr/sites/minagri/files/160517-ae-agrofesterie.pdf (in French).

Box 13 Indian national agroforestry policy

This policy was based on the work of a multistakeholder working group created by the Indian National Advisory Council, comprising government, industry, NGOs, civil society organizations and financial institutions, as well as the CGIAR Program on Forests Trees and Agroforestry, through ICRAF, to provide technical support. After three years, 18 states have changed the laws that had so far prevented the adoption of agroforestry at a wider scale, with new harvesting and transit regulations for tree species grown on non-forest/private lands, especially involving smallholder timber production and marketing; eight states now show significant public and private agroforestry investments, with at least 11.7 million households representing about 11 million ha already benefiting from changes arising out of the policy. At the federal level, India committed about USD410 million (2016–2020) of federal and state government's resources to implement the agroforestry policy accompanied by a new "percentage of green cover" criteria for allocating an additional USD9.0 billion in funds to states. India identified agroforestry as a major tool to fulfil its Nationally Determined Commitment (NDC) to the UNFCCC.

Source: Singh *et al.* (2016).

3.2 Increasing and competing demands on forests

Changes in forest cover, forest types and uses are driven by the interaction of numerous factors, at local and global levels: growing demand for food, feed, wood and energy, driven by population and income growth; and increased importance given to the protection of biodiversity, to carbon stocks, water and soil protection.

These competing drivers will impact specifically the different types of forests and are likely to strengthen the trends described in previous section of decrease in "natural" forests and increase in plantation forests.

Deforestation and forest degradation are predominantly driven by agriculture expansion, while energy, intensive forestry, unsustainable land use and infrastructure development are also contributing drivers (Geist and Lambin, 2002; Gibbs *et al*., 2010). The underlying causes include demographic (e.g. population growth, migration), economic (e.g. poverty and overconsumption), technological, policy, governance and institutional failures, and cultural drivers (e.g. conventional attitudes and practices that attach low value to biological resources) (FAO, 2015; Keenan *et al.,* 2015; Sloan and Sayer, 2015). The dynamics of forest change have shifted these last 25 years. In the tropics, where most forest loss has occurred, deforestation due to smallholder agriculture has given way to large-scale deforestation to supply distant markets (Rudel *et al.,* 2009; Sloan and Sayer, 2015). Forest gains, on the other hand, are driven by two main factors: natural forest regrowth on abandoned agricultural land; and tree plantations to meet the increasing demand for wood either for timber, pulp or energy (d'Annunzio *et al.,* 2015).

Those demographic and socio-economic drivers of forest changes are acting at global and local levels and interacting between them at different scales. For instance, population growth and infrastructure development impact the global level of deforestation but also act as a local driver at the frontier of forests. In a recent study, Dezécache *et al.* (2017) developed a spatially explicit model to explain and predict deforestation and called for a better understanding of deforestation driving forces at different spatial scales.

3.2.1 Increasing demand for food

The world population has increased dramatically from 2.5 billion in 1950 to 7.3 billion in 2015 (UNDESA, 2015); 62 percent of this increase occurred in Asia and almost 20 percent in Africa. This global trend is expected to continue in the twenty-first century, as shown in Table 11, with marked regional differences. Most of the expected increase will take place in Africa.

Table 11 Population growth by region

Population (millions)	2015	2030	2050	2100
World	7 349	8 501	9 725	11 213
Africa	1 186	1 679	2 478	4 387
Asia	4 393	4 923	5 267	4 889
Europe	738	734	707	646
Latin America and the Caribbean	634	721	784	721
Northern America	358	396	433	500
Oceania	39	47	57	71

Source: UNDESA (2015).

Urbanization is also likely to consume more land. The share of the world population living in urban areas increased from 30 percent in 1950 to 54 percent in 2014. By 2050, 66 percent of the world's population is expected to be urban (UNDESA, 2014). In Africa and Asia, the urban population rates are projected to grow faster, from 40 and 48 percent in 2014 to respectively 56 and 64 percent by 2050. Lambin and Meyfroidt (2011) estimated that 48 to 100 million ha would be needed for urban expansion between 2000 and 2030.

As discussed more in depth by the HLPE in a previous report (2016), the evolution of diets driven by urbanization and income growth, and particularly the increased demand for animal-sourced food, is a powerful driver of agricultural development. Between 1961 and 2010, the value of global agriculture gross production increased faster than population, from 700 to 2 100 billion in constant 2004–2006 USD (FAOSTAT).

These trends are expected to continue in the future. FAO (2012b) projects that, between 2005–2007 and 2050, the global GDP per capita would increase by 82 percent (from USD7 600 to USD13 800) at an average rate of around 1.4 percent per year. In response to the growth in global population and incomes and to the evolution of diets, a continuation of recent trends would imply global agricultural production in 2050 to be 60 percent higher than in 2005–2007. This increase would come mainly from an increase in crop yields (80 percent of the production increase at the world level), some increase in cropping intensity (the number of cropping seasons per year) (10 percent of the total increase) and limited land expansion (the remaining 10 percent). According to these estimates, arable land could increase by 4 percent (net increase of about 70 million ha, comprised of an increase of almost 110 million ha in the developing countries and a decrease of nearly 40 million ha in the developed countries). However, these findings could be questioned by the possibility of greater than expected population growth, and by the effects of climate change on agricultural production and land availability (HLPE, 2016). According to other projections, cropland could expand by 5–20 percent to 2050, mainly in Africa and Latin America (Byerlee *et al.,* 2014). Much of the increased crop output over that period will be for livestock feed (HLPE, 2016). Lambin and Meyfroidt (2011) estimate that, in 2030, 81 to 147 million ha could be needed for additional crop production, and up to 151 million ha for additional grazing land.

Moreover, land degradation, defined as the reduction of land capacity to provide ecosystem goods and services, results in further encroachment into natural ecosystems, including forests, as agricultural land competes for space (Gibbs *et al*., 2010). It is estimated that, globally, 33 percent of the world's farmland is moderately to highly degraded (FAO, 2017a). Bringezu *et al*. (2010) mention an estimate of 2 to 5 million ha of global arable land lost every year due to soil erosion and another estimate of 3 million ha lost annually due to severe land degradation, but these estimates should be taken as rough indications only. Lambin and Meyfroidt (2011) estimate that, between 2000 and 2030, 30 to 87 million ha could be lost because of land degradation.

Agriculture expansion, driven by increased demand and by land degradation, is generally considered as the largest direct cause of deforestation. Hosonuma *et al.* (2012) estimate that agriculture expansion accounts for 73 percent of deforestation worldwide, while mining explains 7 percent, urban expansion 10 percent and infrastructures 10 percent. Morales-Hidalgo *et al.* (2015) found a negative correlation between the evolution of population density and of forest area. Using satellite data between 2000 and 2005 in a sample of tropical countries, DeFries *et al.* (2010) found a correlation between urban population density, agricultural exports and deforestation. D'Annunzio *et al.* (2015) found a strong negative correlation between the evolution of natural forest area and of arable land between 1990 and 2010 in almost all the subregions. Some studies estimate that 70–95 percent of forests lost in the tropics are converted to agriculture (Holmgren, 2006; Hosonoma *et al.,* 2012). Data from the FRA (2010) suggest that conversion to agriculture represents 70–80 percent of forest conversion in Africa, around 70 percent in subtropical Asia and more than 90 percent in Latin America (Hosonouma *et al.,* 2012).

3.2.2 Increasing demand for wood and energy

European consumption of forest products increased by 50 percent during the second half of the twentieth century. Industrial and fuelwood removals in the tropics increased by 35 percent during 1990–2015, while stagnating in other climatic domains. They increased most rapidly in lower-middle and lower-income countries (Köhl *et al.*, 2015) where demographic and economic growth were the highest. China has increased its share of log imports three-fold in the last decade. Studies project that such increases will be sustained, with demand for wood products in developing countries expected to double by 2030 (WWF/IIASA, 2012).

In addition, high-income countries import more wood than those countries with lower GDP (Mills Busa, 2013), and countries that experience increased forest cover often rely on imported resources to satisfy their growing wood demand (Meyfroidt *et al*., 2010).

Industrial roundwood demand is derived from the demand for end products (sawnwood, wood-based panels, pulp, paper and paperboard). Science and technology create new uses for wood-based biomaterials in pharmaceuticals, plastics, cosmetics and hygiene, chemicals, textiles and construction material that will trigger additional demand for wood. The Living Forests Model projects that annual wood removals will triple between 2010 and 2050 (WWF/IIASA, 2012).

Wood demand will also depend on the technology employed for production and transformation, as well as on the recycling of wood and fibre waste. Increased use of wood residues and recycled materials is expected to reduce the share of industrial roundwood in total wood and fibre use from almost 70 percent in 2005 to around 50 percent in 2030. While the demand for wood and fibre is expected to double, the global production of industrial roundwood is expected to increase by slightly less than 50 percent from 1.7 billion m^3 in 2005 to nearly 2.5 billion m^3 in 2030 (FAO, 2009b). Between 2010 and 2020, while paper production will increase from 400 million to 500 million tonnes, the share of recycled fibre in total production is expected to rise from 53 to 70 percent (WWF/IIASA, 2012). In addition to increased recycling, more efficient technologies could reduce the pressure on forests. For instance, Enters (2001) estimated that a 10 percent increase in milling efficiency for tropical sawnwood could reduce the annual global demand for industrial roundwood by 100–200 million m^3.

Analyses point to a greater proportion of industrial roundwood coming from planted forests in the future (Payn *et al.*, 2015). D'Annunzio *et al.* (2015) estimate that, at the global level, the share of wood production coming from planted forest could increase from 49 percent in 2013 to 69 percent in 2050. Moreover, the global production of planted forest could increase by 43 percent by 2030 to meet the future demand for wood (either for timber or energy).

In the period from 2001 to 2014, world biofuel production increased six times to reach nearly 130 billion litres (HLPE, 2013). Considering uncertainties both in energy markets and biofuel policies, and considering also the future impacts of advanced biofuel technologies, a pertinent question is whether such high growth will continue, and under what circumstances. The International Energy Agency (IEA) forecasts global biofuel production of 139 billion litres in 2020 (OECD/IEA, 2014). According to the HLPE (2013), using typical biofuel yields, a production of 100 billion litres would represent an equivalent of 20.4 million ha of sugar cane, or 38.5 million ha of maize, or, if it were biodiesel, 58.8 million ha of rapeseed. Lambin and Meyfroidt (2011) consider that 44 to 118 million ha could be needed for additional biofuel production by 2030.

Many studies also suggest that wood is increasingly used as an energy source at the global level, not only in developing countries, but also in developed countries (d'Annunzio *et al.*, 2015). The traditional burning of wood and other biomass for cooking and heating in low-income countries accounts for around two-thirds of the bioenergy used worldwide (FAO, 2017a). Wood required for bioenergy production could increase from 2.6 billion m^3 in 2005 to 3.8 billion m^3 in 2030 (FAO, 2009b).

Lambin and Meyfroidt (2011) estimate that, by 2030, 56 to 109 million ha could be needed to meet this increasing demand for wood (either for timber or energy). According to WWF/IIASA (2012), an annual rate of growth of 2.4 percent of planted forests would be needed to meet the global demand for wood products while preserving natural forests.

3.2.3 Increased recognition of the protective roles of forests

The international community has recognized the importance of forests for biodiversity and acts for its preservation through multilateral agreements and processes. For instance, the Aichi Biodiversity Targets established by the CBD include the objectives to halve the rate of loss of natural habitats including forests (Target 5) and to conserve 17 percent of terrestrial areas through effectively and equitably managed, ecologically representative and well-connected systems of protected areas (Target 11) (SCBD, 2006). Even if deforestation has slowed down, forest loss is still a matter of concern, especially when it occurs in areas with particularly high ecological value.

Designating protected areas is one of the primary strategies for conserving biodiversity (Morales-Hidalgo *et al.,* 2015). The benefits of protected areas extend far beyond their immediate environs. These areas provide a natural safeguard for biodiversity, including the wild plant relatives of crops (Sunderland, 2011). Protected areas also provide ecosystem services, benefiting the surroundings, with mountain areas playing a special role through their contribution to clean water and decreased disaster risks (Foli *et al.*, 2014).

National parks, game reserves and biosphere reserves are part of a growing network of "protected areas" that are considered to be essential for the conservation of biological diversity. Substantial stretches of national territories and forested areas are included in this protection regime, and the total area is increasing on all continents. As of 2014, terrestrial protected areas cover 15.4 percent of the earth's surface, much of which include forests.[35] FAO (2015) reports the forest area within protected areas to be 651 million ha in 2015, which represents a 63 percent increase between 1990 and 2015.[36] In 2015, protected areas cover nearly 27 percent of the tropical domain, 13 percent of the subtropical domain, 11 percent of the temperate domain and less than 3 percent of the boreal domain (Morales-Hidalgo *et al.,* 2015).

In the Democratic Republic of the Congo, forest cover loss within protected areas was more than two times lower than the national average. However, forest-cover loss still increased by 64 percent between 2000–2005 and 2005–2010 (Potapov *et al.,* 2012). Other studies also question the efficiency of protected areas in preventing deforestation and also note that declared protection does not always mean adequate protection (Morales-Hidalgo *et al.,* 2015).

The Millenium Ecosystem Assessment (MA, 2005) reported that many protected areas are specifically situated in forests unsuitable for other human uses. This may limit the impact of the protection strategy on deforestation. Moreover, as noted by Mills Busa (2013), high-income countries tend to import more wood than lower-income countries, suggesting that rich countries practise preservation within their borders but appropriate resources from poorer countries to sustain consumption. In that sense, sustainable consumption strategies (including certification schemes discussed in Chapter 4) might be as important as forest protection. Furthermore, protected areas are often managed in such a way that undermines the FSN of forest-dependent people (see Section 3.4.2).

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[35] See http://www.iucn.org/?18607/New-UNEP-report-unveils-world-on-track-to-meet-2020-target-for-protected-areas-on-land-and-sea

[36] When considering only the countries that reported this figure both in 1990 and 2015.

Beyond the strictly protected areas, the FRA includes under the topic "Biodiversity and conservation", the primary forests (1.277 million ha), as well as 524 million ha of forest mainly devoted to the conservation of biodiversity.

Moreover, it distinguishes two main categories of protective forests, namely: (i) protective forests for soil and water; and (ii) protective forests for ecosystems services, cultural or spiritual values. Over the past 25 years, an increasing number of countries reported forest area devoted to protection of soil and water, reflecting the increasing awareness of the multiple functions of forests (Miura *et al.,* 2015).

Globally, around 1 billion ha (25 percent of the world's forest) have been reported in the FRA 2015 (FAO, 2015) as protective forests for soil and water resources, of which 534 million ha in North and Central America, 195 million ha in Asia (see Box 14 on China), and 123 million ha in Europe (FAO, 2015). Under this category, the FRA distinguishes protective forests for: clean water (3.4 percent of global forest areas); coastal stabilization (0.83 percent); desertification control (3.6 percent of global forest areas, all situated in Africa and Central Asia); avalanche control (0.36 percent of global forest areas, including 14 percent of forest areas in Tadjikistan and 7 percent in Switzerland); erosion and flood control (5.1 percent of global forest area, including 30 percent of Austrian forests, 28 percent in Switzerland and 25 percent in Tadjikistan); and other control (Miura *et al.,* 2015).

Almost 1.2 billion ha have been reported in the FRA 2015 (FAO, 2015) as protective forests for ecosystem services, cultural or spiritual values, of which 642 million ha in North and Central America (including 93 percent of Canadian forests and 100 percent of forests in the United States of America), 167 million ha in South America, 123 million ha in Oceania and 122 million ha in Europe (FAO, 2015). Under this category, the FRA distinguishes protective forests for: public recreation (4.3 percent of global forest area); carbon storage (1.3 percent of global forest area in 1990 and 5.3 percent in 2015); cultural services (1.9 percent, mostly situated in North and South America); and other services (Miura *et al.,* 2015).

Forests and trees can play a fundamental role in the fight against land degradation through the provision of essential ecosystem services (see Chapter 2), such as providing soil structural stability, erosion protection, water regulation and nitrogen fixation (Foli *et al*., 2014). Land degradation is particularly prevalent in the drylands and dry forested regions of the world (Pulla *et al*., 2015). Those dry forest systems that have not been completely destroyed are generally impoverished and fragmented. The degradation process thus initiated has led to a shift away from the original vegetation types to drier, less productive and less resistant forest types, exposing large numbers of people to the threat of desertification and associated disastrous ecological, social and economic impacts (Derroire *et al*., 2016). However, even in very arid areas, forests and trees can be used to fight desertification (see Box 15).

Box 14 Chinese protective forests

In China, protective forest areas have increased from 18 million ha to 58 million (i.e. from 12 to 28 percent of total forest area) between 1990 and 2015. According to the national report on sustainable forest management in China (State Forestry Administration, 2013), at the end of the 1990s, soil erosion (including wind and water erosion) impacted 356 million ha and represented 5 billion tonnes of annual soil losses.

Forest degradation in China had continued for several decades until 1990s, because of population growth, overexploitation of forest resources, and subsequent cultivation on steep slopes (Wenhua, 2004), provoking serious frequent natural hazards and disasters as well as important human and economic loss.

The Chinese Government therefore launched a series of top-to-bottom afforestation projects, implemented natural forest conservation projects and planted shelter forests (for water and soil conservation, windbreaks, sand fixing and desertification control). Areas of shelter forests reached 83.1 million ha in the first decade of the 21st century, occupying 45.8 percent of forest area and 8.7 percent of total national land.

Source: Miura *et al*. (2015).

Box 15 Desertification control

The threat posed by desertification is particularly critical in Northern Africa and in the Arabian peninsula. More than 95 percent of the region is arid or semi-arid and affected by or prone to desertification. Live trees and dead vegetation have been used in different countries for sand-dune fixation and desertification control since the early nineteenth century. In Morocco, 34 000 ha of fast growing species (such as *Eucalyptus* spp., *Acacia cyanophylla* and *Acacia cyclops*) have been planted over 60 years in the early twentieth century, to control sand-dune movements along the Atlantic coast and protect cities such as Tanger, Kenitra and Agadir. In Tunisia, Mauritania and Morocco smaller greenbelts have been planted to protect oases, continental cities or infrastructures.

In Algeria, in the 1960s, overgrazing and cultivation activities provoked the rapid degradation of the Alfa grass steppe at the Sahara border. In the 1970s, to fight desertification, it was decided to contribute to the reforestation of this area of 3 million ha by planting a "green dam" of Aleppo pine (*Pinus halapensis*). After a few years, this programme turned into a large multisector project. Since its creation, the Green Dam Project has enabled the rehabilitation of around 300 000 ha of degraded forests in the Saharan Atlas, the plantation of green belts on 5 000 ha to protect villages and infrastructures, the management of 25 000 ha of pastures and the establishment of 90 water sources to improve potable water availability (Saifi *et al.,* 2015).

The Great Green Wall for the Sahara and the Sahel Initiative*

The Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI), launched in 2007 by the African Union (AU) has become Africa's flagship initiative to combat the effects of climate change and desertification. It aims at reversing land degradation and desertification in the Sahel and Sahara, eradicate poverty and hunger, improve FSN and support local communities in drylands to address climate change adaptation and mitigation. It promotes long-term solutions, integrated interventions and sustainable local practices to tackle the multiple challenges affecting the lives of people in the Sahel and Sahara. It brings together more than 20 African countries, international organizations, research institutes, civil society and grassroots organizations.

* http://www.greatgreenwallinitiative.org/; www.fao.org/in-action/action-against-desertification; www.fao.org/dryland-forestry

Source: Hadri and Guellouz (2011).

3.3 Forests, trees, climate change and FSN

Four main types of interactions between forests, trees, climate change and FSN can be identified:

- the impacts of climate change on forests and trees and thus on their contributions to FSN;
- the contributions of forests and trees to FSN in a changing climate;
- the contribution of forests and trees to mitigation of climate change, and thus to FSN in the medium/long term;
- potential impacts on FSN of policies strengthening the contribution of forests and trees to mitigation of climate change.

3.3.1 Impacts of climate change on forests and trees

There is an increasing understanding of the impacts of climate change on forests and trees (see Table 12). Negative impacts are already apparent in many places, even it is often difficult to separate climate change from other stresses (FAO, 2016b). Signs of climate stress, with increasing tree mortality, changes in fire regime, insect outbreaks and pathogen attacks are becoming increasingly apparent (Settele *et al*., 2014). Evidence suggests that, in a wide range of forest systems, warming and changes in precipitation are increasing tree mortality through heat stress, drought stress and pest outbreaks (Allen *et al*., 2010).

Table 12 Potential impacts of some climate changes on forests and FSN

Climate change variable	Impact on forests	Impact on FSN
Moderate increase in average temperature (e.g. 1 ºC)	Increased rates of regeneration (Lindner *et al*., 2008; IPCC, 2014)	Increased forest biodiversity and food availability, access, utilization and stability
	Decreased forest vitality and productivity (Kirschbaum *et al.,* 2007; FAO, 2015)	Loss of forest biodiversity leading to reduced availability, access, utilization and stability of forest-sourced foods
	Increased forest pests and diseases (Lindner *et al*., 2008; FAO, 2015)	Loss of forest biodiversity leading to reduced availability, access, utilization and stability of forest-sourced foods
	Shift in suitable habitats for many species and forest types	Reduced availability, access and utilization to forest-sourced foods
	Water stress leading to drought-induced forest/tree dieback and land degradation (Williams *et al*., 2013)	Loss of forest biodiversity leading to reduced availability, access, utilization and stability of forest-sourced foods
		Water stress could affect the sustainability of rainfed agriculture in tropical regions, thereby affecting food availability and access (FAO, 2011b SOLAW)
	Increased wildfires (Kirschbaum *et al.,* 2007; FAO, 2015)	Loss of forest biodiversity leading to reduced availability, access, utilization and stability of forest-sourced food.
Changes in precipitation regimes	Inhibition of seed germination, changes in plant anatomy and promotion of early senescence and mortality (Kirschbaum *et al.,* 2007; Lindner *et al.,* 2008; Elbehri, 2015)	Diminished forest biodiversity leading to reduced availability, access, utilization and stability of forest-sourced foods
	Increased water erosion and landslides (Kirschbaum *et al.,* 2007; Elbehri, 2015; FAO, 2015)	Decreased soil fertility due to leaching resulting in low soil productivity and affecting food availability (production)
	Increased storm damage (FAO, 2015; Elbeheri, 2015) elevating disaster risk management costs by government	Elevated budgets for food relief that may be insufficient in most developing countries, thus failing to meet FSN dimensions
		Damage to transportation infrastructure intended to facilitate availability and access to forest-sourced foods by rural households
	Reduced extent and vitality of mangroves and coastal forests (FAO, 2015)	Reduced productivity of coastal fisheries impacting on all FSN dimensions (availability, access, utilization and stability)

In boreal forests, many productivity declines have been attributed to drought (Williams *et al*., 2013). Warming and drying, coupled with productivity decline, insect disturbance and associated tree mortality, also favour greater fire disturbance (Settele *et al*., 2014). In temperate forests, until recently, the overall trend has been an increase in growth rates, thanks to a combination of a longer growing season, higher atmospheric CO_2 and nitrogen deposition and forest management (Ciais *et al*., 2008). Models predict that the potential climatic space for most tree species will shift poleward and to higher altitudes, accelerating faster than natural migration processes. Climate change will also impact the emergence and development of pests and diseases, as well as the spread and survival of populations of invasive species. The composition of species may be affected, which may change ecosystem productivity, hence FSN-relevant goods and services from the forest (Boulanger *et al*., 2016). Climate change is expected to impact on forest biodiversity and the ability of forests to provide soil and water protection, habitat for species and other ecosystem services, that will at the same time be called upon because of climate change (Locatelli, 2016).

The consequences of all those phenomena on forest health and forest functions are expected to vary across regions and forest types (Payn *et al*., 2015). Forest ecosystems identified as being particularly vulnerable to the impacts of climate change include mangroves, boreal forests, tropical forests, cloud forests[37] and dry forests. For tropical forests, a key uncertainty is the strength of direct CO_2 effects on photosynthesis and transpiration. Moist tropical forests have many species that are vulnerable to drought and fire-induced mortality during extreme dry periods; and there is evidence that forest-fire frequency and severity are increasing, due to a combination of land-use change and drought, including in the Amazon. Climate change, deforestation, fragmentation, fire and human pressure place virtually all dry tropical forests at risk of replacement or degradation (Miles *et al*., 2006).

Tropical tree species are expected to be the most affected by climate change as they are already close to their thermal tolerances (IPCC, 2014). The inability of species to adapt to changing climates combined with phenological changes such as earlier flowering (and thus reduced fruit yields and production) could result in direct impacts on the amount of forest resources available for harvest and use by local communities, particularly impacting those communities that are most dependent on forests and trees. A study in Brazil (EMBRAPA 2008) shows that climate change can have important impacts on the areas at low risk for coffee production. In traditional production areas, coffee would be affected by lack of water or high temperatures. On the other hand, with the reduction of the risk of frost, there could be an increase of the production area in other areas. As a result, the global area at low climatic risk for coffee would be reduced by 9.5 percent in 2020, 17 percent in 2050, and 33 percent in 2070. Models predict a reduction of cocoa production by 2050 in Côte d'Ivoire and Ghana, the two main producers, accounting for 53 percent of the world production (CTA, 2012). However, as pointed out in a previous report (HLPE, 2012), data are lacking on many species of interest for FSN.

3.3.2 The contributions of forests and trees to FSN in a changing climate

As shown in Chapter 2, forests and trees play a crucial role to increase resilience of food systems, at landscape, farm and household levels. With climate change modifying and increasing all categories of risks with which food systems and households are confronted (FAO, 2016b), this role of forests and trees to increase resilience will be particularly important, in particular their role for water and temperature regulation, for coastal areas protection against sea level rise, and for protection against floods. Agricultural systems with a diversity of cropping and land-use types are more resilient to extreme weather events caused by climate change (Rahman *et al.,* 2013), as well as to increased climate variability (FAO, 2016b). At household level, forests and trees play important roles in livelihood resilience in the face of climate change, including: as safety nets in times of emergency; as sources of products important for production and income diversification for farm households and rural families; and as sources of employment (particularly important where farming and other rural livelihoods are no longer viable). Wild foods may be of increasing importance as a safety net for communities experiencing climatic shocks (Byron and Arnold, 1997; Wunder, 2014) and as a source of dietary diversity (Phalkey *et al*., 2015).

This invites the integration of forests and trees in adaptation strategies aimed to secure FSN (FAO, 2017b). This, in turn, calls for maintaining forest ecosystems in a healthy state, in order to retain their resilience. Healthy forests are better able to cope with stress, recover from damage and adapt autonomously to change. More broadly, healthy ecosystems are more resilient to negative biotic and abiotic influences than are ecosystems under stress whose ecological processes are impaired. Best practices include integrated pest management, disease control, forest-fire management, employment of reduced impact logging (RIL) in production forests, limitation of gathering of NWFPs or livestock grazing in forests at sustainable levels, and forest law enforcement (FAO, 2016b). Forest managers will need to take additional measures to increase the adaptive capacity of forests. Adaptive management is particularly relevant in environments where the future is uncertain (Robledo and Forner,

[37] Cloud forests include forests that are frequently covered in clouds or mist, thus receiving additional humidity, other than rainfall (Stadtmüller, 1987). They are generally tropical or subtropical, and at high altitude.

2005); it requires continual adjustment and improvement of management practices by monitoring, analysing and learning from the outcomes (Seppälä *et al*., 2009).

3.3.3 The contribution of forests and trees to mitigation of climate change

Forests absorb annually an important amount of carbon dioxide (CIFOR, 2010). However, the average contribution of forests to carbon sequestration has fallen from 2.8 Gt annually in the 1990s to 2.3 Gt in the 2000s, and is estimated at 1.8 Gt in 2014 (FAO, 2016c). At the same time, deforestation and forest degradation account for nearly 11 percent of all GHG emissions (Smith *et al*., 2014), more than the transport sector.

Studies estimate the mitigation potential for forestry from 0.2 to 13.8 Gt CO_2 eq/year at prices up to USD100/tonnes CO_2 eq (Smith *et al.,* 2014). The carbon mitigation potential of reduced deforestation, improved forest management, afforestation and agroforestry differs greatly by activity, region, system boundaries and the time horizon over which mitigation options are compared. Reductions in deforestation dominate the forestry mitigation potential in Latin America and Africa, while forest management, followed by afforestation, dominates in OECD countries, economies in transition and Asia. However, this substantial mitigation potential will not materialize without appropriate financing and enabling frameworks that create effective incentives (FAO, 2016c) (see also Box 18 on REDD+ in Chapter 4). The IPCC (Smith *et al*., 2014) notes that large-scale biomass supply for energy, or carbon sequestration in the agriculture, forestry and other land use (AFOLU) sector, provides flexibility for the development of mitigation technologies in the energy supply and energy end-use sectors, but that there are potential implications for biodiversity, food security and other services provided by land.

3.3.4 Potential impacts on FSN of policies strengthening the contribution of forests and trees to mitigation of climate change

The Paris Agreement recognizes the important role of land use, land-use change and forestry in addressing climate change. Its article 5 recognizes the central role of forests in achieving the 2 °C goal through mitigation options covered by REDD+. It also acknowledges the potential of forests for joint mitigation and adaptation approaches, and their important role in yielding non-carbon benefits.

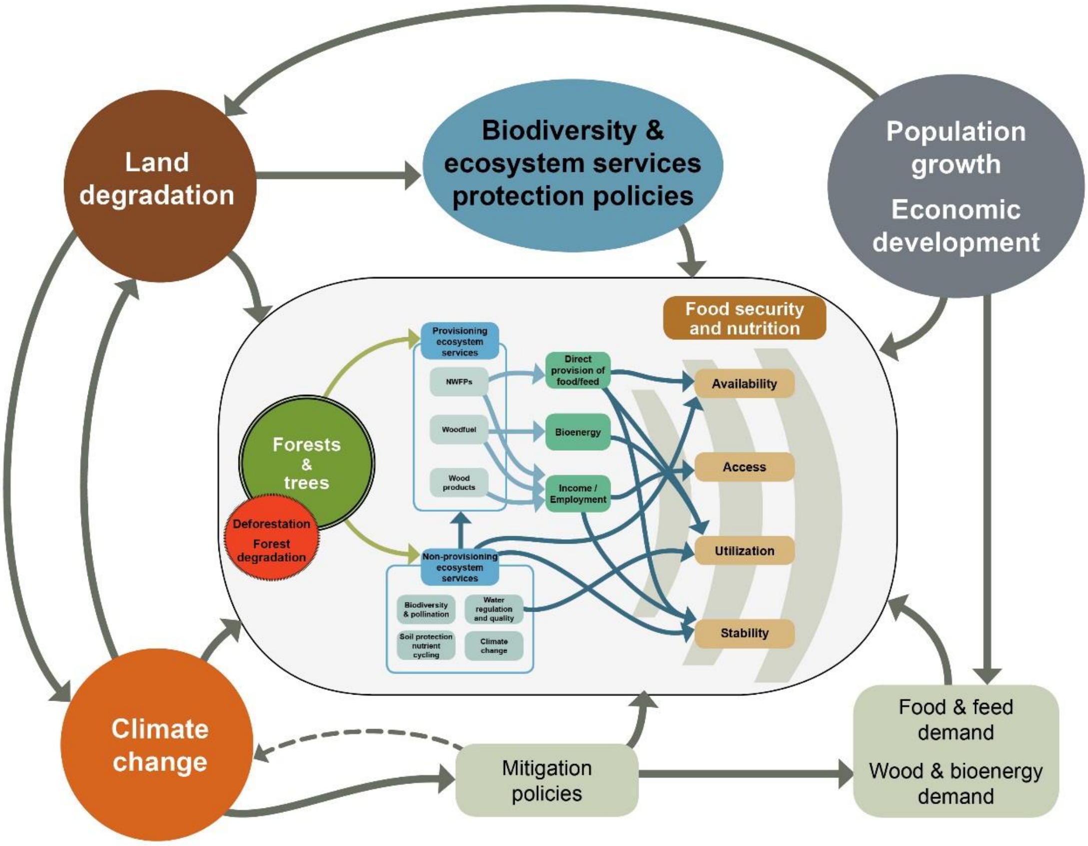
Parties to the Paris Agreement have prepared national determined contributions (NDC), to be renewed every year, recorded in a public registry. The NDCs announce the objectives of parties and include targets, strategies and measures to address the causes of climate change and its effects. Most countries (FAO, 2016d) have integrated forestry and are making reference to policies and measures, existing and/or projected in the forestry sector, to protect and increase carbon stocks and increase the production of renewable materials and renewable energy in forests and through land restoration. Most of these policies and measures will reinforce some of the trends exposed above, either towards forest conservation and development and/or increased production, with accompanying impacts on forests and trees contributions to FSN. Energy production and product substitution will have social, economic and cultural implications (EEA, 2016). For example, policies in the European Union to increase the use of biofuels, including woodfuels, for energy generation are affecting how foresters in the region manage their forests, and how land in developing regions is used (EC, 2013).

Importantly, the recognition of the crucial role that forests and trees can play in climate change mitigation and adaptation can trigger stronger engagement, at both international and national levels, to develop ambitious forestry policies for climate. A key issue will be to ensure that such policies and mechanisms integrate consideration of all contributions of forests and trees to FSN.

3.4 Impacts of changes on FSN

Deforestation, forest degradation, as well as changes in the management of forest either for production or conservation purposes all impact on FSN. Figure 7 illustrates how the drivers of changes identified in this chapter interact with each other, and impact forests and tree-based systems as well as their different contributions to FSN.

Figure 7 Drivers of forest changes impacting their contributions to FSN



3.4.1 Impacts of deforestation and forest degradation

Deforestation and forest degradation threaten income, livelihoods and ways of life of forest-dependent peoples and communities, and compromise the provision of ecosystem services that are essential to FSN and sustainable development in the long term. Deforestation and forest degradation, leading to habitat fragmentation, can also impact human health by increasing the risk of transmission of pests and diseases.

Impact on FSN through income and economic growth

Increased income may lead to greater purchasing power and thus improved nutritional status. Clearly, forest-based communities rarely live solely from forest resources alone, but also need cash to access goods and services from the local and regional economy. The evidence of the positive effects of economic growth on reducing the prevalence of stunting is strong and manifests even over short periods of time, partially explained by associated improvements in female education, lowering of fertility rates and increased asset ownership (Headey, 2013). However, economic growth in some cases may benefit the sections of society least at risk of malnutrition, leaving behind the most malnourished (Subramanyam *et al*., 2011).

The non-linear relationships between income and nutrition may be further complicated in forest-dependent communities (Beddington *et al*., 2012). Economic analyses often fail to take into account the importance of environmentally derived sources of income. For instance, if a community has a higher monetary income but needs to purchase products that were previously provided “for free” by forests and trees (such as firewood, fuel, food and medicinal products), their FSN status will not be necessarily higher. Moreover, the effects of income on nutrition are dependent both on market access to nutritious foods (fruits, vegetables, ASFs) and on consumer preference to use income to purchase these foods.

Though forest resources may contribute positively to income and employment in some areas, it is often argued that deforestation for agricultural expansion may offer greater opportunities for welfare improvement. Higher rates of deforestation have been found to be associated with higher human development indices (HDI) at an initial phase of frontier expansion, less so as the frontier advances (Rodrigues *et al*., 2009), and recent comparative research suggests that the immediate benefits can actually result in an eroded environmental base, simplified diets and compromised livelihoods (Deakin *et al*., 2016; Ickowitz *et al.,* 2016). The number of people employed in forest-related jobs is also affected, as degraded sites tend to be converted most easily to pasture, offering few jobs per hectare converted. Those marginalized by deforestation tend to move outward towards new frontiers where the cycle may begin anew. Sustainable forest management approaches may enable local livelihoods to be stabilized, as has occurred in community forest concessions in Guatemala (de Camino *et al*., 2007) and other case studies presented in this report (see Chapter 4).

Safety-net policies can also play an important role. For example, welfare transfers for food consumption and access to them by forest communities such as those in *Bolsa Verde* and *Bolsa Floresta* in Brazil provide conditional income transfers to residents of forest reserves, contingent on various forest protection measures such as not opening new forest areas for agriculture. Analysis of the food consumption and productive behaviour of *Bolsa Familia* recipients suggests that such transfers make a significant difference in the variety and nutritional value of foods consumed: there is a pronounced impact on intake of sugars and processed foods, meats and cereals, but also foods desired by children with greater proportions of fruit consumption within participating households. Recipients have not fully abandoned agricultural production, though there is some indication that there has been a reduction in NWFP production and bushmeat consumption in the Amazon region (Menezes *et al.*, 2008). Women have changed dietary patterns in response to a shift from subsistence to cash sources of support that permitted them to abandon cassava cultivation in favour of purchased substitutes (Piperata *et al*., 2011).

Impact on FSN through non-provisioning ecosystem services

A healthy ecosystem provides sustainably a balanced set of ecosystem services critical for economic activity, agricultural productivity, human health and sustainability (Cairns, 1997; Colfer, 2008; Sunderland, 2011; Foli *et al*., 2014). Definitions of ecosystem health have been closely allied with the concept of stress ecology, which defines health in terms of system organization, resilience and vigour, as well as the absence of signs of ecosystem distress (Rapport *et al*., 1998). The definition also includes the presence of essential functions and key attributes that sustain life systems (Reed *et al.,* 2017).

Chapter 2 described the multiple ecosystem goods and services provided by forests and trees in healthy ecosystems and showed the contribution of forests and trees to ecosystem resilience, including adaptation to climate change. Deforestation, forest degradation and habitat fragmentation threaten the continued supply of those ecosystem goods and services, upon which the long-term FSN of rural and urban people alike depend (Deakin *et al.,* 2016). While cultivated cropland may retain trees or accommodate natural tree regeneration, these alone may be insufficient to provide the environmental goods and services garnered from formerly intact or largely natural forests (Firbank *et al.*, 2008; Power, 2010; Flohre *et al.*, 2011).

However, even remnant forest patches can play a positive role for adjacent agricultural landscapes. Mitchell *et al*. (2014) show that the provision and level of six ecosystem services (crop production, pest regulation, decomposition, carbon storage, soil fertility and water quality regulation) in soybean fields depend on the distance from forest fragment as well as on fragment isolation and fragment size.

Impact of deforestation and forest degradation on human health

An important effect of deforestation and forest degradation, and more generally of ecosystem degradation, is an increased risk to human population health (Myers *et al*., 2013). These health impacts are likely to arise from a variety of types of ecological and social disruption.

The impacts of deforestation and land-use change on infectious disease can be divided into roughly four categories (Myers *et al.*, 2013).

First, there are physical effects such as the building of roads, reduced tree cover, climatic change and habitat fragmentation. Second, new land-use practices such as mining, agriculture and monoculture plantations also affect the transmission of diseases and introduce new risk factors (Colfer, 2008). Third, changes in habitats result in changes in the ecological regulation of parasitic and vector-borne disease by changing predator–prey relationships or by reducing the diversity of parasites and vectors.

Fourth, demographic changes and migrations result in a shift in exposure, with new diseases being introduced to the area. For example, in-migration and commercial logging activity has been associated with increased prevalence of sexually transmitted diseases including HIV/AIDS as prostitution around logging camps and roads/truck stops increases (Colfer, 1999) and as formally relatively isolated populations intermarry with members of other communities (Ndembi *et al.,* 2003). As population sizes increase through migration and/or natural increase, communities can reach a critical community size threshold whereby diseases such as measles that previously would go extinct become endemic (Nåsell, 2005). With increased population densities, the likelihood of spreading water-borne diseases also increases as sanitation facilities – where they exist – become overburdened (Patz *et al.*, 2005). In many communities, rivers form the focus of all activities including washing, defecating, fishing and sources of clean water (UNICEF, 2012). As population increases, the likelihood of contamination increases without concurrent investments in sanitation and hygiene (Bailie *et al.,* 2004; Myers *et al*., 2013).

Many studies have demonstrated links between deforestation and increases in malaria risk (Pattanayak *et al*., 2006; Patz *et al*., 2008; Vittor *et al*., 2006; Wan *et al*., 2011; Olson *et al*., 2010). Conversely, at least one study has shown a reduced overall burden of malaria with deforestation in Thailand (Yasuoka and Levins, 2007) and draining of swamplands has been associated with decreased prevalence of malaria in many countries (Keiser *et al.*, 2005). Deforestation, road building, mining pits and predatory logging can create new breeding habitats for insect vectors. For example, one study in the Peruvian Amazon showed that the biting rate of the malaria vector *Anopheles darlingi* was proportional to the area of land-use modification and inversely proportional to the area of remaining forest (Vittor *et al*., 2006). There are similar studies for tsetse fly and sleeping sickness. Also, in temperate and boreal forests, there may be a risk of infectious diseases, e.g. tick-borne diseases such as Lyme or encephalitis (Karjalainen *et al*., 2010).

Likewise, there is a strong link between ebola and the deforestation of tropical rainforests (Olivero *et al*., 2016). The recent outbreaks in Guinea and Sierra Leone are hypothesised to be the result of an exceptionally arid and prolonged dry season, coupled with the extreme deforestation of the area over recent decades that somehow influenced the number or proportion of ebola forest-dwelling virus-infected bats and/or the frequency of human contact with them (Bausch and Swartz, 2014).

The forest-dwelling poor, however, are often neglected by the services of the state and less likely to benefit from increased healthcare provision than local elites (Stephens *et al.,* 2006). This concern of who receives the benefits of improved access to pharmaceutical medicine and state healthcare infrastructure is central to the question of how land-use modification will affect the healthcare of local people. Timber-producing companies have different approaches: from very primitive installations and poor food provision for the workers, to companies that provide for adequate food and nutrition, and that take on public responsibilities by having on their premises healthcare posts and medical services. This is especially true in cases in which the forest management operation has attained conformity with standards of the FSC or the PEFC (see Chapter 4).

3.4.2 Protected areas and FSN

The extension of protected areas raises new questions. The successful recovery of declining or near extinct species populations (Fall and Jackson, 2002) through wildlife management and protection from overexploitation (Messmer, 2000) has also led to compounded human–wildlife conflicts. Effective protection and habitat management within the Gir National Park and Sanctuary in the Indian state of Gujarat doubled the Asian lion (*Panthera leo persica*) population between 1970 and 1993. The social organization, habitat and prey requirements of the species were difficult to accommodate within the human-defined home range, and resulted in many lions straying out of the reserve into local villages (Vijayan and Pati, 2002). Around Bénoué National Park in Cameroon, communities lost an estimated 31 percent of their annual crop income and 18 percent of their annual livestock income per household: the species inflicting the majority of the crop losses are elephants, baboons, green parrots and warthogs, while the civet is the main predator causing losses to livestock (Weladji and Tchamba, 2003). In the ranches of North America, European settlement almost exterminated wolves. Recent recovery programmes, however, have contributed to the recolonization by wolves of their original home range and in the process have increased the potential for conflict, especially where domestic livestock is a major economic activity (Musiani *et al.,* 2003). Hunting bans or regulations in protected or certified forest favour wildlife conservation but may also increase human–wildlife conflicts and impact the FSN of local communities where bushmeat is a significant source of protein (Burivalova *et al.,* 2017).

Forested protected areas also have an important role to play for FSN of many people depending on those areas as a means of subsistence. In some cases, they benefit directly, through the consumption of food produced or obtained in or around protected areas. In others, employment and income provide indirect benefits that contribute to sustaining livelihoods and may even attract immigration (Joppa, 2012). The growing interest in ecotourism and increasing access to nature reserves have increased the human presence in protected areas and raised concern about the sustainable management, including regulation of public access, of those areas (Distefano, 2005).

However, global forest conservation benefits can collide with the need to improve FSN and alleviate the poverty of local forest dwellers (Kremen *et al.,* 2000). In Mexico, while a PES project provided communities with cash to protect forests for watershed services, traditional use of forests for food collection was prohibited (Ibarra *et al.,* 2011). Management strategies of protected areas for the conservation of natural resources often restrict resource use for local communities (Sylvester *et al.,* 2016), and neglect their needs and aspirations, their traditional knowledge and management systems, their institutions and social organizations, and the value they attribute to wild resources. As a result, forest-based national parks and protected areas have led to extensive resource alienation and economic hardships for many rural social groups, particularly in Africa, Asia and Latin America (Ghimire and Pimbert 1997; Dowie, 2009). In many situations, this has undermined the FSN and livelihood security of local communities living nearby or excluded from protected areas (Colchester, 1994; Pimbert and Pretty, 1997).

3.4.3 Production forests and FSN

As shown in section 3.2.2, wood production is expected to increase to answer the increasing demand for wood for fiber, energy and as renewable material in buildings and for furniture. This increase could contribute to economic and employment development, depending on the ways it is managed and in particular the groups that would benefit from it. Depending on situations, and in particular on the systems that would be modified, increased wood production could provide more income and jobs for local populations or impact negatively FSN of local populations while benefitting to actors far away.

The corporate business sector grows forests basically to satisfy final consumer demands, or those that serve as intermediate inputs into industrial and commercial production processes. Forestry enterprises may restrict access of forest-dependent people to forest resources, while providing them with marginally more significant monetary income or, conversely, allow the local population to collect NWFPs while also providing employment.

In Chile, for example, communities near to large-scale pine plantations are occasionally prohibited from harvesting fuelwood and NWFPs from these forests (Armesto *et al.,* 2001), while in natural forests managed in the Brazilian Amazon under public forest concession, arrangements for community use of extractive NWFPs in the regeneration cycle are legally permitted but management plans have not been approved, effectively restricting access and sustainable use (Calorio and Silva, 2014).

In Brazil, the important benefits of use and production of NWFPs by communities are constrained by the proliferation of regulatory requirements (sanitary, environmental, organizational, labour and tax law, etc.) that can make it practically impossible to produce and market these products (Shanley *et al.,* 2002).

Although increases in household income are generally considered to result in improved food security, such effects can be confounded by other variables. Factors such as gender, market and resource access, purchasing power and social and cultural food preferences all affect the relationship between income and food security in forested areas (Kennedy and Peters, 1992).

Certification as well as governance mechanisms examined in chapter 4 can play an important role to ensure better consideration of FSN of local communities.

3.5 Conclusion: challenges and opportunities for FSN

Increasing demands on land, forests and trees, create new challenges and opportunities for their contributions to FSN. They can threaten some of the contributions of forests to FSN, particularly when such contributions are less visible or concern marginalized and most vulnerable groups. On the other hand, they can create additional reasons to protect and invest in forests and generate new jobs and opportunities for sustainable development. Global figures seem to show important potential for forest restoration as well as for the development of agroforestry systems. This calls for a better understanding of the drivers of change, and of the dynamics at play in evolving and complex landscapes such as secondary forests, landscape mosaics, agroforestry systems and their impact for FSN and sustainable development, and for a better support for forest restoration in degraded areas.

Given the global population growth and overall economic development, land is becoming an increasingly scarce resource and multifunctional landscapes will have to fulfil multiple uses. Conflicts are likely to arise not only on the most desirable use of agriculture and forestlands but also on the best way to accommodate increased and competing demands for land and natural resources, as well as on the governance mechanisms to be put in place for providing local and global ecosystem services. These issues are further explored in the next chapter.

4 HOW TO OPTIMIZE THE CONTRIBUTIONS OF FORESTS AND TREES TO FSN IN A SUSTAINABLE WAY?

Forests and trees provide multiple direct and indirect contributions to FSN through several channels illustrated in Figure 4 (Chapter 1). These contributions vary largely across countries, populations, forest types and management regimes. They benefit different groups, at different scales, within different timeframes. They are also likely to be profoundly modified by ongoing trends affecting land use and forestry.

There can be either synergies, or trade-offs across the various contributions of forests and trees to FSN, which depend on several parameters: the very existence of forests and trees, their location, type and composition, management, use rights and income distribution. All of these parameters are, in turn, dependent on decisions made by various actors, determined by governance arrangements.

This last chapter will discuss the importance and challenges of governance in the forestry sector, review available tools at different scales and suggest ways forward to promote SFM for FSN.

SFM strategies and multiscale governance mechanisms are a way to better balance different functions and objectives of forests and trees (that impact FSN in different ways, at different spatial and temporal scales, as shown in previous chapters), and to integrate global challenges and concerns in local sustainable management of forest resources. Such mechanisms will help to prevent and manage conflicts between stakeholders.

4.1 Governance of forests and trees: an overview

Hyden *et al.* (2004) define public governance as "the formation and stewardship of the formal and informal rules that regulate the public realm, the arena in which state as well as economic and societal actors interact to make decisions*"*.

More precisely, governance can be defined as the set of political, social, economic and administrative systems, rules and processes that (i) determines the way decisions are taken and implemented by various actors and (ii) through which decision-makers are held accountable (HLPE, 2015).

According to these definitions, governance can be seen as comprising the three following elements: (i) the rules themselves (including formal and informal ones); (ii) the process by which those rules are established, and the decision taken; and (iii) the way those rules and decisions are implemented, assessed and monitored (HLPE, 2014b).

As a prelude to understand which are the possible ways forward in terms of enhancing the governance of forests and trees for FSN (section 4.3), this section presents the key governance issues of forests and trees as a shared resource, highlighting the importance of forest and tree ownership regimes as well as of access and use rights for local peoples and communities.

As illustrated in previous chapters, forests provide many different benefits, at different geographical and temporal scales. They are used by many different stakeholders, with contrasting power, for many different purposes. This diversity of perspectives, interests and objectives might generate tensions or pave the way to conflicts. Several specific potential areas of tensions can arise between:

- different objectives, for instance between conservation and production;
- different scales, between local, national and global;
- different actors, either at the same or at different levels.

Three broad categories of governance instruments of forests and trees can be mobilized to articulate and manage these different objectives and scales:

- direct management, given the importance of public actors in ownership and management of forests;
- rules, mandatory or voluntary, including incentives;
- market mechanisms.

A particularly difficult point is that many issues need to be considered at both local and global levels, with sometimes contradictory interactions between them, while there is often no institutional mechanism to appropriately integrate these various dimensions in decision-making processes.

4.1.1 Forests and trees as a shared resource

The governance and sustainable management of a shared resource requires a common understanding of its scarcity and values. It also requires an understanding of diverging perspectives, the specific roles and the interactions between the different categories of stakeholders – states and public agencies, private corporations, civil society organizations, local communities and individuals – involved in the decision-making process at different levels (Krott, 2005). It finally requires appropriate tools to manage the resource collectively and accommodate short-term concerns of most of the private actors with the longer-term general interest.

A prerequisite for successful governance solutions is a clear and recognized rights situation (Ostrom, 1990). Use rights and access to forest resources are essential for sustainable development and improved FSN, but are also a challenge as the forest is used for different purposes by a wide range of stakeholders.

Samuelson (1954), elaborated a typology of goods and services based on two properties:

- non-rivalry: each individual's consumption of the good or service leads to no subtraction of any other individual's consumption;
- non-excludability: no individual can be excluded from consuming the good or service.

These two properties allow four categories of goods or services to be distinguished, as described in Table 13.

Table 13 Private and public goods and services

Property	Excludable	Non-excludable
Rivalrous	Private goods	Common-pool resources
Non-rivalrous	Club goods	Public goods

Clear examples of public goods and services provided by forests and trees are biodiversity conservation as well as the qualitative and quantitative regulation of climate and water. Other goods and services, such as fuelwood and NWFPs, may be classified either as private goods, club goods or common-pool resources, depending on the property and use rights in force in the considered forest, these being different across countries and forest types.

Public goods and common-pool resources are typically difficult to govern (Ostrom, 1990), and likely to suffer from the "tragedy of the commons" described by Hardin (1968), resulting in unsustainable depletion or irreparable deterioration of the resource. Unregulated access can cause overexploitation of forest resources, thus undermining their capacity to contribute to FSN in a sustainable way. And poor governance has been identified as a key proximal cause of deforestation and forest degradation (see Box 16).

Box 16 Impacts of poor governance on deforestation and forest degradation

Poor governance is widely acknowledged as a major issue in the forestry sector. It plays a central role in forest cover change in many tropical nations (Colfer and Pfund, 2011). According to Kanninen *et al.* (2007), elements that may contribute to uncontrolled deforestation include poorly defined property rights, non-transparent decision-making processes, corruption, lack of accountability, inappropriate and contradictory forest laws, and weak law enforcement capacity.

Illegal logging refers to forestry activities that violate national and international laws on harvesting, processing, transporting and exporting wood products (Brack and Buckrell, 2011). Illegal activities include: logging in protected areas or logging without authorization; harvesting over allowed quotas; processing logs without licences; avoiding payment of taxes and duties; and violation of international trade agreements. Widespread occurrences of illegal logging and illegal conversion of land to agricultural use are symptomatic of the failure of governance, particularly in remote frontier areas (Brack, 2003). Although it is impossible to calculate exact figures, it has been estimated that illegal timber may represent up to 10 percent of the global trade in primary wood products (Putz *et al*., 2012).

According to a World Bank study, more than half of all logging in southeast Asia, central Africa and South America may be illegal, although the rate may be considerably higher in some countries: for example, 70 to 80 percent of logging activity in Indonesia, Gabon, Bolivia and Peru may be illegal (Pereira-Goncalves *et al.*, 2012). Between 1995 and 2005, illegal logging represented for developing countries governments an estimated USD15 billion per year in lost revenue (Pereira-Goncalves *et al*, 2012). Illegal logging also causes numerous other problems, including environmental damage, loss of timber resources for future generations, and provision of revenues for insurgent groups involved in conflict (Brack. 2003; Brack and Buckrell, 2011). The widespread nature of illegal logging and poor law enforcement provides little incentive to invest in improved (and more costly) logging practices, nor in forest regeneration.

The problem of poor forest governance is addressed through a range of initiatives at the international, regional, national and subnational scale (Saunders and Nussbaum, 2007). For example, since 2001, around 60 percent of all World Bank programmes in the forestry sector have included governance components (Pereira-Goncalves *et al.*, 2012). Broad governance reforms that have been proposed for the forest sector include: the presence of effective institutions, with clearly defined roles and responsibilities; clear and appropriate legislation; the ability to enforce legislation; clear, reliable land tenure; creation of national verification and monitoring systems; participation of all stakeholders in decision-making processes (including civil society and the private sector); development of accountability; and policy reform to remove ”perverse” economic incentives to deforest (Eliasch Review, 2008).

When it is difficult to exclude users from a common-pool resource, leading to risk of overexploitation, sustainable use can be reached through clearly defined user rights, regulations and policy instruments, e.g. quotas and licences (Ostrom, 1990; Sandström and Widmark, 2007). From that perspective, Ostrom (1990) defines eight design principles of sustainable common-pool resource management:

- clearly defined boundaries (effective exclusion of external unentitled parties);
- rules regarding the appropriation and provision of common resources that are adapted to local conditions;
- collective-choice arrangements that allow most resource appropriators to participate in the decision-making process;
- effective monitoring by monitors who are part of or accountable to the appropriators;
- a scale of graduated sanctions for resource appropriators who violate community rules;
- mechanisms of conflict resolution that are cheap and easy to access;
- self-determination of the community recognized by higher-level authorities;
- in the case of larger common-pool resources, organization in the form of multiple layers of nested enterprises, with small, local common-pool resources at the base level.

However, such common-pool resource management systems are now facing broad challenges such as transnational resource management or the need to manage resources for more diverse stakeholders with more diverse interests and time scales and, often, with increased pressure on the resource itself. Decisions taken by states or non-local actors to deal with broader challenges, such as biodiversity conservation through, for instance, the designation of new protected areas, might conflict with the access and use rights of local communities to forest resources for their FSN and livelihood (West *et al*., 2006).

4.1.2 Forest and trees ownership

The FRA defines forest ownership as the legal right to freely and exclusively use, control, transfer or otherwise benefit from a forest (FAO, 2012a). This includes ownership of trees growing on land classified as forest, regardless of whether or not the ownership of these trees coincides with the ownership of the land itself (Whiteman *et al.,* 2015).

Forest ownership

Three categories of ownership are distinguished (FAO, 2012a):

- Public ownership: forest owned by the state at national level; by administrative units; or publicly owned institutions or corporations at subnational levels.
- Private ownership: forest owned by individuals and families; by private, profit or non-profit entities or institutions; by local, tribal or indigenous communities.
- Unknown ownership: forest area where ownership is unknown, unclear or disputed.

Ownership of forest is a different concept than exploitation and use rights. The exploitation and use of publicly-owned forests can be transferred to private actors via time-bound concessions for instance: in this case forest ownership is public but the use is private. Conversely (see section 4.2), rules can limit private ownership and use rights.

The last FRA (FAO, 2015) estimates that, in 2010, public ownership covered three-quarters of the world's forest (nearly 3 billion ha), private ownership around one-fifth (nearly 0.8 billion ha) and unknown or unclear ownership only around 4 percent (Whiteman *et al.,* 2015). Tables 14 and 15 show the repartition of forest ownership by regions and climatic domain in 2010.

Public ownership of forests remains the dominant form of ownership and control in the forest sector in all regions and all climatic domains (except the subtropical domain). The high percentages of public forests in Europe and in the boreal domain are partly explained by the importance of the Russian forest, reported in the FRA to be publicly owned at 99 percent. In Canada, 91 percent of forests are publicly owned, the vast majority of which are owned and administrated by the federal government (FAO, 2015).

Table 14 Forest ownership (percent of total forest area) in 2010 by regions

Region	Public	Private	Unknown
Africa	84%	11%	0.3%
Asia	77%	23%	0.2%
Europe	89%	11%	0.8%
North and Central America	61%	32%	4.5%
Oceania	56%	42%	0.8%
South America	62%	17%	11.2%
World	***74%***	***19%***	***3.5%***

NB: Total of percentages in each row might be different from 100 percent because available data do not cover 100 percent of forest area in all regions.

Source: FAO (2015).

Table 15 Forest ownership (percent of total forest area) in 2010 by climatic domains

Region	Public	Private	Unknown
Boreal	93%	6%	0.7%
Temperate	52%	48%	0.1%
Subtropical	48%	34%	10.3%
Tropical	74%	15%	5.5%

Source: FAO (2015).

Between 1990 and 2010, public forest area decreased by 0.24 percent per year, while private forest area increased by 1 percent per year (FAO, 2015).[38] This decrease in public forest area is more pronounced in Asia and Africa (by 0.65 and 0.49 percent per year respectively). In Africa, this decrease can be explained by net deforestation as private forest area is also reported to have decreased slightly (–0.16 percent per year). Conversely, in Asia, private forest area is reported to have increased by 5.32 percent per year (+87 million ha between 1990 and 2010); 72 percent of this increase is explained by privatization of public forest area, 24 percent by net afforestation, the rest by a decrease in unknown ownership over the period.

This trend towards privatization is the strongest in the temperate climatic domain, where public forest area is reported to have decreased by 0.53 percent while private forest area is reported to increase by 1.76 percent per year between 1990 and 2010. In the temperate domain, the reported increase of 95 million ha in the private forest area between 1990 and 2010 is explained by a 40 million ha decrease in public forest area, the remaining 55 million ha coming from private sector investment in afforestation (Whiteman *et al.,* 2015). In the tropics, public forest areas decreased by 0.45 percent per year between 1990 and 2010, while private forest areas increased only by 0.36 percent per year.[39]

The first decade of the twenty-first century has seen a new wave of large-scale land acquisition for oil palm and rubber plantations in Central Africa and Southeast Asia. This represents an economic opportunity for host countries but also a threat for natural forest conservation and for local communities' access to land and resources. To transform risks into opportunities, new governance mechanisms are needed at national and regional scales that design and manage integrated land-use plans, considering the interest of different stakeholders as well as the power relationships among them (Feintrenie, 2014).

Interestingly, the results of the FRA 2015 (FAO, 2015) did not demonstrate any correlation between private ownership of forests and expansion of forest plantations or production forest area. Similarly, available data on the evolution of forest ownership are not detailed enough to determine whether changes in ownership lead to any major changes in the achievement of SFM (Whiteman *et al.,* 2015). These results could be due to the FRA definition itself. In fact, the category "private ownership" encompasses very different kinds of forest managed by very different stakeholders (individuals and families, small- or large-scale private corporations, NGOs and local communities) for very different purposes (timber production, collection of NWFPs, biodiversity and forest conservation, etc.). Moreover, in many countries where the state owns the major share of managed forests and tree plantations, it commonly delegates management and/or use rights to state's local bodies or local communities (Vira *et al.,* 2015). It is estimated that 11 percent of the world's forests are legally owned or administered by communities, rising to up to 22 percent in developing countries (RRI, 2015).

At the global level, in 2010, the proportion of unknown or unclear forest ownership is relatively small. In many countries, state ownership may be considered as a default position in the absence of any other clearly defined and recognized ownership. In reality, while technically owned by the state, many of these areas are used by local people for different purposes,

[38] These trends cover only the countries that reported the data over the whole period, i.e. 169 countries and 76 percent of the total forest area for public ownership; 170 countries and 89 percent of the total forest area for private ownership.

[39] In the temperate domain, available data cover 100 percent of the total forest area, while in the tropics, available data cover 86 percent of total forest area for private ownership but only 58 percent for public ownership.

meaning that the state does not always have exclusive control and use rights (as per the definition above). Countries that reported unknown ownership might consider that state ownership without oversight control is unsustainable in the long run and might be willing to address this issue (Whiteman *et al.,* 2015).

Tree tenure

It is important to distinguish between land tenure and tree tenure, as the two are often different, particularly in some customary tenure systems (FAO, 1989; Howard and Nabanoga, 2007) and as tree tenure systems have a profound influence in inhibiting or stimulating tree growing (Fortmann, 1984), particularly on agricultural land.

In many cases, ownership of land does not grant automatic rights to the trees growing upon it (Fortmann and Riddell, 1984). Examples have been reported where property rights or use rights of certain specific trees, even inside a forest, were held by distinct rights' holders other than the owners or users of the forest itself (Castro, 1983). In other instances, tree-growing generated the rights to the land on which they grow; this was a common practice throughout humid West Africa (FAO, 1989).

In other cases, even in areas where farmland is privately held, woodland would remain under the jurisdiction of communities or other local groups. In some countries, the ownership of all the trees in the country is officially vested in the state, with penalties for cutting trees without permission, even those standing on a farmer's own land. In Morocco, for example, argan trees (*Argania* spinosa) are owned by the state even if they are grown on private land (Biermayr-Jenzano *et al.,* 2014). Although designed to protect trees, this kind of legislation often has the opposite effect and discourages farmers from taking the initiative and planting trees themselves (Murray, 1981).

When farmland is rented, the details of the arrangement, formal or not, may be of critical importance to encourage or discourage plantation of trees by the tenant. The length of the contract, the need or lack of need to ask for the authorization of the owner and the existence of compensation at the end of the contract are among the factors to consider.

4.1.3 Access and use rights

Multiple rights over land and natural resources can be held by different stakeholders, or groups of stakeholders, on the same parcel, simultaneously or successively. This means that even a single landscape would be subject to a complex web of different property rights (Fortmann and Bruce, 1988; Bruce, 1999; Fuys and Dohrn, 2010). In Thailand, for instance, upland dwellers have rights to collect bamboo on individually owned lowland farms (Fuys and Dorn, 2010). This complex web of rights may cause conflicts between right holders despite the existence of mediation mechanisms (Bruce, 1999). For instance, in southwestern Morocco, conflicts are frequent between nomadic camel and goat herders with grazing rights and local residents with rights to exploit the argan fruit (Biermayr-Jenzano *et al.,* 2014).

This question of access and use rights is critical for the FSN of many forest-dependent people and communities, including indigenous peoples. Communities with *de facto* access and use rights are more vulnerable than private landowners or communities with *de jure* rights over forest resources (RRI, 2012). For instance, logging concessions and illegal logging on indigenous peoples' lands have displaced thousands of people who depend on forests for their FSN and livelihoods (UN, 2009).

Rules of access to private land vary across countries. Box 17 develops the specific case of Scandinavian countries. In Finland, Norway and Sweden, the right to hunt is held by the landowner and regulated by hunting permits. In Canada, hunting permits also regulate hunting. However, the landowner has no exclusive right comparable with Scandinavian measures (Heikkila and Aarnio, 2001; Storaas *et al.*, 2001).

Box 17 Access rights and provision of berries and mushrooms in Finland, Sweden and Norway

In Finland, Sweden and Norway, the percentage of privately owned woodland is large: respectively 70, 75 and 80 percent in 2010 according to the last FRA (FAO, 2015).

In these countries, the public is allowed by law to access all land, whether public or private. Therefore multiple use for different objectives (not only timber production, but also NWFP collection by the public) can create conflicting situations among stakeholders, especially as there is a common-pool resource situation due to the public right of access.

For Finland, Sweden and Norway, the public right of access offers the general public the right to enter private land, for example, to pick berries, mushrooms and herbs both for individual consumption and for commercial purposes. However, in some areas in Finland and Norway, cloudberries (*Rubus chamaemorus*) are exempted from the public right. Also, some private land, such as yards and garden areas, are exempted from the access right. Additionally, in Sweden, it is not allowed to pick nuts, a historical legacy still in use of nuts for feeding pigs (Nordiska ministerrådet, 1997). With the growing interest for Swedish berries and as the economic value of the berries has increased, conflicts over public access and berry picking for commercial purposes has arisen (Sténs and Sandström, 2013).

Customary use of forest resources

Many communities have substantial knowledge and beliefs transmitted through oral traditions derived from first-hand long-term observations about the local environment and developed systems of self-management that govern resource use. Traditional indigenous knowledge and practices, and customary uses of biological resources, are the fundamental basis of FSN for forest-dependent people in many territories. Some empirical studies in Canada (Elliot *et al.,* 2012) and Central Africa on traditional knowledge and FSN have shown evidence that harvesting, preparing and conserving wild forest foods by indigenous peoples according to customary traditions can have positive impacts on FSN, especially at the local level (CCA, 2014).

The complex relationship that indigenous communities have with the forest took time to be recognized and formalized at the international and national levels. But even today, this recognition is limited to the principles and international declarations that several states have adopted but to which they still have not attributed any legal value. The report *Our common future* (Brundtland, 1987) set the tone by insisting that the starting point for a just and humane policy for such groups is the recognition and protection of their traditional rights to land and the other resources that sustain their way of life.

The Rio Declaration on Environment and Development (1992)[40] proclaimed (in its principle 22) the vital role of indigenous peoples in environmental management and development because of their knowledge and traditional practices. Since then, most international legal instruments maintain that sustainable development cannot be achieved without protecting and including local communities, especially indigenous peoples, who must have access to specific rights according to their particular traditions. The Rio+20 Declaration (2012) *The future we want*[41] recognized "that traditional knowledge, innovations and practices of indigenous peoples and local communities make an important contribution to the conservation and sustainable use of biodiversity, and their wider application can support social well-being and sustainable livelihoods" and also "that indigenous peoples and local communities are often most directly dependent on biodiversity and ecosystems and thus are often most immediately affected by their loss and degradation". In 2007, the United Nations General Assembly adopted the UN Declaration on the Rights of Indigenous Peoples (UNDRIP)[42], setting a minimum standard for the survival, dignity and well-being of the indigenous peoples of the world, including "the right to determine and develop priorities and strategies for the development or use of their lands or territories and other resources".

[40] Available at http://www.unesco.org/education/pdf/RIO_E.PDF

[41] Available at http://www.un.org/disabilities/documents/rio20_outcome_document_complete.pdf (accessed May 2017).

[42] Available at: http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf

One proposed reason for the success of customary forest use is that the relationship indigenous peoples have with food is deeply cultural. A case study on some First Nations in Canada proposed the concept of "cultural food security" to emphasize the ability of aboriginal peoples to reliably access important traditional food through traditional harvesting methods (Power, 2008). Similarly, in Central Africa, several studies have provided evidence that when forest products were harvested for local consumption, the harvesting techniques employed by forest communities were more sustainable, and facilitated forest regeneration and biodiversity conservation (Rerkasem *et al.*, 2009). The challenge is now to ensure the *in situ* protection of indigenous peoples' traditional use of local knowledge and forest resources, in a way that develops and continues to improve FSN, and to learn from these diverse knowledge systems.

Access to forest resources depends on the use and property rights organized at different levels within the framework of international agreements and national legislation. The *Voluntary guidelines to support the progressive realization of the right to adequate food in the context of national food security* (VGRTF) (FAO, 2005) encourages states to facilitate sustainable, non-discriminatory and secure access and utilization of resources, and protect the assets that are important for people's livelihoods.

4.2 Governance instruments and tools for forests and trees

Many governance tools for forests and trees already exist at international and national levels. Some of those instruments are specialized, focusing on one function of forests and trees, while others integrate their different benefits for sustainable development. Those instruments can be either regulatory, or market-driven, or combine those two approaches.

4.2.1 International interventions and agreements

International agreements or treaties may be voluntary or mandatory, with the main purpose of achieving a joint goal. There are several UN conventions on, for example, climate (see section 3.3.4 and Box 18), biodiversity (CBD), and the International Labour Organization's indigenous and Tribal Peoples' Convention (ILO Convention No. 169), most of them with a very specific objective, that are of consequence for forests. The UN-initiated *Forest principles* is a non-legally binding document adopted in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro[43] that outlines suggestions for sustainable forestry.

Directly touching on FSN matters are the CFS (FAO, 2012c) *Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security* (VGGT). They provide concrete guidance for countries to improve governance of tenure of land, fisheries and forests, in the perspective of the progressive realization of the right to adequate food, poverty eradication and sustainable development, focusing particularly on vulnerable and marginalized peoples.

In 2017, the United Nations Forum on Forests adopted the UN Strategic Plan for Forests 2017–2030 (UNSPF). Its mission is to "promote sustainable forest management and the contribution of forests and trees outside forests to the 2030 Agenda for Sustainable Development, including by strengthening cooperation, coordination, coherence, synergies and political commitment and actions at all levels". It provides a global framework "for actions at all levels to sustainably manage all types of forests and trees outside forests and halt deforestation and forest degradation", as well as "for forest-related contributions to the implementation of international forest-related instruments, processes, commitments and goals".[44]

[43] See http://www.un.org/documents/ga/conf151/aconf15126-3annex3.htm

[44] Including the 2030 Agenda for Sustainable Development, the Paris Agreement adopted under the UN Framework Convention on Climate Change, the Convention on Biological Diversity, the UN Convention to Combat Desertification, and the United Nations Forest Instrument (UNFI).

Box 18 REDD+: potential and pitfalls

REDD+ is a cross-country effort to reduce emissions from deforestation and forest degradation, particularly in developing countries. The aim of REDD+ is to develop and implement conservation practices in a sustainable management system, enhancing forest carbon stocks. The initiative was first negotiated in the UN Framework Convention on Climate Change (UNFCCC) in 2005. A developing country that aims at undertaking REDD+ needs: to develop strategies to prepare a national forest plan and a national forest monitoring system for reporting REDD+ activities; and to provide information on social and environmental values are safeguarded. Among the critiques of REDD+ is that induced changes in land tenure and economic benefits may negatively affect local people's previous revenue from the forest. [45]

There is concern that, by valuing forests for this globally important service, REDD+ programmes could undermine some of the ecosystem services that forests provide locally, including food, fuelwood and medicine to the millions of poor who live in and depend on the forests. REDD+ could create new incentives for states to restrict these people's access to forests. The insecurity of land tenure for many indigenous and other forest-dependent communities may make them especially vulnerable to this risk (Phelps *et al.,* 2010; Espinoza-Llanos and Feather, 2011). There is a risk for communities to unknowingly accept terms that sign away land-use rights, assume liability for forest loss, or accept payments that undervalue the true opportunity costs of the land use foregone.

Some potential risks to forest dwellers associated with REDD+ are: violations of customary land rights and harsh enforcement measures; loss of access to forests for subsistence and income-generation needs; land-use conflicts; and physical displacement from forests. The capture by elites of intended REDD+ benefits, due to inadequate forest governance systems, could result in decreased production of food locally, creating food security risks and deepening poverty (Poudyal *et al.,* 2016).

While there is a need to focus REDD+ investment on bolstering national-level forest governance, particularly in countries facing illegal logging and inadequate forest-sector institutions, focusing only on the forest sector is not enough to confront and reconcile agricultural drivers of forest clearing. In order for REDD+ carbon emission mitigation targets to be reached, it is important for governments to address the role of agriculture, which is the primary driver of forest clearing globally. However, despite the fact that REDD+ offers an unprecedented opportunity to establish policies, institutions and capacity to respond to these pressures, many countries have a long way to go before fundamentally addressing agricultural drivers of deforestation and forest degradation. Kissinger (2013) argues that in order for REDD+ carbon emission mitigation goals to be reached, it is important for governments to address the role of agriculture, main driver of forest clearing globally, by:

- aligning REDD+ targets with transformational change in agricultural systems that intensify production, satisfy domestic needs before serving export markets, are geared towards stabilizing food security in the face of increasing climate change impacts, and solidify forest-dependent community and smallholder tenure and access rights;
- ensuring that national governments engaging in REDD+ focus their REDD+ readiness activities and development of national strategies on: establishing and enabling adequate legal institutional frameworks (such as low-carbon development commitments); governance; and measurement, monitoring, reporting and verification (MRV) systems that account for and are responsive to the role of agriculture in forest clearing, stretch beyond the forest sector, and align long-term objectives of safeguarding terrestrial carbon stocks while providing food for a growing population.

See: http://www.un-redd.org/

There are also some initiatives related to forests and trees at the regional level, for instance in Central Africa that, with the Congo Basin, contains the second largest area of tropical forest in the world. The increasing pressure exerted on those forests could lead to considerable deforestation and degradation and increased poverty and food insecurity for a large number of forest-dependent people. To tackle this issue, six Central African states signed the

[45] See http://www.unredd.net/documents/redd-papers-and-publications-90/un-redd-publications-1191/fact-sheets/15279-fact-sheet-about-redd.html

Yaoundé Declaration in Cameroon (17 March 1999),[46] and established the Central African Forest Commission (COMIFAC).[47] COMIFAC drew up a Convergence Plan that defines common objectives for forest conservation and encourages the development of coordinated regional conservation efforts. The Congo Basin Forest Partnership (CBFP), created in 2002, brings together 97 partners[48] willing to invest in the achievement of the Yaoundé Declaration objectives (de Wasseige *et al.,* 2012).

4.2.2 National rules and policies

At national level, public authorities have considerable means of intervention to orient forest management. As shown above, they are often owners of most of the forest and as such either manage it directly or delegate it to non-state actors, providing them more or less guidance on management. National authorities also provide both normative principles and orientation for the whole forestry sector. To do so, they can use a mix of instruments: direct or delegated management of public forests, laws and regulations, incentives, including specific taxation regimes, market instruments and, increasingly, combinations of these various instruments.

National legislations and regulations define what is a forest (see section 1.1), and the rules applied to it. They can in particular determine land deemed as permanent forest (see section 4.3). They establish property and tenure rights for forest land and for trees. They can restrict property rights, for instance by including provisions for the protection of trees on private land.

National rules also fix the way access and use rights, including customary ones, are recognized and protected, including for indigenous groups and local communities. For instance, in most European countries public access to forests is allowed, with forest owners having specific rights to limit this access, mainly for nature protection in order to protect replanted or naturally regenerated forest stands. In most of these countries the public has usage rights to collect some NWFPs, often requiring consent from the forest owner, with considerable variations between countries and some rights being subject to regulation and specific restrictions (UNECE, 2004).

National rules also establish the institutional organization of forest administration at national, subnational and local levels including, the case being, the institutional organization of forest management that can be different for public and private forest. It can delegate part of it to various entities, public or not, including at community level. National rules also set the respective roles and responsibilities of different stakeholders in the forest sector, and create a legal framework for economic and financial relationships between them, including the role of public–private partnerships.

Increasingly, national rules also includes dispositions creating a zoning for forest activities and/or specific forest functions and roles. These can include protection areas, such as national parks or other protected areas, or areas where forests are considered to exercise specific protective functions (see section 3.2.3); with generally specific management rules, both in terms of governance and/or to better fulfil this specific function. National legislation can also establish or recognize silvicultural standards, and, increasingly, environmental or sustainability standards, that can be linked to certification schemes (see section 4.2.2).

Increasingly national forest policies and legislation tend to consider the multiple functions of forests and trees and pursue multiple objectives, including wood production, energy, biodiversity conservation, climate change adaptation and mitigation, water and soil protection, empowerment of local communities (see Chapter 3 and section 4.3.3). This manifests itself by an increasing number of countries implementing enabling conditions for SFM (see section 4.3) and defining broad orientations that integrate the multiple functions of forests and trees.

[46] Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Gabon (see http://pfbc-cbfp.org/docs/key_docs/declarationyaounde.pdf [in French]).

[47] See http://www.comifac.org/. Since its creation, Burundi, Equatorial Guinea, Rwanda and Sao Tome and Principe have also joined the COMIFAC.

[48] Including African governments, donors agencies and governments, IGOs, NGOs, scientific institutions and the private sectors (see http://pfbc-cbfp.org/home.html).

Box 19 Swedish forestry model – a management system of forests focused on sustainability

Sweden is a country that is dominated by forests: 1 percent of the world's commercial forests are found in Sweden, but 10 percent of global sawn timber, pulp and paper is provided by Swedish forests. In 1993, a major shift occurred in Swedish forest policy, as a result of a strong environmental lobby. In this reform, the production goal that had until this point been dominant, was set equal to environmental goals. The new law applied equally to private forest land (50 percent), corporate forest land (25 percent) and state-owned forest land (25 percent).

At the same time that the goals of forestry changed, forest law was also deregulated, abolishing all detailed regulations on how to manage the forest. The term "freedom under responsibility" was introduced in forest policy and, without detailed regulation, the forest owners have to consider a number of goals in managing the forest:

- production goals;
- environmental goals;
- social goals;
- recreational goals (including tourism);
- other land users utilizing forest land (such as reindeer husbandry); and
- cultural environments in the forest (e.g. ancient monuments).

The environmental consideration is defined as the sum of the consideration of nature values, ground, water, culture environments (including biological culture values) and social values in managing the forest (Johansson *et al*., 2009).

The challenges in the Swedish forestry model are to find a balance between the multipurpose use of the forest, both ensuring all values of the forest as well as continuing to have high production of timber. In management, not only timber production is important, but also the improvement of the environment, which indirectly affects FSN, and the production of NWFPs linked to FSN, such as berries, mushrooms, game and the provision of grazing areas for reindeer.

See: https://www.skogsstyrelsen.se/en/about-us/

The Swedish forestry model (see Box 19), along with many others, provides one such example of an integrated approach to forest management, combining forestry that is built on science and evidence with an active commitment to multiple uses (Lindahl *et al*., 2015; Pülzl *et al.,* 2014).

An important condition of success for forestry policies, given the time frame of forest growth, is to provide the conditions for stability and long-term support, oriented by a clear identification of priorities. A good example is provided by the succession of rules and plans for forestry in China, focusing from the 1970s to the 1990s on both timber production and ecological development, with then an even stronger emphasis on SFM and protective functions of forests (State Forestry Administration, 2013). Box 15 on desertification control provides other examples of such successful long-term forest policies against desertification in northern Africa.

An analysis of case studies from seven countries (Chile, Costa Rica, the Gambia, Georgia, Ghana, Tunisia and Viet Nam) demonstrates the opportunities for improving FSN while maintaining or increasing forest cover (FAO, 2016a). Successful cases enable to draw some important lessons. They all recognized and integrated in their policies the range of economic, social and environmental benefits of forests, including their contributions to wider sustainable development, poverty reduction and climate-change programmes. They showed the importance of using the right mix of policy instruments, including regulatory tools, incentives and tax breaks to promote SFM and increase agricultural productivity. All the case studies showed the need for effective legal and institutional frameworks, with predictable and secure land tenure, land use planning and measures to regulate land-use change, including requirements for environmental impact assessments and special protection for designated areas. They also showed the importance of adequate funding through public-sector investment in the agriculture sector, the forest sector and wider rural development programmes. They also demonstrated the importance of integrated land-use approaches at the national, landscape and local levels (FAO, 2016a).

Another condition of success is often the combination of various instruments. New Zealand for instance has several programmes designed to protect forests and/or encourage afforestation;[49] some of them explicitly aimed at increasing carbon stocks either as a main objective or a co-benefit of reduced erosion, and use carbon credits of the New Zealand carbon credit scheme as collateral for grants provided by the government. This combination enables to combine the pursuit of a global objective and mitigation of climate change, with objectives at local and landscape levels, with a prioritization on degraded or sloppy areas for soil conservation.

4.2.3 Certification and other market-based instruments

There is an increasing push for the use of market-based mechanisms, including payments for environmental services (PES) or certification schemes, with a variable engagement of public stakeholders, along with the private sector and civil society.

PES has been defined as a voluntary transaction between a service buyer and service seller that takes place on the condition that either a specific ecosystem service is provided or land is used in a way to secure that service (Wunder, 2005). Originally promoted as a form of non-state governance, using market-based approaches to reduce forest degradation and deforestation, it is more often taking hybrid forms operating across scales and involving public, private and civil society stakeholders. States have often a major role in such programmes, either by providing the legal framework for private PES or even by setting-up PES schemes defined and financed by public funds (Vira *et al.,* 2015).

The emergence of markets for forestry-related services (such as their role in carbon sequestration, recognized in REDD+) has led to a new wave of interest of private actors for forestry, often in collaboration with either state, non-state (NGO and commercial) or local communities. In Indonesia, Brazil and other countries with significant remaining tropical forests, REDD+ projects have attracted private investment on the voluntary carbon market. Certification of carbon and community interests in these projects are essential ingredients to market valuation (Ecosystem Marketplace, 2015) and would improve governance and the relationships of companies with communities and rural neighbours (McDermott *et al.,* 2015). In any case, it is necessary to underline that carbon is a limited proportion of income generation from forest management.

Scientists disagree on the capacity of market and incentive-based forest governance approaches to deliver synergies between environmental and social goals, between ecosystem services, local livelihood and FSN. Some consider that those approaches are able to bring new incomes to rural communities and to support ecosystem services that enhance FSN in the long term (Harvey *et al.,* 2014; Smith *et al.,* 2013). Others consider that the cost of such approaches outweighs the expected benefits, favours large operations and wealthier farmers (in terms of land or education) over smallholders and women, and enhances the risk of local and indigenous peoples and local communities to be dispossessed of their right to access land and resources (Vira *et al.,* 2015).

Certification schemes and voluntary standards

Certification schemes are market-based instruments involving “non-state” standards established and monitored through networks of producers, NGOs and/or private partners.

Forest certification schemes allow an independent assessment of the respect of a defined set of management standards that promote and measure SFM (CEPI, 2006), providing final consumers with an assurance that their demands are being met from well-managed and sustainable sources. As such, forest certification plays an important role in assessing and monitoring the sustainable management of forests in an independent way, determining whether forest administration and management correspond to approved criteria and indicators, and to legal regulations for the use of forest resources at the national level, in accordance with accepted international principles.

[49] https://www.mpi.govt.nz/funding-and-programmes/forestry/

Independent international certification schemes of forest management were introduced in the late 1990s as voluntary tools to raise awareness and promote the sustainable management of forests and the trade of products coming from sustainably managed forests (see Box 20).

Available data show the success of those schemes, with a sharp increase in area covered at the global level, from 13.8 million ha in 2000 to 438 million ha in 2014[50] (FAO, 2015), representing an annual average increase of some 30 million ha (MacDicken *et al.,* 2015). This increase is expected to continue in the future although other alternatives, such as voluntary partnership agreements, are also available to ensure that forest products come from sustainably managed forests. As of 2014, forest certification, however, is primarily focused on boreal and temperate forests – which account for 90 percent of all internationally certified forest area – while certification in the tropics only represents 6 percent of the total certified forest area (MacDicken *et al.,* 2015).

Private voluntary standards call for the engagement of all stakeholders, including private corporations, in progressing towards sustainable production. But they also raise the question of the respective roles of public and private stakeholders in the design and implementation of such standards (Rival *et al*., 2016).

Box 20 International forest certification schemes

The Programme for the Endorsement of Forest Certification (PEFC) claims to be the world's largest forest certification system, aiming at transforming the way forests are managed around the world, to make sure that humans can enjoy the environmental, social and economic benefits of the forest. The North American (59 percent) and the European regions (31 percent) have the largest forest areas certified by PEFC, while Asia and Oceania (both 4 percent) and Central and South America (2 percent) have a much lower share of forest land certified by PEFC. PEFC is absent in Africa.

The Forest Stewardship Council (FSC) is an international organization with three main goals: environmentally appropriate forest management; socially beneficial (in particular for indigenous peoples and local communities; and economically viable. FSC covers 47.4 percent of forest land in Europe; 35.9 in North America; 6.9 percent in South America and Caribbean; 4.3 percent in Asia; 4.2 percent in Africa; and 1.4 percent in Oceania.

FSC is built on decision-making bodies (one for each goal), while PEFC builds on consensus between different goals. PEFC is based on a national forest management standard (bottom-up approach), while FSC builds on international standards against which national standards are evaluated (top-down approach).

In many regions, it is common that clients are certified by both certification schemes.

These certification schemes are organized on two levels: international and national. On the international level, overarching vision, objectives and goals are set, while the national level is more detailed, outlining national goals and objectives, with respect to local prerequisites. National standards for forest certification have been elaborated in 39 countries for FSC and in 32 countries for PEFC: in some countries, such as China and Indonesia, certification is part of state forest policy. As of 2013, 61 countries reported public forests certified under FSC and around 30 countries under PEFC, mostly in Europe and North America (FAO, 2014a).

Both schemes, while not directly related to FSN, contain elements that are linked to it. For instance, FSC standard 5 and PEFC criterion 4 relate to benefits from the forest including ecosystem services (in which FSN may be included), and FSC standard 6 and PEFC criterion 3 deal with the control of hunting and fishing. Both certification schemes also talk about the food chain in relation to pesticides. Further, both certification schemes relate to the indigenous people's rights to forests, however not specifically mentioning FSN (FSC, 2015; PEFC, 2010).

See: https://ic.fsc.org/en; http://www.pefc.org/about-pefc/who-we-are/facts-a-figures.

[50] These figures contain some double accounting (approximately 2 percent), as some forest management units are certified under both schemes.

Voluntary green building programmes, building codes and standards also contribute to promote the use of legally and sustainably harvested wood products. For instance, the NGO-led International Green Construction Code of the United States of America was finalized in March 2012 and has now been adopted in whole or in part by ten states in that country. The voluntary Leadership in Energy and Environmental Design (LEED) Green Building Certification Program is widely recognized in the United States of America, as is the Building Research Establishment Environmental Assessment Method (BREEAM) that has country-specific schemes in seven European countries (Austria, Germany, Netherlands, Norway, Spain, Sweden, United Kingdom) (FAO, 2014a).

Green procurement policies can support and increase demand for legal and sustainable timber and timber products. By end-2010, a total of 14 countries worldwide had operational public sector procurement policies at the central government level for wood and wood-based products (Austria, Belgium, Denmark, Finland, France, Germany, Japan, Mexico, Netherlands, New Zealand, Norway, Switzerland, United Kingdom) (EU Standing Forestry Committee, 2010). Countries where green procurement policies or laws for timber products existed by 2013 include Australia, China, India, Italy, Republic of Korea and Slovenia.

The Round Table on Sustainable Palm Oil, which gathers private stakeholders of the palm oil supply chain as well as NGOs, commits itself to transform markets to make sustainable palm oil the norm by developing and implementing credible global standards for “RSPO-certified sustainable palm oil”, and by involving all stakeholders across the supply chain. One of its central claims is to reduce deforestation. Almost 12 million tonnes (2.5 million ha) of palm oil are already certified, which represent 21 percent of global production.[51] Similarly, the Roundtable on Responsible Soy[52] set up sustainable production standards and involves multiple stakeholders along the value chain, including governments, NGOs, industry, importers and exporters. Elgert (2012) expressed the concern that such schemes, while enhancing new partnerships between private corporations and environmental NGOs, could marginalize smallholders and threaten access to land and resources for indigenous peoples and peasant communities. As smallholders represent 40 percent of the global palm oil production, financing and supporting their engagement in RSPO certification is critical (Rival *et al.,* 2016).

4.3 Ways forward: sustainable forest management for FSN

While the critical ecosystems services provided by forests and trees are progressively better integrated in forest management, the role they play for FSN, especially of some of the most vulnerable, can conflict with other functions of forests and trees and is still relatively neglected (Vira *et al.,* 2015). Local communities’ and smallholders’ rights over their farmland and forest resources can also be undermined by powerful non-local stakeholders such as private corporations receiving concessions for developing new infrastructures or industrial projects (Agrawal *et al.,* 2008).

The Rio+20 Declaration *The future we want* highlighted the social, economic and environmental benefits of forests and called for enhanced efforts and strengthened forest governance to achieve SFM while slowing, halting and reversing deforestation and forest degradation.

SFM, as defined in Chapter 1, has to consider and integrate: the multiple uses of forests and trees; the trade-offs and synergies between those uses; as well as the interests, needs and rights (including rights of access to resource) of different stakeholders, paying specific attention to the more vulnerable. For the purpose of the FRA, information is collected on a set of enabling conditions for SFM:

- *permanent forest land:* the intent to retain some areas as forest is the starting point for sustainable management;
- *legal framework*: policies, legislation and institutions supporting SFM;
- *national data reporting:* the quality of forest inventory data as well as the existence of regular monitoring and reporting mechanisms are indispensable to SFM;

[51] See http://www.rspo.org/about (updated 31 May 2017).

[52] See http://www.responsiblesoy.org/?lang=en

- *forest management plans;*
- *stakeholder involvement* in the decision-making process: such involvement can inform political debates, help mitigate conflicts, enhance cooperation across stakeholders and, finally, improve the quality of national forest policy (FAO, 2009c).

In the last FRA, 163 countries reported a total area of 2.2 billion ha of "permanent forest land", out of which slightly less than 1.5 billion have been legally assigned as "permanent forest estate" [53]; almost 150 countries declared having a policy and legal framework supporting SFM, and 126 to have a national platform for stakeholder involvement in SFM (FAO, 2015). According to MacDicken *et al.* (2015), the above enabling conditions for SFM are met on 1.1 billion ha globally (i.e. half of the permanent forest land) and tropical forests have by far the smallest proportion of their total area (23 percent) under an intermediate or good level of sustainable management.

SFM implies setting up governance mechanisms at different geographic scales, from landscape to global level, articulating short- and long-term objectives, involving many stakeholders, including indigenous peoples and local communities, recognizing and managing conflicts (see example of Quebec in Box 21)

Box 21 Local governance in Quebec and social networks in forest governance: what lessons for sustainable forestry for FSN?

In Canada, public forests are under provincial jurisdiction, and each province is able to define its own legislative and regulatory framework. In Quebec, since several decades, forest policy has undergone significant changes (Blais and Boucher, 2013). In March 2010, Quebec adopted a law on the sustainable management of the forest area, to put in place a new forestry regime. This Act modifies the roles and responsibilities of all stakeholders in forest planning, and develops an integrated approach to the use of forest resources. Recent research in Québec revealed that the emergence of new actors in forest governance introduced new arrangements wherein the state shares authority and responsibilities with other forest stakeholders, moving towards a model of governance that ensures coordination between the different stakeholders in the forest sector (Chiasson and Leclerc, 2013).

The **regional round tables for integrated resource management planning** are the principal governance instruments at the local level in Quebec. Their purpose is to promote the sustainable development of natural resources on public land, through integrated management, for the benefit of all communities in the region. These round tables bring together representatives from a variety of sectors directly interested in public land.

The role and mandates of these regional round tables are:

- to promote local cooperation and harmonization of uses;
- to identify shared goals for the protection and development of resources and land;
- to participate in the preparation of tactical and operational integrated forest management plans in collaboration with the Regional Office of the Ministry of Forests, Wildlife and Parks.

In many of Quebec's regions, the regional round tables for integrated resource management planning are made up of six sectoral groups representing the major relevant partners (i) Forestry; (ii) Wildlife; (iii) Other Users with Rights; (iv) Nature; (v) Territory; and (vi) First Nations.

This model of regional round tables for integrated resource management planning could be used to promote synergies between the stakeholders and different users of forest resources. In particular, this model could create and improve local social networks based on FSN in relation to forest resources governance for FSN.

Regional round tables for integrated resource management planning are similar in certain aspects to social networks in forest governance. A social network is a set of relationships between different actors, and can be organized or informal. In forestry, some empirical studies have demonstrated the importance of social networks when different stakeholders have come together to deal with natural resource problems and dilemmas (Bodin and Crona, 2009).

[53] The FRA distinguishes "permanent forest land" and "permanent forest estate". "Permanent forest land" identifies a "forest area that is designated or expected to be retained as forest and is highly unlikely to be converted to other land use", whereas the "permanent forest estate"is the forest area "that is designated by law or regulation to be retained as forest and may not be converted to other land use" (FAO, 2012a).

The following subsections highlight four important aspects of governance that could help develop SFM for FSN:

- develop forest management plans;
- promote an integrated landscape approach that integrates forests and trees as key components;
- foster stakeholder involvement in order to raise awareness and to optimize the direct and indirect contributions of forests and trees to FSN;
- adopt a rights-based approach.

4.3.1 Forest management plans

In the FRA, FAO monitors the forest area under "forest management plans (FMPs)", defined as "a long-term documented management plan, aiming at defined management goals, which is periodically revised". Such plans must detail the operations planned on individual operational units but may also present more general management strategies. FMPs may define a main objective, whether production or conservation, or pursue multiple goals (FAO, 2012a).

In the last FRA (FAO, 2015), 167 countries, representing 98 percent of global forest area, reported having at least some area under forest management plans (FMPs). At the global level, in 2010, the forest area under a management plan had increased to 2.1 billion ha (52 percent of the total forest area). FMPs are seen as one of the enabling conditions for SFM, although the presence of an FMP is not a guarantee of effective implementation (MacDicken *et al.,* 2015). Table 16 shows that if FMPs are now the norm in Europe and very common in Asia, there is still a need to promote them in South America and Africa, where the challenges to sustainable management of forests and FSN of local communities are more extreme.

Table 16 Area under a forest management plan in 2010, by region

Region	Area under FMP	
	(million ha)	(% of total forest area)
World	2100	52
Africa	140	22
Asia	410	70
Europe	950	94
North and Central America	430	57
Oceania	46	27
South America	125	15

Source: adapted from FAO (2015).

Since the 1950s, the area under FMPs for conservation purposes has increased sharply and, in 2010, the global area under FMPs was equally distributed between production and conservation purposes in all climatic domains, as shown in Table 17.

Table 17 Area under a forest management plan in 2010 by climatic domains

Climatic domain	Area under FMP		FMP for production		FMP for conservation	
	Million ha	% of domain forest area	Million ha	% of domain forest area	Million ha	% of domain forest area
Boreal	1074	88	443	36	401	33
Temperate	425	63	176	26	209	31
Subtropical	91	28	37	11	29	9
Tropical	510	28	191	11	204	11
World	***2100***	***52***	***846***	***21***	***843***	***21***

Source: MacDicken *et al.* (2015).

4.3.2 Towards integrated landscape approaches

Agricultural, forested and aquatic ecosystems are dynamic systems sharing space within a landscape. A landscape is a socio-ecological system that consists of a mosaic of natural and/or human-modified ecosystems, with a characteristic configuration of topography, vegetation, land use and settlements that is influenced by ecological, historical, economic and cultural conditions (Bioversity/Earth Institute, 2013). It is therefore at the landscape level that key interactions among biophysical, socio-economic and institutional factors occur and can be observed (Jackson *et al.*, 2005; Sachs *et al.*, 2012).

The challenge is to achieve multiple, and often competing objectives within a limited space and with limited natural resources, while minimizing the damage to the environment. This supposes moving beyond the “land-sparing” vs ”land-sharing” debate, towards more integrated landscape approaches.

The “land sharing” vs “land sparing” debate

The central question in this debate has been how to increase agricultural production to meet a growing demand while protecting biodiversity: whether by increasing productivity on existing agricultural land and preserving natural ecosystems for biodiversity conservation (land-sparing), or by privileging complex landscapes incorporating low-intensity farmlands and natural features and integrating production and conservation objectives within the same land units (land sharing) (Acton, 2014; Fischer *et al.,* 2014; Vira *et al.,* 2015; Phalan *et al.,* 2016).

Many studies in different countries found that “land-sparing” is the best strategy to reconcile production and biodiversity conservation (Vira *et al.,* 2015; Deakin *et al.,* 2016). Some argue that sustainable increases in productivity on existing farmland can be reached that would reduce the pressure on the environment and spare land for biodiversity (Garnett and Godfray 2012; Pretty and Bharucha, 2014). Strassburg *et al.* (2014) found that, with modest increases in productivity, Brazil could stop deforestation driven by agriculture expansion. However, this “land-sparing” strategy has also raised some concerns. Firstly, enhanced productivity would increase the profitability of agricultural land, providing further incentives for agricultural expansion and deforestation (Belassen and Gitz, 2008; Phelps *et al.,* 2013; Byerlee *et al.,* 2014; Oliveira and Hecht, 2016). Second, sustainable intensification on agricultural land has to be explicitly linked with natural habitat protection on “spared” lands, which is not always the case (Vira *et al.,* 2015). Third, intensification of agricultural practices may provoke declines in agrobiodiversity (Green *et al.,* 2005; Kleijn *et al.,* 2009).

“Land-sharing” is seen by its proponents as a way to address those concerns by creating multifunctional landscapes that aim to achieve both production and conservation objectives. According to those studies, these complex “eco-agricultural” landscapes, mimicking natural ecological processes within a socio-cultural context, are likely to be more resilient than simpler ones (Elmqvist *et al.,* 2003; Tscharntke *et al.,* 2005; Scherr and McNeely, 2008). For instance, in Japan, traditional landscapes, called *satoyama* (from “*sato”* home-village; and *“yama”* wooded hills and mountains), comprise socio-ecological networks of villages and their surrounding agricultural lands, as well as multifunctional forests (Indrawan *et al.,* 2014). Enhancing the connectivity of forest fragments in a landscape may sometimes be a more efficient strategy for optimizing the long-term delivery of multiple ecosystem services than simply limiting further forest loss (Mitchell *et al.*, 2014). For instance, in a study on Northern Bornean landscapes, Labrière *et al*., (2015) show how traditional landscapes shaped by swidden agriculture, rubber tapping and logging, have created multifunctional mosaic landscapes that largely outperform oil palm or rubber monocultures in terms of biodiversity, carbon storage and soil erosion control, and that prove to be more resilient to price volatility. However, this “land-sharing” approach is also limited because many species cannot survive in human-dominated agricultural landscapes and because, with lower yields, more land will be needed for agriculture (Kleijn *et al*., 2006; Jackson *et al*., 2007; Phalan *et al*., 2011).

Integrated landscape approach

This somewhat polarized and theoretical opposition between “land-sparing” and “land-sharing” fails to consider broader perspectives (Perfecto and Vandermeer, 2010; Fischer *et al.,* 2014; Deakin *et al.,* 2016).

First, it does not consider interactions between different scales: what appears as land-sparing at a local level may be considered as land-sharing in a broader landscape (Grau *et al*., 2013; Baudron and Giller, 2014).

Second, it focuses on the tensions between production and biodiversity conservation but overlooks other goals (whether environmental, economic or social) and other trade-offs between these goals at different spatial and temporal scales (see Chapter 3). In particular, difficult choices will have to be made to design and implement appropriate land use in landscape mosaics as well as appropriate decision-making process to limit and manage conflicts between stakeholders with conflicting needs and interests (Vira *et al.,* 2015; Reed *et al.,* 2016).

Third, it neglects the political dimension of landscape management (Fischer *et al.,* 2014) and the influence of distant actors in local decisions. What are the interests at stake? What are the power relationships between stakeholders? Who owns what in the landscape? Who benefits or loses from any management choice and its impacts at different spatial and temporal scales? How to compensate the owner or producer for the cost of practices that benefit to other stakeholders?

Therefore, the scientific and political debate should move beyond the controversy between "land-sharing" and "land sparing" towards fully integrated landscape approaches, consistent with the "adapting mosaic" scenario of the Millennium Ecosystem Assessment (MA, 2005),[54] and involving the relevant stakeholders (see section below).

Because of the multiplicity of contexts and the plasticity of approaches, scientists have been reluctant to give a too strict definition to what constitutes landscape approaches (Sayer *et al.,* 2013). However, the CGIAR programme on FTA has characterized them in the following way: "*As it relates to agriculture, forestry and other land uses, and to the livelihoods they sustain, the landscape approach transcends traditional management and governance boundaries, seeking to provide tools and concepts to identify, understand and address a complex set of environmental, social and political challenges, and to enable evidence-based and inclusive prioritization, decision-making and implementation*" (FTA, 2017).

Watershed management is a good example of an approach that can be applied at different scales, from small-scale mountain watersheds to extended river basins. It contributes to deliver various ecosystem services such as landslides and flood control or climate regulation (FAO, 2006, 2007b). It integrates different land uses (including agriculture and forest) at a landscape level, taking into consideration the links between natural resources management and livelihood improvement (Turner, 1989).

The concept of nutrition-sensitive landscapes (NSL) aims to integrate FSN concerns in the sustainable management of landscapes. Nutrition-sensitive approaches, as defined by Ruel and Alderman (2013), are those that incorporate underlying, rather than immediate, determinants of malnutrition and include sectors such as agriculture, health, education and water and sanitation. The NSL approach adds an important dimension to nutrition interventions by applying an integrated landscape approach. NSLs are those in which diverse types of food are sustainably produced or procured to meet human nutrient requirements, while also protecting the environment from which those foods are sourced. A NSL approach considers the diverse interactions and interconnectivity within a given landscape to pursue the multiple goals of FSN, and the sustainable use of natural resources and conservation of biodiversity, both for human health as well as for environmental health.

The NSL approach moves beyond "do no harm" towards pro-active interventions and practices in ecosystems and the services they provide (Daily, 1997) to contribute to healthy and sustainable diets (DeKlerck, 2016). A NSL tends to produce a diversity of foods while managing other ecosystem functions that are critical for sustainability, human FSN and well-being. The main research area related to NSLs focuses on how ecosystems can contribute to food availability, access and utilization, and stability as well as the impact of food system activities on the health and sustainability of these ecosystems (Bioversity/Earth Institute, 2013).

[54] See http://www.millenniumassessment.org/documents/document.332.aspx.pdf

The real challenge for the future will not merely be to measure the evolution of forest area but to evaluate the capacity of a landscape to meet a diversity of societal needs, in order to allow appropriate choices to be made at different spatial scales (Sloan and Sayer, 2015). This will require the design and implementation of appropriate governance arrangements and mechanisms, including exploring the possibility of labelling multifunctional rural landscapes (Torquebiau *et al.,* 2012; Ghazoul *et al.,* 2009; Ghazoul, 2010), and defining adequate metrics for assessing the different conservation and production values of forests and trees in mosaic landscapes (Sloan and Sayer, 2015). To a great extent SFM itself could be a source of inspiration for sustainable landscape management, provided that landscapes could be defined as management units, with adequate governance, including, as appropriate, mechanisms for cost and benefit sharing, such as in successful watershed management schemes.

4.3.3 Stakeholder involvement

Stakeholder involvement in the governance mechanisms at different scales is increasingly recognized as an enabling condition for SFM and a way to manage tensions between different functions of forest and conflicts between different stakeholders, whether local or distant. More than half of the national forest policies and programmes revised since 2007 in 42 different countries now include measures designed to enhance the involvement of traditional users in the decision-making process (FAO, 2014b). For instance, the Central African Republic's 2008 Forest Code formally recognizes the traditional rights of local communities living in or near protected areas or forest concessions. In Peru, the concept of indigenous peoples' forests, as well as the traditional knowledge and management of forests and wildlife, is formally recognized in the forest and wildlife law enacted in 2011. In Ecuador, the Constitution (2008) formally guarantees the participation of indigenous peoples in decision-making processes concerning their territories, while the codified forest law and the environmental management law give priority to indigenous and Afro-Ecuadorian peoples in the use of their lands and forest products (FAO, 2014a). Yet, the effective implementation and enforcement of these codes and laws is crucial.

Paradigms of management of forests and trees have considerably evolved in the last 50 years in many countries, from a state-controlled, production-centric approach to more collaborative systems that prioritize the needs of local communities, and value the different environmental, economic and socio-cultural roles of forests and trees (Mace, 2014; Vira *et al.,* 2015). There is a growing consensus that new, decentralized, inclusive and multiscale forms of forest governance are needed (see Larson *et al.,* 2010; Mwangi and Wardell, 2012; Ojha, 2014) to better balance national and global objectives with the rights and needs of local communities, in particular their right to adequate food (see Box 22).

Three main non-centralized forms of forest governance can be distinguished (Vira *et al.,* 2015):

- decentralization: where responsibility is transferred to locally-elected government;
- deconcentration: where responsibility is transferred to local offices of the national government, as in Senegal (Ribot, 2006); and
- devolution or "community management": where responsibility is transferred to local communities, as in Nepal (Pokharel *et al.,* 2008).

New forms of multiscale approaches also appear, involving a co-management of forests that share the rights and responsibilities between local communities and either the national state or private corporations.

Box 22 New and inclusive forms of forest governance in Central and South America

Concrete examples of a shift towards greater decentralization of forest governance away from previously state-dominated structures include: (a) the transfer of the forest concessions from semi-public companies, to the *ejidos* communities in Quintana Roo, Mexico in the mid-1980s; (b) the Community Forest Concessions in the Petén in Guatemala in the mid-1990s; and (c) the decentralization, municipalization and devolution of rights to the local communities in Bolivia through forest concessions, municipalities, social associations of villagers and original community territories assigned to indigenous peoples. Prior to the 1990s, these forests belonged to the state or to private owners.

The important common feature of these cases is that governance was transferred to local people, municipalities and also to private companies. In the case of Quintana Roo, the first planning decision and action was to undertake land-use planning in which the communities designated land for agriculture, pastures and for permanent forest use, resulting in a more balanced use of the landscape for food production and income generation. In Quintana Roo, Petén and in many concessions in Bolivia, the forest management plans are FSC-certified, which provides some assurance that the three dimensions of sustainability have been taken into account.

Another important example of devolved governance is the establishment of extractive reserves in Brazil. As Ruiz-Pérez *et al.* (2005) indicate: "extractive reserves constitute an innovative approach to match conservation and development objectives, which were originally envisaged as part of a land struggle by forest dwellers in Brazil." They present a detailed analysis of deforestation and demographic and socio-economic changes in Alto Juruá, the first extractive reserve created in Brazil in 1990, and find that forest cover has remained fairly stable, while population has declined slightly, with some internal displacements by people positioning themselves to better benefit in other locations within the reserve. The cash economy base has shifted from the original rubber production to a diversified portfolio of agriculture and livestock, and there has been a dramatic rise in non-agrarian income. They conclude that the reserve represents a very dynamic setting with positive conservation and development outcomes during its first decade. Further, in the State of Acre in Brazil, there has also been a process of value addition to enhance incomes, both in the case of rubber (with a processing plant of rubber products, especially condoms) and Brazil nut (with a processing plant).

Community forest management

Although community forest management (CFM) started to be officially recognized only in the 1970s, many forests were managed, often sustainably, by local communities, before land began to be appropriated by colonial powers worldwide since the sixteenth century (Charnley and Poe, 2007). Social forestry projects of FAO in the 1960s in Ecuador established plantations on a sharing investment arrangement (government provided the land, private sector provided funding and communities provided labour) (Kenny Jordan *et al.,* 1999).

Conservation and development practitioners have increasingly promoted CFM as a means to achieve multiple benefits. However, in a systematic review of the effectiveness of CFM, mainly focused on South Asian and Latin American forests, Hajjar *et al.* (2016) highlighted mixed results. For instance, the Indian social forestry programme has been heavily criticized because it was dominated by priorities of the state, which reduced community enthusiasm for collaboration and led to the breakdown of such arrangements (Arnold, 1990; Blaikie and Springate-Baginski, 2007). Conversely, the Korean Community Fuelwood Project was seen as a great success due to massive government investment, mobilization of local resource users and the creation of a supportive institutional environment (Oh *et al.,* 1986, see also Box 23). According to Burivalova *et al.* (2017), the success of CFM depends on several factors, including the community traditional experience in forest management and its power in the decision-making process, as well as its possibility to derive income from forest resources.

Box 23 Forests and FSN in the Republic of Korea – a model to follow?

The Republic of Korea is a mountainous country where the people traditionally relied heavily on forests for timber, fuelwood and non-wood forest products such as mushrooms and edible wild greens. In the 1950s and 1960s, it was one of the poorest and least-developed countries in the world. Half of the country's forest cover had been lost through slash-and-burn agricultural practices, large-scale land conversion and overextraction of fuel and timber. The deforestation resulted in severe erosion and exacerbated damage from repetitive droughts and floods, leading to decreased agricultural production and loss of lives and property. In short, attempts to meet FSN needs resulted in severe deforestation and paradoxically became the main factor threatening FSN.

Breaking this vicious circle was the rationale for an intensive forest rehabilitation programme that began in the 1960s, crowned in the 1970s and 1980s by two Ten-year Forest Rehabilitation Plans that achieved complete rehabilitation in merely two decades. The Government perceived that restoring forests, especially in mountain watersheds, would help prevent agricultural disaster, provide a solid foundation for food production and be fundamental in overcoming poverty and developing the national economy. These goals were achieved by integrating forestry, rural development and community mobilization in the rehabilitation policy. To mobilize people's participation nationwide, the Government integrated the rehabilitation plans with the New Community Movement (*Saemaul Undong*), a community-based, integrated rural development programme initiated in the early 1970s to improve village conditions, introduce new attitudes and skills and reduce the income gap between urban and rural communities. *Saemaul Undong* contributed to the reforestation through small-scale village-level self-help projects emphasizing community cooperation.

Community projects on nurseries, forest plantations, erosion control and fuelwood plantations galvanized people's participation and were central to the success of the forest rehabilitation effort. They provided job opportunities compensated by food or wages, which helped people overcome hunger and brought vitality to the rural economy.

Source: modified from FAO (2016e).

The term "indigenous peoples' and community conserved territories and areas" (ICCAs) is increasingly used to describe these initiatives. The International Union for Conservation of Nature (IUCN) defines ICCAs as: "natural and/or modified ecosystems, containing significant biodiversity values, ecological benefits and cultural values, voluntarily conserved by indigenous peoples and local communities, both sedentary and mobile, through customary laws or other effective means" (IUCN-CEESP, 2008). The community is the major actor in making decisions about the local adaptive management of forests and trees in ICCAs. This decentralized governance implies that local institutions have – *de facto* and/or *de jure* – the capacity to develop and enforce decisions (Borrini-Feyerabend *et al*., 2007).

In the context of protected areas, SFM for FSN calls for greater emphasis on community-based natural resource management and the accompanying enabling policy frameworks. However, the devolution of conservation to local communities does not mean that state agencies and other external institutions have no role. Understanding the dynamic complexity of local ecosystems, recognizing customary rights of access and usufruct over forests and their products, honouring local intellectual property rights, promoting wider access to information and funds, designing technologies, markets and other systems on the basis of local knowledge, needs and aspirations all call for new partnerships between the state, rural people and the organizations representing them (Pimbert and Pretty, 1997; Ostrom, 2011). Building appropriate partnerships between states and rural communities requires new legislation, policies, institutional linkages and processes in order to reconcile biodiversity conservation with sustainable forestry for FSN.

Co-management

The most common form of co-management, or joint forest management (JFM) occurs between the state and local communities, most frequently for the regeneration of degraded forests, although there are similar initiatives in the context of the management of protected areas and mature forest ecosystems (Borrini-Feyerabend *et al*., 2007). In this form of co-management the state remains the landowner, but the local community can receive use rights over trees and NWFPs. The final timber harvest is usually shared in a pre-arranged proportion between the state and the local community. The state invests in the planting material and equipment while the community volunteers invest time, often in the form of unpaid labour, and bring their own local traditional knowledge and skills. Villagers can also assist in the safeguarding of forest resources through protection from fire, grazing and illegal harvesting, which reduces policing and monitoring costs for the state. In Viet Nam, the state pays local communities to protect local forests and plant trees, to enforce regulations and control illegal logging (FAO, 2016a).

Co-management arrangements can also occur between private corporations and local communities, with the corporation retaining, the case being, ownership of land and rights over wood production while granting local community rights over NWFPs in return for their participation in management. Such agreements have been made in the Brazilian Amazon, where local populations have been granted access to private forest lands for collection of NWFPs.

Box 24 Management of commons and co-management in northern Sweden – an example of a multiple-use situation and co-management

In northern Sweden, the Sami have the exclusive right to continue their millennial practice of reindeer herding, a right formally recognized by the Swedish Government. In the same areas, private forest owners are utilizing the same forest land for forestry, typically timber harvest for commercial benefits. This parallel land use causes negative effects on both stakeholders: forestry causes negative effects on reindeer herding as timber harvest has a negative effect on lichens (vital for winter forage); and reindeer husbandry causes negative effects via trample damage in young forest stands (Bostedt *et al.*, 2015; Widmark *et al.*, 2011).

The conflicts over land use between the two categories of stakeholders have evolved over time, since the 1950s when forestry started to mechanize harvest. Conflict resolution was initiated with the 1979-year forestry act in which forestry had to consider other land uses, and further developed over time until the FSC was established in the 1990s. A co-management system between the private landowners and the reindeer herders started to develop (Widmark, 2009).

Forest companies are instructed to initiate *a priori* consultations beforefinal harvest, soil scarification, fertilization and forest road construction, which means that the forest company has to consult each reindeer herder (organized in small communities) to consider the negative effects of management plans. This is typically done each year. The minutes from the consultations have to be included in the management report that the forest company is required to submit to the Forestry Agency *before* the planned measure is carried out (Widmark *et al.*, 2011).

Research shows that the co-management system did not work as well as intended as consultations were characterized more as information meetings or dialogues and less of what a partnership as co-management is intended to be (Sandström and Widmark, 2007). However, with the revision of FSC in 2010, the role of consultations was clarified and a conflict-resolving tool was initiated in cases where the two stakeholders could not agree (Bostedt *et al.,* 2015).

To further strengthen the position of the Sami reindeer herders in consultations, the Government established an indigenous mapping project to ensure that the traditional knowledge of the forest and grazing land would be equally represented in consultations as the knowledge of the forest from the commercial point of view. This geographical information system is, as of 2014, implemented in 49 of the 51 reindeer herding communities in Sweden (Bostedt *et al.,* 2015).

Brazil and the Philippines report an important proportion of public forests managed by communities (respectively 37 and 47 percent) (FAO, 2011b). In Brazil local communities have management rights over 160 million hectares of public forests (FAO, 2013c). In the Amazon Basin, private management of public forest is not common, although this could change in Brazil as a result of the 2006 forest concession law (Banerjee and Alavalapati, 2008). Conversely, in Cameroon, the Democratic Republic of the Congo and Indonesia, more than 40 percent of publicly owned forests are managed by private corporations and institutions (FAO, 2011b).

In Cameroon, forest management relies mainly on large logging concessions. However, small-scale logging has been developed in the last decades in two different forms. First, the creation of community forests in the late 1990s allowed local communities to legally harvest, process and trade timber, often with the support of external actors, whether NGOs or private operators. Second, individual chainsaw milling, mainly informal, has grown considerably, creating a flow of revenues around EUR30 million for the benefit of local communities (Lescuyer *et al.,* 2016).

These different forms of co-management may help to solve conflicts between different stakeholders (for instance between timber harvesters and reindeer herders in boreal forests, see Box 24), whether local or not, using land for different purposes and sharing legal rights over land and resources (Widmark, 2009).

Evidence of such co-management regimes suggests a considerable variation in field-level outcomes (Hobley, 1996; Poffenberger and McGean 1996; Saxena, 1997; Brown, 1999; Ribot, 1999; Khare *et al.,* 2000; Sundar *et al.,* 2001; Widmark, 2009). Some projects retain the rhetoric of participation, but are no more than extensions of forest agency priorities, with local communities providing a cheap source of labour. Others have made a significant transition towards collaboration, with formalized management agreements establishing each partner's rights and responsibilities (see the example from Quebec in Box 21). The most successful projects have been in existence for over two decades, and have reached the stage of harvesting the first crop of mature trees, and are encountering ”second generation problems” such as re-investing and equitably sharing revenues from tree sales (Ojha, 2014).

4.3.4 A human rights-based approach

Human rights provide a normative framework and impose on states three obligations, namely: to respect, protect and fulfil human rights (HLPE, 2015). Indisputable causal links exist between the violation of human rights and the economic, social, cultural and political deprivations that characterize poverty. The realization of all human rights and efforts to eliminate extreme poverty are therefore mutually reinforcing, and human rights' norms and principles can guide efforts to reduce poverty (Sepúlveda and Nyst, 2012).

The right to food is enshrined in the Universal Declaration of Human Rights (UDHR) and in the International Covenant on Economic, Social and Cultural Rights (ICESCR). In its article 11, ICESCR established the right to food as a legally binding right for all states parties.[55] The content of the right has been further developed by the Committee on Economic, Social and Cultural Rights (CESCR) – the supervisory body of the ICESCR – in its General Comment No. 12 (GC12) on the right to adequate food and General Comment No. 15 on the right to water. Through these authoritative interpretations, the different components of the right to food and its corresponding obligations have been further clarified.

According to CESCR, the right to food is realized “when every man, woman and child, alone or in community with others, has physical and economic access at all times to adequate food or means for its procurement” (CESCR, 1999). Food should be “sufficient, adequate and culturally acceptable, produced and consumed sustainably, preserving access to food for future generations” (UNGA, 2014). The UN General Assembly (UNGA, 2012) also recalled that all people have a right to food that not only meets minimum requirements for survival but is also nutritionally adequate.

[55] Up to May 2017, 165 states are party to the ICESCR.

The CESCR considers that the core content of the right to food implies “the availability of food in a quantity and quality sufficient to satisfy the dietary needs of individuals, free from adverse substances, and acceptable within a given culture; the accessibility of such food in ways that are sustainable and that do not interfere with the enjoyment of other human rights” (CESCR, 1999).

In 2004, FAO developed practical voluntary guidelines for national governments to support the progressive realization of this right to adequate food (VGRTF), especially for the most vulnerable groups in their societies (FAO, 2005).

Rights-based approaches can be understood as integrating rights and standards into policy, design, implementation and evaluation to ensure that forest and FSN practice respects rights in all cases, and supports their further realization where possible (Campese, 2009). Thus, laws, policies and interventions related to forest should not only avoid infringing rights but advance human rights standards (outcomes) as well as ensure compliance with human rights obligations in the processes by which they implement them. Such processes should respect the human rights principles of non-discrimination and equality, transparency and access to information, participation, empowerment, legality and accountability (UNICEF, 2004). They should also ensure free, prior, and informed consent (FPIC) processes.

Mainstreaming the right to food also requires policy-makers to undertake a situation analysis to identify the immediate, underlying and root causes of development problems and prioritize the marginalized, disadvantaged and excluded groups with the aim of achieving substantive equality rather than formal equality, and the monitoring and evaluation of both outcomes and processes.

The realization of the right to adequate food of local communities, forest dependent communities and indigenous peoples requires ensuring their access to forest resources. To this end, states should take a variety of measures, including: facilitating sustainable, non-discriminatory and secure access, use and tenure rights of vulnerable and marginalized peoples; protecting the assets that are important for their livelihoods (Guideline 8.1 in the VGRTF); pursuing inclusive, non-discriminatory and sound forestry policies, which will permit foresters and other food producers, particularly women, to earn a fair return from their labour, capital and management; and encouraging conservation and sustainable management of natural resources, including in marginal areas (Guideline 2.5 in the VGRTF). Overall, the VGRTF call for policies that permit foresters and other food producers, particularly women, to earn a fair return from their labour, capital and management, and encourage conservation and sustainable management of natural resources, including in marginal areas.

Forest-based goods and services are crucial for the realization of social, economic and cultural rights of people around the world, and these relationships have been studied in considerable detail, especially in the contexts of forest conservation (Johnson and Forsyth, 2002; Campese *et al*., 2009) and climate change (Seymour, 2008). These studies affirm the necessity of fair and equitable access to forest goods and services (see section 4.2.1), and the importance of communities’ and individuals’ participation as principal components (see section 4.4.3) with respect to rights and responsibilities in relation to forests.

4.4 Conclusion

As shown in previous chapters, forests and trees, if sustainably managed, can make a substantial contribution to face global challenges such as FSN, climate change or conservation of biodiversity and natural resources, all of which, ultimately, contribute to FSN. Managing forests and trees to optimize their contributions to FSN, locally and globally, short-term and long-term requires taking into account a vast number of parameters, perspectives and interests so as to recognize and address synergies and trade-offs.

It will require coordination across different sectors at multiple scales and within different time frames. There is a need for an intersectoral approach to overcome the compartmentalized and fragmented nature of decision-making.

For this, governance mechanisms need to be articulated with management regimes at different geographic scales, from international to national, local, and landscape levels. Increasing the links between different instruments can go a long way in facilitating the articulation between global demands and local needs. For instance, certification schemes could better integrate as a criterion the fact that forest management plans explicitly integrate impacts on FSN of forest-dependent communities.

Forest management is often characterized by multiple-use that complicates the governance of the resource. Institutions, legislation and regulations need to make sustainable forestry profitable for people (Sterner and Coria, 2012). Forest policies must explicitly address the role of forests in providing livelihood benefits and FSN, taking into account ownership structure, use and access rights, as well as cultural settings. While many countries have made considerable progress in strengthening forest tenure and access rights, there remains a major disconnect between a policy focus on formal forest sector activities (such as timber extraction) and the considerable numbers of people using forests and trees to meet their livelihood needs. Conservation efforts should avoid any potential negative impacts (and enhance positive impacts) on FSN, especially of the most vulnerable forest-dependent people. SFM strategies could use FSN concerns, in particular FSN of the most vulnerable and marginalized forest-dependent people, as a lens to set their priorities and define the best balance between the different functions and objectives of forests and trees.

To make further progress in enhancing the benefits from sustainable forestry, policies must be underpinned by capacity building. Numerous policies and measures to promote sustainable forestry have been adopted in the past 20 years, including incorporating sustainable forestry as a broad national goal. This involves increasing the full and effective participation of stakeholders as well as great openness to voluntary and market-based approaches and capacity building and strengthening to turn such perspectives effective.

CONCLUSION

Forest and trees contribute directly and indirectly to FSN in numerous ways. They are a source of food, wood, bioenergy, medicinal plants and many other products. They are providing livelihoods and income for an important part of the global population, often the most vulnerable. Forests perform vital ecosystem services, including the regulation of the water and carbon cycles and protection of biodiversity, that are essential to sustainable food production and FSN in the long term. These contributions vary according to types of forests and the way they are managed. They are of course particularly important locally for forest-dependent people, but also have considerable impacts at broader scales, including global.

This report, while taking stock of the breadth of existing knowledge on the roles of forests and tree-based systems for FSN and their potential contributions to the reduction of global hunger and malnutrition, also highlights the need for further data collection and analysis that enable to assess all these contributions case by case, to whom they benefit, at which geographical and temporal scales in a diversity of contexts and situations. Some of them are more easily quantified (e.g. carbon stocks, formal markets of industrial wood) than others (in particular the direct provisioning of food and contribution to livelihoods of the most vulnerable, or non-provisioning ecosystem services, including the role of forests in regulating the water cycle downstream or downwind). If left unaddressed, these knowledge imbalances, often accompanied by power imbalances, can have severe consequences for policy-making. Some of these long-term and/or afar consequences risk being overlooked. The impacts of forest management decisions on the FSN of the most vulnerable risk being ignored, because they are not known well enough and because the most affected are not fully involved in decision-making. This can be aggravated by the fact that decisions are increasingly driven by factors and actors very far from the actual landscape that they affect.

Increasing demands on land, forests and trees create new challenges and opportunities for contributions of forests and trees to FSN. They can threaten some of these, particularly when they are less visible or concern marginalized and most vulnerable groups. On the other hand, they can create additional reasons to protect and invest in forests and generate new jobs and opportunities for sustainable development. This calls for a better understanding of the drivers of change, and of the dynamics at play in evolving and complex landscapes such as secondary forests, landscape mosaics, agroforestry systems and their impact for FSN and sustainable development, and for better support for forest restoration in degraded areas.

Given global population growth and overall economic development, land is becoming an increasingly scarce resource and multiple functions will have to be fulfilled by/within the same landscape. Conflicts are likely to arise not only on the most desirable use of agriculture and forest lands but also on the best way to accommodate increasing and competing demands for land.

The evolution of governance regimes and structures towards more inclusive and decentralized processes can offer new possibilities to integrate different interests and goals related to forest and food systems. These processes can help to prevent and manage conflicts between stakeholders with diverging needs and interests. It is important to articulate governance mechanisms and management regimes at different geographic scales, from international to local, and landscape levels. Articulating better the different instruments can go a long way in facilitating the articulation between global and local needs. For instance, certification schemes could better integrate as a criterion the fact that forest management plans explicitly take into account the impacts on FSN of forest-dependent communities.

Sustainable forest management aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations, "leaving no one behind". As such, sustainable forestry is a key component of sustainable food systems. Conversely, optimizing the contributions of forests and trees to FSN could be a key objective of SFM.

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APPENDIX

The HLPE project cycle

The High Level Panel of Experts for Food Security and Nutrition (HLPE) was created in October 2009 as the science-policy interface of the UN Committee on World Food Security (CFS).

The CFS is the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition (FSN), for a broad range of committed stakeholders to work together in a coordinated manner and in support of country-led processes towards the elimination of hunger and ensuring FSN for all human beings.[56]

The HLPE receives its working mandate from CFS. This ensures the legitimacy and relevance of the studies undertaken, and their insertion in a concrete political agenda at international level. The report elaboration process ensures the scientific inclusiveness and the independence of the HLPE.

The HLPE produces scientific, policy oriented reports, including analysis and recommendations, serving as a comprehensive and evidence-based starting point for policy debates at CFS. The HLPE aims at providing a better understanding of the diversity of issues and rationales when dealing with food and nutrition insecurity. It thrives to clarify contradictory information and knowledge, elicit the backgrounds and rationales of controversies, and identify emerging issues.

The HLPE is not mandated to conduct new research. The HLPE draws its studies based on existing research and knowledge produced by various expertise-providing institutions (universities, research institutes, international organizations etc.), adding value by global, multi-sectoral and multidisciplinary analysis.

HLPE studies combine scientific knowledge with experiences from the ground, in the same rigorous process. The HLPE translates the richness and variety of forms of expert knowledge from many actors (knowledge of local implementation, knowledge based on global research and knowledge of “best practice”) that draw on both local and global sources into policy-related forms of knowledge.

To ensure the scientific legitimacy and credibility of the process, as well as its transparency and openness to all forms of knowledge, the HLPE operates with very specific rules, agreed by the CFS.

The HLPE has a two-tier structure:

1. A Steering Committee composed of 15 internationally recognized experts in a variety of FSN related fields, appointed by the Bureau of CFS. HLPE Steering Committee members participate in their individual capacities, and not as representatives of their respective governments, institutions or organizations.
2. Project Teams acting on a project specific basis, selected and managed by the Steering Committee to analyse/report on specific issues.

The project cycle to elaborate the reports (Figure 8) includes clearly defined stages, starting from the political question and request formulated by the CFS. The HLPE institutes a scientific dialogue, building upon the diversity of disciplines, backgrounds, knowledge systems, the diversity of its Steering Committee and Project Teams, and open e-consultations. The topic bound and time bound Project Teams work under the Steering Committee’s scientific and methodological guidance and oversight.

The HLPE runs two open consultations per report: first, on the scope of the study; second, on a V0 “work-in-progress” draft. This opens the process towards all experts interested as well as to all concerned stakeholders, who are also knowledge-holders. Consultations enable the HLPE to better understand the issues and concerns, and to enrich the knowledge base, including social knowledge, thriving for the integration of diverse scientific perspectives and points of view.

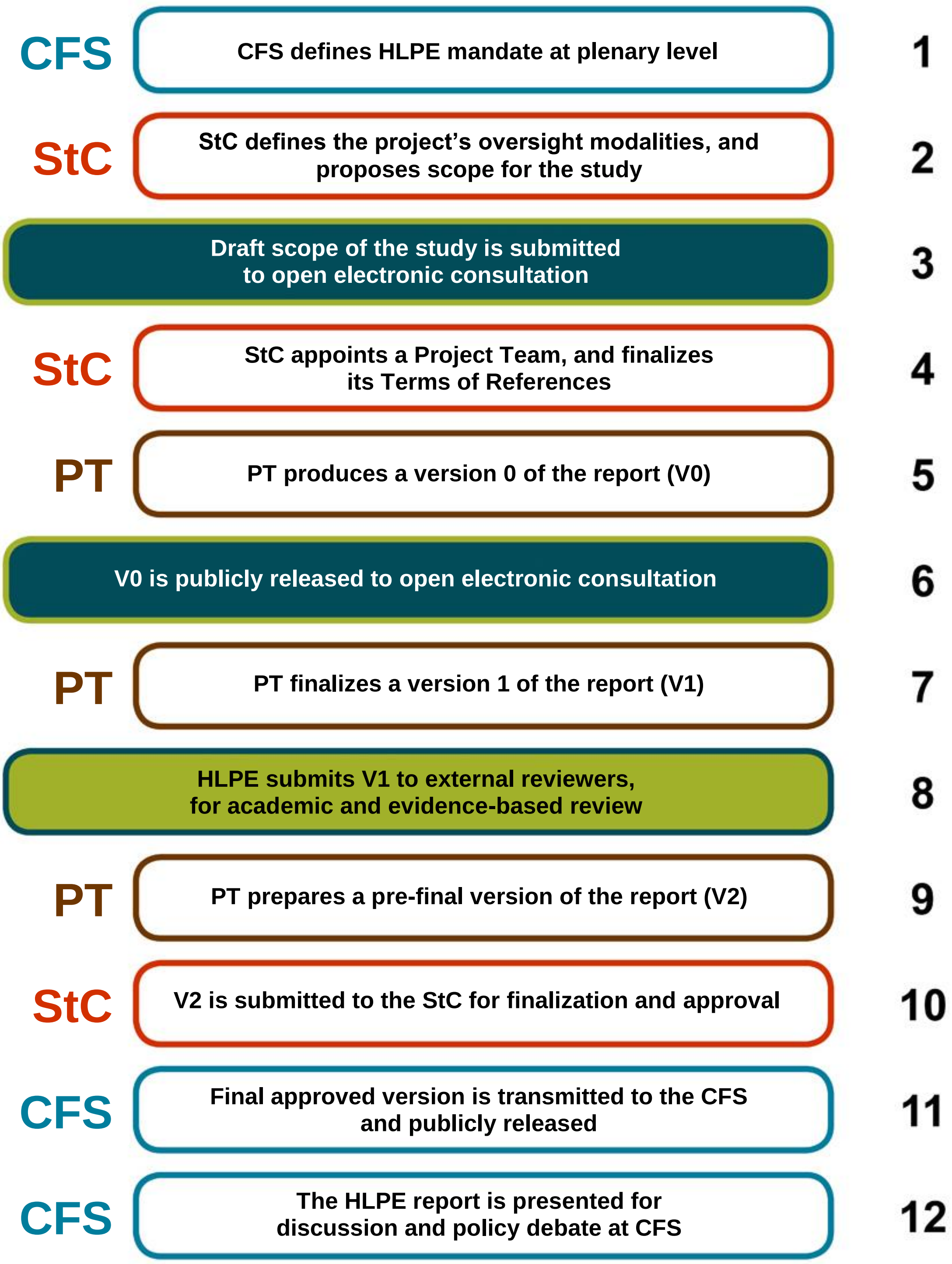
It includes an external scientific peer-review on a pre-final draft. The report is finalized and approved by the Steering Committee during a face-to-face meeting.

[56] CFS Reform Document, available at www.fao.org/cfs

HLPE reports are published in the six official languages of the UN (Arabic, Chinese, English, French, Russian and Spanish), and serve to inform discussions and debates in CFS.

All information regarding the HLPE, its process and all former reports are available at the HLPE Website: www.fao.org/cfs/cfs-hlpe.

Figure 8 HLPE project cycle



CFS	Committee on World Food Security
HLPE	High Level Panel of Experts on Food Security and Nutrition
StC	HLPE Steering Committee
PT	HLPE Project Team

Cover photo: ©CIFOR/ Aulia Erlangga

Forests and trees contribute to food security and nutrition in multiple ways. They provide wood, energy, foods and other products. They generate income and employment for many people, often the most vulnerable. They deliver ecosystem services vital for food security and nutrition in the long term, including water and carbon cycle regulation and protection of biodiversity. These contributions vary according to types of forests and the way they are managed. Increasing and competing demands on land, forests and trees create new challenges and opportunities and impact food security and nutrition. This report calls for a renewed understanding of sustainable forestry in order to fully integrate the different functions of forests and trees, from farm and landscape to global levels, as well as at different timescales, for enhanced food security and nutrition and sustainable development. This requires inclusive and integrative governance mechanisms at different scales that enable the full and effective participation of concerned stakeholders, particularly of forest-dependent indigenous peoples and local communities.

CFS
COMMITTEE ON WORLD FOOD SECURITY
HLPE
High Level Panel of Experts

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