Committee on World Food Security

High Level Panel of Experts on Food Security and Nutrition

Sustainable Forestry for Food Security and Nutrition

V0 DRAFT REPORT

31st May 2016

Submitted by the HLPE
to open electronic consultation
until 4 July 2016

This V0 draft is publicly available on the HLPE consultation platform:

http://www.fao.org/fsnforum/cfs-hlpe/Sustainable-Forestry-V0

Please read the consultation cover letter on pages 2 and 3 of this document

Comments can be sent by e-mail to: cfs-hlpe@fao.org or to fsn-moderator@fao.org.

This consultation will be used by the HLPE to further elaborate the report, which will then be submitted to peer review, before its finalization and approval by the HLPE Steering Committee.

This V0 draft may be thoroughly corrected, modified, expanded and revised after the present consultation.

For this reason we kindly invite you not to cite nor quote elements from this V0.

Please only refer to the final publication for quotations.

COVER Letter from the HLPE to this V0 Consultation

HLPE consultation on the V0 draft of the Report:

Sustainable Forestry for Food Security and Nutrition

In October 2014, the UN Committee on World Food Security (CFS) requested the High Level Panel of Experts on Food Security and Nutrition (HLPE) to conduct a study on "Sustainable Forestry for Food Security and Nutrition". The findings of this study will feed into CFS 44 Plenary session (October 2017).

As part of the process of elaboration of its reports, the HLPE is organizing a consultation to seek inputs, suggestions, and comments on the present V0 draft. This open e-consultation will be used by the HLPE to further elaborate the report, which will then be submitted to external expert peer review, before finalization and approval by the HLPE Steering Committee.

HLPE V0 drafts are deliberately presented as a work-in-progress to allow sufficient time to give adequate consideration to the feedback received so that it can play a really useful role in the elaboration of the report. It is a key part of the scientific dialogue between the HLPE Project Team and Steering Committee, and the broader knowledge community. In that respect, the present V0 draft report also identifies areas for a series of recommendations at a very early stage, and the HLPE would welcome suggestions or proposals to strengthen and focus them.

At this early stage of the draft report we are in the process of better integrating boreal and temperate forests, and would welcome inputs on these types of forests. In order to strengthen the report as a whole, the HLPE would welcome submission of material, evidence-based suggestions, references, and examples, in particular addressing the following important questions:

1. The V0 draft is wide-ranging in analyzing the contribution of forests and trees to food security and nutrition (FSN). Do you think that the draft adequately includes the range of contributions that sustainable forestry and forests can make to FSN? Is there additional important evidence or aspects that would enrich the report?

2. The report's structure consists of: the context and conceptual framework; the role and contributions of forests and forestry to FSN; the challenges and opportunities for sustainable forestry in relation to FSN; and governance issues for an integrated approach to sustainable forestry and FSN. Do you think that this structure is comprehensive enough, and adequately articulated? Does the report strike the right balance of coverage across the various chapters? What are the important aspects that could be covered more thoroughly?

3. The report uses four broad categories of forestry systems, in order to better identify distinct challenges and sustainable development pathways for each of them. Do you find this approach useful for identifying policy responses and actions in different socio-economic and environmental contexts? Do you think the terminology used in this report for forest, sustainable forestry and agroforestry are comprehensive and relevant?

4. Are there other studies that the report needs to reference, which offer different or complementary perspectives on the integration of sustainable forestry in FSN strategies?

5. The report has identified a range of challenges likely to be faced in the future that policy makers and other stakeholders will need to take into account so that sustainable forestry can meaningfully contribute to FSN. What are other key challenges/opportunities to be addressed for the development of approaches that integrate forestry and agricultural systems, including landscape approaches?

6. The social and cultural dimensions of sustainable forestry and FSN have often been less well described and understood for many reasons, including due to a lack of comprehensive as well as disaggregated data. Submission of examples and experience related to issues such as livelihoods, gender, equity, tenure and governance would be of particular interest to the team.

7. What are the key policy initiatives or successful interventions needed to improve the sustainability of our global food systems related to sustainable forestry and FSN, both in different countries and contexts, that merit discussion in the report?
8. Is there evidence of the potential of economic incentives (e.g. REDD+), regulatory approaches, capacity building, Research & Development, and voluntary actions by diverse stakeholders or actors that could enhance the contribution of forestry to sustainable food systems? Could you provide examples or case studies of such key policies, initiatives or successful interventions?
9. The design and implementation of policies for FSN require robust, comparable data over time and across countries. What are the data gaps that governments, national and international organizations and other stakeholders might need to address in the future in order to understand trends and formulate/propose better policies for sustainable forestry and FSN? What roles could diverse stakeholders play in relation to addressing these data gaps, and identifying ways in which the data could be disaggregated for more effective formulation of policies?

We thank in advance all the contributors for being kind enough to read and comment and suggest inputs on this early version of the report. We look forward to a rich and fruitful consultation.

The HLPE Project Team and Steering Committee

HLPE Project Team

Project Team Leader: Mr Terence Sunderland (UK)

Project Team Members: Fernande Abanda (Cameroon), Ronnie de Camino Velozo (Chile), Patrick Matakala (Zambia), Peter May (Brazil), Anatoly Petrov (Russia), Bronwen Powell (Canada), Bhaskar Vira (India), Camilla Widmark (Sweden)

HLPE Steering Committee

Chairperson: Mr Patrick Caron (France)

Vice-Chairperson: Ms Carol Kalafatic (USA)

Steering Committee Members: Mr Amadou Allahoury (Niger), Ms Louise Fresco (the Netherlands), Ms Eileen Kennedy (USA), Mr Muhammad Azeem Khan (Pakistan), Mr Bernardo Kliksberg (Argentina), Mr Fangquan Mei (China), Ms Murphy Sophia (Canada), Mr Mohammad Saeid Noori Naeini (Iran), Mr Michel Pimbert (United Kingdom), Mr Juan Ángel Rivera Dommarco (Mexico), Ms Magdalena Sepúlveda (Chile), Mr Martin Yemefack (Cameroon), Mr Rami Zurayk (Lebanon)

Experts participate in the work of the HLPE in their individual capacities, and not as representatives of their respective governments, institutions or organizations

Contents

List of Figures

List of Tables

List of Boxes

1 INTRODUCTION

The global food system is a major determinant of both food security and environmental outcomes: adequate nutrition and sustainable food production are fundamental prerequisites for achieving global sustainable development. However, the current model of global food production is characterized by negative impacts on both human and planetary health (Pinstrup-Andersen and Watson, 2011; Whitmee *et al.*, 2015). Fifty years after the Green Revolution, the world still faces multiple burdens of both over- and malnutrition while much of the agricultural expansion related to achieving global food security is often at the expense of natural systems, including forests.

Yet the goal of achieving global food security is not the sole preserve of the agricultural and health sectors. The Millennium Ecosystem Assessment (MA, 2005) and, latterly, the Sustainable Development Goals (SDGs), have demonstrated decisively that human health and nutrition are "inextricably linked" with the health of natural ecosystems, including forests, managed on a sustainable basis. Forested landscapes, forests and trees perform a variety of functions that contribute to food security and nutrition (FSN) and will be described in this report.

After fossil fuel combustion, deforestation is the second largest contributor to greenhouse gas emissions (van der Werf *et al.*, 2009), contributing to climatic changes that threaten food security throughout much of the world. Agricultural expansion is the largest single cause of deforestation. While this opens up new agricultural land, it may also erode the very ecosystem services upon which agricultural production itself depends (Gibbs *et al.* 2010).

FSN is a prominent global development priority. Achieving reductions in global rates of food insecurity and malnutrition, including meeting the FSN targets set out in the SDGs and the "zero-hunger challenge",[1] will require the cooperation of multiple sectors, including forestry. There exists today a triple burden of malnutrition: a burden of undernutrition, consisting of deficiencies in dietary energy intake (hunger), estimated by FAO to affect around 790 million people worldwide; a second burden in the form of micronutrient deficiencies, such as iron, iodine and vitamin A, which affect more than two billion people worldwide;[2] and a third burden from the rapidly growing number of people with chronic "lifestyle" diseases associated with overnutrition or consumption of calories, sugars and fats and animal-sourced foods (ASFs). The number of people who are overweight is estimated by the World Health Organisation (WHO) at 1.4 billion adults (35 percent of the world's adult population) in 2008, of which 500 million (11 percent) were classified as obese.

Global efforts to tackle the issues associated with malnutrition and food insecurity have historically focused upon reducing the prevalence of protein-energy malnutrition through economic and food-supply based solutions, followed by micronutrient deficiencies through supplementation and fortification schemes (Allen *et al.* 2010). In the past two decades there has been increasing focus on more integrated solutions to the issues of FSN with growing calls for food-based, diet-based and agriculture-based solutions. Today, debates around agriculture and nutrition increasingly focus on how best to create a food system that is productive, equitable and sustainable in the long term (Pinstrup-Andersen, 2013; Ruel *et al.*, 2013; Carletto et al, 2015).

It is often postulated that to meet global needs for food of a growing population, given the current trends in consumption, global agricultural production in 2050 will need to be 60 percent higher in volume than in 2005/2007 (FAO, 2012a) . However, production alone is not the sole determinant of an adequate, equitably distributed global food system. Such urgent need to match agricultural supply with presumed and predicted demand is reigniting debates over the nature of the impacts of agrarian change, particularly in the tropics (Deakin *et al.* 2016). Whereas in the past debate has focused on whether agricultural innovation is a prerequisite or consequence of population growth (Lambin *et al.*, 2000), today's focus is on the optimal landscape configurations that allow for the increase in agricultural production, without undermining the capacity of natural ecosystems to support agriculture (Baudron and Giller, 2014). In boreal regions, the trend seems to be that agricultural land is not utilized for active farming, rather left unmanaged, and in some cases transformed into forest land. Today, the "grand challenge" is to feed a growing population with more nutritious diets in an environmentally

[1] http://www.un.org/en/zerohunger/

[2] Estimate for anaemia worldwide from WHO, accessed 25 June 2014 (available at: http://www.who.int/nutrition/topics/ida/en/).

sustainable manner (Frison *et al.*, 2006; Burlingame and Dernini, 2012; Fanzo et al, 2013; Powell *et al.*, 2015), in the context of climate change and natural resource scarcity.

Forested ecosystems, however, also offer scope to address many of humanity's greatest challenges, including the achievement of FSN. It is being increasingly recognized that sustainable forestry for FSN 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 wellbeing (Ickowitz et al 2014; Vira *et al.* 2015; Ickowitz et al 2016). Sustainable forest management can safeguard and deliver a wide range of social, cultural, environmental and economic benefits that can support FSN and livelihoods more generally.

Meeting the twin objectives of sustainable forestry and global FSN, however, will require a conceptual shift away from the notion of agriculture and natural ecosystems as separate systems towards an integrated approach that sees them as mutually beneficial and co-dependent (DeKlerck *et al.* 2011). Climate-smart agricultural practices such as conservation farming, agroforestry and crop–livestock–arboreal integration, along with the targeted protection and restoration of forests specifically to generate ecosystem services, are required to ensure the long-term sustainability of food production systems.

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 food security and nutrition to inform the debates at the 44th CFS Plenary Session of October 2017.

The report uses as its conceptual framework the roles, both direct and indirect, that sustainably managed forest systems contribute to each of the four dimensions of food security outlined by FAO – availability, access, utilization and stability.

Since sustainably managed forests contribute via multiple roles to fulfil the multiple dimensions of food security, the interactions between factors are highly complex and hard to disentangle in a short report. As a result, the report is structured to consider the roles of sustainable forestry using forest typologies derived from broad classifications of management systems. The report focuses on both direct and indirect roles, in forest types ranging from natural forests through managed forests, agroforestry systems to monoculture plantations. The report is organized as follows. Chapter 2 examines the state of the world's forests, linkages between sustainable forestry and FSN, proposes for the sake of this report a conceptual framework and a forest-use typology for FSN. Chapter 3 examines the challenges and opportunities of forestry relating to FSN issues. Chapter 4 provides an in-depth analysis of the pathways through which forests affect FSN. Chapter 5 examines the challenges of governing sustainable forestry for FSN. Finally, recommendations are made drawing on the findings of the preceding chapters.

2 CONTEXT AND CONCEPTUAL FRAMEWORK

This chapter begins with a short introduction to forest definition and issues of contention (Box 1), an analysis of the current state of the world's forests along with historic and current trends. A conceptual framework is presented, situating global forestry within the context of global trends and challenges. Finally, a typology of sustainable forestry and forest-use activities is created for use throughout the report.

With FSN high on the agenda in many political and scientific arenas (e,g, this report), it is thus crucial to understand the contribution of sustainable forestry to a food and nutrition secure future. This improved understanding will be essential for building on synergies and minimizing trade-offs between biodiversity conservation and sustainable agriculture. It will also help build capacity to mitigate and adapt to an ever-changing climate and meet the demands of a growing population whose changing dietary demands will put ever-increasing pressure on global resources.

Box 1 Forest definitions

Defining what constitutes a forest is not easy, and is often characterized by contentious debate.

Recent studies of the various definitions of forests (Lund, 2008; Chazdon *et al.*, 2016) found that more than 800 different definitions for forests and wooded areas were in use round the world – with some countries adopting several such definitions at the same time. It should be kept in mind that different definitions are required for different purposes and at different scales.

Common definitions

FAO has been assessing the world's forest resources at regular intervals. Its Global Forest Resources Assessments (FRA) are based on data provided by individual countries, using an agreed global definition of forest that includes a minimum threshold for the height of trees (5 m), at least 10 percent crown cover (canopy density determined by estimating the area of ground shaded by the crown of the trees) and a minimum forest area size (0.5 hectares) (FAO 2015). Urban parks, orchards and other agricultural tree crops are excluded from this definition – as are agroforestry systems used for agriculture. According to this definition, there are at present just under 4 billion hectares of forest in the world, covering in all about 30 percent of the world's land area (FAO, 2015).

The United Nations Framework Convention on Climate Change (UNFCCC) uses a slightly different approach. It requests industrialized countries to estimate the forest area according to their own national definitions that should be documented in the greenhouse gas inventory report. For supplementary reporting to the Kyoto Protocol, however, these countries have to apply a forest definition with threshold values within certain parameters; 0.01–1.0 ha for minimum area, 2-5 m for minimum tree height and 10–30 percent for minimum crown cover. The threshold values chosen must be used for all subsequent assessments made during the reporting period and, if the definition is different from the definition used by FAO, the country should explain why a different definition was chosen.

The crown cover threshold and the land-use criterion are, in most cases, the most critical factors defining forests. The 10 percent threshold of crown cover encompasses both open and closed forests. The term "closed forest" refers to areas where tree cover exceeds 40 percent, while the term "open forest" refers to areas where tree cover is between 10 and 40 pe cent. In order to assess the state of the world's closed forests, the United Nations Environment Programme (UNEP) has recently employed other definition criteria, including a minimum crown cover of 40 percent. It has also used remote sensing to ensure compatibility across countries. According to the UNEP assessment, there were an estimated 2.87 billion ha of closed forest worldwide in 1995, equivalent to 21.4 percent of the total land area. Half of this area was located in the Russian Federation, Canada and Brazil (FAO, 2006).

Several other regional and global maps and assessments of forests have been produced – often with differing results, reflecting the various definitions and methodologies used and also the differing interpretations made. Problems that arise in trying to assess the extent of forests worldwide are compounded by the fact that even when using a commonly held definition, data from one country are not necessarily comparable with data from another due to the different methodologies used. For example, the use of satellite imagery might produce very different results to a ground-based survey. In addition, remote-sensing techniques for assessing forest areas can result in areas used for agricultural purposes or urban development being included rather than excluded in overall calculations of forest area (c.f. Hansen *et al.* 2015).

A factor not included in the above-mentioned definitions concerns just what a particular forest is made up of. Is it largely composed of indigenous (native) or introduced species? If planted, is it a monoculture – consisting of only one species? The definitions outlined above also exclude the condition of the forest. Is it an undisturbed primary forest, severely degraded forest or something in between? Is the forest healthy or has it been subject to attacks by pests, disease or forest fire, or damaged by wind or air pollution?

Area is only one factor in assessing the world's forests: it is also vital to present comparable data on various specific forest types, examine forest health and look at usage, management regimes and resource values.

Modified from UNEP, FAO & UNFF (2009) http://www.unep.org/vitalforest/Report/VFG_full_report.pdf

2.1 The state of the world's forests

Almost 30 percent of the world's landmass is covered by forests and tree-based configurations of some kind (Keenan *et al.*, 2015). Populating these forested areas are around three trillion individual trees (Crowther *et al.,* 2015), with the greatest densities occurring in the tropical humid forests. Across the globe, forests and tree-based agricultural systems contribute directly and indirectly in some way to the livelihoods of an estimated one billion people (Agrawal *et al.,* 2013).

Box 2 The forest biome

Today, forests occupy approximately one-third of Earth's land area, account for over two-thirds of the leaf area of land plants, and contain about 70% of carbon present in living things. They have been or continue to be held in reverence within diverse peoples' religious or spiritual belief systems. However, forests are becoming major casualties of economic systems whose reliance on unsustainable development brings deforestation, environmental degradation and industrial usage problems to this important biome.

Present-day forest biomes, biological communities that are dominated by trees and other woody vegetation can be classified according to numerous characteristics, with seasonality being the most widely used. Distinct forest types also occur within each of these broad groups.

There are three major types of forests, classed according to latitude:

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 degrees N and 23.5 degrees 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 degrees.
- 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 kilometer 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. 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 kilometer. 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.

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 terrestial biome. Occuring between 50 and 60 degrees north 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.

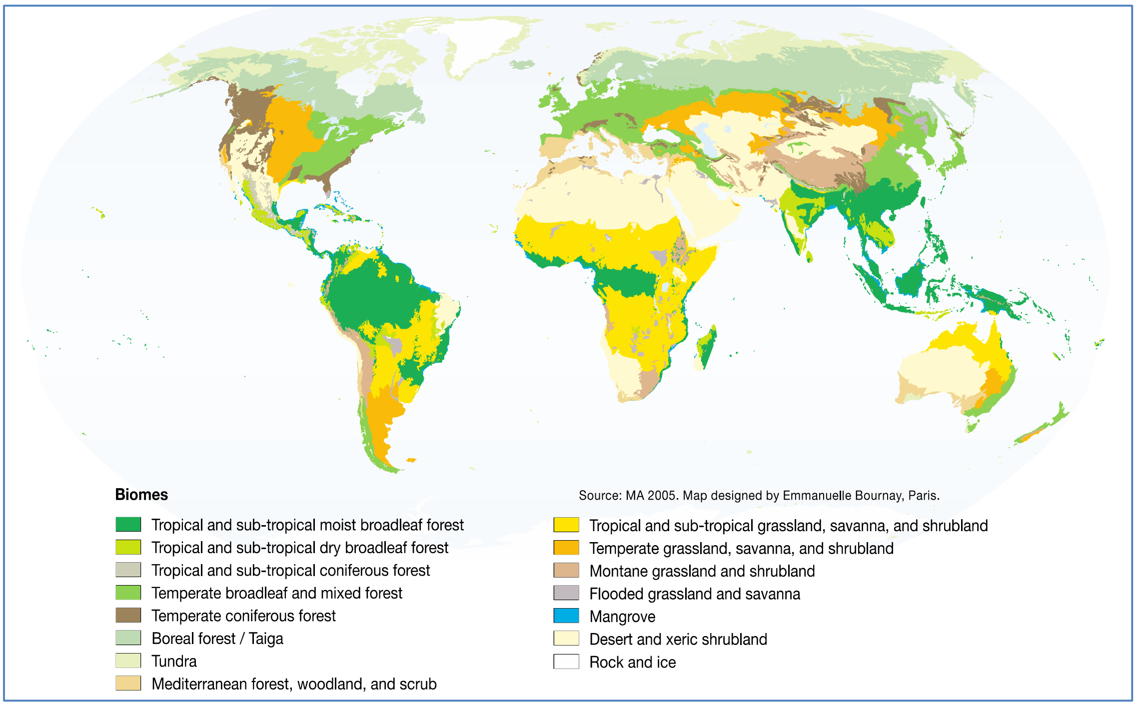
- Temperatures are very low.
- Precipitation is primarily in the form of snow, 40-100 cm annually.
- Soil is thin, nutrient-poor, and acidic.
- Canopy permits low light penetration, and as a result, understory is limited.
- Flora consists mostly of cold-tolerant evergreen conifers with needle-like leaves,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

Source: Adapted from http://www.ucmp.berkeley.edu/exhibits/biomes/forests.php

Despite ongoing high rates of deforestation, particularly in the tropics, the overall rate of deforestation has slowed over the past two decades (MacDicken 2015; Keenan *et al.* 2015). For example, deforestation in the Brazilian Amazon has been reduced to 25 percent of the rate in 2004 (INPE, 2015). At the same time, there have been increasing efforts to reforest degraded lands, as well as natural regeneration (Payn *et al.* 2015). Since forest cover is a net balance between forest loss and forest gain such trends (Figure 2) – if they continue – offer the potential of a forest transition from net deforestation to net afforestation – a transition that has already occurred in a number of countries, including middle-income countries (Sloan and Sayer 2015). The apparent 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 the focus on a small number of tree species. But there are also some countries in which natural regeneration of degraded pastures and agriculture areas have recovered important forest areas, even more important that the plantations areas, such as in the case in Costa Rica in which the increase in forest cover from 40 percent in 1986 to 51.4 percent in 2010 mainly consists of secondary forests

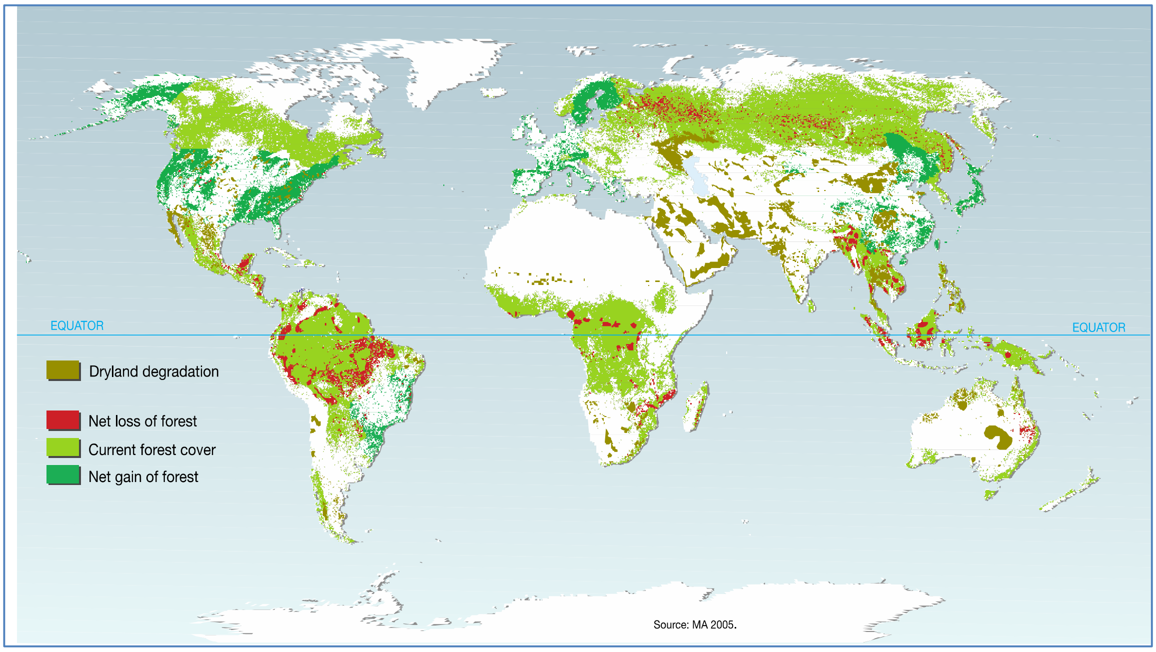
(Sanchez, 2015). In Latin America, by 1997, there were around 160 million ha of secondary forests, which may have increased as a result of the recovery of deforested areas (Smith *et al.*, 1997).

Figure 1 Forested biomes of the world



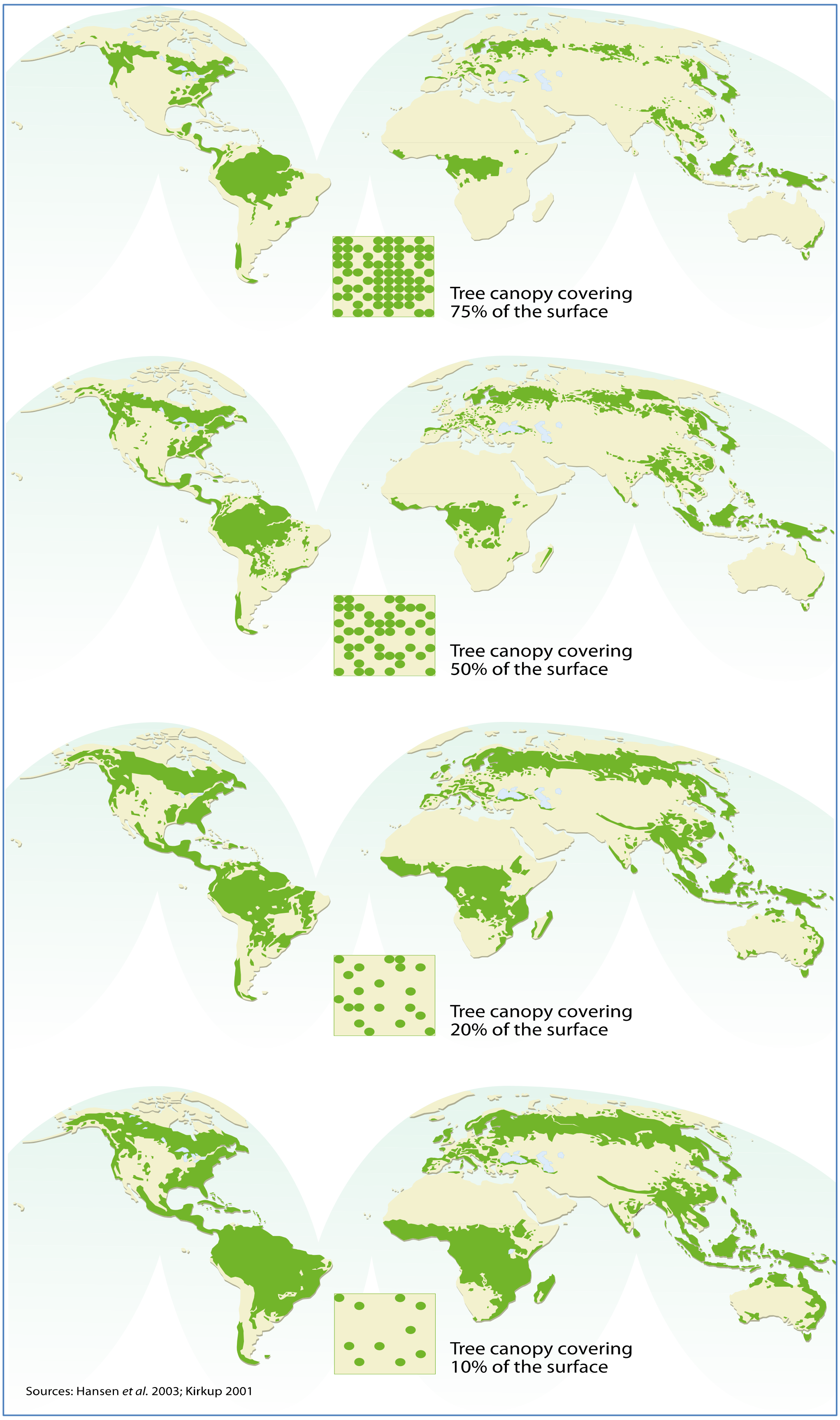
Source: UNEP: *http://www.unep.org/vitalforest/graphics/PDF/0101-biomes.pdf*

Figure 2 Changes in forest cover



Source: UNEP http://www.unep.org/vitalforest/graphics/PDF/0101-biomes.pdf

Figure 3 Global forest cover



Source: UNEP, http://www.unep.org/vitalforest/graphics/PDF/0101-biomes.pdf

Box 3 The contribution of forest and wild foods: global evidence

Farmers and communities around the world manage their landscapes for their livelihoods and food security. Landscape management often balances the production of cultivated and wild resources (Padoch and Sunderland 2014). The management of wild food species can range from completely unmanaged to almost domesticated or escaped species which are cultivated under some circumstances and wild in others (Anderson 2006; Bharucha and Pretty 2010; Padoch and Sunderland 2013; Turner *et al.* 2011). The most common types of wild foods include fruits, vegetables, mushrooms and animal source foods (Powell *et al.* 2013, Vinceti *et al.* 2008, Price *et al.* 1997).Two recent papers, one using data from the Poverty and Environment Network (PEN) study and one a review of existing literature, show very high levels of variation in the contribution and importance of wild foods in sites across the tropics.

Tropics-wide PEN data: Rowland *et al.* 2016 (in press) investigate the dietary contributions of wild forest foods in smallholder dominated forested landscapes in 24 tropical countries. Also using PEN data, the study estimated the intake of forest foods and compared these intake levels to dietary recommendations. Only 53.5% of households in the data set had consumed forest foods and 3 sites had no forest food consumption at all. The study highlighted very high variability in forest food use and create four forest food use site typologies to characterize the variation; forest food-dependent, limited forest food use, forest food supplementation and specialist forest food consumer sites. For example in one site in Nepal, 100% of households had consumed forest foods, but the median yearly consumption per adult was only 7kg (forest food supplementation). Forest fruit or vegetables contributed only 3.7% of their international recommended intake of 400g of fruits and vegetables per day. When compared to the relative importance of agriculture in the supply of fruits and vegetables and animal source foods, forests contributed around 14% of the total supply of fruits and vegetables (sites ranged between zero to 96%) and between zero to 92% of meat and fish obtained from forests.

Review of Studies from Developing Countries: Powell *et al.* (2015) conducted a review of the literature looking for primary research papers that assessed the contribution of wild foods to diets or nutrition, relative to intake of foods from other sources and identified 24 papers. The relative importance of wild foods varied greatly between studies. In a number of the studies, wild foods made up a significant portion of the diet, especially for wild vegetables, which in some contexts, appeared in a large portion of meals and made up the majority of all the vegetables consumed (between 83% in a study from Tanzania (Newman 1975) and 43% in a study site in Vietnam (Ogle *et al.* 2001)). Across 8 studies, wild meat and fish contributed between 88% (in the Brazilian Amazon, DaSilva and Begossi 2009) and 0% (in a pastoral community in Kenya, Iannotti and Lesorogol 2014) of the fish and meat consumed. The contribution that wild foods made to total energy intake low in most studies; despite this, wild foods accounted for a large portion of micronutrients consumed at a number of sites. In Gabon, Blaney *et al.* (2009) reported 36% of total vitamin A and 20% of iron in the diet came from "natural resources" (wild foods); in Tanzania, Powell and colleagues (2013), reported 31% of RAE (vitamin A) and 19% of iron in the diet from wild foods; and, in a traditional swidden agricultural community in the Philippines, wild foods contributed 42% of calcium, 32% of riboflavin, 17% of vitamin A and 13% of iron (Schlegel and Guthrie 1973).

2.2 What is "sustainable forestry for food security and nutrition"?

2.2.1 Definitions and scope

This report defines sustainable forestry as "a dynamic and evolving concept, which aims to maintain and enhance the economic, social and environmental values of all types of forest, for the benefit of present and future generations (United Nations General Assembly 2008). It aims to restore and reverse the effects of deforestation and degradation and provides multiple benefits for people and society (FAO, 2011a).

The Sustainable Forestry Management (SFM) concept encompasses both natural and planted forests in all geographic regions and climatic zones, and all forest functions, 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.* 2015). This is in line with the Convention on Biological Diversity's (CBD) five strategic goals on biodiversity conservation and with Sustainable Development Goal #15 – "to manage natural resource assets sustainably" of which forests are a key component (Reed *et al.* 2015). The main objective of sustainable forestry is to achieve multiple benefits, including forest protection, production and income generation (Brandt *et al.* 2015).

Sustainable forest management is rooted in two main premises: first, that ecosystems have the potential to renew themselves and secondly 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). In the tropics, it is estimated that there are up to 400 million hectares of forest managed for sustainable timber production and other uses; this comprises more than half the remaining permanent tropical forest estate (Brandt *et al.* 2015).

2.2.2 Global trends and impacts on sustainable forestry for FSN

Population growth

Current estimates suggest that the increase in food production needed to feed a growing population will result in the further conversion of roughly 1 billion ha of land by 2050 (FAO, 2012a). Much of this agricultural expansion is speculated to come at the expense of natural systems, including forests and other tree-based systems (Sayer *et al.* 2013). There is significant evidence that agricultural production is sufficient to achieve global food security and that we grow sufficient staple foods to provide for current and future populations at estimated human growth rates (Holt-Gimenez *et al.* 2012). Where production must increase, needs can often be met by increasing efficiency and intensification in areas where potential productivity gains are highest – particularly among smallholder farmers . Thus there is little need to convert forests and other land for agriculture (Bajželj *et al.* 2014). In addition, the focus on staple crop production, while important, neglects the essential role that food diversity plays in nutrition and food security (Byron and Arnold 1997; DeKlerck *et al.* 2011; Sunderland 2011; Ickowitz *et al.* 2016).

Dietary transitions

Efforts to achieve universal food security must be viewed within the context of a broader nutritional transition away from traditional foods, towards higher consumption of processed foods and higher quantities of fats and oils (Tilman and Clark 2014). Such a transition is increasing the demand for certain food groups such as oil (e.g. palm oil), meat products, dairy and others, while simultaneously increasing pressure on existing agricultural landscapes (Ickowitz *et al.* 2016). In addition, low consumption of fruits and vegetables and increased consumption of fats and oils can lead to calorie-rich and nutrient-poor diets which, coupled with more sedentary lifestyles, can result in significant increases in the burden of “lifestyle diseases” such as obesity, stroke and cardiovascular disease (Lee *et al.* 2012).

Thus future FSN scenarios must take into account the shift in global consumption patterns towards different food groups and the health implications of this shift. Sustainable forestry can contribute in a small way through meeting the demand for healthy food groups such as fruits and vegetables but will likely be adversely affected by increased demand for other foods through competition with agricultural land. A forthcoming HLPE on Nutrition and Food Systems, to be published in 2017, will cover these aspects in depth.

2.3 Conceptual framework

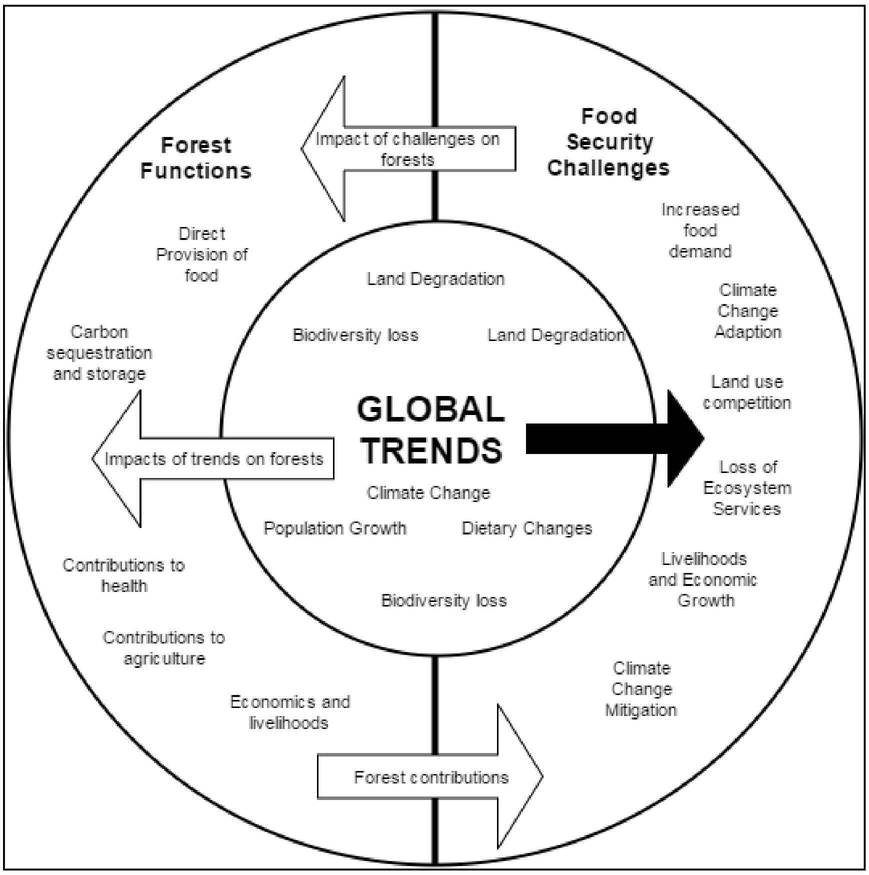
The conceptual framework of this report places forests within the context of challenges arising from global trends. The world is faced with a problem: how can forests contribute to FSN for all? This report posits that sustainable forestry can play a substantial role in reconciling these issues.

The SDGs represent a significant challenge and opportunity for the global community. Overlaps between the framework of sustainable forestry and FSN and the objectives of the SDGs are clear; as is the potential value of integrated landscape approaches – when applied effectively – as an implementing framework for addressing multiple targets both within and between SDGs, including those related to forestry and FSN.

The framework in Figure 4 shows the contributions of forests within the context of global trends and challenges and the pathways through which sustainable forestry can contribute to FSN. Population growth, combined with dietary changes and a worldwide nutrition transition, is increasing the quantity and affecting the type of foods that agriculture needs to provide. Loss of biodiversity and natural habitats, particularly forests, is driving major changes in the global ecosystem including the loss of ecosystem services, climate change and competing land-use requirements. Degradation of agricultural land, driven by over-intensification and poor management of agriculture, may reduce future yields from existing agricultural land, as will climate change and global environmental change. This will increase land-use competition between natural habitats including forests and agriculture must be resolved if the ecosystem services upon which agriculture depends are to be protected.

The same global trends also impact the state of the world's forests, while at the same time several forest functions can play a role in mitigating the food security challenges. Sustainable forestry can contribute to food availability by increasing food supply through the provision of wild forest foods, agroforestry and the protection of ecosystem services, and thus, agricultural productivity. Through increasing the income of those within the sector, improving productivity and efficiency, and contributing to economic growth, sustainable forestry can contribute to access to food security. Sustainable forestry also contributes to the utilization dimension of food security through reduced infections and through provisioning more nutritious foods, richer in micronutrients and lower in fats and refined sugars. Sustainable forestry can also contribute to the stability dimension of food security through the provision of income and food safety nets, and through mitigating crop failures driven by land degradation and global environmental change.

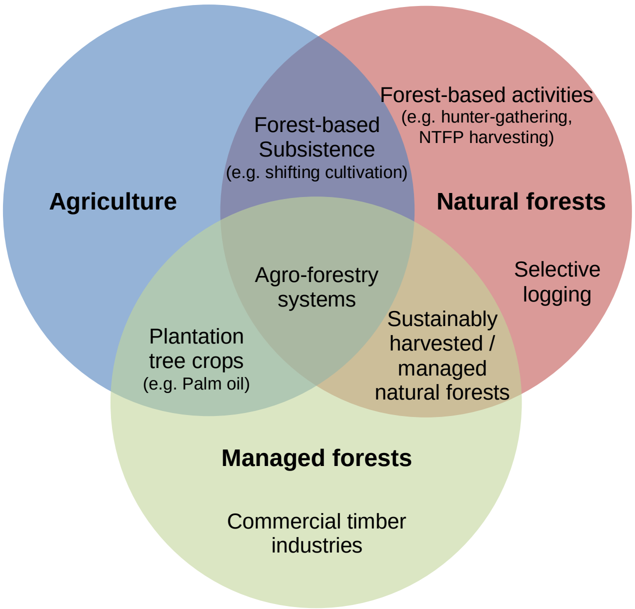
Figure 4 Framework for forest contributions in the context of global challenges and the contribution pathways towards food security challenges



2.4 Typologies of forests for food security and nutrition

Building on the pathways identified in the conceptual framework of this report we use a forest system typology based upon both the forest function and the type of forest use. Figure 5 shows the relationship between natural and managed forests and agricultural production.

Figure 5 Venn diagram showing overlapping forest typologies and the relationships between different forests and agricultural land uses



Based upon these relationships outlined in Figure 5, several broad categories of forest management emerge: natural forests where little to no conscious forest management takes place (although land-use practices such as shifting cultivation and selective logging can alter the forest structure); plantation forests (including monospecific timber plantations and tree-crop plantations); and actively managed forests (including agroforestry and managed natural forest concessions).

2.4.1 Natural forests

Natural forests (temperate, boreal and tropical) contribute directly and indirectly to the livelihoods of an estimated one billion people globally (Sunderland *et al.*, 2013) through provisioning services such as forest-source foods, fiber, fuelwood, freshwater and natural medicines; regulating services such as air quality, water quality, climate regulation and pollination; and supporting services such as nutrient cycling, water cycling, soil formation and photosynthesis; as well as cultural values such as aesthetics, recreation and tourism.

Natural forests, often characterised by little to no formal management outside of protected areas (Pimbert and Pretty 1997), contribute to FSN, through the direct collection for immediate consumption and derivation of income through the sale of NTFPs and a broad suite of forest resources (Angelsen 2013). The provision of ecosystem services is also an important facet of natural forests, although payment and compensation schemes remain somewhat nascent in their development, thus benefiting few people resident in their proximity (Wunder and Borner 2013). Aside from the direct harvesting of goods and products from the forest, the wider environment is often managed for agricultural systems, characterised by shifting cultivation, or swidden.

While large areas of forests occur in landscape mosaics outside of formal management systems, a considerable area of the forest estate is under formal protection. As of 2014, terrestrial protected areas cover 15.4% of the Earth's surface, much of which include forests[3]. While some of these protected areas are afforded the highest level of protection, they have an important role to play in rising to this FSN challenge. At a global level, millions of people depend on protected areas as a means of subsistence (FAO 2014). 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 which contribute to sustaining livelihoods and may even attraction immigration (Joppa 2012).

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

The benefits of protected areas extend far beyond their immediate environs. These areas natural safeguard biodiversity, including the wild plant relatives of crops (Sunderland 2011). The biodiversity of terrestrial and aquatic ecosystems has provided food, including fish, plants, seeds, honey, fruits, mushrooms and insects, as important components of the diets of local inhabitants for thousands of years. Protected areas also provide ecosystem services, such as pollination and pest control, with mountain areas playing a special role through their contribution to clean water and decreased disaster risks (Foli 2014).

In some forested regions of the world, notably dry forests (Sunderland *et al.* 2015) natural “parklands” also provide important functions for FSN. Parkland agriculture/pasture provides important contributions to FSN through the provision of woodfuel, shade, crop protection, soil and soil fertilization through nitrogen-fixing trees. For example, parklands containing nitrogen-fixing tree species have been shown to more than triple yields of maize in Zambia (Baudron *et al.,* 2007). Similarly, trees in agroforestry parklands also directly provide diverse sources of nutritionally-rich foods that otherwise may be lacking in diets. As is the case in southwest Burkina Faso where *Vitellaria* butter was found to be the only source of fat in the diets of children (Crélerot, 1995) and *Parkia biglobosa* seeds – widely consumed in parklands in West Africa – contained a source of lycine unobtainable from the most common staple foods of millet and sorghum (Campbell-Platt, 1980).

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 (World Parks Congress, 2014). Substantial stretches of national territories and forested areas are included in this protective regime, and the total area is increasing on all continents. The growing prominence of protected area networks in the context of rural or agricultural development is problematic for food security and nutrition because of its specific method of restricting resource use for local populations. In its dominant form this style of conservation often neglects the needs and aspirations of local people, their indigenous knowledge and management systems, their institutions and social organizations, and the value to them of wild resources. As a result forest based national parks and protected areas have usually led to extensive resource alienation and economic hardships for many rural social groups, and 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 populations living nearby or excluded from protected areas Colchester, 1994; Pimbert and Pretty, 1995)

In the context of protected areas, sustainable forestry for FSN calls for greater emphasis on community-based natural resource management and 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 ecologies, recognising customary rights of access and usufruct over forests and their products, honoring 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 organisations representing them (Pimbert and Pretty, 1997). 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.

Box 4 Swidden agriculture – the example of the Karen of Thailand

Forest-based subsistence agriculture, characterized by shifting cultivation or “slash-and-burn”, while suitable in cases where there is abundance of land and low human population, could lead to forest degradation in situations where there is human population coupled with scarcity of land for agriculture. This in turn compromises FSN due to lost biodiversity upon which many rural poor households depend for their livelihoods.

The extent and impacts of shifting cultivation throughout the forests of the tropics is debated (van Vliet *et al.* 2012). Swidden and fallow systems are typically not recorded in statistical data sets and the dynamic nature of swidden systems makes remote sensing a challenge at large scales. Regional estimates for Southeast Asia suggest the practice is common in most countries with relatively large areas of forest remaining (Schmidt-Vogt *et al.*, 2009). It is estimated that, in Southeast Asia alone, there are between 14 and 34 million shifting cultivators (Mertz *et al.*, 2009). Most traditional peoples in the region still rely on swidden agriculture for their livelihoods, crucial to rural food security, particularly among indigenous societies, with supplementary foods and income derived from wild product harvest (Erni, 2015; Ickowitz *et al.* 2016).

The indigenous Karen of Eastern Thailand have traditionally been secondary forest swidden farmers, whereby they cleared a small patch of secondary forest, farmed it for one year, and then left it fallow for a number of years. When the vegetation on that land had recovered, it was burned again (thereby returning the nutrients to the soil), and the cycle was repeated. In Thung Yai Naresuan, the Karen used to leave their fields fallow for 10 to 15 years or so. This allowed for a sustainable harvest with no needs for artificial fertilisers and pesticides. However, it was rather land intensive, and to limit the amount of forestland cleared by the Karen, the government imposed a fallow period of five years at most. Over the years, this has led to a sharp reduction in the level of the harvest, since five years of fallow are not sufficient for the soil to regain its original fertility. Many Karen now need to buy rice. In spite of this, the needs for cash are still rather small, also because the availability of NTFPs diminishes the amount of food that the Karen need to buy. The Karen have traditionally lived in small, isolated hamlets far from the market, growing the rice they needed and extracting from the forest the wild food plants that supplemented their rice harvest. Food plants gathered in the forest still form an essential part of Karen diet: 80% of the food plants they eat come from the forest.

Source: Adapted from Delang 2006: http://www.sciencedirect.com/science/article/pii/S0921800905004611

2.4.2 Managed forests

Managed forests can contribute to FSN through the provision of income from timber, cash crops, the provision of food from agroforestry systems and semi-cultivated/semi-wild food provision. In addition, managed forests contribute to FSN through the provision of ecosystem services. Managed forests can consist of timber concessions, secondary forests , community forests, indigenous community land or private forests. In many countries, the communities (*mestizo* or indigenous peoples) have access to the forests through concessions (Guatemala) (Orjuela, 2015), communal property (Nicaragua) (Henao Bravo *et al.*, 2015) or forest use rights (Honduras) (Forest Trends, 2013), and they produce wood, food, fodder and NTFPs.

Sustainable forest management was not a concern for many nations until the ***Forest Principles*** were adopted in 1992 at The United Nations Conference on Environment and Development in Rio de Janeiro[4]. The *Forest Principles* is a non-legally binding document that outlines suggestions for sustainable forestry but has provided an invaluable framework for implementation (Sloan and Sayer 2015).There are over 400 million hectares of forest set aside for timber management in the tropics (Brandt *et al.* 2015). Formal forest management is much more prevalent, and diverse, in the Boreal and temperate forest biomes (MacDicken *et al.* 2015) where the majority of the permanent forest estate is under some type of formal management regime.

2.4.3 Agroforestry

Agroforestry is a collective name for land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in spatial mixture or temporal sequence. Today there is a consensus of opinion that agroforestry is practiced for a variety of objectives. It represents, as depicted in Figure 6, an interface between agriculture and forestry and encompasses mixed land-use practices. The term is used to denote practices ranging from simple forms of shifting cultivation to complex hedgerow intercropping systems; systems including varying densities of tree stands ranging from widely-scattered *Faidherbia albida* trees in Sahelian millet fields, to the high-density multistoried homegardens of the humid tropics such as the rubber gardens of Indonesia (Rahman *et al.* 2016); and 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 to local communities, the environment and local economies that contribute to FSN. The benefits include provision of shade in parklands and agricultural landscapes, important for shade-tolerant agricultural crops/species especially garden vegetable crops such as potato, cabbage, kale, carrot, lettuce, chive, oregano, parsley, beans and peas, broccoli, mint, lettuce, spinach and cauliflower (Ahsan, 2014), improved soil

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

fertility resulting in increased crop yields, provision of fodder for livestock, provision of fuelwood and improving household resilience through the provision of additional products for sale or home consumption. Many 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 is not widespread in European forests. However, hedgerows and windbreaks are still very common, especially in central Europe (Herzog, 1998). Pasturing on forest land does also exists with for example cattle, sheep and goats, or wild boars and pig husbandry (von Maydell, 1994; Brownlow, 1992; 1994). A more widespread agroforestry system through out western, central and eastern Europe is the *streuobst*[5] system which is a system of plantations of trees in combination with pastures. The system can be found in central Europe, e.g., Switzerland 3,9 %, Croatia 2,14 % and Germany 2,9 % of agricultural land. In the more northern forests and in the boreal zone, the system is very limited (e.g., in Sweden, Finland and Netherlands the system is non-existent). The system is often underrated as a provider of fruits for household use and few studies are available although the system is considered an important form of land use, especially in hilly terrain for family farmers combining crop and cattle production (Herzog, 1998).

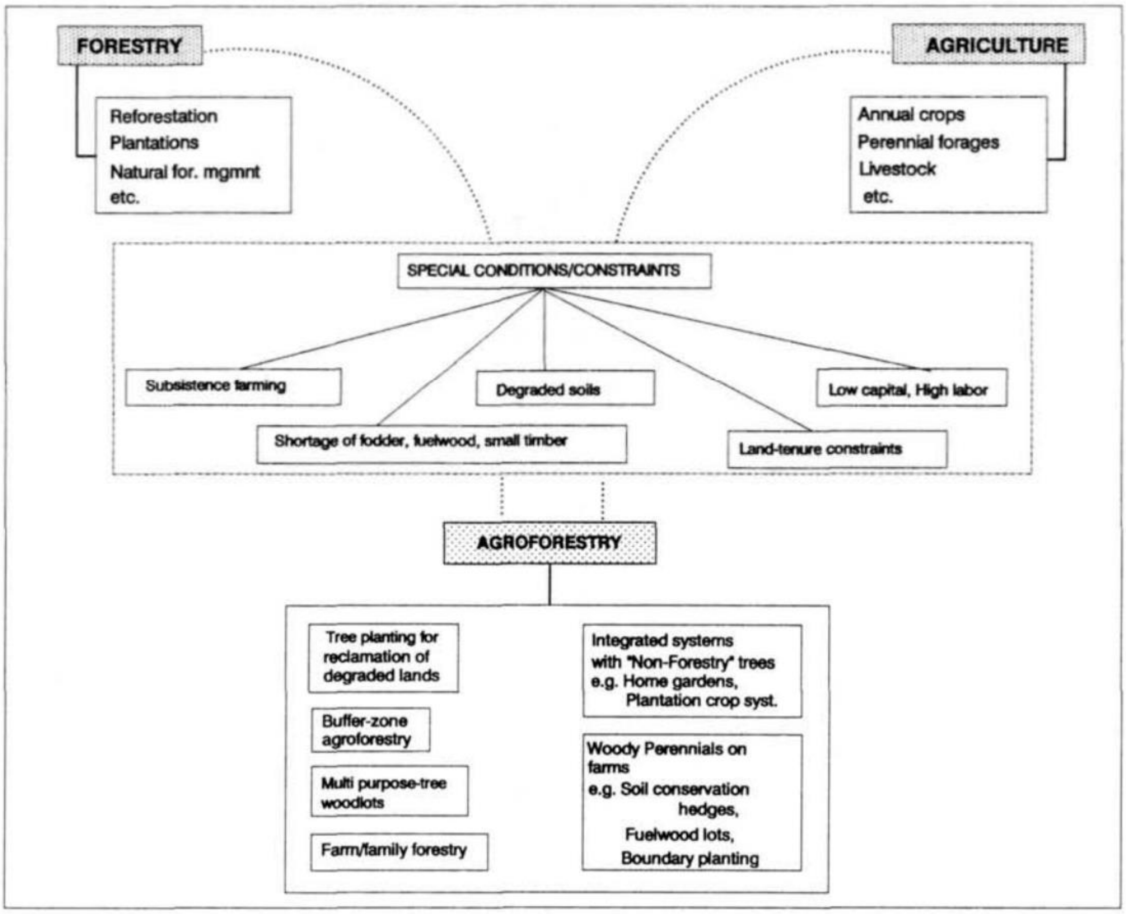
Silvopastoral agroforestry is the most dominant form of agroforestry found in developing countries (Sharrow *et al.,* 1999), notably the drier parts of the tropics, and also in many temperate zones such as North America (Clason, 1995). Silvopastoral systems contribute to FSN by providing grazing pasture for livestock, fodder and protection for animals. In addition to livestock, fruit or legume trees are often incorporated providing an additional direct source of foods. For example, in one district of the United Republic of Tanzania, silvopastoral agroforestry systems were found to contribute 34 percent of all household food supply (Shilabu, 2008). 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). In Europe agroforestry has had a strong tradition. However, with the intensification of agricultural activities in Europe, agroforestry have declined since the 1950s (McAdam *et al.*, 2009).

In silvo-arable systems, agricultural or horticultural crops are grown simultaneously with a long-term tree crop to provide annual income while the tree crop matures. Trees are grown in rows with wide alleys in-between for cultivating crops and can increase productivity of arable crops by protecting crops from wind, pests and environmental degradation. In addition, trees can often be edible species providing additional sources of food. Silvoarable systems has been shown to reduce environmental degradation and loss of fertility of arable land by reducing the leaching of nitrates and maintaining soil integrity. 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).

Forest farming typically focuses on commercially or locally important crops, grown under a canopy. The canopy provides shade to crops sensitive to the extremes of light and temperature. Forest farming typically provides high levels of NTFPs including fruits and other edible plants as well as mushrooms, nuts and seeds. Forest gardening, sometimes considered a subset of forest farming, involves intentional management of forest systems to create understory conditions suitable for herbaceous plants, shrubs and vines. Forest gardens utilize all layers of the forest with fruit trees dominating the canopy layer, nut trees in the lower-tree layer, shrubs consisting of fruit and berries, and herbs and vegetables in the herbaceous layer. In addition, vegetables can be grown on the ground layer and tubers and root staples in the subterranean layer. An additional vertical layer consisting of vines and figs can also connect the layers. Typically forest gardens are highly diverse, contributing to dietary diversity through the provision of fruits, nuts and green leafy vegetables.

[5] Streuobst is defined as "*tall trees of different types and varieties of fruit, belongong to different age groups, which are dispersed on cropland, meadows and pastures in a rather irregular pattern*" (Herzog, 1998:62).

Figure 6 Agroforestry has developed as an interface between agriculture and forestry



2.4.4 Plantation forests

Plantation systems such as timber plantations, agribusiness plantations of tree crops (e.g. oil palm) and smallholder plantations generally contribute to FSN through providing a source of income, employment and economic growth. In addition, they provide some, but not all ecosystem services to agriculture. Generally these plantation systems provide low quantities, if any, of edible NTFPs and do not directly provision foods. Sustainable forestry systems however, often incorporate or set aside areas of high conservation value (HCV) – areas of forest assessed to be of high importance for local communities and biodiversity conservation. Such HCV areas can provide sources of NTFPs 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 remains a challenge. Community access to commercial plantation areas for such use is also contentious in many contexts. Nevertheless, there are 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. In these systems, the non-forest crop provides food, cattle or a permanent crop in order to keep a positive cash flow in the system. In such systems is possible to find mixes such as teak/cattle, mahogany/parsley/cocoa/cattle, eucalyptus/coffee; eucalyptus/rice/soybeans/ sunflower/cattle, etc. (de Camino *et al.,* 2012).

Plantation systems comprise timber and agribusiness plantations. Timber plantations are mostly for sawlog and pulp production. Indufor (2012) estimated the world's total area of industrial timber plantations at 54 million ha with Asia having 17.7 million ha, followed by North America (12.8 million ha) and Latin America (12.8 million), Africa (5 million ha), Oceania (3.7 million ha) and Europe (2 million ha) (Table 16).

Table 1 Industrial timber plantations by region

Region	Area (million ha)	Percentage
Asia	17.7	32
North America	12.8	24
Latin America	12.8	24
Africa	5.0	9
Oceania	3.7	7
Europe	2.0	4
Total	54.0	100

Source: Indufor, 2012.

Oil palm, rubber and jatropha (for bio-diesel production) plantations dominate agribusiness plantations especially in Southeast Asia, the Amazon and Congo basins. While both timber plantations and agribusiness plantations contribute in a limited way to FSN through income generation and employment to surrounding local communities, they provide low quantities of NTFPs and forest foods due to diminished biodiversity compared to indigenous forests that contain higher levels of biodiversity. The contribution of plantation systems to FSN and livelihoods is often at the cost of negative environmental and social impacts.

2.5 Characterising the social and economic importance of forests

Forest dependence

FAO defines three typologies (Fisher *et al.*, 1997) of forest dependent people: across the broad spectrum of the forest transition.

- (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 the proximity to forests, are usually involved in more extensive agricultural practices either within or outside the forest, and who 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 productivity. These landscape mosaics are of immense importance for the provision of ecosystem services.
- (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. Where these people differ from the first two categories is in the fact that they depend on direct cash income both from forest-dependent labour and from direct subsistence use of forest products. It is important to note, however, 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.

Various attempts to quantify the number of forest-dependent people have been made, although all rely on different methodologies and definitions. While such figures should not be considered anything other than "guesstimates", various estimates have placed number of people considered forest dependent at between 250 million (Pimental *et al.,* 1997), 500 million (Lynch *et al.*, 1995) over one billion (WCFSD, 1999; Agrawal *et al.* 2013) up to 1.6 billion (Chao 2012). In terms of direct forest income the Poverty and Environment Network calculated that almost one fifth of rural income is derived from forest and environmental resources, often outstripping that of direct income from agriculture (Box 5).

Box 5 Indicative figures for forest dependence

- Up to 1.6 billion people dependent on forests
- In developing countries, ca. 1.2 million people rely on agroforestry farming systems
- 1 billion out of 1.2 billion extreme poor depend on forest resources for all, or part, of their livelihoods
- 300-350 million people are highly dependent on forests and live within, or adjacent to, dense forests on which they depend for their subsistence and income
- 600 million forest users qualify as long-term users
- 200 million forest dependent people are indigenous peoples

Source: Chao; 2012

Situated within the forest typologies based upon management practices outlined above (Fisher *et al.,* 1997), we can assume that forest dependence type A is found most commonly within natural forests, forest dependence type B in natural and managed forests, including agroforestry systems, while forest dependence type C is predominantly found within plantation forests and managed forest.

Box 6 Rural 'environmental income' on par with crop income

Natural forests and wildlands across 58 tropical research sites provide 28 percent of total household income — nearly as much as crops — according to a new study. The study, titled "Environmental Income and Rural Livelihoods: A Global-Comparative Analysis," is the product of the Poverty and Environment Network (PEN), a collaborative effort led by the Center for International Forestry Research (CIFOR). The largest quantitative global-comparative research project to date on forests and rural livelihoods, it analyzes data gathered from some 8,000 households in 24 developing countries

In addition to research on income generation and rural livelihoods, the global study tackles the themes of safety nets during shortfalls, gender and forest use, forest clearing and livelihoods, and tenure and forest income. The researchers define "environmental income" as extraction from non-cultivated sources including: natural forests, other non-forest wildlands such as grass-, bush- and wetlands, and fallows, as well as wild plants and animals harvested from croplands. The study was also designed to explore questions about the relative and absolute importance of environmental income across different socio-economic groups. Whereas previous research has suggested that a household's dependence decreases with higher incomes, the PEN study adds nuance to these findings.

Environmental income varies considerably across the study sites. Two sites in Indonesia, for example, have forest income shares of about 5.5 percent, while a site in Bolivia generated 63 percent of household income from forest products, mainly in the form of the valuable Brazil nut. The study found that 77 percent of environmental income comes from natural forests. Of this percentage, wood fuels dominate, accounting for about 35 percent of forest income. Food, including fish and bush meat, wild fruits, vegetables and mushrooms, make up 30 percent. Structural and fiber products, including both wood and non-wood products, account for the balance.

In another thread, the study found that environmental income is particularly important for male-headed households, younger households and larger households. Analysis suggests that older households have more assets and rely more heavily on crops and livestock. Older people may also be less physically able to access forest and wild resources. The study did not find any universal support for the claim that environmental income is more important to households that are female headed. Since rural households rely on foraging in forests and wildlands for a large share of household income they might be better off than what their often-modest income from agriculture, wages, and small businesses alone would suggest.

Source: http://blog.cifor.org/22173/rural-environmental-income-on-par-with-crop-income-study-finds

Angelsen et al. 2013: http://www.cifor.org/online-library/browse/view-publication/publication/4499.html

Box 7 Associations between forest cover and dietary quality and diversity, examples from Africa and South-East Asia

The relationship between forests and human diet and nutrition is not yet well understood: A better understanding of this relationship is vital at a time when the majority of new land for agriculture is being cleared from forests. A number of recent studies have paired satellite-based land cover data with dietary data collected by survey to examine the relationship between forest cover and diet quality and diversity.

Africa: Ickowitz *et al.* (2014) analysed the USAID Demographic Health Survey data on food consumption for children from 21 African countries combined with Global Land Cover Facility tree cover data to examine the relationship between tree cover and three key indicators of nutritional quality of children's diets: dietary diversity, fruit and vegetable consumption, and Animal Source Food consumption. This study found that there is a statistically significant positive relationship between tree cover and dietary diversity; fruit and vegetable consumption increases with tree cover until a peak of 45 percent tree cover and then declines; and there is no relationship between animal source food consumption and tree cover.

Malawi: Johnson *et al.* (2013) also use Demographic Health Survey data from 23,000 households across Malawi (2010) and remote sensing data on tree cover loss (from Modis). They find that children in Malawi who lived in communities that have higher forest cover were more likely to consumed vitamin A rich fruits. The study also reports that children living in areas that had experienced deforestation were 19% less likely to have adequate dietary diversity, and 29% less likely to have consumed vitamin A rich foods than those living in areas with no forest loss.

Tanzania: A study from the East Usamabra Mountains, in north-eastern Tanzania, paired remoting sensing data on forest cover with a dietary intake of 274 children between ages of 2 and 5 years old. The study found a positive correlation between children's dietary diversity (1 day and 7 day DDS, number of food groups and FVS, number of food items) and MAR (mean adequacy ratio) and tree cover within a 1 to 2km radius of the home (Powell 2012, Powell and Johns 2015)

Indonesia: Micronutrient deficiency remains a serious problem in Indonesia with approximately 100 million people, or 40 percent of the population, suffering from one or more micronutrient deficiencies. In rural areas with poor market access, forests and trees may provide an essential source of nutritious food. This is especially important to understand at a time when forests and other tree-based systems are being lost at a historically high rate in Indonesia. Ickowitz *et al.* (in press) use food consumption data from the 2003 Indonesia Demographic Health Survey and data on vegetation cover from the Indonesian Ministry of Forestry to examine whether there is a relationship between forests and consumption of micronutrient-rich foods in Indonesia. Ickowitz *et al.* (in press) find that the frequency of consumption of vitamin A-rich fruit, green leafy vegetables, ASFs, and "other" fruits and vegetables is positively associated with surrounding landscapes of "medium" tree cover (20–50 percent) characteristic of shifting cultivation and smallholder agroforestry. The results suggest that Indonesian children living in areas with diverse tree-filled landscapes enjoy more micronutrient-rich diets.

3 ROLES AND CONTRIBUTIONS OF FORESTS AND FORESTRY TO FOOD SECURITY AND NUTRITION

3.1 The four dimensions of food security and nutrition

Forests and trees contribute to all aspects of food security: availability, access, utilization and stability. These tree- and forest-based services are vital for many populations, particularly for forest-dependent people, and need to be enhanced in order to reduce global food insecurity of the 800 million people worldwide, and reduce the global rates of malnutrition (Sunderland *et al.*, 2013; IFPRI, 2015). The relevance of the contribution of forests to food security is more important in rural areas and in populations residing within and near forests. This is especially true in Africa and Asia with 59.6 and 46.1 percent, respectively, of rural population whose locale of residence is related to forest abundance (UN, 2014).

Where information exists, it is possible to estimate the direct and indirect contribution of forests to the provision of food (availability dimension of food security). In most cases, however, forest foods are procured by people on an informal basis. Official statistics do not therefore correspond to the actual volume of forest food resources used by people, and estimates must also be derived indirectly from food consumption, forest proximity and dependence.

Forests and trees contribute to food availability (i.e. supply) through the provision of wild foods and through tree-based agricultural systems. In addition, the contributions of forests to agriculture through the provision of ecosystem services also affect food availability. Such foods are often rich in micronutrients; diets incorporating forest foods are often more diverse than those dependent on conventional agriculture alone. Income derived from forest-based activities, whether the extraction of timber or of non-timber forest products (NTFPs) and forest commodities such as oil palm, coffee and cocoa, or payment for ecosystem services and tourism schemes, directly affects economic access to foods.

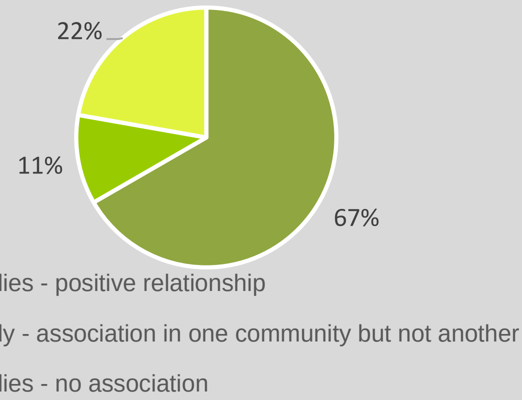
Utilization, the factor ultimately determining nutritional status, is affected by intrahousehold distribution of food, dietary choice, nutrition, the bioavailability of micronutrients, food safety, infection and disease. Forests, through their provision of rural housing, charcoal and fuelwood, contribute towards food safety and livelihood improvement, while the complex interaction between forests, health and infectious diseases means that the nutritional status of an individual is highly influenced by interactions with the environment. In many places forests also play an essential role in the provision of clean drinking water.

Finally, forests and trees may play a significant role in maintaining the stability of food systems by providing resilience against agricultural and economic shocks through the provision of wild foods and alternative sources of income as well as the supply of ecosystem services. The resilience of forest-based activities to withstand environmental shocks and economic shocks will become increasingly important in the face of global climate change and its local and regional impacts.

Box 8 Diversity within agricultural landscape and food security and nutrition

Diversity within agricultural systems can include genetic, species, farm and landscape level diversity. More diverse agricultural systems often include more trees and forests. There is growing body of evidence suggesting that agricultural diversity supports dietary diversity and quality.

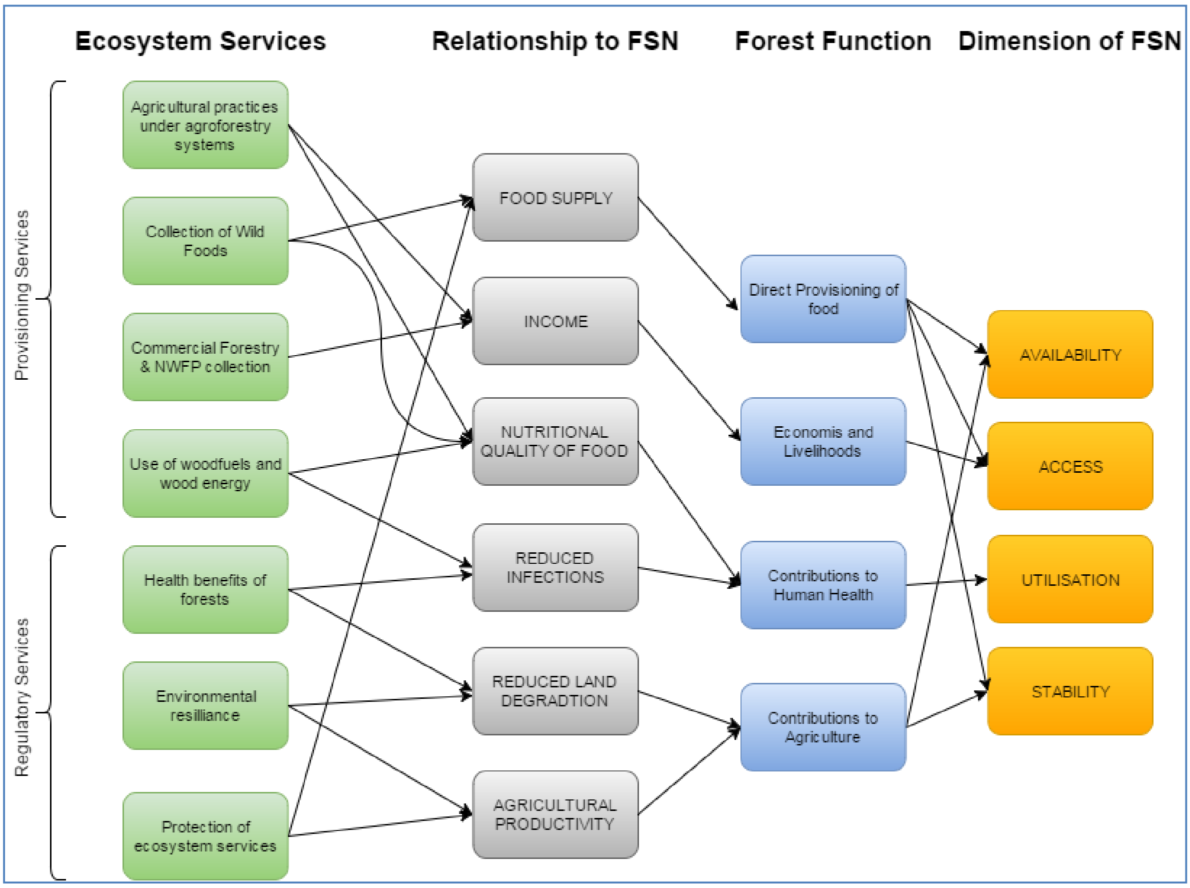
A review of the evidence: A recent review of the literature looking for primary research papers that examined the relationship between agrobiodiversity (production diversity) and measures of dietary diversity or diet quality (Powell *et al.* 2015). Of the nine studies that looked at the relationship between agrobiodiversity and dietary diversity identified by the review, 6 reported a positive relationship, 1 reported a positive relationship in one site but not another and two reported no relationship (see chart below). The review also identified two studies reporting a positive relationship between agrobiodiversity and mean nutrient adequacy (MAR); one study reporting a positive association between agrobiodiversity and infant and young child feeding practices; and two studies reporting a positive association between agrobiodiversity and intake of nutritious foods such as fruits and vegetables. Despite limitations, and a possible bias for publication of positive results, the consistency of a relationship between dietary outcomes and crop diversity across existing studies is notable.



Many recent studies: In addition to those included in this review a number of additional studies that also show a positive relationship between agrobiodiversity and biodiversity in the past year. A number of studies were included in a recent special issue in the Journal of Development Studies (Carletto *et al.* 2015, Kumar *et al.* 2015). Two recent studies highlight that although the impact of agrobiodiversity on dietary diversity is significant in the majority of studies, the magnitude of the impact is modest relative to other factors that mediate dietary quality (Dillon *et al.* 2015, Sibhatu). As with the impact of wild forest foods, maintaining or increasing agrobiodiversity alone will not likely enough to overcome food insecurity and malnutrition but rather, can be one “tool” in a tool box that includes multiple diverse options and strategies.

Figure 7 shows how multiple ecosystem services provided by forests relate to FSN. Under this model, individual functions of forests are grouped according to their relationship with FSN categorized into the four main functions of forests to FSN. The figure also shows the linkages between each of forest functions and each of the dimensions of FSN.

1 **Figure 7 Forest functions and their links to FSN**



2

Box 9 Forestry and FSN linkages at a glance

Micronutrients

Foods from forests — leaves, seeds, nuts, fruits, mushrooms, honey, insects and wild animals — are rich in micronutrients. Globally, they tend to contribute only a small amount of caloric energy, but make an important contribution to diet diversity and nutrition. For example, in rural parts of Tanzania, wild foods contribute 2% of energy intake and 19–30% of vitamin A, vitamin C and iron. In developing countries, where people with micronutrient deficiencies number in billions, forest foods contribute to the fight against this so-called "hidden hunger". Stable access to food is income sensitive Cash income can give households greater access to nutritious foods and serve as a buffer when their own food production has gone awry.

Direct employment and cash income

Forests provide formal employment to 13.2 million people worldwide and a source of income in informal systems to at least another 41 million. Fuelwood and charcoal production are estimated to contribute to the income of 20% of Africa's population.

Stability and resilience

Forest foods are rarely the sole source of caloric energy for families. Yet people eat more wild foods — including those from forests and trees — in seasons when other food is less plentiful. For some households, forests also provide safety nets in times of scarcity. Having access to wild foods for both household consumption and sale can increase households' diversification and hence strengthen their resilience to climate variability and external shocks.

Biodiversity and ecosystem services

Globally, forests also hold up to 80% of terrestrial biodiversity, a repository of genetic resources that may prove crucial for adapting to climate change in the future. Many forest ecosystem services underpin food production Forests protect soil and water, maintain soil quality, help regulate local climates, provide habitats for pollinators and predators of agricultural pests, and are storehouses for biodiversity. These ecosystem services are crucial for maintaining the sustainability and nutrition sensitivity of farms, and provide a strong case for mosaic landscapes that integrate trees with agriculture.

Gender issues

Empowering women can strengthen food security for communities. The roles of women and men in collecting, producing and using tree and forest resources tend to differ, depending on the region.14 Usually, women's specialist knowledge revolves around household food and nutrition, and is crucial for communities navigating through food crises. Yet women often have limited access to and benefits from forests and trees.5 Researchers argue that empowering women in the forestry sector and achieving gender balance in decision-making groups will help increase the contribution of forests to food security.

A part from the above considerations, it must be said that the relationship between forests and human nutrition is not yet fully understood: a better understanding of this relationship is vital at a time when the majority of new land for agriculture is being cleared from forests. To further explore this understanding, a series of macro-level data-rich assessments has been undertaken. Their coverage includes Indonesia, 23 counties representing humid and dry forests in Africa and a tropics-wide assessment, using data from the Poverty and Environment Network (PEN).

Indonesia. Micronutrient deficiency remains a serious problem in Indonesia with approximately 100 million people, or 40 percent of the population, suffering from one or more micronutrient deficiencies. In rural areas with poor market access, forests and trees may provide an essential source of nutritious food. This is especially important to understand at a time when forests and other tree-based systems are being lost at a historically high rate in Indonesia. Ickowitz *et al.* (in press) use food consumption data from the 2003 Indonesia Demographic Health Survey and data on vegetation cover from the Indonesian Ministry of Forestry to examine whether there is a relationship between forests and consumption of micronutrient-rich foods in Indonesia. Ickowitz *et al.* (in press) find that the frequency of consumption of vitamin A-rich fruit, green leafy vegetables, ASFs, and ”other” fruits and vegetables is positively associated with surrounding landscapes of ”medium” tree cover (20–50 percent) characteristic of shifting cultivation and smallholder agroforestry. The results suggest that Indonesian children living in areas with diverse tree-filled landscapes enjoy more micronutrient-rich diets.

Africa. Ickowitz *et al.* (2014) analysed the USAID Demographic Health Survey data on food consumption for children from 21 African countries combined with Global Land Cover Facility tree cover data to examine the relationship between tree cover and three key indicators of nutritional quality of children's diets: dietary diversity, fruit and vegetable consumption, and ASF consumption. This study found that there is a statistically significant positive relationship between tree cover and dietary diversity; fruit and vegetable consumption increases with tree cover until a peak of 45 percent tree cover and then declines; and there is no relationship between ASF consumption and tree cover. Overall, the findings of Ickowitz *et al.* (2014) suggest that children in Africa who live in areas with more tree cover have more diverse and nutritious diets.

Tropics-wide. Rowland *et al.* 2015 investigate the dietary contributions of wild forest foods in smallholder dominated forested landscapes in 24 tropical countries. Also using PEN data, the study estimated the contributions of micronutrient-rich forest foods to meeting dietary recommendations, compared quantities of forest-sourced plant and ASFs consumed with national averages and compared the relative contributions of forest foods to smallholder agriculture. Rowland *et al.* (2015) find high variability in forest food use and create four forest food use site typologies to characterize the variation; forest food-dependent, limited forest food use, forest food supplementation and specialist forest food consumer sites. Their results suggest that forest foods do not universally contribute significantly to diets but in some sites where large quantities of forest foods are consumed their contribution towards dietary adequacy is substantial.

Source: *http://www.cifor.org/publications/pdf_files/factsheet/4876-factsheet.pdf*

3.2 Direct provision of forest foods

Box 10 Tapping into Congo Basin's forest foods for increased nutrition security

Forest products make a major contribution to household food and nutrition security in the Congo Basin, However, these products are overlooked by governments in the policy guidelines on nutrition. Nutrition specialists are advocating that forest foods and their products should be promoted as important components of peoples' subsistence food needs, diversifying diets and generating income.

Food products from wild forest trees complement agricultural crops in several important ways that enhance nutrition and food security, notably providing important macro and micronutrients otherwise lacking from family diets of rural people in these countries. For example, 200 g of moabi fruit (*Baillonella toxisperma*) or nuts of the bean tree (*Pentaclethra macrophylla*) tree could supply 100% of the daily requirement of iron and zinc for a 1-3 year old child. In order to increase the nutritional quality and diversity of peoples' diets and decrease levels of malnutrition affecting forest dependent communities of Congo Basin countries, crops that can be found on farm should be enriched with the consumption of food from forests. Despite this potential, researchers found that most communities in the forest areas suffer from food insecurity and malnutrition. This reflects, to a large degree, their choice to sell many of these products rather than consuming them, the lack of complementary protein sources (for example meat, fish, eggs and dairy products) and their low awareness levels regarding forest foods' nutritious capabilities.

Nutrition specialists found that the forest dwellers of the Congo Basin did not appreciate the potential of forest tree foods to address malnutrition in children. About 70% of the individuals interviewed in these communities did not know that these forest foods could improve the health of their children. However, those in most need turn to forest products more often, researchers discovered. The poorest households, which suffered the effects of chronic illness or even death related to malnutrition relied more on forest resources for food and medicine. Fruits of the moabi tree (*Baillonella toxisperma*) and the nuts of the bean tree (*Pentaclethra macrophylla*) - nutritious forest foods, with high proportions of bioactive ingredients, micronutrients and vitamins, become highly coveted for, when there is a young ill child or a pregnant or breastfeeding woman in a household.

An environment rich in wild foods does not automatically correlate with knowledge, a positive attitude and full use of forest foods to complement the diets of forest dependent communities. Also, food security does not directly translate into nutrition security, as even diets that provide enough calories do not provide a balance of needed nutrients. In order to change the negative attitudes and perceptions towards forest foods among the communities of the Congo Basin, it's important to raise awareness of the value of nutrient rich forest foods. Furthermore, given the importance of forest foods, it is imperative that the forestry sector is included in the formulation and implementation of policies for food security and nutrition, poverty alleviation and rural development. Governments should encourage community ownership of policy guidelines, by engaging vulnerable groups, such as indigenous peoples, local communities, women, youth and the disadvantaged men, in the development of tenure, governance, use and management of forests.

Source: Adapted from "Beyond Timber. 2014.
http://www.bioversityinternational.org/news/detail/tapping-into-congo-basins-forest-foods-for-increased-nutrition-security/

3.2.1 Global supply of forest foods

Based upon macro-level indicators, an estimated 76,138 tonnes of forest foods are consumed globally, the vast majority of which come from plant-based NTFPs (95 percent) and from Asia and Oceania (81.5 percent). Forest food has been calculated to contribute 0.6 percent of global food energy supply (FAO, 2014a). Such figures, however, almost certainly vastly underestimate the contribution of forest foods to global supply due to the lack of available data. There is a need to complete regional and local analyses and collect more accurate and informative data. It may be that for a country the proportion of supply of food from the forests is minimal, but for a region or a rural and remote community it can be fundamental (Food Secure Canada, 2008). A recent review of wild food consumption found major variation in the importance of wild foods from one site to another (Powell *et al.*, 2015). Moreover, because the majority of wild forest foods consumed are fruits and vegetables, these figures do not accurately represent the contribution of wild forest foods to dietary quality. For example, despite low to moderate contribution to energy intake, wild foods contributed 36 percent of total vitamin A and 20 percent of iron in the diet in a study from Gabon (Blaney *et al.,* 2009), and 31 percent of RAE (vitamin A) and 19 percent of iron in the diet in a study from the United Republic of Tanzania (Powell *et al.,* 2013b), and in a traditional swidden agricultural community in the Philippines, wild foods contributed 42 percent of calcium, 17 percent of vitamin A and 13 percent of iron (Schlegel and Guthrie, 1973).

When converted to calories, the above figures on forest food contribute very low amounts of nutritional energy. Overall, forest foods appear to contribute only 16.5 kcal per capita per day. As stated above, such figures probably vastly underestimate but also they crucially vastly underappreciate the nutritional role these foods may play in people's diets. The problem with the estimates can be attributed to the informality of the exchange and trade of products and the lack of statistics at state and province level within countries, because the relative importance changes depending on the degree to which the areas in focus are rural in nature. While forest foods provide little of the global energy requirements (FAO, 2014a), they are often an important source of micronutrient-dense foods such as fruits, vegetables and ASFs (Vinceti *et al.*, 2008; Powell *et al.*, 2013a). Because of this, in some contexts they contribute a significant amount of the micronutrients in the diet (Powell *et al.*, 2015). As a result, they contribute significantly to dietary diversity and nutritional quality (Powell *et al.*, 2015). A significant diversity of traditional wild foods has been lost due to the global food supply becoming increasingly homogenized (Khoury *et.al.,* 2014). This is true for people living in or near the forests and less so in regions, countries and places where urban population is the higher proportion. Forests supply nutritious fruits and vegetables to supplement diets during lean seasons. In Sahel ecosystems with dry spells lasting up to seven months a year, trees and shrubs are crucial sources of food to supplement cereal staples (Nyong *et al.*, 2007) and also fodder for livestock (Frantzel *et al.* 2014).

Fruit is an essential part of healthy balanced diets (Siegel *et al.,* 2014). There is strong evidence that fruit and vegetable consumption is associated with increased consumption of certain micronutrients and is strongly associated with reduced risk of chronic diseases: recent WHO/FAO guidelines recommend 400 g/person/day of fruits and vegetables (WHO/FAO, 2004). Global production of fruits and vegetables is far below these requirements, while at the same time approximately 50 percent of the fruit that is produced globally is produced on trees (Powell *et al.,* 2013a). From the total fruit production in 2013, 64.4 percent consisted only of five species (bananas, apples, grapes, oranges and mangoes) of a total of 21 species of fruits traded internationally; there are no records available for forest fruits alone.[6] Nevertheless, there has been increasing interest in many wild fruits over the last two decades, and their products are not consumed only by forest dependent people, but may also be found in urban markets in the cities and even in international markets (WHO/CBD, 2015; López *et al.,* 2004).

There is emerging evidence of a positive link between tree cover and fruit and vegetable consumption (Powell *et al.*, 2015). Initial evidence suggests that forests and areas with tree cover may play an important role in enhanced vegetable access and production among smallholder farmers, as shown by recent statistical research in Africa (Ickowitz *et al.,* 2014). Forests and areas with tree cover may enhance vegetable intake by providing vegetables in the form of leaves and fruit. Ecosystem services provided by trees and forests may also increase the productivity of fruit and vegetable production within agricultural systems. Such integrated systems also support the availability of wild and cultivated vegetables by providing the microclimates needed for vegetables to grow as well as other ecosystem services.

Micronutrients found in ASFs are highly bioavailable, meaning they are easily absorbed and utilized by the body. In contexts with high rates of micronutrient deficiency and low rates of overnutrition, 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, as an important form of ASFs should not be underestimated.

---

[6] Statista. 2015. Global fruit production in 2013, by variety. http://www.statista.com/statistics/264001/worldwide-production-of-fruit-by-variety/

Box 11 Bushmeat, forests and food security, potential and risks

In Madagascar, it has been estimated that removing access to wild meat would increase the rate of anaemia in children by 29 percent (Golden *et al.*, 2011). But at the same time this potential contribution needs to be managed in order not to exhaust the supply: sustainability is an important issue (van Vliet *et al.*, 2015). In Central Africa, recent analysis suggests that in low population density regions, bushmeat may be able to contribute to nutrition without threatening biodiversity conservation (Fa *et al.*, 2015). But in most contexts, all but the fastest-reproducing species are often quickly overharvested (Nielsen, 2006). Especially for the highest demand species, the development of regulations and the design of the regulations' enforcement strategies needs to include the full and effective participation of the people who depend on the forests in their design and enforcement strategies (Mbotiji, 2002; Nasi *et al.*, 2011).

In many rural areas bushmeat provides much of the ASFs consumed (even in many of the most developed countries). In tropical areas where livestock production is limited due to tsetse fly and other environmental constraints, bushmeat is a particularly important source of micronutrients. Numerous case studies have identified the positive effects of ASFs on nutritional status and health. 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). 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 capita bushmeat consumption ranged from 3 to 89 g/person/day, depending on the distance from the national park boundary (Ceppi and Nielsen, 2014). Fallows and secondary forests that attract wild animals play a critical function in the food and dietary security of millions of rural families in Amazonia and Central America (for example, Smith, 2005; Parry *et al.*, 2009).

In many countries, overconsumption of meat is also a health risk, leading to increased risk of cancers, stroke and cardiovascular disease (World Cancer Research Fund/ American Institute for Cancer Research, 2007). Dietary concerns associated with the consumption of meat in general should however be extended to bushmeat. For instance, in the tri-state region of Brazil, Columbia and Peru, while bushmeat-consuming households consume significantly more protein and iron than non-bushmeat consuming households, they also consume higher quantities of cholesterol and saturated fatty acids (van Viet *et al.*, 2014) such as those found in beef cattle.

Congo Basin

Meat from wild terrestrial or semi-terrestrial animals, termed "bushmeat", is a significant source of animal protein in Central African countries, and a crucial component of food security and livelihoods in rural, forested areas. Estimates of bushmeat consumption across the Congo Basin range between 1 million tonnes and 5 million tonnes and harvest rates are estimated to range from 23 to 897 kg/km2 /year. 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 forestdependent people have few alternative sources of protein and income. Bushmeat is thus the main source of animal protein available and is cheaper than any source of domesticated meat. Even where it is more expensive than alternatives, bushmeat is essentially a "free" source of protein as it can be captured rather than purchased. As such, bushmeat plays an essential role in people's diets. In rural communities, wildlife provides significant calories, as well as essential protein and fat. Even where bushmeat is used to satisfy basic subsistence requirements, many families also use hunting to supplement short term cash needs. For hunters, the distinction between subsistence and commercial use is often blurred, with meat from the forest supplementing both diets and incomes. It is important to understand to what extent rural people depend on bushmeat, rather than simply use it, and would therefore suffer if the resource diminished. 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. Barriers to access mean that in some cases it is the middle income or wealthier households in a community that benefit most from hunting, although the relative importance of this to development is negligible where all members of a community may be poor.

Source. Van Vliet et al. 2010. http://carpe.umd.edu/Documents/2010/SOF_2010_EN_Chap_6.pdf

Box 12 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% 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 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 significant value and income to 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 people, control commercial trade, manage forest access and off takes, and also promote alternative livelihoods for potential commercial hunters.

Source: *Adapted from Kümpel, 2006*. https://www.zsl.org/sites/default/files/document/2014-01/Incentives-sustainable-hunting-bushmeat-kumpel-2006-phd-thesis-765.pdf

3.2.2 Regional supply of forest foods

When forest and tree food products enter markets, they may contribute to the food supply over relatively large distances. Data from the DRC for instance, show that approximately 4.5 million tonnes of bushmeat are extracted annually from the Congo Basin forests alone (Nasi *et al.,* 2011). Much of this enters local and regional markets contributing to overall food supply.

Bushmeat markets in some regions are highly developed and can stretch hundreds of miles from the source of the bushmeat. So great is the difference between the supply and the national and regional demand for bushmeat, that bushmeat crises have developed in some areas such as central Africa (Bennet *et al.,* 2007; Nasi *et al.,* 2008). Scarcity of bushmeat as a result of such crises has in turn led to price increases, and bushmeat can in some areas be more expensive than conventional protein sources (eggs, beef meat, etc.). Recent case studies on the consumption of bushmeat between rural and urban children from Kisangani in the Democratic Republic of the Congo (van Vliet *et al.*, 2015) shows evidence that despite the tendency towards more urbanized population profiles and increased livelihood opportunities away from forest and farms, wildlife harvest remains a critical component of nutritional security 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” (FAO, 1999). Nasi *et al.* (2011) estimated that in central Africa 289 000 tonnes per year (or 6 percent) of the 4.6 million tonnes per year of total bushmeat extracted in Congo Basin, was consumed primarily in urban areas. Conversely, in the Amazon Basin, the 1.3 millions to tonnes of bushmeat extracted was consumed mainly in rural areas (Nasi *et al.*, 2011). In Columbia, bushmeat consumption was found to be lower in urban areas than rural ones, and in urban areas wealthier families consumed bushmeat more frequently than poorer ones (van Vliet *et al.,* 2015).

The alternative to domesticate bushmeat producing animals has also to be taken carefully. Bushton *et al.* (2004) state that there are many factors to be taken into account before exploring a the possibility to try a high scale of domestication, for example: species need to have the complete set of biological characteristics; ii) wildlife farming is more associated with the production of high-value products (skins, live animals, primates and ornamental or songbirds); iii) costs of meat are higher per kilogram than meat from conventional farming or bushmeat from hunting; iv) people that consume wild meat have low purchasing power; v) it might encourage increased hunting given the economics, regulating and policing such farms are subject to; the medium- to long-term objective of wildlife farming; and vi) the need to reduce costs to similar levels as meat produced by conventional farms. In some cases, wildlife farming for meat production is not a biologically viable activity and, in all cases reviewed, not an economically viable activity (Rushton *et al.,* 2004). This statement does not mean that wildlife farms are not feasible, bur a careful approach is necessary.

There may be as many as 5,000 forest products that reach local markets (Ndoye, 1997). In parts of West Africa, shea butter is one of the main sources of cooking fat; baobab and other tree leaves are one 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 the Maya forest in the North of Guatemala, Belize and Southern Mexico, the forests provide many NTFPs 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 (*Camaedora ernestii-agustii*), which is an ornamental palm for export; bayal (*Desmoncus orthocantos*), a fibre for handycrafts; guano (*Sabal* sp.*),* a palm leaf for roofing or local consumption; ramón tree seeds (*Brosimum alicastrum*) for cookies 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; copal resin (*Protium copal*) for perfumes and cosmetics (Godoy, 2010).

These products do not contribute primarily to communities as staple foods. However, they provide income through trade in local, national and international markets, and some (e.g. copal) play a significant role in the community health systems and spiritual/religious practices of the Maya and other indigenous peoples. In Amazonia there are some 100 species that were domesticated and widely distributed prior to the arrival of Columbus. 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 are traded commodities. More recently, many more species are being introduced to local, regional, national and international markets (Lescano, 1996).

Box 13 Forests, food security and nutritional quality in populations near forests, Petén, Guatemala

The community of Ixlu, near Flores in the Department of Petén in Guatemala, has developed a project called Sound Forests–Sound Children, together with Rainforest Alliance. The programme involves 100 families and 3 000 children. The project targets to recover the tradition of consumption of the ramón products and export the tradition outside Petén and outside Guatemala. Ramón, *Brosimum alicastrum*, also called the Maya nut, has multiple uses, such as: the fruit, the seed and bark as cattle fodder, the fruit and seed as human and animal food: the latex as a substitute to milk and as a medicine; and the wood for construction, veneer, wood panels, furniture, fuelwood. Taking only one nutritional element 100 g of ramón contains 250 mg of calcium, while the same amount of maize, wheat or rice contains only 25 mg. The project is beginning to process ramón products industrially, and now in the villages and small town of Petén the processed food can be bought in flour, cookies, bread, etc. There is also a Mayan Nut Institute that is contributing to:

- The formation of two local NGOs: ANARAMON (*Asociación Nacional de Nuez Maya*) and CODEMUR (*Comité para el Desarrollo de la Mujer Rural*).
- In Salvador there is a process to form a national cooperative, while in México there are many cooperatives of women that have brought the Mayan nut to local and national markets.
- In Nicaragua the local counterpart of the Mayan Nut Institute, MASAGNI is also implementing the Sound Forests–Sound Kids (*Boseques sanos – Niños* sanos) initiative in 25 communities (http://mayanutinstitute.org/es/inicio/)
- The distribution of *Brosimum* is very wide, from the Mayan forest to the Amazon (in the state of Amapá in Brazil), thus the product has a larger potential than is now the case and the tree is now beginning to be harvested in a more intensive way (Vega García, 2014a, b).

Hundreds of examples like this exist worldwide.

Forests clearly play a significant role in the FSN of indigenous peoples. One particular example is that of the forest-dependent reindeer/caribou herders. In several countries, the forests are a vital habitat of their main meat source. In winter a main food source of semi-domesticated and wild reindeer is a number of related species of lichen called “reindeer lichen” (including *Cladina stellaris*). In North America (Canada and Alaska) and in northern Europe[6], more specifically in Sweden, Finland[7], Norway, and parts of the Russian Federation indigenous peoples (Sami) manage reindeers (*Rangifer Tarandus Tarandus*). Reindeers are semi-domesticated animals grazing in the forest and are used mostly for meat production, but also providing material for handicraft (like antlers and hides). However, in Sweden for instance, land use for reindeer husbandry is causing conflicts between reindeer herders and forest owners due to parallel land use with different objectives (Widmark, 2009). In Canada, the reindeers are wild and hunted indigenous peoples.

Food gathering/hunting in boreal forests among diverse indigenous communities includes other important food and nutrient sources (e.g. elk, 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, 2010; Nuttall *et al.*, 2009).

In the Amazon Basin, fish consumption by local people is in many cases the most important source of protein; this is likely also the case for riparian and coastal communities in other continents. In freshwater streams and rivers, fish feed on fruits and seeds deposited by riparian vegetation on which their survival depends (Goulding, 1981). Additionally, aquaculture is being practised now at large scales in many water bodies, such as the Amazon river itself and in the lakes of Southern Chile – now the largest global farmed salmon exporter. Forests contribute to maintenance and regulation of aquatic food webs and thus the health of the people whose food security and nutritional needs are dependent on them, by regulating flow extremes, controlling sedimentation rates, regulating instream temperature and contributing energy flows through terrestrial resource subsidies in the form of terrestrial fauna entering the aquatic food web. Forests thus contribute significantly to maintaining and regulating aquatic food webs on which many people rely. Deforestation, overexploitation, contamination of water by agriculture and mining can all drastically disrupt aquatic food webs and therefore have large “downstream” effects on the people reliant on these systems for income, nutrition and food security. Furthermore, aquaculture itself – though beneficial for FSN, as stated previously – can involve high inputs of hormones and antibiotics, and the introduction of invasive fish species that can outcompete and predate native species, inadvertently impacting FSN (Junk, 1984; Gram *et al.*, 2001; Katz, 2006; Soto *et al.*, 2001). When aquaculture is conducted on a large scale, as is the case in Chile with salmon and Costa Rica with tilapia, the product is targeting opulent external markets and not contributing directly to the food and nutrition of local people where the production is based. The contribution of aquaculture to FSN is a matter of scale and purpose because, in other cases and at a local scale, aquaculture is important to food supply.

3.2.3 Forest foods as a safety net at the local level

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). For example, in the Niger, for example, 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, 6 out of the 9 showed higher dependence on wild foods in the lean or food insecure season, while the other 3 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).

[6] Reindeer husbandry on Greenland is very limited and most reindeers are wild and subject for game.

[7] In Finland reindeer husbandry is not an exclusive right to Sami, rather based on long tradition of carryng out reindeer husbandry.

At these critical moments, the roles that forests play in preventing hunger can be worth much more than can be captured by the global annual estimates of the proportions of household food consumption that can be attributed to forest-based sources. To focus, therefore, on these aggregated data may lead one to overlook the importance of forests as sources of supplementary crop-based nutrients in household diets, and how they play especially important roles in times of scarcity and vulnerability. These roles also include the economic contributions that forestry makes to incomes (especially during lean seasons), which enables households to command access to food through markets. For example, tree foods provide some 30 percent of rural diets in Burkina Faso, and many rural people in tropical countries depend on trees for livestock fodder. In West Africa, over 4 million women earn about 80 percent of their income from the collection, processing and marketing of oil-rich nuts collected from shea trees that occur naturally in the forests (UNEP, 2014). Another example is the one of *Araurafria araucana* in south Chile and Argentina, where the Pehuenche people in pre-modern times used the seed as their main staple food. Today, it remains part of their diet despite their now having access to urban markets to buy food. Furthermore, in the Pehuenche communities they have been introducing the seeds into national markets and are utilizing the seeds 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)..

Table 2 Daily average wild meat consumption (kg/person/year) in rural communities and indigenous people settlements

Indigenous group (or site) and country	Annual consumption of bushmeat based on deadweight (kg/person/year)	Source
AMAZON		
Bari, Colombia	35.8	Ojasti (1996)
Cuiba, Colombia191.6	191.6	Ojasti (1996)
Jivaro, Peru and Ecuador	101.5	Ojasti (1996)
Kainsang, Brazil	34.7	Ojasti (1996)
Transamazon highway, Brazil	2.1–15.8	Smith (1976)
Japuaranä, Nova Bandeirantes, Brazil	73	Trinca and Ferrari (2007)
Sharanahua, Peru	99.6	Ojasti (1996)
Shipibo, Peru	17.2	Ojasti (1996)
Siona, Secova, Ecuador	74.8	Ojasti (1996)
Trio, Suriname	47.5	Ojasti (1996)
Sirino, Bolivia	79.9	Ojasti (1996)
Yanomano, Venezuela	52.2	Ojasti (1996)
Yékwana, Venezuela	58	Ojasti (1996)
Yukpa, Venezuela	10.2	Ojasti (1996)
CONGO		
Ituri Forest, DRC	58.4	Bailey And Peacock (1988)
Ituri Forest, DRC	43.8	Aunger (1992)
Ogoué Ivindo, Gabon	36.5–62.05	Lahm (1993)
Mossapoula, CAR	18.3	Noss (1995)
Dja Reserve, Cameroon; Ngotto, CAR and Odzala National Park, Congo	29.2–58.4	Delvingt (1997)
Campo Man Reserve	69.4	Dounias *et al.* (1995) reported in Dethier (1995)
Mvae, Cameroon	67.0	Bahuchet and Ioveva (1999)
Kola, Cameroon	79.0	Bahuchet and Ioveva (1999)

Northern Congo (forest villages)	33.0	Auzel (1997)
Northern Congo (forestry camp)	53.0	Auzel (1997)
Badjoué, Cameroon	16.4–35.9	Delvingt *et al.* (2001)
Azande, DRC	14.6	De Merode *et al.* (2004)
Dibouka and Baniati villages, Gabon	97.8	Starkey (2004)
Forest villages near Okondja, Gabon	94.9	Starkey (2004)
Coastal villages near Omboué, Gabon	18.3	Starkey (2004)

Source: Nasi et al. (2011).

Forests can also play a safety-net function by providing cash through timber and NTFP extraction in times of crisis. However, recent evidence from a large global data set suggests this role of forests to be less important, relative to other coping strategies, than previously thought (Wunder *et al.*, 2014).

Other 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 income transfers to residents of forest reserves. 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. At the same time, despite concerns to the contrary, recipients have not abandoned agricultural production, though there is some indication that there has been a reduction in forest extractivism in the Amazon region (Menezes, 2008).

3.3 Provision of ecosystem services: sustainable forestry supporting agriculture

There has been a rapid increase in awareness and a surge in work on ecosystem services in recent years. This increased attention is linked to international research and policy processes on environmental sustainability and climate change: the Convention on Biological Diversity (CBD) in 1992, Kyoto Protocol (Kyoto Protocol) in 1997, the Millennium Ecosystem Assessment (MA) 2001–2005 and the most recent 2010 synthesis report from the TEEB programme at UNEP (The Economics of Ecosystems and Biodiversity).

Box 14 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. Thus forests are 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 1949–1953 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.

Source: Petrov and Lebovikov (2012)

There is substantial evidence to assert that forests underpin many agricultural systems through ecosystem services provisioning (Richardson, 2010; Foli *et al.,* 2014). Regulatory services of pollination and soil protection are two important examples. Forests provide habitat to wild pollinators that are crucial to sustain crop yield in animal pollinated crops (Aizen *et al.,* 2009). This excludes the global cereal crops of maize, wheat and rice that are wind-pollinated. For rural smallholders that grow a variety of crops that are largely removed from global food markets, animal pollination services are needed to provide sufficient and diverse food. Despite there being adequate evidence to acknowledge the importance of ecosystems services and to justify the importance of forests to food production systems, a holistic understanding of these biophysical processes is limited. This is especially true once we move away from a focus on pollination or, to a lesser degree, pest control services.

Table 3 List of ecosystem services provided by forests and trees across multiple scales

Ecosystem services	Spatial scale		
	Local	Landscape	Global
Primary production (feed and fodder, wood and NWFPs)	X	X	X
Pollination services	X		
Nutrient cycling	X		
Habitat for beneficial species	X		
Natural pest control	X	X	
Soil formation	X	X	
Water regulation	X	X	
Climate regulation	X	X	X
Genetic biodiversity	X	X	X

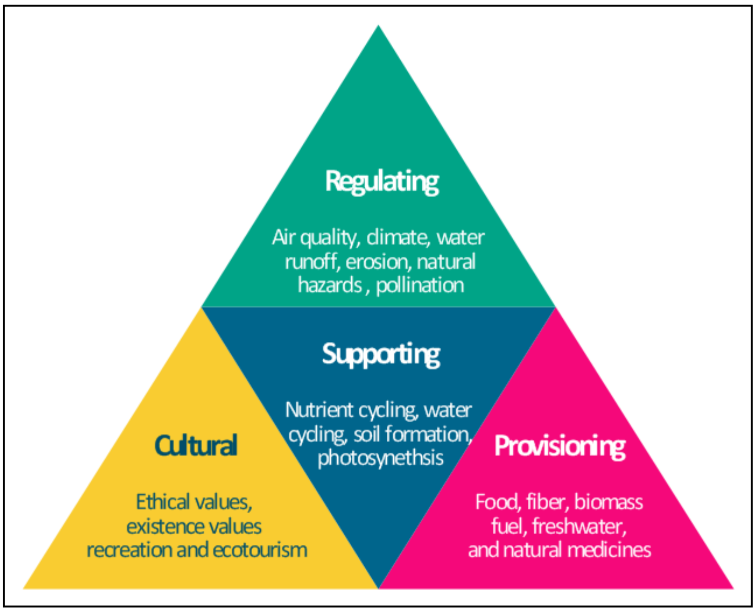
Agricultural productivity is also dependent, to a greater or lesser degree, on biodiversity – especially that which is sustained through forest ecosystems. Globally, as commercial agriculture has trended toward large-scale land conversion and monoculture production systems, it has become evident that there has been an associated loss of essential pollinating species (Klein *et al.,* 2014). Forests also provide habitat for diverse assemblages of pollinating species needed to ensure crop outputs and guarantee food security. Similarly, the biodiversity maintained by forests has also been shown to mitigate the effects of disease and crop damage through the regulation of pest species and disease vectors (Foli *et al.*, 2014), therefore also contributing to food production and security. It is estimated that products derived from genetic resources (including agricultural crops, pharmaceuticals, etc.) are worth an estimated USD500 billion/annum (Ten Kate and Laird, 1999). Thus the current, rapid, global loss of biodiversity and natural habitats threatens the future global food supply.

Also, forest can be an important protection to prevent flooding, which may threaten both water quality as well as housing and crops (Bradshaw, *et al.*, 2007). Further, forests help mitigate air pollutions to improve air quality (Nowak *et al.*, 2014).

3.3.1 Provisioning services, regulating services and supporting services

Ecosystem services is a term borrowed from the conservation research, and can defined in multiple ways, which illustrate the complexity of the concept (Danely & Widmark, 2016). The term thus needs to be carefully defined. In this work, ecosystems services can broadly be defined as the structures and functional attributes of ecosystems that result in the provisioning of good and services that contribute to human well-being (Daily, 1997; Boyd and Banzhaf, 2007). Ecosystems services can be classified into direct and indirect, however consider that this classification combine several definitions and services with the aim of being inclusive, however potentially leaving some ecosystem services unconsidered (Danley & Widmark, 2016). Direct services are the fruits, tubers and leaves but also fibres, timber, water and various plants that are readily harvested as food, fuel and medicines. Indirect services are largely biophysical environmental processes that support production of food, access to clean water and enhance quality of life (MA, 2005). The sum of goods and services are divided into four groups (Figure 8) namely regulatory, supporting, provisioning and cultural ecosystem services. Regulatory services are those functions that provide conducive environments for human well-being and protection against natural disasters. Regulatory services 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 global transportation of pollinators (both wind and animal pollinators). Supporting services are the crucial functions of soil and the atmosphere that enable to production of crops and livestock. They include photosynthesis and bioavailability of soil nutrients for plant growth. Long-term processes of soil formation and cycling of nutrients mediated by soil organisms as well atmospheric interactions nitrogen and phosphorous deposition also fall under this category. Cultural ecosystem services are described as the intangible values that society derives from the environment. Such services are provided by forests and include sites of recreational and religious value. Ecosystem goods, on the other hand, are the directly available food, medicines, building material, and fuel that can be harvested from marine and terrestrial ecosystems.

Figure 8 Concept pyramid diagram of the various types and examples of ecosystem services



Source: conceptdraw.com based on the Millenium Ecosystem Assessment (2005).

3.3.2 Forest contribution to ecosystem stability, protection of biodiversity and downstream resources

Forests contribute to the provisioning of ecosystem services and to sustaining their availability. Trees provide shelter and habitat for a number of species that provide beneficial services at various spatial scales. Habitats for pollinators and natural enemies of pests are key examples of trees and forests enhancing ecosystem stability. Such processes occur at local scale but inevitably have an effect on landscape and regional scales in adjacent agricultural systems, for example. Forests and various other degrees of tree cover regulate watersheds and water provisioning at the regional scale. At the global scale, forests contribute to climate regulation including carbon sequestration but also cycling of oxygen and water. They are also stores of genetic diversity and conserve endemic species in various hotspots. The Amazon and forests of central Africa both hold important biodiversity of global relevance. Examples of forest and tree-based ecosystem services are shown by Foli *et al.,* 2014).

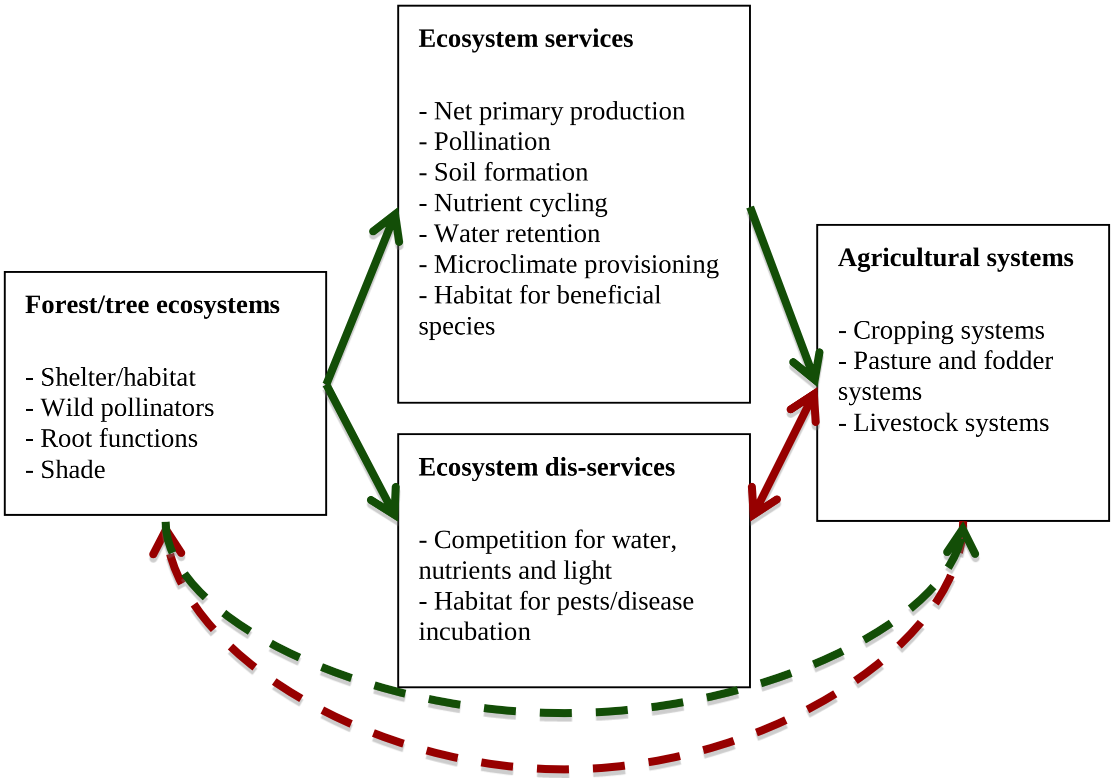
The expansion of large-scale agricultural production systems often comes at the expense of more diverse, heterogeneous landscapes. In particular, the loss of forests and tree-based agricultural systems in tropical regions, primarily to monocultural agricultural expansion, threatens the integral contributions to improved livelihoods, food security, equity, income security, dietary diversity and nutrition of communities in proximity to such systems (Deakin *et al.* 2016).

There is growing pressure from ever-expanding agriculture on natural resources, including land, water, marine ecosystems, fish stocks, forests and biodiversity. Unsustainable pressure on natural resources threatens the very ecosystem services on which the global food system depends (Howe *et al.* 2014). Agriculture is the major consumer of the world's land and water resources and is an important contributor to GHG emissions (Alig *et al.* 2010). Yet conserving natural resources is fundamental to sustainable production in the long term, especially given the vulnerability of agriculture and fisheries to climate change (Berry *et al.* 2006). Historical trends in productivity are no indication of the future prognosis. There are already signs that global productivity growth is slowing and that "business-as-usual" will neither meet future demand, nor will it ensure universal accessibility (Tilman and Clark 2014).

Regulation and provision of an adequate volume of water of quality appropriate for human and animal consumption are also strongly associated with forest cover in watersheds, hillsides and streambanks. Adequate water supply clearly is essential to FSN in all of its dimensions. There is some dispute in the forestry community regarding the benefits to be had from maintenance of forest cover vis-à-vis volume of water supplied in comparison with evapotranspiration and infiltration (FAO, 2013), but water quality is strongly enhanced by forest protection of streams and vegetative coverage of hillsides subject to erosion.

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

Figure 9 Contribution of ecosystem services and disservices from trees to agricultural systems



Source: Foli *et al.* (2014).

Figure 9 shows the contribution of ecosystem services and disservices from trees to agricultural systems. Trees and forest regulate functions that produce services and goods directly to produce food or can be transformed indirectly to support crop and livestock production. Forests and trees also compete with agriculture for productive resources. Additionally, tree-based ecosystems may serve as habitat for pests and diseases in what is often referred to as ecosystem disservices.

There is adequate evidence to ascertain that forests underpin agricultural systems through ecosystems services provisioning (Richardson, 2010; *Foli et al.*, 2014). Regulatory services of pollination and soil protection are two important examples. Forests provide habitat to wild pollinators that are crucial to sustain crop yield in animal pollinated crops (Aizen *et al.*, 2009). This excludes the global cereal crops of maize, wheat and rice that are wind-pollinated. For rural smallholders that grow a variety of crops that are largely removed from global food markets, animal pollination services are needed to provide enough and diverse food. Despite there being adequate evidence to acknowledge the importance of ecosystems services and why forests are important for food production systems, a holistic understanding of these biophysical processes is limited. This is especially true once we move away from that focus on pollination.

3.3.3 Pollination

Pollination is the most widely studied ecosystem service, largely because of its tangible significance to food production. Approximately 70 percent of crops are dependent on animal-mediated pollination and, globally, 35 percent of crop production relies on some form of animal pollinator (Winfree *et al.,* 2011). Bees and especially the honey-bee are the backbone of agricultural pollination. Globally, agricultural intensification has focused on the efficiency of a single honey-bee species to provide pollination services to intensively managed systems. Managed honey-bees are declining, caused by disease die-offs, and the attention is shifting back to native wild bees that are more resilient. Wild bee pollinators 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.

Recent research has shown fruits and vegetables depend upon pollination services more heavily than staple crops, thus proximity to forests may play a role in the provision of these services. The nature of these relationships have yet to be thoroughly explored and may extend to forest frontiers, agroforestry systems and even plantation forestry, or the many variations therein. Interestingly, some studies indicate that forest strips can serve as corridors to restore animal mediated pollination in fragmented tropical forest landscapes (Korman *et al.*, 2016). There is also evidence suggesting the abundance of coffee pollinators is directly proportional to the distance to forest fragments (Ricketts, 2004).

Forests provide the natural habitat needed to maintain diverse assemblages of wild species. For example, Freitas *et al.* (2014) highlighted the importance of forest fragments on cashew productivity in Northeast Brazil, in 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 (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). Additional evidence suggests that:

"(U)sing pollination experiments along replicated distance gradients, found that forest-based pollinators increased coffee yields by 20% within ≈1 km of forest. Pollination also improved coffee quality near forest by reducing the frequency of "peaberries" (i.e., small misshapen seeds) by 27%" (Ricketts, *et.al*., 2004).

At a broader, geopolitical level, land-use change has been shown to end up as a losing proposition for agricultural development. Recent simulation studies by climatologists in the Amazon basin suggest that deforestation to expand pasture and soybean cultivation could exhibit negative feedback effects to the productivity of the expanded crops and pasture grasses, so that the net effect of deforestation may be a decline in output:

> "These climate feedbacks, usually ignored in previous studies, impose a reduction in precipitation that would lead agriculture expansion in Amazonia to become self-defeating: the more agriculture expands, the less productive it becomes." (Oliveira *et al.,* 2013: abstract)

Research over three decades on the minimum critical size for tropical forest ecosystems to conserve species and biodiversity suggests that isolated fragments smaller than 1 km^2 in size tend to lead to severe erosion of wildlife habitat, primarily due to edge effects (Laurance *et al.,* 2011).

Indirectly forests also contribute to the provisioning of fish resources, both for the local communities and for the local, regional and national markets. Often sport fishing is also an important contributor the income generation. In the USA there are over 150,000 miles of streams and 2.5 million acres of lakes found on the national forests and grasslands.

3.3.4 Ecosystem disservices

While forests are important sources of pollination services, proximate tree cover can also adversely affect food production systems and have unintended negative outcomes for crop yield. This includes the harbouring of pests within adjacent forests or acting 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. This interaction has 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. Zhang *et al.* (2007) coined the term "ecosystem disservices" within agricultural systems. However, there is sufficient evidence from ecosystem services (see Table 4) to suggest that such benefits are superior to their purported costs. Additionally, the forests at the borders with cattle and agriculture fields can be managed, controlling density of trees, wind circulation, etc. In a territory there are all kind of services and disservices known by economists as positive and negative externalities) and in a wide analysis, disservices are produced by agriculture and cattle farming over forests, like the expansion of the agricultural frontier at the margin of the forests.

Table 4 Summary table of evidence for ecosystem services for agriculture

Component of FS	Ecosystem service	Function	Evidence
Availability	Primary production	Provisioning of foods that are directly harvestable from forested landscapes (NTFPs, etc.)	TEEB (2010)
	Pollination	Crucial for fruit set of animal pollinated cops. Annual crops for example depend these ES for seasonal fruit set and yielding.	Garibaldi *et al.* (2013) Winfree *et al.* (2011) Blanche *et al.* (2006)
	Nutrient cycling	Annual/seasonal capture of plant nutrients in the root zones of trees and in the subsoils is important for the bioavailability of plant nutrients in crop production systems that retain tree cover (e.g. agroforestry systems). Additionally, cropping systems with nitrogen-fixing tree species enhance the availability of nitrogen to crops and increases yield.	Jose (2009)
	Pest control	The provisioning of natural enemies to pests reduces damage to crops. Forests are breeding grounds for biological control organisms especially in low input smallholder systems that apply little to no agro-chemicals.	Bale *et al.* (2008) Karp *et al.* (2013)

Component of FS	Ecosystem service	Function	Evidence
Stability	Pollination	Pollinator diversity, provided by a variety of wild insect pollinators, provides a stable base as the crucial service in the case of disease infestation in other species. This is the ongoing case of colony collapse disorder in honey-bees. Wild/native bee species are stabilizing pollination gaps resulting from die-offs in honey-bees especially in intensive crop systems.	Garibaldi *et al.* (2011) Garibaldi *et al.* (2013)
	Soil formation and protection	Forest floor and organic matter accumulation.	Kimble *et al.* (1995)
	Water cycling	Interception, percolation, run-off, protection from erosion.	Gerten *et al.* (2004)

3.4 Economic contribution of forestry

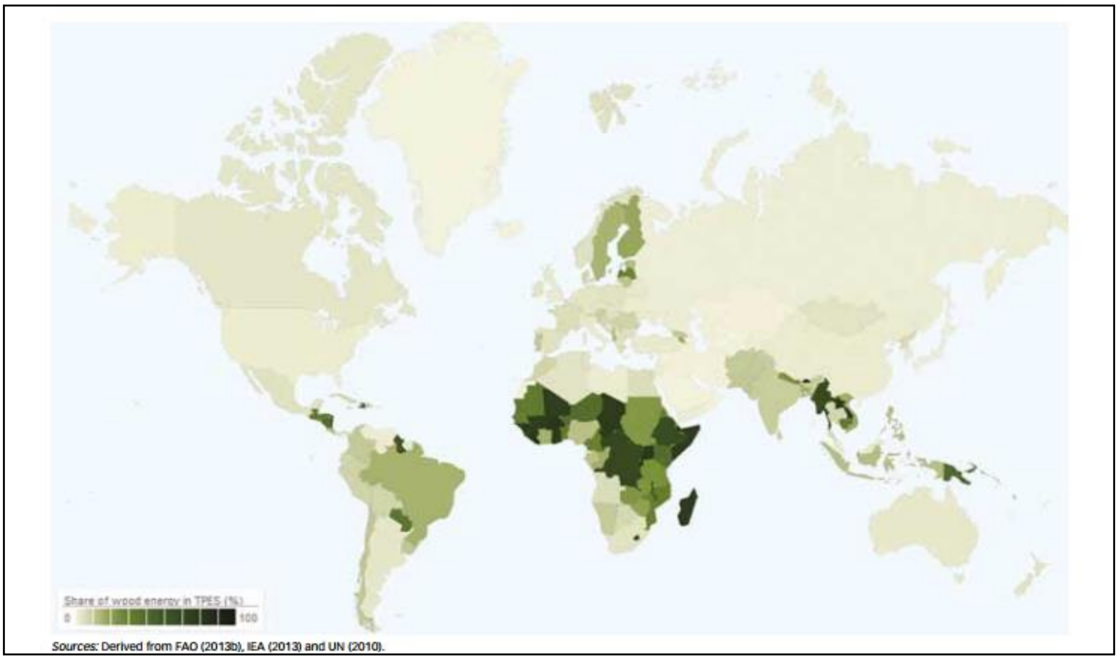
In this section we consider not only the direct and indirect benefits associated with forest resource use and services, but also the FSN effects of incomes associated with forestry-related employment in different parts of the world.

3.4.1 Economic growth, income and livelihoods

The forestry sector contributes significantly to global, national and regional economies and provides a source of employment and income to 60 million people. In 2012, forest industries contributed more than USD450 billion to national incomes, contributing nearly 1 percent of global GDP in 2008 and providing formal employment to 0.4 percent of the global labour force (FAO, 2012b, cited by Agrawal *et al.*, 2013). In 2014, the formal forest sector employed some 13.2 million people across the world and at least another 41 million were employed in the informal sector (FAO, 2014a). Similarly, forestry contributes significantly to the national economies of many countries. However, value-added contributions of the forest sector to national economies vary considerably, being estimated to average less than 1 percent of global GDP, with a maximum of 1.6 percent in the developing regions of the Asia–Pacific region and 1.5 percent in sub-Saharan Africa, to a low of less than 0.4 percent in Northern Africa (FAO, 2014a). However, in Canada, for example, non-wood forest products (NTFPs) have a current yearly value of CAD241 million and contribute significantly to the welfare of rural and First Nations communities (Canadian Forest Service, 2003). Other estimates of maple tree products alone valued the Canadian Maple industry in 2006 at CAD354 million dollars (Government of Canada, 2016). In any case, these figures underestimate the contribution of forests to the GDP because, in the accounts, the value chain derived from wood is accounted to the industry sector, and the production of environmental services is not considered at all in its real value.

Figure 10 shows the percentage contribution of the forestry sector to national GDP around the world. The highest contributions come from Liberia where the forestry sector contributes around 15 percent of GDP, with Latvia, Sierra Leone and the Solomon Islands contributing between 5 and 10 percent (FAO, 2014a). As a percentage of national income, the forestry sector is most important in Northern Europe, the Russian Federation, Canada, East and Southeast Asia and parts of Latin America. Forestry makes almost no contributions relative to other industries in Central Asia and North Africa.

Figure 10 Contribution of forestry sector to GDP



Source: FAO (2014a). (image quality to be improved)

National regional and country level statistics can be misleading. First, they consider only the formal forestry sector. Second, they are calculated as a proportion of overall economic growth. Third, they do not account for population sizes and so give no indication of the number or extent of people benefiting from forest related activities. Fourth, in the national accounts many of the links in forest production chains are not added, such as harvesting, transportation and primary and secondary processing, largely because these activities are included in the services and industry sectors. Figure 10 shows the contribution of the forestry sector to GDP by country population size (as a percentage of global population). Most countries where contributions of the forestry sector are high have relatively low populations, and for half the global population forestry contributes only 1.6 percent of national income.

Households that reside in or near forested areas experience a greater degree of forest dependency than those who live in purely agricultural and urban areas (and a lower dependency on the global and national markets and commoditization). There are both positive and negative aspects to this: in that forests provide important supplementary sources of food and non-food products, they complement the typically low incomes of forest dependent families. On the other hand, development of forestry enterprises may restrict access by forest residents to some of these benefits, while providing them with marginally more significant monetary incomes, or, in the case of some companies, open the resource to the local population to collect NTFP while also providing employment. In Chile, for example, communities nearby pine plantations are prohibited from using 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 NTFP in the regeneration cycle is legally permitted but management plans have not been approved, effectively restricting access and sustainable use (Calorio and Silva, 2014). And in Mexico, one payment for environmental services project provided communities with cash to protect forests needed watershed protection, but prohibited traditional use of forests for harvesting of food (Ibarra *et al.,* 2011). Thus, 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 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; Herforth & Ahmed, 2015). However, this is a matter of trade-offs, in the sense that many rural communities do not live only from the fruits of the forests, but also need cash to participate in the goods and services markets of the local and regional economy.

Box 15 Amazon forest foods for global and institutional markets

Long supply chains, including different value added schemes and recognition of the quality of the product is often presented as a means to add value to forest foods and related agroforestry products to support sustainable forest management. This type of arrangement has been promoted in different regions of the Amazon involving NTFPs (medicinal plants, fruits, nuts, resins, etc.) or agricultural products grown in multiple use or agroforestry systems (cocoa, guarana, cupuaçu, peach palm etc.). However, short circuits of production, including direct marketing of products by farmers and extractivists, relations established by family farmers with networks and consumer cooperatives, and the direct sale of products by farmers through the institutional market for the public supply programs at local and regional level, offer potential advantages.

In Brazil, the institutionalization of purchases from family farming, has been undertaken since 2003 through the national Food Acquisition Program (PAA). There are now several mechanisms in place that enable both public officials and social organizations to use purchases from forest dwellers and small farmers as a toolbox to promote sustainable local development alternatives. Foods marketed through the PAA are intended for building up government stocks or donation to people in food insecure situations served by a social assistance network coordinated by the Government or for distribution through public food and nutrition programs. In the case of a sister program, the National Program for School Meals (PNAE), products are intended for the school lunches for students served by basic education, through public or philanthropic schools. The law which established the PNAE in 2009 innovates in requiring that at least 30% of funds transferred by the Federal Government be applied in the direct purchase of family farming products, prioritizing local municipal sources, organic production and land reform areas (Schmitt, *et al.*, 2015). In the Amazon, these programs have been extended to support forest peoples.

In one case in Juruena, northwest Mato Grosso state, agrarian reform beneficiaries have partnered with indigenous and extractivist communities to harvest native Brazil nut trees, whose nuts are processed in a women's cooperative to produce oil, porridge, cookies and pasta. The oil enters into long supply chains to the national and international cosmetics industry, while the food products are channeled through PAA and PNAE to 42,000 school children, pregnant women, elderly and infirm in the region. Incomes derived from these products have fortified protection of remaining forests in settlements and reserves (Nunes and Rugnitz, 2011).

Table 5 Income from wood forest products

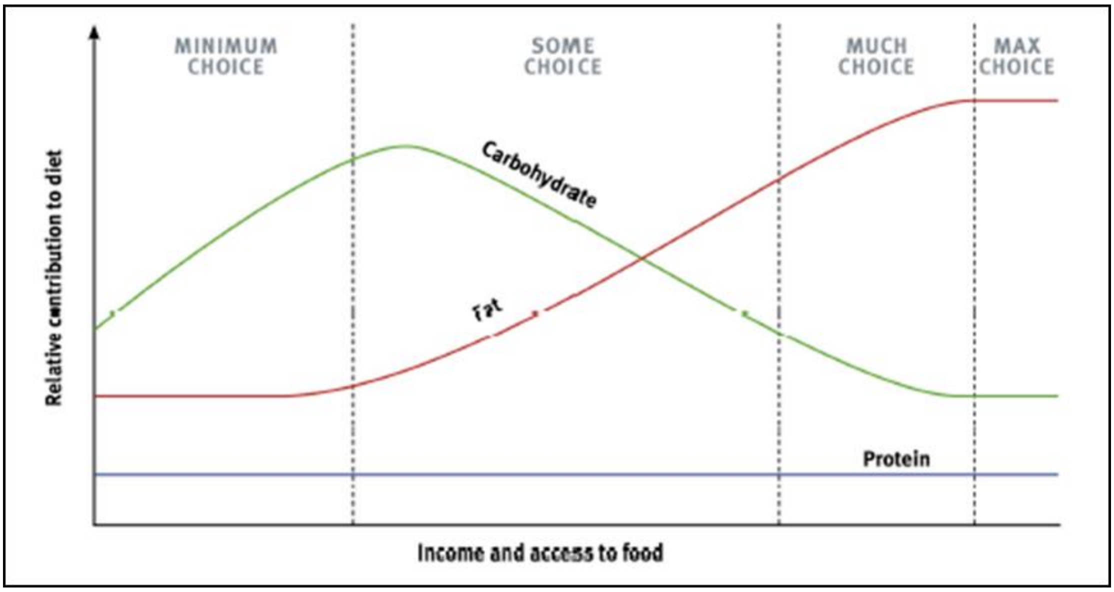
Region	**Income (in million USD at 2011 prices)**			
	Woodfuel	Charcoal	Construction	**Total**
Africa	3 705	10 585	112	**14 402**
Asia and Oceania	4 446	5 403	47	**9 896**
Latin America and Caribbean	3 909	5 067	0	**8 976**
World	12 060	21 055	159	**33 274**

Source: FAO (2015). Note: Derived from a comparison between national census data (on woodland and bulking material use) and reported woodfuel and solid wood product consumption (from FAOSTAT) and income or value added per unit of output.

In theory, increased income leads to greater purchasing power and thus improved nutritional status. Increased household income does indeed appear to have positive effects upon calorie consumption, though the size of the effect varies significantly by geographical location (Gibson and Rozelle, 2002). With respect to nutritional status, however, the effects must be viewed in terms of a broader nutritional transition away from traditional foods towards processed foods, ASFs and higher quantities of fats and oils (Popkin, 2001). Micronutrient consumption has been demonstrated to improve with higher household incomes in several countries (Liu and Shankar, 2007) mainly through the increased consumption of micronutrient-rich ASFs. In addition, the increased consumption of fats and oils can lead to calorie-rich and nutrient-poor diets which, coupled with more sedentary lifestyles, can result in significant increases in the burden of "lifestyle diseases" such as obesity, stroke and cardiovascular disease (Popkin *et al.*, 2012; Doak *et al.,* 2005). Economic growth is widely regarded as "necessary but not sufficient” for improving nutrition (FAO, 2012c). Economic growth has been called a “double edged sword for nutrition” because, while national economic growth is associated with lower rates of undernutrition and stunting among children under five years of age, it is also associated with increased rates of overweight and obesity (10 percent increase in GDP is associated with a 7 percent increase in overweight and obesity among women) (Ruel and Alderman, 2013). Clearly, however, these trends are by no means associated solely with incomes derived from forest employment. In forest areas, access to forest foods, more beneficial in some respects, is facilitated, but the substitution of non-forest food sources for other reasons (economic status, for example) may have negative effects on nutrition.

The non-linear relationships between income and nutrition (Figure 11) may be further complicated in forested communities. Economic analyses often fail to take into account the importance of environmentally derived sources of income. If, for instance, a community without forest has a higher income but now needs to purchase firewood, fuel, food, medicinal products, etc., products that were previously “free” in that they were provided by nature, the net state of economic security is not necessarily higher. In addition, the effects of income on nutrition are dependent both on market access to nutritious foods (fruits, vegetables, ASFs) and a preference to use income to purchase these foods. The relationship between income and nutrition remains controversial, as is the relationship between forest dependency and disposable cash income. If forest-related income permits one to buy more food and thereby leave the poverty cycle, then governments need to encourage people to derive their incomes from forestry, but at the same time educate families in food and nutrition issues.

Figure 11 Non-linear relationship between income and diet



Source: Beddington, et al. (2012a).

Similarly, it can be debated whether forest cover contributes positively to income, or whether deforestation for agricultural expansion may not offer greater opportunities for welfare improvement. At the forest fringe, it has been found that higher rates of deforestation are associated with higher human development indices (HDI) at an initial phase, while they go “bust” as the frontier advances (Rodrigues, 2009). The number of people employed in forest-related jobs at the deforestation frontier is also affected by this “boom–bust” pattern, particularly as the most common immediate land use in degraded sites tends to be pasture, which provides low employment rates per hectare converted. Those marginalized by deforestation tend to move outward towards new frontiers where the cycle may begin anew.

Regional economic growth, although often associated with improved health and nutrition, does also not automatically lead to improved food security. The effects of economic growth on food security have mostly been examined in terms of energy (calorie) consumption and protein consumption and have been shown to have significant positive effects upon reducing the prevalence of hunger and undernutrition. The evidence for the effect of economic growth on reducing the prevalence of stunting is strong and manifests even over short periods of time, partially explained by associated (though not necessarily linked) improvements in female education, lowering of fertility rates and increased asset ownership (Headey, 2013). Thus this issue needs to be analysed in the context of integrated policies that link health and education policies.

In addition, economic growth in some cases may benefit the most the sections of society least at risk of malnutrition, leaving behind the most malnourished sections of society (Subramanyam *et al.*, 2011). This is another reason that broadly adopted development policies should consider appropriately the differences in resources and territorial contexts. A national development policy is not effective unless it is translated at the territorial scale.

3.4.2 Employment

In the context of FSN and sustainable forestry it is important to describe the role of forest-based employment (e.g. timber and fuelwood gatherers) on the generation of income to provide for household food and nutrition. There are no reliable data on the generation of income and employment from forests, especially because silviculture (wood production in the forest) is included in the agriculture sector in the national accounts and the extraction, transportation and production of sawn timber and timber products are not included in forestry but in the industry sector. Conversely, a large proportion of income and employment generation is informal and thus not registered in most data collection. FAO (2014a) makes the only systematic collection of statistics and reports on income generation and employment in the forest sector, and both variables contribute to provide income to have access to food.

Table 6 Estimates on employment in forest sector

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 America 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**

Sources: ILO (2014a), supplemented with employment statistics from country sources.
Note: Forest = forestry and logging activities; SWP = sawnwood and wood-based panel production; PP = pulp and paper production.

As well as contributing income and economic growth, the formal forestry sector is a major source of employment. Globally around 13 million people are estimated to be employed in the formal forestry sector in 2011, equivalent to 0.4 percent of total workforce (FAO, 2014a, see Table 6). An additional 4.6 million are estimated to work in furniture manufacture, most of which is wood-based.

While forestry employment has declined in the north, mostly due to mechanisation of forest harvesting and processing, employment in developing country forest enterprise has grown (FAO, 2014a). It is estimated that global industrial roundwood production is on the order of 1.7 billion m^3/year (FAO, 2013), 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, as well as charcoal and pellets for biomass energy.

Few reliable data are available on the contribution of the informal forestry sector to employment, but some post-hoc calculations have been made for low- and middle-income regions where the informal sector is assumed to be highest, although such data only exists for certain forest products such as wood fuel and charcoal (see Table 7). Non-formal enterprises, which employ most forest workers in developing countries, are estimated to provide employment for an additional 41 million workers, chiefly in woodfuel collection and charcoal manufacture (FAO (2014a). If such figures are accurate, that would suggest that the informal forestry sector may employ more than three times as many people as the formal sector. In many parts of the world fuelwood sources are becoming increasingly scarce as the time needed to gather fuelwood, chiefly by women and children, increases relative to the distance to the resource and to burgeoning populations dependent on them.

Estimates on employment in NTFP gathering and utilization are scanty and unreliable (May *et al.*, 2001). The informal forestry sector consists of those forest products and services that go untaxed and unmonitored by governments including wood production for fuel, illegal timber and NTPFs such as bushmeat and medicinal plants. Globally an additional USD33 274 million is estimated to be generated from woodfuel, charcoal and construction (seeTable 7) and a further USD88 013 million from NTPFs. Such data, based upon estimates derived from surveys, are likely to vastly underestimate the importance of forest products in the informal sector, and few surveys accurately calculate the true value of environmental benefits (Angelsen *et al.*, 2014). A concrete example of the undervaluation of employment and production is the case of fuelwood in Guatemala: while the production of fuelwood for industry is 300 000 m^3/year, the overall production of fuelwood is around 17 million m^3/year. This last production figure does not, however, appear in the GDP figures (FAO, 2015), although it is estimated that employment in fuelwood gathering and charcoal production accounts for employment of an equivalent of over 115 million FTE workers.

Box 16 Valuing NTFPs in the Mediterranean

The potential of non-timber forest products (NTFPs) in the Mediterranean region as a source of livelihood and sustainable development has been widely recognized. Mediterranean forests supply a diversity of non-timber forest products (NTFPs). Some, such as honey in Lebanon and fodder in Algeria contribute substantially to the welfare of many rural people. Others play a key role in national economies: for example cork contributes about 3% of Portugal's gross domestic product. Some other NTFPs are believed to have a strong potential to improve welfare and rural development in many Mediterranean countries. They however fail to do so, partly because their value is not fully recognized by decision-makers.

Surprisingly few efforts have been made to value them comprehensively. Valuation efforts usually focused on selected NTFPs traded on formal markets, at local level. Criotoru (2007) provides comprehensive estimates of NTFPs benefits at national and regional level in the Mediterranean region. Six major groups of NTFPs are identified: firewood, cork, fodder, mushrooms, honey and other NTFPs. Valuation is based on a wide variety of techniques, drawing on official statistics, and supplemented by results of local surveys. It shows that at Mediterranean level, NTFPs provide annual benefits of about €39/ha of forests, accounting for about a fourth of the total economic value of forests estimated by this study. The average estimate for southern countries (€54/ha) is considerably higher than for northern (€41/ha) and eastern countries (€20/ha).

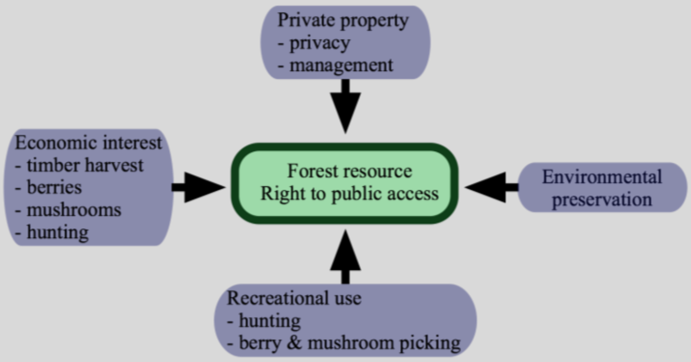
In southern and eastern Mediterranean countries, most forests are publicly owned. Forest communities havesome free usage rights (e.g. collection of firewood, grazing, etc), but often have little incentive to preserve forests. In addition, a large share of the rural population is poor and depends on forest benefits as the major source of income. In Tunisia, NTFPs – raising livestock, charcoal making, honey making, tobacco cropping – contributed as much as 73% of household income with the majority of forest extraction being undertaken by the poor who are disproportionately dependent on NTFPs. In many cases, this results in excessive pressure on forests through over exploitation of certain resources such as firewood and fodder, or in deforestation for conversion to alternative land uses (usually agriculture). In Morocco, for example, the rate of deforestation is said to be 31,000 ha/year, while illegal exploitation of firewood is twice the legal amount. These practices are quite common in rural areas of the southern and eastern Mediterranean and can cause substantial damage such as erosion that affects downstream communities.

Source: *Adapted from Criotoru 2007.*
http://www.sciencedirect.com/science/article/pii/S0921800907000973

Box 17 Access rights and provision of berries and mushrooms in northern Europe

Fundamental for the provision of plant-based NTFP is the access rights for land. In most countries, private land is restricted to the owner and the public is not allowed to enter. In northern forests of Europe, i.e., Finland, Sweden and Norway, the share of privately owned woodland is large (85 % for Sweden (Statistics Sweden 2010), 70 % for Finland (LUKE, 2016), and Norway 82 % (Agerskov, 2007). In these countries, the public is allowed to access all land, regardless of ownership structure according to the public right of access, stipulated in law. Plant-based NTFP can thus be considered a common pool resource (a resource in which the use cannot be restricted). A common good is typically difficult to govern, and conflicts are common if governance is not successful (Ostrom, 1990). The multiple-objective use of woodland renders high demand on the woodland's ability to not only provide timber values, but also NTFP, which creates conflicting situations between stakeholders, especially as there is a common pool resource situation due to the public right to access, which can be illustrated by the figure below.

Figure 12 The conflicting land use related to public right of access in Sweden



For Finland, Sweden and Norway the public right of access offers the general public the right to enter private land to e.g., 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 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).

The collection of plant-based NTFP in Sweden and Finland has decreased over the years, although there are still a large share of individuals that state in different surveys that they pick berries and mushrooms. In Sweden for instance, 69 % stated in 1977 that they pick berries and mushrooms. In 1997, corresponding number was 58 % and in the recent study, in 2011, 63 % stated that they pick mushrooms and berries. The younger generations are underrepresented among the berry- and mushroom picking population (Fredman *et al.*, 2013). The trend is the same in Finland. However the share of berries and mushrooms left in the forest are very high. In general researchers estimate that 95 % of berries are left unharvest. In Finland, estimations show that no more than 10 % of berry species and 1-3 % of mushrooms are collected each year (Salo & Ralliola, 2014).

With the growing interest for Swedish berries and as the economic value of the berries increased, conflicts over the issue of public access and berry picking for commercial purposes arose (Sténs & Sandström, 2013). Together with the increasing commercialisation of berries, a market place for berries developed in Sweden and Finland. Today, most of the production of berries is exported. Especially berries from northern Sweden are highly demanded due to the midnight sun and its effect on berries, accelerating anti-oxidant properties (for medical industry), as well as pigmentation (for cosmetic industry). In combination with the high demand and the right of access, thousands of migrating workers, typically from Eastern Europe or East Asia, travel to Sweden and Finland to work for approx. 3 months. Problems in both Finland and Sweden occur each year with either unserious berry companies, or conflicts with local people who consider the berries their property. 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 market place all over the world (Salo & Ralliola, 2014).

3.4.3 Wood energy and food security and nutrition

The forestry sector contributes heavily to energy supply. Often wood energy is the only source of energy in rural areas. Globally, forestry contributes around 6 percent of total primary energy supply, around two-thirds of which comes from woodfuel. Also at a global level, 2.4 billion or 34 percent of households are dependent on wood as their primary source of energy for cooking (see Table 8). African countries are by far the greatest proportional consumers of wood energy as their primary cooking fuel (63 percent), with significant consumption in Asia and Latin America. There is also significant woodfuel use for heating in the northern temperate and sub-Arctic zones such as Northern Europe and the Russian Federation (Figure 13). Cooking is essential towards contributing to the safety of food and the bioavailability of micronutrients. As such, wood fuel contributes significantly towards the utilization dimension of food security.

Wood energy allows billions to get the most out of available food in developing countries, 40% of the population relies on fuelwood for cooking, and 784 million of those people use it for boiling water. Being able to cook expands the variety of foods consumed, which is key to nutrition. Yet overextraction is reducing the availability of fuelwood. In rural areas of developing countries, where people have no alternative energy sources, the lack of firewood can reduce the quality and variety of food consumed. Cash income can give households greater access to nutritious foods and serve as a buffer when their own food production has gone awry.

Table 7 Estimated number of people using woodfuels

Region	**Estimated number of people required to produce woodfuel and charcoal (in million FTE)**					Contribution of woodfuel and charcoal to employment
	For urban use		**For rural use**		**Total**	
	Woodland	Charcoal	Woodfuel	Charcoal		
Africa	4.9	11.2	26.2	2.9	**45.3**	4.6%
Asia and Oceania	7.1	2.6	42.6	1.7	**54.0**	0.6%
Latin America and Caribbean	6.3	2.3	5.7	1.8	**16.0**	3.6%
World	18.3	16.1	74.5	6.4	**115.3**	1.2%

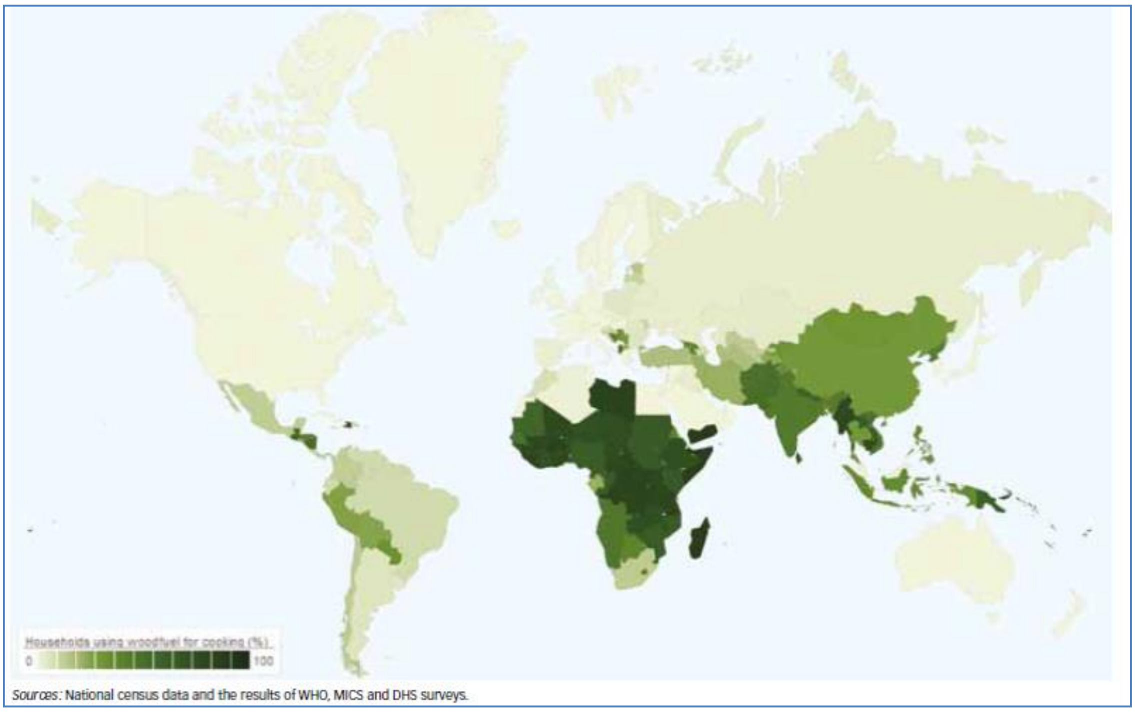
Source: Based on ILO (2013a) and FAO (2013b). Note: The calculation of the contribution of woodfuel to employment only includes the time spent producing charcoal or collecting woodfuel for urban markets, and the contribution shown at the bottom of the table is the contribution to global employment (i.e. employment in these three regions divided by the total global workforce).

Table 8 Share of households using woodfuel for cooking by region

Region	**Share of households where wood is the main fuel used for cooking (%)**			**Estimated population using woodfuel for cooking (%)**		
	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	0	3	19 001	156	19 157
North America	0	0	0	0	0	0
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

Sources: National census data and the results of WHO, MICS and DHS surveys. FAO (2015).

Figure 13 Proportion of households using woodfuel for cooking by region



Source: FAO (2014a). (image quality to be improved)

3.5 Forest contributions to nutrition and human health

Plants, including forest products have been used for medicinal purposes traditionally for centuries (Nilsson, *et al.*, 2011). 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. From an economic perspective, health issues are important, both poor physical and mental health are expensive for the society. Herein we will focus on but a few of these contributions, specifically those that are underexamined, have emerging evidence or have the greatest potential to impact FSN. A number of reviews have examined the relationships between forests and human health over the years (Arnold *et al.*, 2011; Colfer, 2008; Colfer *et al.*, 2006; Karjalainen *et al.*, 2010; MA, 2005; WHO/CBD, 2015).

3.5.1 Complex effects of forests on physical health

The forest provides several eco-system services that are essential for human health. Some of these eco-system services are direct, e.g., food provision, water provision, pastures, and fuel wood, while others are indirect, like pollination, carbon sequestration etc.

Human health and well-being is directly related to the nutrition, food acquisition and income derived from forests. In many parts of the world human health is also reliant on forest ecosystem services, primarily through the provisioning of wood fuels for boiling and cooking foods. An estimated 2.4 billion people rely on fuelwood and charcoal for cooking, among whom about 764 million may also sterilize their water using wood fuels. Boiled water and cooked food dramatically reduce the risk of infections from water- and food-borne infections, leading to improved health and increased absorption of essential nutrients. Additionally, forests may play a substantial role in environmental and ecological regulation of diseases, especially vector- and water-borne pathogens. On the relationship of forests and human health, Pierce Colfer *et al.* (2006) report on health and forests both from the problems that the forests can have on human health, as well as about the forests and medicines provided by the system, including the role of culture on linking health and forests. Considering population in general there is also empirical evidence that the forest environment can have a positive impact on the cognitive and emotional health of people, both in the country side and in the cities, be it through activities in the forest or by experiencing the forest environment (Shin *et al.,* 2010).

3.5.2 Complex impacts of fuelwood on health

Fuelwood is an essential, but often overlooked component of local food systems (FAO, 2014a). The impact of fuelwood on human health and nutrition is complicated: access to fuelwood ensures proper cooking of foods and prevention of food-borne illness; lack of access to adequate fuel may modify dietary behaviour; the links between use of wood as cooking fuel and respiratory illness in women and children (which impacts nutritional status) are well established; the collection of fuelwood is physically demanding – leading to illness from excessive work-loads in contexts where wood sources are far, and carrying burdens are excessive (FAO, 2014a; MA, 2005; Wan *et al.*, 2011).[8]

Wood fuel is also essential for the sterilization of water. Globally 765 million people are estimated to boil water with woodfuel providing safe drinking water. Clean and safe drinking water is perhaps the most fundamental requirement for human health, and therefore nutrition (PLOS Medicine Editors, 2014). However, use of fuelwood and charcoal for cooking also increases the risk of respiratory ailments due to smoke exposure.

Time-use, hygiene and food choice

The collection of fuelwood can be very time-consuming. Especially as deforestation reduces availability, the collection of fuelwood can replace time not spent engaging in agriculture or other income-generating activities, not spent cooking and caring for children and not spent achieving full educational potential (all of which are linked to improved FSN outcomes) (Sunderland *et al.*, 2013; Wan *et al.*, 2011). To date there is very little research that has examined the drivers of fuelwood demand or the adaptations to reduced availability. Recent regional estimates from FAO suggest that the amount of time needed to collect the same amount of fuelwood varies across regions, lowest in Latin America and the Caribbean and highest in Asia and the Oceania (FAO, 2014a). Similarly, who in the household is responsible for fuelwood collection varies significantly between regions, with women responsible for 55.8 percent of unprocessed fuelwood collection in Latin America, 39 percent in Asia and 77 percent in Africa (Sunderland *et al.*, 2014). The amount of time needed to collect fuelwood naturally increases as deforestation progresses, causing forests to become further from villages and homes. Even in areas with moderate fuelwood scarcity, women have often been reported to travel up to 10 km to collect wood in many countries (Wan *et al.*, 2011).

Cooking improves the bioavailability of some nutrients, and reduces the chances of contracting food-borne diseases. Boiling of water dramatically reduces risk of water-borne infections, a key mitigating factor that affects nutrition (and thus food security) in many developing country populations. Fuelwood availability can also impact cooking and dietary decisions, with scarcity leading to omission of meals, or of foods that require longer cooking times (Brouwer *et al.*, 1996; Brouwer *et al.*, 1997; Wan *et al.*, 2011). During a recent research project in Ethiopia, Gumuz women report that the number of days they are obliged to cook only one meal for their families is increasing. Recent government policies have put significant pressure on Gumuz communities to abandon their traditional practices of shifting cultivation, under which they would traditionally move their village location ever three to five years in search of better access to wild resources such as fuelwood. Under the current sedentary villagization policies, forests are being rapidly lost in close proximity to villages and women's already high work burdens are increasing rapidly (Wan *et al.* 1997).

Deforestation combined with continued high demands for fuelwood in developing countries has resulted in a looming fuelwood shortage crisis in many areas. Although there are now global estimates for the extent of fuelwood dependence, there is a significant lack of research on what conditions cause a shift to other fuel types and the impact of fuel scarcity on cooking and dietary choice. More research

[8] Note from the authors: there is a difference in how things are and how things could be. The negative effects of the collection and use of fuelwood could be mostly avoided: (a) fuelwood lots near the small villages; (b) proper management of dry forests and scrub areas; (c) create enabling conditions for the adoption of smokeless ovens, etc. Things like this would help not to consider fuelwood use as a nature- and people-damaging action. The consumption of gas, fossil fuels or electricity can have greater impacts on the environment and human health. What is lacking is the political will to take the issue of forests and energy seriously in national forestry development strategies. The Bonn Challenge, to restore 130 million ha of degraded soils and forests by 2020, should take the energy dimension on board.

is needed to understand these impacts across different settings. Remedial efforts associated with woodlot planting near o communities have been successful in combating the increased effort associated with dwindling fuelwood supplies (Kumar *et al.*, 2015).

Fuelwood, smoke, respiratory disease and other illnesses

The link between the use of fuelwood, indoor smoke inhalation and respiratory illness in women and children (which impacts nutritional status) is well established (Kiraz *et al.*, 2003; WHO, 2015). Combustion of biomass, including fuelwood, releases significant quantities of air pollutants that are one of the key factors in respiratory infection in many settings (Wan *et al.*, 2011). Because women are the primary cooks in almost all cultures, the burden of illness affects them much more significantly than men. Respiratory infection resulting from smoke inhalation affects the food security of the whole family – when the primary cook/cooks are ill, the whole family and especially the children are less likely to eat properly. And because small children spend much of their time with their mothers they are also impacted (Wan *et al.*, 2011). One systematic review and meta-analysis from 2011 reported over 2 700 studies and much higher risks of acute respiratory infection in children (odds ratio 3.53, 95 percent; confidence interval 1.94 to 6.43) and chronic bronchitis in women (odds ratio 2.52, 95 percent; confidence interval 1.88 to 3.38) with exposure to solid biomass fuel smoke (Po *et al.*, 2011).

WHO and FAO publish estimates of the impacts of indoor air pollution on health globally (acute lower respiratory infections (ALRI) and chronic obstructive pulmonary disease (COPD)); revised figures from 2011 show indoor air pollution (largely from woodfuel smoke) responsible for approximately 2.5 million deaths annually, including 12 percent of the deaths of children (under five years old) and 3 percent of adult deaths (FAO, 2014b). Almost all of these deaths occur in Africa and Asia and Oceania (FAO, 2014b). Given the well-established cyclical relationship between infection and nutrition, these statistics cannot be overlooked in terms of their impact on FSN (Stephensen, 1999). The introduction of more efficient cooking stoves can make a significant improvement in the amount of fuel required and on health effects. Difficulties in overcoming cultural norms regarding cooking techniques represent a serious barrier to such technical solutions. The health problem of using fuelwood in rural areas, especially in closed spaces, would be substantially reduced if appropriate burning technologies are developed and used. Long-run efforts have been made to introduce better technologies, but some of these attempts have failed because of the lack of participation of people in the development of technologies and at the same time the reduced investments in the dissemination and construction of the cooking units. Other more culturally sensitive efforts to introduce improved cooking stoves have been extremely successful and widely replicated. A set of examples and principles for successful project design are provided in Soini and Coe (2014).

Fuelwood and physical work

The majority of fuelwood collection for household use undertaken globally is by women (Sunderland *et al.*, 2014). Due to the physiological demands of childbirth, breastfeeding and menstruation, women also have higher nutritional requirements than men. The additional demands placed on women's bodies from regular collection and carrying of very heavy burdens on women's bodies increases their nutritional requirements (Wan *et al.*, 2011). A number of case studies document women regularly carrying loads over 50 kg, and greater in a few cases under severe fuelwood scarcity (Wan *et al.*, 2011). Burdens of this weight are associated with "several health problems such as, musculoskeletal disorders, miscarriage, stillbirth, or uterine prolapse" (Messing and Östlin, 2006, in Wan *et al.*, 2011).

3.5.3 Forests and infectious diseases

The impacts of deforestation and land-use change on infectious disease can be divided into roughly four categories. First, there are the physical effects such as the building of roads, reduced tree cover, climatic change and habitat fragmentation. New land-use practices such as mining, agriculture and monoculture plantations also effect the transmission of diseases and introduce new risk factors. Changes in habitats result in changes in the ecological regulation of parasitic disease by changing predator prey relationships or by reducing the diversity of parasites and vectors. At the same time, rapid in-migration and natural population growth result in a shift in exposure, with new diseases being introduced to the area and diseases becoming endemic that were previously unviable in small populations. Such effects, however, appear few in number compared with cases where deforestation is associated with increases in infectious diseases transmission (Melrose, 2001).

Malaria and other vector-borne diseases

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). Physical changes in habitat and environment can affect populations of disease-related organisms through the creation of new breeding sites for disease vectors, altering the climatic conditions. Changes in habitat type can have both positive and negative effects upon the prevalence of infectious diseases. For instance, draining of swamplands has been associated with decreased prevalence of malaria in many countries including much of sub-Saharan Africa (Keiser *et al.,* 2005). Deforestation, road building, mining pits and predatory logging can create new breeding habitats for insect vectors. Sustainable selective timber extraction would rarely provoke such significant changes, however. 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). Additionally, climatic changes such as increases in temperature and changes in precipitation patterns can favour some vectors over others (Sutherst, 2004). For example, altered vegetation structure can alter the breading sites of *Anopheles* mosquitos to favour *Anopheles vestitipennis* over *Anopheles albimanus*. Since A.*vestitipennicas* is a more effective malaria vector, the end result is an increased incidence of malaria in the surrounding regions (Grieco *et al.,* 2002). There are similar studies for tsetse fly and sleeping sickness. Also in temperate and boreal forests, there may be a risk of infectious diseases, such as tick-borne diseases such as Lyme or encephalitis (Karjalainen, *et al.*, 2010).

Two main ecological processes are thought to confer a degree of regulation upon disease vectors in highly biodiverse ecosystems: ecological regulation and dilution effects. The regulation of disease related organisms (i.e. parasites or vectors) by the ecological system is termed ecosystem-regulation of infectious diseases and is recognized as a tangible ecosystem service under the Millennium Ecosystem Assessment. Under this system, population numbers of disease-related organisms are kept in check by the complex web of predation, parasitism and competition, just like any other organism within an ecological system (McCallum *et al.,* 2001). For example, declines in predator populations and increased grassland associated with deforestation and land-use change in Brazil has led to increases in populations of capivaras (Verdade and Ferraz, 2006), a natural host for ticks transmitting Brazilian spotted fever (BSF) between animals and humans (Sangioni *et al.*, 2005). Such population changes have been associated with increased incidence of BSF in landscapes experiencing widespread deforestation (Cesario and Andrade-Morraye, 2008). Dilution effects occur when the main disease vector or animal host is diluted by the diversity of similar, less competent hosts and reservoirs. For example, mice, the most effective host for ticks transmitting lyme disease, are common in degraded and fragmented landscapes, but their effectiveness as a reservoir for lyme disease is diluted in habitats where less competent reservoirs such as squirrels and shrews thrive (LoGiudice *et al.,* 2003). Other ecosystem-regulation functions become apparent when biodiversity loss results in the loss of natural predators to disease hosts or vectors.

As land-use modification occurs, communities undergo considerable demographic and livelihood transitions. These demographic changes can result in new diseases being introduced and new diseases becoming endemic. 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 inter-marry 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, such as forested areas of Indonesia, rivers form the focus of all activities including washing, defecating, fishing and sources of clean water. As populations increase, the likelihood of contamination increases without concurrent investments in sanitation and hygiene (Bailie *et al.,* 2004).

While mounting evidence shows that deforestation and land-use change are often associated with negative consequences for health and nutrition of local people, forestry and sustainable development can lead to rises in household income which, combined with improved infrastructure and access to state provisioned healthcare, can results in improved health overall. Evidence from Indonesia suggests that remote forested communities suffer from higher infant mortality rates than those in less remote areas (Levang *et al.*, 2005) but also that standards of nutrition may be higher among more traditional forest-based societies (Dounias and Froment, 2011). It is clear that improved access to healthcare and higher cash income, along with access to schooling and markets, lowers poverty rates and increases health. Indeed, this is the vision of development that many indigenous peoples in Indonesia themselves profess to want (Levang *et al.*, 2007).

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 obtained Forest Stewardship Council (FSC) certification.

3.5.4 Forests and psychological health

Forests also provide psychological and psychosocial benefits to human health. 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 (Kapos *et al.,* 2013, Sonntag-Öström, *et al.*, 2015). Other research has shown the environment surrounding hospitals and clinics that have a high component of vegetation (trees, gardens) reduces the post-operation recovery period of patients. The effect may extend beyond even forests to include wooded environments. Houses or schools with wooded environments have been shown to influence heart rhythm and lower blood pressure (Kapos *et al.,* 2013).

At present, much research on the topic of health and nature examines the effects and mechanisms, and whether there are optimal interactions. Questions being asked include: what benefits can be found from nearby nature, either in residential or working environments; is there a specific type of forest that is best; how much nature is needed to have a positive effect; and are there any additional requirements to boost the positive effect (Nilsson, *et al.*, 2011)? It is also pointed out that the issue of human health in relation to forests should be studied in integration with other benefits of forests for human kind (Karjalainen, *et al.*, 2010).

In the boreal region several studies have examined forest effects on mental health. 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.*, 2015). Another study concludes that the forest it self 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 proves that young girls' wellbeing is enhanced by activities in the forest, like roaming in nature or encountering animals. The interaction with nature gave the girls a sense of freedom and possibility to, at least for a while, forget problems (Wiens, V. *et al.*, 2016).

4 CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLE FORESTRY IN RELATION TO FOOD SECURITY AND NUTRITION

This Chapter highlights the key challenges faced by the different forest systems at both global and local levels especially deforestation and forest degradation, the trade-offs between sustainable forestry and agriculture as well as the impacts of climate change on the forest types and consequent threats to FSN. The forest typology includes: Natural forests, Managed forests, Agroforestry systems and Plantation forests.

4.1 Deforestation and forest degradation

In many developing (and some developed) economies, the sectors causing deforestation and forest degradation are predominantly agriculture, energy, intensive forestry, land use and infrastructure development (Geist and Lambin 2002). The underlying causes include demographic (e.g., population growth, migration), economic (e.g., poverty and over-consumption), technological (e.g., application of inappropriate technologies), policy and institutional failures, and cultural (e.g., conventional traditional attitudes and practices that attach low value to biological resources) (FAO 2015). Deforestation and forest degradation ultimately lead to loss of forest biodiversity upon which many livelihoods in these economies, especially among the rural poor, largely depend for their food security and nutrition including employment and income generation. Land use and infrastructure development encompasses mining, oil and gas explorations, hydro-electricity dams, road infrastructure and real estate development in both rural and urban areas. These developments convert forested lands to other uses that are devoid of or diminish biodiversity that is important for FSN thus impacting negatively on all four dimensions of FSN at local, regional, national and global levels.

Box 18 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 many source 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% of women's income, which then used to supplement diets with purchased foods in seasons of resource scarcity (Lamien & Vognan, 2001, in Djenontin and Djoudi 2015).

The drivers of land degradation and deforestation in Burkina Faso include the expansion of agriculture driven, cash cropping (which require large areas), agro-business and bush fires. Joining international efforts, forest restoration began in Burkina Faso in the early 2000s and have been led by an NGO, NewTree/Tiipaalga, primarily in 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 hectares 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 8 provinces in Burkina Faso has been recorded, accounting for a total of 722 hectares of reforested lands under Tiipaalga's leadership.

A recent assessment of the impact of forest restoration on food security and nutrition 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 produce and the role of the reforested lands as a safety net during the lean seasons. The results indicated that informants harvested on average 6 different types of products from restoration areas, ranging from non-timber forest products (NTFPs) used for food to non-edible forest products, fodder for livestock, small wildlife, and crops including cereals and legumes. More than 26% of Fruits, Nuts, Leafy vegetables and spices produced by the HHs were obtained from restoration areas and 40% 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 to food supply when other sources of foods were most limited.

According to the results from the Global Forest Resources Assessment 2015 (FAO, 2015) of the Food and Agriculture Organization of the United Nations, natural forest area declined from 3961 M ha to 3721 M ha between 1990 and 2015 (FAO, 2015) with the majority of the loss occurring in sub-tropical and tropical climatic domains (Table 9). Changes in land cover and land use from forest to non-forest have both natural causes (e.g. drought, fire, storms and disease), and human causes (e.g. clearance for agriculture, over-exploitative timber harvesting, the expansion of settlements, and infrastructure development) (Keenan *et al.*, 2015). Changes to other land uses are linked to a complex and multi-faceted set of underlying driving forces characteristic of many countries in the tropics and sub-tropics, which include population growth, poverty and inadequate government policies; and controlling forces, such as technological development, rural to urban migration, changes in cultural attitudes toward forests, and lack of stronger incentives for conservation (Achard *et al.*, 2014).

Table 9 Trends in natural forest area (calculated as total forest area minus planted forest area) from 1990 to 2015 by climatic domain (K ha) (calculated from FAO, 2015). All totals involve rounding.

Year	1990	2000	2005	2010	2015
Boreal/polar	1,189,195	1,178,980	1,171,757	1,170,451	1,166,747
Temperate	529,131	531,922	534,774	538,836	545,759
Sub-tropical	307,123	303,746	301,332	295,502	295,331
Tropical	1,935,226	1,831,358	1,785,725	1,745,219	1,713,324
Total	3,960,676	3,846,005	3,793,590	3,750,008	3,721,160

Source: Keenan *et al.*, 2015.

Scientists today agree that agricultural expansion is the most important direct driver of land use change globally, followed by infrastructure development and wood extraction[9]. Conversion of natural forests to agriculture leads to loss of biodiversity thus impacting negatively on FSN dimensions and local livelihoods. The conversion is mostly driven by increased demand for wood products such as timber and pulpwood as well as agribusiness products such as oil palm, rubber, jatropha, sugarcane, soybean, etc. The following examples from three of the world's largest forest basins (Malaysia and Indonesia, Brazil and Congo) demonstrate how agriculture expansion is compromising FSN (Rademaekers *et al.*, 2010).

Land degradation

It is estimated that, globally, 40 percent of agricultural land is "seriously degraded" by over intensification, salinization, soil erosion or waterlogging (Jie *et al.* 2002). As agricultural land becomes degraded, productivity decreases, threatening the productive capacity of agricultural land to produce sufficient food to meet the population's needs. Such degradation will result in further encroachment into natural ecosystems as agricultural land competes for space (Gibbs *et al.* 2011). At the same time, forests and trees can reduce the rates of degradation through the provision of essential ecosystem services such as providing soil structural stability, erosion protection, water regulation and nitrogen fixation (Foli *et al.* 2014). Sustainable forestry is thus threatened by and is part of the solution to agricultural land degradation.

4.2 Trade-Offs Between Sustainable Forestry and Agriculture

Agricultural development plays a major role in improving food security and nutrition by increasing the quantity and diversity of food; as a driver of economic development; and because agriculture is the main source of income for most of the poorest (Ruel and Alderman 2013, Carletto *et al.* 2015). However, there are different views on whether FSN is likely to be improved more by protecting labour-intensive agriculture or from productivity improvements in agriculture through adoption of less labour intensive technology and changed practices. Economic growth leading to a lower share of agriculture in GDP but higher purchasing power of consumers can facilitate off-farm rural and urban employment opportunities that improve FSN through increased incomes generated. In fact, both agricultural and

[9] These three direct drivers are mentioned in 96%, 72%, and 67 % of the studies investigating causes of deforestation in a meta-analysis of Geist and Lambin (2002).

economy-wide development is needed to improve FSN. And any agricultural development pathway that does not take into account its long-term impacts on natural resources threatens sustainability and vulnerability of local livelihoods. A forthcoming HLPE report on sustainable agricultural development, to be published in 2016, develops this concept building on different possible pathways.

There is growing pressure from ever-expanding agriculture on natural resources particularly forests and biodiversity. These pressures have reached critical levels, if not tipping points, in some countries due to high levels of deforestation and forest degradation (FAO, 2015). Unsustainable pressure on forests threatens the very ecosystem services upon which the global food system depends. Agriculture is the major consumer of the world's land and water resources, also being a significant and important contributor to greenhouse gas emissions. Agricultural expansion must be weighed against the need to conserve forests for sustainable production in the long-term, especially given the vulnerability of agriculture, fisheries, livestock and wildlife to climate change.

If the result of forest conversion is large-scale and involves intensive mono-cropping, this change presents significant challenges not only to biodiversity but also agro-biodiversity, smallholder agriculture and the continued supply of ecosystem goods and services upon which the long-term food security of rural and urban people alike depends. 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) While conversion of forest to agriculture can in some cases improve rural incomes, all too often deforestation leads to the impoverishment of both ecosystems and of livelihoods in the long term. Sustainable forestry, agroforestry and agroecosystem practices would aim to counter the negative environmental effects of natural forest conversion. The loss of these environmental goods and services has implications for the food security of millions across the tropics. Paradoxically, although intensification of agro-pastoral systems is seen as one way to reduce pressure on native forests, increased returns on intensified agriculture may increase incentives for further expansion of monocultures and pastures into forest frontiers (Pretry and Bharucha 2014). Policies must therefore balance the benefits and trade-offs of agricultural intensification, expansion and the conservation of biodiversity through appropriate and institutionalized land-use planning and enforcement coupled with policy harmonization to avoid policy distortions that negate achievement of balance between benefits and trade-offs. In the face of climate change and variability, this will be crucial in the long-term perspective.

For the majority of those focused on future agriculture, sustainable intensification underpins much of their thinking (Pretty and Barucha 2014). However, it has also been argued that sustainable intensification is a repackaging of intensive high-input agriculture that has been responsible for the fractured food system that we are currently trying to fix and for deforestation on forest frontiers especially where it has been market-driven by global demand for food (The Royal Society, 2009; Byerlee *et al.* 2014; Campbell *et al.*, 2014). Focusing solely on crops also neglects the important role of livestock, fish, forest foods and other nutritionally-important food sources.

It has been posited that "sustainable intensification" of farming systems could spare land for biodiversity (Garnett and Godfray, 2012). The goal of sustainable intensification is to increase food production from existing farmland while minimising pressure on the environment. The theory suggests that as crop productivity per unit of land is increased, less land will be required to supply a given level of harvest. Some studies show reduced expansion of agricultural areas as crop yield increases. But, simply increasing yield has been shown to not necessarily reduce deforestation, particularly if farmers are responding to market opportunities, particularly in the absence of effective regulatory measures. Local deforestation rates have been shown to increase in line with increases in commodity prices (Byerlee *et al.*, 2014). In Africa, Asia and Latin America, forest loss increased from the year 2000 to 2005 (FAO, 2015) concurrently with urban population and exports of agricultural products have grown. Although sustainable intensification has become a recognised process in achieving sustainable agricultural growth, alternative schemes also need to be considered, such as agro-ecology, agroforestry and climate smart agriculture (Garnett and Godfray, 2012; Campbell *et al.*, 2014). Bringing ecological principles to bear in agro-ecosystems can suggest novel management approaches that would not otherwise be considered. For instance, there is a growing body of research showing that small-scale, ecologically-based, organic and even traditional peasant systems can approach, match, and even exceed the productivity of industrial systems when measured by the number of people fed per unit of land or the food biomass produced per unit area (Rosset and Martinez-Torres, 2012; McCune, 2014). These agro-ecosystems are usually the kinds of diverse, multi-layered and integrated systems that are most common in smallholder, traditional farming systems in the developing world, with a focus on meeting local needs, providing food for the larger communities in which they participate and maintaining the productive capacity of the soil for the long term (FAO, 2014c).with some further difficulties particularly relevant for farmers who own small areas of land and who may be unwilling or unable to spare land for agroforestry, and for farmers who face insecurity in terms of their land ownership and are reluctant to invest in the immediate cost of planting trees that may benefit the next owner of the land. At the global level, the key challenge is that not all agroforestry options are viable everywhere, and the current state of knowledge offers very little guidance on what systems work where, for whom and under what circumstances.

Box 19 Land sharing or land sparing? Reconciling agriculture and sustainable forestry

Managing, and negotiating, trade-offs between conservation and agricultural production involves maximizing food security benefits while minimizing damage to the wider environment. To this end, two contrasting approaches; 'land sparing' and 'land sharing' have been proposed to minimize the negative consequences of agriculture on biodiversity and aim to consider land-use change in such a way that competing demands for food, commodities and forest services can be reconciled (cf Phalan et al 2015; Fischer *et al.* 2014).

'Land sparing' aims at intensifying production and maximizing agricultural yields by trading off its negative consequences on the environment by 'sparing' areas of natural capital (often in the form of protected areas) and therefore reducing the need for agricultural expansion into forest areas. 'Land sharing' on the other hand is based on a land use model that integrates production and conservation within the same land units. It proposes to minimize the use of external inputs and to retain patches of natural habitat within farmlands in a form of extensive agriculture. Under this land management regime, landscapes consisting of low-intensity productive areas are combined with areas of natural biodiversity. Such strategies include agroforestry systems and traditional swidden farming practices.

Recent studies (see Deaking et al 2016 for a synopsis) suggest that efforts to emulate land sparing through the application of incentives, regulations and land-use planning could lead to the best outcomes for food production, climate change mitigation and biodiversity conservation. This perspective has had considerable influence on policy-makers and donors, and provides some of the underpinning logic for a range of high-profile interventions under way around the world (e.g. Alliance for the Green Revolution in Africa, and the Commission on Sustainable Agriculture and Climate Change, USAID's Africa Rising Initiative). Land sparing was regarded to be a more promising strategy than land sharing to secure crop production with minimum negative impact on the abundance and diversity of birds and trees in Southwest Ghana, Northern India and Southern Uganda. Consequently, the notion of securing forest conservation and food security through land sparing offers a convincing narrative for achieving desirable agrarian change, particularly in the developing world. However, the approach has also attracted sharp criticism as it has been shown that this strategy rarely occurs 'naturally', because increased productivity can also increase incentives to further clear forests.

Meanwhile land sharing is supported by the fact that many species are dependent on farmland and other habitats maintained by humans, and that farmlands that are structurally similar to the original native vegetation, such as tropical agroforests support biodiversity often as effectively as native vegetation. This land sparing versus land sharing debate has become somewhat polarized in the scientific literature. There is increasing opinion that a 'black and white' dichotomy has been formed that over-simplifies issues that in practice are highly complex.

Source: Deakin *et al.* (eds) 2016. Agrarian change in tropical landscapes. Centre for International Forestry Research, Bogor, Indonesia. 323pp.
http://www.cifor.org/publications/pdf_files/Books/BCIFOR1601.pdf

Forest-based subsistence agriculture, characterized by shifting cultivation or "slash-and-burn", while suitable in cases where there is abundance of land and low human population, could lead to forest degradation in situations where there is human population coupled with scarcity of land for agriculture. 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 to local communities and the impacts of such transitions on diet quality and food security (Parrotta *et al.* 2015).

4.3 Climate change

Forests are of critical importance in relation to climate change and food security. Not only is forest loss and degradation the second largest source of greenhouse gas (GHG) emissions, but sustainable forestry may form a crucial component of adaptive strategies. Thus sustainable forestry is central to both climate mitigation and adaption (Bajželj *et al.* 2014). Every year, forests sequester billions of tonnes of carbon dioxide and protecting them is one of the most cost-effective methods of climate change mitigation (Stern, 2007). However, forests are also a major source of carbon emissions, as soil degradation, peat oxidation and forest fires release vast quantities of carbon dioxide to the atmosphere. It is estimated that forest biomass stores around one trillion tonnes of carbon, while emissions from deforestation and degradation amount to around six billion tonnes of carbon per year, around 17–29 percent of all global carbon emissions (van der Werf *et al.,* 2009). Mitigation efforts must therefore reduce the rate of deforestation and simultaneously restore and reforest degraded lands.

Ecosystem services provided by forests and trees also act to protect households against climate change by reducing exposure and sensitivity to climatic variability (Howe *et al.* 2014). Wild foods may be of increasing importance to communities experiencing climatic shocks as a safety net (Byron and Arnold 1997; Wunder 2014) and as a source of dietary diversity (Phalkey *et al.* 2015). It is essential to collect a diverse set of case studies documenting how local communities draw on forest resources and ecosystem services during specific episodes of climate variability and related effects (e.g. early cropping floods, late cropping floods, landslides, drought) in order to maintain their food and nutrition security (Koffi *et al.* 2016).

4.3.1 Impact of climate change on forests

As demonstrated in this report, forests are an integral part of food systems. Thus any changes to the structure, functioning and distribution of forests will have knock-on effects for FSN. Climate change has both negative and positive impacts on forests. Climate change effects on forests may result in the change of species composition of forests, and entire forest types may disappear, while new assemblages of species and hence new ecosystems may be established (IPCC, 2014). Recognizing that deforestation and forest degradation are among the most significant global sources of carbon emissions, estimated at 10 percent according to the latest IPCC data (2014), the international community has tried to create a financial value for the carbon stored in forests through the mechanism of REDD+ (Reducing Emissions from Deforestation and Forest Degradation, including the role of conservation, sustainable management of forests and enhancement of forest carbon stocks), and has placed REDD+ high on the climate agenda.

The following are a list of potential effects of climate change on forests:

1. Even moderate increases in average temperatures could cause significant changes in the structure and function of forests. In some places this may be beneficial, such as through increased rates of regeneration, but in other places it may cause total loss of forest cover (the Amazon basin is predicted to lose significant forest cover due both to deforestation and climate change impacts such as forest fires; the resulting ecosystems may be closer to savannahs than to tropical rainforests, a dramatic loss in carbon stocks and global climate regulation).

2. Climate change will result in the shifts of suitable climate envelopes of tree species, often over large distances. In these situations, selection pressures will favour fast-growing, early-colonizing species with good seed dispersal capabilities. This is anticipated to result in a shift of species composition and thus ecosystem functioning.

3. Invasive species, pests and diseases will also shift in geographic distribution as a result of shifting climate envelopes, potentially leading to outbreaks of disease, ecological shifts and modification of tree physiology and defense mechanisms. Invasive species will have negative effects on plant productivity through competition. For many forest types, forest health questions are of great concern with pest and disease outbreaks likely. The effects vary from defoliation and growth loss, to timber damage and massive forest diebacks. The vast outbreak areas of *Dendroctonus poderosae*, the mountain pine beetle, in the western United States of America and Canada are most prominent examples of climate change-induced increase and expansion of bark beetle infestations outside Europe (Lindner *et al.*, 2008).

4. More extreme temperatures, combined with changes in precipitation patterns, will likely exacerbate the continuing effects of forest fires. Forest fires seen in Indonesia during *El Niño* years (e.g. 1997–1998, 2015) and the recurrent forest fires in the *miombo* forest ecosystem of

Eastern and Southern Africa during drought periods are widely seen as comparable to the effects of long-term climate change. Severe fires can cause significant removal of organic matter, deterioration of both structure and porosity, considerable loss of nutrients through volatilization, ash entrapment in smoke columns, leaching and erosion, and marked alteration of both quantity and specific composition of microbial and soil-dwelling invertebrate communities,

5. Increased concentrations of carbon dioxide in the atmosphere could lead to increases in biomass through more rapid primary production. However, the net effects may be restricted due to increases in pests and fires. Although extended growing seasons and potential fertilization effect of CO_2 enhance forest productivity, competition between tree species is likely to increase as suitable habitats shift to favour more species and some forest types begin to replace others. Increased carbon dioxide levels may also trigger changes in the chemical composition of vegetation.

6. Extreme events (floods, storms and drought): Plant responses to flooding during the growing season include injury, inhibition of seed germination, changes in plant anatomy and promotion of early senescence and mortality. High wind events can damage trees through branch breaking, crown loss, trunk breakage or complete stand destruction. Increased evapotranspiration and decreased soil moisture are likely to exacerbate summertime drying and contribute to drought-induced plant stress and decreases in productivity and survival (Lindner *et al.*, 2008). Other adverse effects of extreme events include reductions in biodiversity and non-timber forest products, negative impacts on erosion and hydrology, and loss of aesthetic and recreational values of forests.

7. Other effects on forests that are a result of climate include air-borne pollutants such as ground-level ozone, acids and nitrogen compounds. These can change productivity and influence how trees respond to climate change. Ground-level ozone can damage plant tissue and decrease photosynthesis. Acidic deposition can impair nutrient availability, reduce reproductive success and frost hardiness, cause physical damage to leaf surfaces, and increase susceptibility to decline. While nitrogen is an essential plant nutrient, too much of it can mobilize acids and damage forests (Rustad *et al.*, 2012).

8. Climate change affects wildlife in forests through changes in the quality and distribution of habitat, the availability of food, the abundance of parasites and diseases, and the incidence of stress from heat and drought. This may even have an impact on the nutrient cycles of trees and wildlife.

Box 20 Indirect food and nutritional effects of Amazon deforestation and dieback

The largest intact contiguous tropical forest remaining in the world, the Amazon forest and its associated river basin cover a total of 5.5 million km^2 constituting 40 percent of the total land area of South America and reaching into parts of eight countries: Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela (Bolivarian Republic of), Guyana, Suriname and French Guiana. The possible impacts associated with ongoing deforestation and burning associated with agricultural and infrastructure expansion into the Amazon frontier have been studied by scientists for many years. Deforestation has been particularly rampant since the 1970s when the Brazilian Government began its Transamazon highway and directed settlement projects. More recent efforts to link transport, energy generation and communication infrastructure sponsored by regional development banks (Initiative for Integration of the Regional Infrastructure of South America - IIRSA) and to stimulate growth in cattle and soybean production have wreaked havoc on considerable portions of the basin. Current estimates suggest that 20 percent of the Brazilian Amazon has been deforested, and a significantly larger area degraded through selective timber extraction (INPE, 2015).

While in Brazil deforestation reduced from 2005 to 2012 (Hansen *et al.*, 2013), it seems that over the last few years this rate has been maintained at around 5 - 600,000 ha/year due mostly to continued agribusiness (beef cattle and soybean) expansion in Mato Grosso and Pará (INPE, 2015).

Risk of a considerable transformation of the character of the Amazon basin itself due to global climate change from deforestation and other emissions is predicted by a number of long-term climate models developed by Britain’s Hadley Centre since 2000. The result of global temperature rise is predicted to be dramatic dieback of Amazon forests. In combination with deforestation, degradation and burning; the feedbacks associated with climate change may result in the transformation of much of the eastern Amazon into savannah (Betts *et al.*, 2004; Malhi *et al.*, 2009). Obviously this threat would significantly affect the forest food availability from areas accessed by traditional peoples of the region, as well as the indirect ecosystem service benefits derived from the forest by regional agriculturalists and urban inhabitants whose food supplies are largely regional in origin. Recent droughts affecting large areas of the Amazon are prescient of the situation to come.

Potentially more devastating are the plausible regional effects of Amazon forest dieback on areas of southern Brazil and northern Argentina whose rainfall volume and regularity rely substantially on the regulatory services furnished by the Amazon basin. The “Flying Rivers” or “biotic pump” phenomenon suggests that rainfall levels are highly dependent on the level of forest cover remaining in the region, and this may also affect neighbouring regions Spracklen *et al.*,2012). The conceivable long-term effects on food productivity of forest change would be significant.

4.3.2 Potential synergies between forests, climate mitigation/adaptation and food security and nutrition

FAO recognizes three essential responses to climate change: adaptation and mitigation. Adaptation refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities, while mitigation is actions directed to prevent or reduce climate change (IPCC, 2014).

Forests will likely play a significant role in both mitigation and adaptation of climate change. Forests have been an essential component of all climate change mitigation strategies following the UNFCC Conference of Parties in Bali where forests were taken up on the agenda and included in the Bali Action Plan. Given the likely adverse effects of run-away climate change on food security, climate mitigation must be a priority for the FSN community. Even small rises in global average temperature will have profound effects upon agricultural systems, biodiversity and the global food system.

Climate change, among other threats, will force a total rethinking of agricultural systems. There is increasing recognition that future agricultural policies will have to be increasingly flexible, putting resilience and adaptability at their heart (FAO, 2011a). This will require broadening our understanding of agriculture to include the roles of biodiversity and ecosystems. Looking at forests therefore – not as a competition to agriculture – but rather as integral part of agricultural systems, will be necessary to achieve this.

Mitigation

It is estimated that forest biomass stores around one trillion tonnes of carbon, while emissions from deforestation and degradation amount to around six billion tonnes of carbon per year (FAO, 2006), around 17–29 percent of all global carbon emissions (Fearnside, 2000; IPCC, 2014). Mitigation efforts must therefore reduce the rate of deforestation and simultaneously restore and reforest degraded lands.

Trees within agricultural landscapes already contribute to the mitigation of climate change through carbon sequestration. Approximately 40 percent of agricultural land worldwide has greater than 10 percent tree cover and 21 percent of global agricultural land has greater than 20 percent tree cover (Zomer *et al.*, 2014). Despite this, the removal of trees from agricultural landscapes continues to be pursued by many agricultural policies especially in developing countries aimed at increasing the scale and technological efficiency of agricultural systems. To reverse this trend, a greater case for the benefits of trees inside agricultural systems – both for agricultural production and for climate mitigation – needs to be made.

Box 21 REDD+ : Potential and pitfalls

In order for REDD+ carbon emission mitigation targets to be reached, the primary driver of forest clearing globally, agriculture must be fundamentally addressed by governments implementing REDD+ programmes. However, despite the fact that REDD+ offers an unprecedented opportunity to establish policies, institutions and capacity to address agricultural drivers of land conversion,. Many countries have a long way to go before fundamentally addressing agricultural drivers of deforestation and forest degradation.

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. Kissinger (2013) argues that in order for REDD+ carbon emission mitigation goals to be reached, the primary driver of forest clearing globally – agriculture – must be fundamentally addressed 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.
- National governments engaging in REDD+ must 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 and reporting (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.

In contract, however, 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, such as providing food, fuel 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 (Sunderlin *et al.* 2008) may make them especially vulnerable to this risk. Some potential risks to forest dwellers associated with REDD are:

- violations of customary land rights and harsh enforcement measures. These could lead to loss of access to forests for subsistence and income generation needs, land use conflicts, or physical displacement from forests; 272 Rights-based approaches Exploring issues and opportunities for conservation
- marginalisation by new land use zoning exercises. Governments might undertake such exercises to capitalise on forest carbon revenues for the state, stalling or reversing the recent trends of decentralising forest ownership and management responsibilities to communities;
- decoupling forest carbon rights from forest management or ownership rights, blocking communities' legal right to financially benefit from new forest carbon programmes;
- inability to participate in conservation payment programmes due to lack of property rights (to forests or forest carbon), lack of information, high implementation and transaction costs,[10] or because historical contributions to conservation render them ineligible;
- exploitative carbon contracts. These could lead 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, which could create food security risks;
- capture by elites of intended REDD benefits, due to inadequate forest governance systems; and
- decreased production of food locally, creating food security risks and deepening poverty.

Agroforestry, and sustainable forest management, directly sequesters atmospheric carbon but also reduces soil carbon losses by preventing erosion. Agroforestry is one tool, among sustainable management practices, that can simultaneously increase production yields and contribute to climate change mitigation (Albrecht and Kandji, 2003; Dixon *et al.,* 1993; Krankina and Dixon, 1994; Schroeder, 1993; Winjum *et al.,* 1992). Table 10 shows the carbon storage potential of agroforestry systems in different regions of the world with carbon storage standardized to a 50-year rotation.

[10] Transaction costs are costs for up-holding rights, e.g., costs for information, coordination and enforcement (Widmark *et al.*, 2011)

Table 10 Potential carbon storage for agroforestry systems in different ecoregions of the world

Region	Ecoregion	System	Mg C ha^{-1}
Africa	Humid tropical high	Agrosilvicultural	29–53
South America	Humid tropical low	Agrosilvicultural	39–102
	Dry lowlands		39–195
Southeast Asia	Humid tropical	Agrosilvicultural	12–228
	Dry lowlands		68–81
Australia	Humid tropical low	Silvopastoral	28–51
North America	Humid tropical high	Silvopastoral	133–154
	Humid tropical low	Silvopastoral	104–198
	Dry lowlands	Silvopastoral	90–175
Northern Asia	Humid tropical low	Silvopastoral	15–18

Sources: Albrecht and Kandji (2003); Dixon et al. (1993); Krankina and Dixon (1994); Schroeder (1993); Winjum et al. (1992).

But the analysis is not completed if we do not consider the sequestration and mitigation potential of any kind of forest: forest plantations (obviously good reforestation systems considering biodiversity and social issues replacing degraded pastures and agriculture soils) (van Minnen *et al.,* 2008; Maier and Johnsen, 2010; Juntheikki, 2014) as well as natural forest management, in which harvesting trees transfers carbon from the forests to durable goods, and at the same time stimulates the growth of wood and sequestration of carbon in the forest (de Jing *et al.*, 2000; Houghton *et al.*, 2015; Parajuli, 2011).

Adaptation

As populations around the world increasingly experience the impacts of climate change, there will be a need to explore appropriate strategies to enhance their ability to adapt. It is thus essential to study and document how local communities draw on forest resources and ecosystem services during specific episodes of climate variability (early cropping floods, late cropping floods, landslides, drought) in order to maintain their food and nutrition security. The ability to employ forest goods and services to support climate change adaptation would also be enhanced though long-term modelling of climate change scenario projections for net primary productivity (NPP) and specific crop suitability, and assessment of how present trends in government policies for land-use change are likely to result in improved or reduced local/regional/national food self-sufficiency.

Research on livelihood resilience and local people's coping strategies during times of economic or climatic shocks (Pain and Levine, 2012) suggests that households use their assets to mitigate the impact of a shock on their food and nutrition security. In rural communities, many such assets are derived from forests. In many parts of the world, livestock represent one of the most common and most valuable (and transferable) assets. In areas with forest cover, the maintenance of livestock is directly dependent on access to forest resources, either through grazing on communal or state-owned forested land or through fodder collected from uncultivated areas.

There is significant evidence that communities around the world already use forests and trees to cope with food shocks caused by climatic variables (Cotter and Tirado, 2008). Evidence reviewed in Jamnadass *et al.* (2015) demonstrates the diverse ways in which forests and trees contribute to household level FSN under a variety of circumstances. These include the regular consumption of animals, birds, fish, insects, fruits and vegetables from forest-based sources. This type of forest product consumption typically provides nutritious supplements to otherwise monotonous diets.

Agricultural systems with a diversity of cropping and land-use types are more resilient to extreme weather events caused by climate change. This presents the opportunity to diversify agricultural systems, which, at the same time, will increase dietary diversity and reverse trends towards homogeneous food systems. Increasing agro-biodiversity in agricultural landscapes reduces the chances of catastrophic crop failure while simultaneously providing more diverse diets. Tree crops, silvi-arable and silvopastoral systems are one of a multitude of contributions trees can make towards increasing agricultural diversity.

Diversity in agricultural practices helps mitigate risk from crop failures and environmental change. As markets increasingly dominate the global food system, those on the poverty line are increasingly susceptible to price fluctuations and especially soaring food prices. Climatic events resulting in crop failures are no longer localized to the region in which they occur; rather the shock is spread and absorbed throughout global food markets. Economic crises and food price shocks have demonstrable negative effects on nutritional outcomes and child mortality. Thus, sustainable smallholder agriculture and access to forest resources may mitigate against the extremes of global food price fluctuations.

Forests are a vast repository of genetic information, containing wild relatives for a number of agricultural tree-crops as well as fruits and vegetables. As a result of the homogenization of the global foods system, there has been a substantial reduction in the genetic diversity of food crops. Homogenization of food crops began at the same time as domestication of species, during the origins of agriculture. This homogenization trend has continued throughout human history, through selective breeding of high-yielding, pest-resistant varieties and cultivars – a trend that has vastly accelerated since the Green Revolution (Tanksley and McCouch, 1997).

Lack of genetic diversity increases susceptibility to disease and pests and reduces the raw genetic material on which plants can adapt to changing environmental conditions. For example, corn that had been bred for a male sterility factor in the United States of America increased the susceptibility to Southern corn leaf blight, resulting in a widespread outbreak and loss of corn supply in the 1970s (Ullstrop, 1978). Given the likely range expansion and increases in pest densities and emerging infectious diseases as a result of climate change, lack of genetic diversity poses a serious threat to the worlds food supply. The role of forests in protecting and preserving genetic resources is crucial in finding new genetic variants and new wild cultivars that can adapt to a rapidly changing climate.

Substantial evidence shows that trees in agricultural landscapes can enhance crop production, water retention and soil stability, buffer soil acidity, reduce insect pests, prevent erosion and desertification, fix nitrogen and provide suitable agricultural conditions for shade-tolerant crop species (Gibbons *et al.*, 2008). These functions will be essential in providing stable agricultural conditions in the face of rapid climate change and variability as long as climate-smart agricultural (CSA) practices are adopted and scaled up.

4.4 Key specific challenges by forest systems

4.4.1 Community forests

Community forests, when sustainably managed, can provide improved benefits for FSN. Community forestry systems make up 4 percent of global public forest ownership and 7 percent of private forest ownership but are concentrated in developing countries where the percentages of public and private ownership of community forests are 8 percent and 14 percent, respectively (White and Martin, 2002). Community forestry typically contributes to food security through income generation from the sale of both timber and NTFPs (Charnley and Poe, 2007). Income and employment benefits typically go to local people, in contrast with commercial timber concessions which often employ a combination of local people and some more educated migrant labourers. There are important examples in which community forestry is in reality in the hands of the communities like in the State of Acre in Brazil, in gthe Community Concessions in Guatemala, and in numerous ejidos in México (Orjuela, 2015; de Camino and Breitling, 2007; Villalobos *et al.*, 2013). However, in some cases it may happen that, even within local communities, benefits from forests can be skewed towards local elites who dominate management systems and forest user groups Malla *et al.,* 2003). In addition to income pathways to food security, community forests formally recognize access to forests and may therefore increase access to edible NTFPs and increased income.

4.4.2 Sustainable forest management: commercial timber concessions

Forest concessions for timber production have been the primary means of allocating harvesting rights for tropical forests in developing countries, as well as in several developed countries with temperate and boreal forests. Well-managed public forest concessions have the potential to sustainably deliver both direct and indirect environmental and social benefits to neighbouring populations as well as to society as a whole. Besides helping to maintain forest coverage and providing services such as water storage, relatively high level of biological diversity and climate regulation, forest concessions can play an important role in structuring and managing the conservation units/forest landscapes where the concession process takes place, through reinforcement of governmental presence in those areas and legalization of property rights in the region (FAO and ITTO, 2015). Better, more equitable and transparent forest concession systems in public forests can contribute to FSN and creation of forest-based economies capable of generating benefits at the local and regional levels – i.e. an inclusive, sustainable forest-based economy. This requires strong, coherent and transparent forest governance systems, which are often weak in most developing countries and some developed countries.

Key challenges with forest concessions are primarily inherent in their design where sometimes they are seen as infringing on local communities' rights through inadequate recognition of customary rights (Howard *et al.* 2001), poor performance (Schulze *et al.*, 2008), inadequate benefit sharing, lack of monitoring and enforcement of regulations governing concessions, and low concession fees charged to the concessionaires largely due to under-valuation of timber resources (Howard *et al.* 2001; Gray, 2002). These challenges impact negatively on all dimensions of FSN especially for communities adjacent to the timber concessions through, for example, reduced biodiversity due to poor logging practices and reduced incomes due to undervaluation of timber resources (Brandt *et al.* 2016).

4.4.3 Managed forests for multiple-objectives – forests in Europe

Forests in Europe are subject to a multiple-use scenario. The forests are used for different purposes often simultaneously being both timber benefits and non-timber benefits. In most of the boreal forest-based nations in Europe, timber production has a long and strong tradition. Private forest owners' economy as well as local communities' and national economies are based on the existents of a strong forest industry (thus not only timber production per se, also refine industries). In countries like Finland, Norway and Sweden, timber production has a long tradition, and natural consideration and recreational values were introduced rather late in forest policy. The forest has, apart from economic benefits, also a strong cultural value to people in these countries. When it comes to provision of food from forests, there is a strong tradition of picking berries, mushrooms and herbs. Hunting is also an important feature of forests. However, for most both hunting for berries etc. and game is a recreational activity and not vital for survival. In recent years, increasing problems have occurred from forest fires or windthrow. Also, some problems with diseases and insect infestation can be found in the boreal area.

In the Russian Federation forests are used as a source of foodstuffs and forage, as well as for hunting and recreation; a similar point that can be made about temperate forests. While hunting bushmeat, wild berries and mushrooms may not appear to be of considerable economic importance, it is extremely important for cultural reasons and for helping to provide a source of physical exercise that contributes to human health in many ways, thus reinforcing the positive food security aspects.

The relationship to forests is somewhat different in central and southern Europe. Emphasis on timber production is not as strong in these parts of Europe and in many countries, the forest is important for biodiversity enhancement. Larger areas of forest are protected, in comparison with northern European forests, and social values of forests are important. The access to private woodland is more restricted. In some countries (like England and France) recreation can only be carried out on public land using public roads or paths. Access to private land is possible only after achieving a permit from the owner. Protection of biodiversity is also strong in most central European countries. For instance in Slovakia, there is a protection program in five levels, where level five is the strongest protection where public is not allowed to enter. Sustainable and ecological forestry where timber production is combined with conservation and climate protection is the focus of German forests. Like in boreal areas, the problems for forests are windtrhow and forest fires as well as diseases and insect infestations, especially in central Europe the bark beetle (Ips typographus) is problematic not only attaching sick trees but also healthy older trees.

4.4.4 Agroforestry and tree-based subsistence agricultural systems

Agroforestry and forest-based subsistence agricultural systems face a number of challenges. These challenges were recently addressed by Mbow *et al.* (2014) in an article featured in a special issue of Current Opinion on Environmental Sustainability (COSUST). The benefits of agroforestry and forest-based subsistence agricultural systems are often overshadowed by the challenges of establishing tree-based systems in areas marred by poor land use and lack of governmental oversight: while many smallholder farmers in Sub-Saharan Africa practice agroforestry, adoption has not been widespread and this may be attributed to the political and socioeconomic environment, or the farmers' disposition towards trees on their farms (Mbow *et al.*, 2014). These obstacles are compounded by the lack of support for tree-based systems through public policies (Bishaw *et al.* 2013), or inadequate policy framework and guidance for governing land and tree tenure and non-forest tree resources management and the common failure of extension services to address the issue of sustainable rural land use, something that would require shifts in regional and national-level institutional frameworks. Consequently, agroforestry is often absent from recommendations for ensuring food security under climate change (Beddington *et al.* 2012), even though many practices have been shown to deliver benefits for rural development, buffer against climate variability, help rural populations adapt to climate change and contribute to climate change mitigation (Noordwijk *et al.* 2011; Thorlakson *et al.* 2012) The practical issue of implementing agroforestry practices at the local-level is met with some further difficulties particularly relevant for farmers who own small areas of land and who may be unwilling or unable to spare land for agroforestry, and for farmers who face insecurity in terms of their land ownership and are reluctant to invest in the immediate cost of planting trees that may benefit the next owner of the land. At global level, the key challenge is that not all agroforestry options are viable everywhere, and the current state of knowledge offers very little guidance on what systems work where, for whom and under what circumstances.

4.4.5 Plantation Forests

The key environmental challenge is that plantation systems cause drastic changes in ecosystems due to heavy manipulation of both abiotic and biotic factors (Indufor, 2012). Intensive plantation systems are often single species cultivations that require massive land clearing leading to deforestation, soil scarification, chemical use for fertilization and plant protection. Rotation cycles are also short, typically 5-25 years, which prevents forest ecosystems from stabilizing to provide forest goods critical for FSN. In drought prone regions exotic tree species that have deep rooting systems and poorly adapted transpiration systems (e.g., eucalyptus) may lower the water table (Bowyer, 2006). Drinking water, especially clean drinking water, is an elementary part of food security that must be assured among communities living around plantations – a requirement under SDG #6 "*Ensure availability and sustainable management of water and sanitation for all*".

Addressing these environmental challenges will require holistic planning at the landscape level through balancing the various services plantation systems can produce to mitigate their negative impacts. For instance, within a landscape, single species plantations could be part of a mosaic comprising mixed species plantations, enrichment plantings in indigenous forests (with indigenous species that are local to those areas), indigenous forest areas left alone to regenerate naturally (assisted natural regeneration) and areas set aside as High Value Conservation (HVC) Forests.

Key social challenges of plantation systems relate to potential displacement of indigenous peoples and local communities through land-grabbing to pave way for their establishment thus exacerbating conflicts over land. This undermines the availability of and access to food and nutrition by local communities. This change of production format is often based on, and enabled by, weak forest tenure rights. For instance, in the province of Niassa in northern Mozambique, Chikweti Forests, a Swedish-Norwegian enterprise with shareholders in the United States and Mozambique, established a eucalyptus monoculture plantation project on an area of 140,000 hectares. No community consultation took place prior to its establishment: there was no free, prior and informed consent (FPIC) of surrounding local communities – in clear violation of the Mozambican Land Law, which requires investors to have the consensus and approval of the surrounding local communities. In addition, there have been reports of the invasion of inhabited community lands and the restriction of access of local peasants to their "machambas" (family farming plots) by the investing multinational corporation (Monjane, B., 2011).

Box 22 West Kalimantan (Indonesia)

The rapid expansion of oil palm plantations in West Kalimantan (Indonesia) has accompanied significant deforestation, the dispossession of indigenous peoples' access to rubber and rice smallholdings and a casualisation of employment of plantation workers. Migrant labourers are compelled to bear all risks associated with migrating and being apart from their families; they have limited control over their work environment and scant means to negotiate for change. Indigenous Dayaks in comparison, lose access to forests and trees on which they had relied for direct food provisioning, income and livelihood. Food security amidst declining mosaic landscapes is therefore a challenge for both migrants and indigenous peoples alike

Source: Vira *et al.*, 2015

Lack of recognition of or unfair treatment of indigenous peoples and local communities when establishing plantations is a common phenomenon in Africa, Southeast Asia and Latin America. In many cases, once customary land is converted to private leasehold to establish plantations, that landceases to be customary land and becomes state land. While many governments in these regions recognize customary land tenure and ownership rights, there is often unclear relation between customary and statutory law. Often, customary laws are respected as long as they do not contradict statutory laws – meaning that where there is conflict, statutory laws prevail. To effectively address these social and legal challenges will require formal recognition of customary land tenure in statutory laws, strict enforcement of the statutory laws and social and environmental safeguards to protect indigenous peoples and local communities against usurpation and elite capture.

5 GOVERNANCE: TOWARDS INTEGRATED APPROACHES TO SUSTAINABLE FORESTRY FOR FOOD SECURITY AND NUTRITION

5.1 Introduction

A key challenge, in relation to integrating the role of sustainable forestry into FSN comes from the compartmentalized and fragmented nature of decision-making in relation to these issues at local, national, regional and global governance levels. Responsibilities for agricultural production and storage, provision and distribution of food, social welfare and safety nets are often handled in separate ministries and organizations that do not necessarily engage with the forestry sector, or see any relevance of forestry-related activities in relation to their core mandate.

More problematically, in a territorial sense, priorities for forestry and other forms of land use are often perceived to be competing with each other. While there are growing calls for more integrated approaches to decision-making across these divisions, such a holistic vision has been difficult to achieve. Even in the recently concluded 2030 Agenda for Sustainable Development, goals for hunger (Goal 2) have targets and indicators that are separate to those that are associated with the sustainable management of forests and terrestrial ecosystems (Goal 15), encouraging a piecemeal and fragmented approach to the delivery of these ambitious plans (Reed *et al.* 2015). Line agencies that are concerned with these issues will, inevitably, interpret their mandate in a narrow sense, and fail to recognize the considerable overlaps and synergies that can emerge from addressing these issues in a more integrated fashion. Along this line of thinking, the landscape and adaptation approach considered in the “Adapting Mosaic“ scenario of the Millennium Ecosystem Assessment[11] seems to be the strategically appropriate way to go. This means to increase food security at the landscape level, but with support from the national and global policies

Whether managed for production or protection, the governance of forest resources and their surrounding landscapes will involve multiple actors. Managing forest landscapes will inevitably involve making choices and acknowledging trade-offs between multiple competing land uses and users. Developing ways to manage trade-offs in a manner that is transparent, equitable, participatory and delivers with respect to socially-desired objectives that are inclusive of local actors’ needs and aspirations is the essence of improved forest governance for FSN.

This final chapter reviews issues of governance that impact on the ability of forestry to be compatible with maintenance and improvement of FSN, and ways in which the synergies between these agendas can be enhanced through appropriately designed and implemented strategies.

Both forest management and food production involve making informed decisions about the landscapes in which they occur, how they should be managed, and in whose interests. These questions are partly technical, and involve strategies to enhance the long-term flow of desired goods and services from the land. Social, cultural and political considerations must also be taken into account, often requiring attention to the rights and responsibilities of local actors, different competing visions for land management and of differing world views. Furthermore, ways in which these alternative values can be reconciled or negotiated inclusively and at multiple scales must be explored. If management is to be at landscape level, acknowledgement of jurisdictional and multiscale governance processes will be required in order to enable legislative frameworks for effective governance. These choices are not neutral, and specific stakeholders often support their interests by imposition of power and influence, thereby generating the potential for conflict with others. As populations grow, develop and urbanize, land becomes ever scarcer relative to demands placed on it (although, in some cases, urbanization is resulting in rural land abandonment and a depopulation of the countryside). These changes in land use, and new pressures, may lead to an increased potential for conflict. Therefore, it is imperative that greater emphasis be placed on the adoption of appropriate governance mechanisms to manage these difficult choices.

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

A universally accepted definition of governance does not exist as it has been defined variously for different purposes. Hyden *et al.* (2004) refer to 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*. Such a definition incorporates overlapping administrative, social, political and economic systems, which develop rules, processes and structures that:

1. define the ways in which decisions are made;
2. provide plans and pathways for the implementation of these decisions;
3. allow an assessment of the implications of these decisions for different actors and their interests; and
4. provide ways of holding those responsible for decision-making accountable for the consequences of their choices and actions.
5. With respect to the objectives of this study for the purpose of this report, governance refers to the entire range of land use and management decisions that affect forest stewardship and management, competition with other uses such as the cultivation of land for agriculture, livestock and food production. In particular, it refers to decisions regarding trade-offs between or complementarities among these land uses, and includes decisions made by different actors – state and non-state – in different sectors, especially at the levels of government, communities and businesses as well as individuals.

5.2 Diverse institutions, actors and their roles in forest governance

While governance is often characterized as an activity that primarily involves the ”state”, a broader understanding of the term recognizes that a variety of governance structures exists, with varying levels of involvement of state and non-state actors, including when these entities transact with each other in international and transboundary governance contexts. Apart from the question of ”who” governs, there are related issues that need to be considered, including the principles that guide governance regimes (for instance, economic efficiency, equity, representativeness, participation, inclusion, among others); the processes by which rules are set and modified, and how these relate to political, administrative and legal (including constitutional) structures; and how conflict is negotiated and managed. Governance of forest systems affects FSN outcomes by directly impacting *how* forest landscapes are used (**availability**), determining *who* gets access to forest-based foods, income-earning opportunities and access to ecosystem services (**access**), and also affects the *resilience* of these relationships in the face of change, shocks and other pressures (e.g in terms of the safety net that forests provide), as well as the complementary roles of forests in agricultural production (e.g. ecosystem services that ensure sustainability) (**stability and utilization**).

As Chapter 2 has elaborated, trends since the eighteenth century show that the impact of human activities has generally resulted in the loss of area under forests. In the eighteenth and nineteenth centuries, ”Industrial”, commercially-oriented forestry was the dominant form of forest use, with operations typically being managed through concessions granted to the private corporate sector, or directly by state agencies. During this period, these forestry activities were largely concentrated in temperate regions, but expanded to the tropical regions by the twentieth century, alongside processes of imperial expansion and colonization. In many cases, such logging concessions interfered with traditional “common pool” resource and land management systems previously in operation for millennia, especially in parts of the world that had previously not been integrated into global production and consumption systems. Although there are vast areas of forests that are under the traditional governance structures of local indigenous peoples (and there has been a slight increase in community control in the last decade; see RRI, 2014), as Chapter 2 has pointed out, public ownership of forest lands remains high across all regions.

By the 1970s, however, concerns about the long-term ecological implications of the loss of tropical forest areas and declining biodiversity, as well as about livelihood options for poor forest-dependent populations in the developing world, combined to create a qualitatively different environment for forest planning and management. There is not only a concern for the loss of tropical forest areas, but also declining biodiversity, challenges of climate change and the social importance of forests for recreational purposes.

At the same time, burgeoning populations and increased per capita food consumption placed growing pressures on the forest resource base. Thus, at the same time that forestry in the developing world became subject to additional pressures for conversion to food and fibre production, demands from groups concerned with conservation, rural development and poverty alleviation found a political voice (Anderson*,* 1999; Wollenberg *et al.*, 2001). To attend to these conflicting pressures, it was felt that the only way to continue expanding the use of forest products was to undertake a large-scale campaign of afforestation, tree plantation and protection, which would ease the pressure on existing natural reserves (Barraclough and Ghimire, 1995). Concerns about the direct consequences of forest loss have coupled with the recognition of the importance of land-use management as an essential component of climate change mitigation, as well as for ecosystem health more generally, and have resulted in a number of new initiatives designed to address global deforestation (see Chapter 2).

In response to the need to reverse forest loss, a range of new governance approaches has emerged in the forest sector, developed in conjunction with stakeholders who were historically excluded from decision-making and benefit-sharing (Anderson *et al.*, 1998; Anderson, 1999; Wollenberg *et al.*, 2001, Villalobos *et al.,* 2013) (see Box 23). The current forestry context is one in which a wide variety of actors and organizations have an interest in resource management and outcomes.

Objectives in the forestry sector have also multiplied, and it is unsurprising that forest governance is considerably more complex than it was during the early period of the last century. In particular, exclusive management of forest resources for single objectives appears unfeasible as a long-term strategy, given the competing resource demands within a broader context of land scarcity. A multitude of ideologies, interests, actors and organizations have come together to define the current scenario in the forest sector, and the relationship between different forestry objectives and those that relate to FSN. Although management of forest resources takes place at the forest management unit (FMU), these units are part of a bigger landscape where there are multiple stakeholders and multiple possible uses, and these need to be integrated into a more holistic approach to integrated landscape planning.

In their analysis, Grimble *et al.* (1995) adopt a broad definition of forestry-sector stakeholders, and proposed a macro to micro continuum, which could be used to classify stakeholders at different levels (global, national, regional and local), as well as to identify their resource interests. Adopting such an approach (Table 11) allows an identification of the principal potential stakeholders with interests in the forest sector, ranging from the global to the local level. It is recognized that these broad categories of stakeholders (especially at the local level, such as farmers or forest dwellers) are likely to be further differentiated by a range of other social variables, such as age, gender, wealth, class, caste, ethnicity and so on. Thus, there is no assumption that the individuals and groups identified in this typology have homogenous interests or preferences with respect to forest resources, especially in relation to how forests relate to the different dimensions of FSN.

Table 11 Potential stakeholders in the forestry sector

Level	Potential stakeholders
Global	Present generations
	Future generations
	Multilateral organizations/donor agencies
	Foreign governments/bilateral agencies
	International pressure groups, including environmental organizations, and industry coalitions
	International forestry industry, both extractive and forest-based industry
	International consumers
	International NGOs
	Foreign academics/intellectuals
National	Present generations
	Future generations
	National governments, policy-makers, and state agencies
	National political parties
	Forest departments
	National pressure groups, including environmental organizations, trade unions, and industry coalitions
	Forest-based industry, including traders
	Consumers
	National NGOs
	Academics/intellectuals
Provincial/ Regional	Provincial/regional governments
	Provincial/regional political parties
	Forest departments
	Provincial/regional pressure groups
	Forest-based industry, including traders
	Extractive industry, especially logging companies and sawmills
	Consumers
	Provincial/regional NGOs
	Downstream communities
Local	Local government
	Local forest bureaucrats
	Local groups, including traditional and community groups and indigenous peoples
	Forest-based industry, including traders
	Extractive industry, especially logging companies and sawmills
	Local consumers
	Local NGOs
	Downstream communities
	Forest dwellers
	Farmers
	Collectors of timber and non-timber forest products
	Livestock herders, including migrants and transhumant populations
	Cottage industry and small-scale artisans

Adapted from Grimble et al. (1995).

Box 23 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 are: (a) the transference of the forest concessions from semi-public companies, to the *ejidos* communities in Quintana Roo, Mexico in the mid-80s; (b) the Community Forest Concessions in the Petén in Guatemala in the mid-90s; 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. The cases of Quintana Roo and Petén are still functioning well, but the current government of Bolivia has cancelled some of the private concessions. In the case of Quintana Roo, the first planning decision and action was to undertake land-use planning in which the communities designed land for agriculture, pastures and for permanent forest use, resulting in a more balanced use of the landscape for food and income generation. In Quintana Roo, Petén, and in many concessions in Bolivia, the forest management plans are Forest Stewardship Council (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. 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 of nuts for snacks sold in the international and national market) (Villalobos *et al.*, 2013).

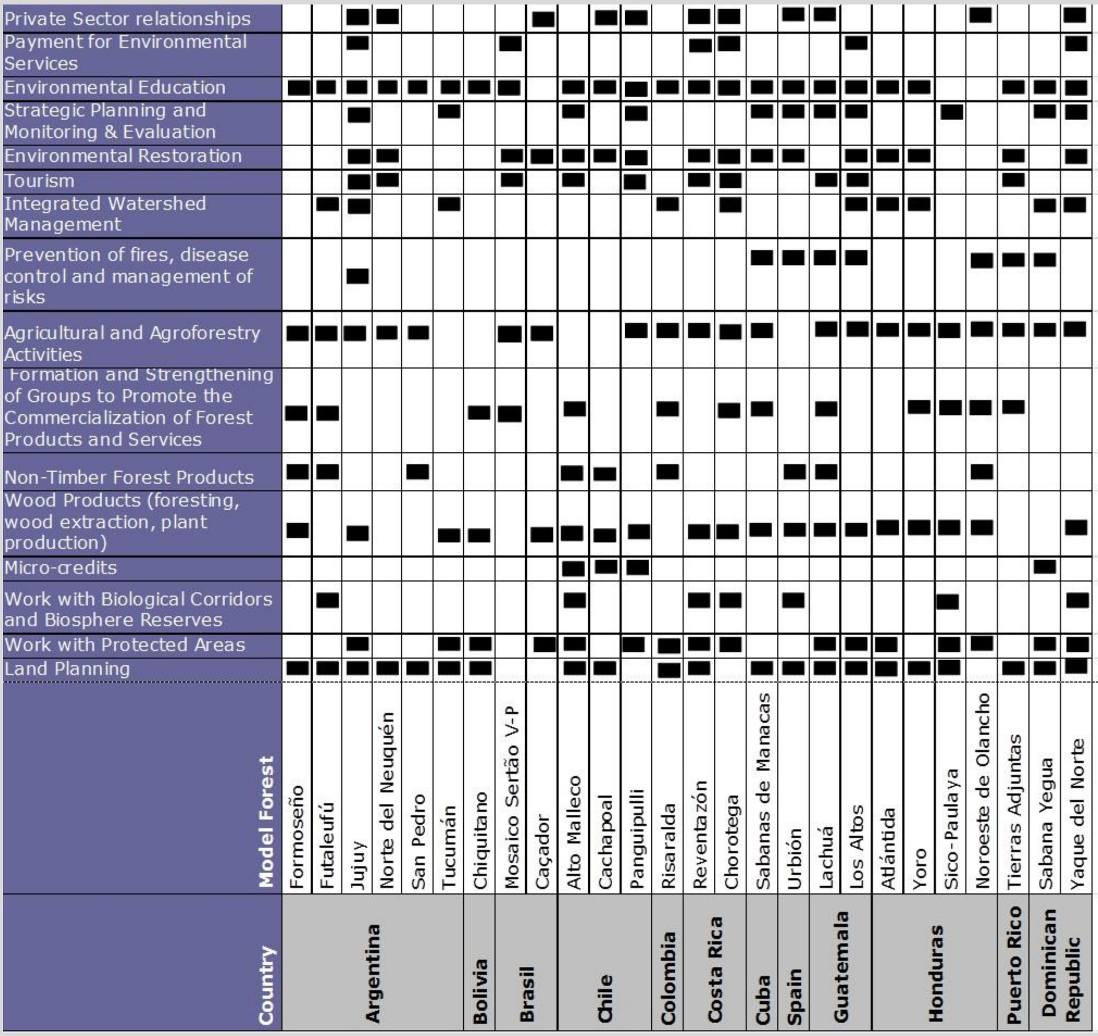
A number of intermediate approaches have replaced the traditional dichotomy between public (or state) and private sector arrangements for the delivery of goods and services in this sector (Anderson, 1999; Arnold, 2001). Box 24 describes the case of model forests of the Iberoamerican network, where there is a vast forest-rich territory in which stakeholders and land uses co-exist, and where there is a governance platform of representatives of various and multiple land and forest uses in which the main stakeholders are represented (including hunting and collecting, as well as industrial agriculture and forestry). Model forests are social, inclusive and participatory processes that seek the sustainable development of a territory and thus contribute to global targets related to poverty, FSN, climate change, desertification and sustainable development.

The contemporary context for forest governance is characterized by the existence of a plurality of interests, ideologies and actors. The following section describes some of the dominant forest governance regimes and practices across a variety of land ownership tenure types in different parts of the world. This provides a classification of different ownership and management regimes, and the interface between these property rights approaches with those adopted for food production. In most territories, all these forms of ownership and control co-exist and interact in different ways. Specifically, we outline forest governance regimes under four different ownership structures: (i) state ownership (ii) community ownership; (iii) individual ownership; and (iv) corporate ownership

Box 24 Model forests of the Iberoamerican network

Model forests reflect a mosaic of uses and ownership, where people's livelihoods combine various activities ranging from agriculture, livestock, forestry, tourism and conservation. Stakeholders seek to advance sustainable land management in a collaborative and coordinated way, often creating local leadership strategies to coordinate activities related to protected areas, biological corridors, forest management, sustainable agriculture, rural tourism, access to microcredit, organic farming, watershed management and forest certification. In the model forests there are multiple activities as the figure below shows.

Model forest of the Iberoamerican model forests network and activities developed



Source: http://www.bosquesmodelo.net/en/que-es-un-bosque-modelo/ and http://www.imfn.net/

The model forests of the Iberoamerican network cover 16 countries, 32 model forests territories, more than 30 million ha and a population of around 7 million people. These model forests are a territory, as well as a governance model, in which there is wide participation and the stakeholders have developed a governance structure that is appropriate for themselves. There are more than 70 model forests in the world, one national network (Canada) and five regional networks (Lorenzo *et al.*, 2014).

5.2.1 Who owns the world's forests?

It is estimated that 86 percent of the world's forests were publicly owned in 2005[3]. This public dominance is also true at the regional level across the board, where total public ownership of forests is high: Africa (98 percent), Asia (95 percent), Europe, including the Russian Federation (90 percent), Oceania (76 percent), North and Central America (70 percent) and South America (82 percent). For example, 94 percent of Canada's forests are on public lands, the vast majority of which are owned and administrated by the federal government, while individual provinces/territories and First Nation peoples (indigenous peoples) own and administer 2 percent each, respectively. This leaves only 6 percent of Canada's large forested areas in the hands of private owners. The overall trend, most strongly evident in the boreal and temperate zone, is nonetheless towards greater privatization of public forest lands, whether by private individual landowners (e.g. second-home owners and recreational users), corporate enterprise (timber extraction) or private nature conservation. In the tropics, public lands have been ceded to other owners, though it is not clear to whom, since private lands have not increased commensurately.[4] These patterns of public ownership are evident when looking at property domains across different forest types (Table 12).

Table 12 Percentage of forest area owned by the public by climatic domain (1990–2010)

Region	1990	2000	2005	2010
Boreal	94.3	94.3	94.3	94.3
Temperate	41.4	28.4	17.5	7.4
Subtropical	34.6	32.1	32.7	30.4
Tropical	90.0	89.9	89.2	88.7
Global	83.5	81.6	79.9	78.4

Source: adapted from Whiteman et al. (2015).

.

In the forest sector, state management remains the dominant form of ownership and control. The pre-eminence of the state in forest management expanded with the colonial expansion from Europe into the tropics, at a time when the major European powers had exhausted their own domestic resource base. The early colonialists found themselves in resource-rich parts of the world with relatively low levels of human demands, areas ripe for the extractive process of colonization. Few recognized the existence of indigenous systems of resource use and management, and the assumption was that any land not explicitly defined as private property was *terra nullius* – land owned by no one. The state stepped in to define itself as the owner of all such land, implicitly rejecting the claims of communities and societies who were unaware of Western notions of property and property rights. Once lands had been claimed as state property, they were managed for the benefit of the (colonial) state, and this process often required the rights of the earlier inhabitants to be commuted or curtailed. Scientific principles of sustained yield management could then be applied to maximize the flow of returns – primarily commercial – from these resources.

The second dominant force in the nineteenth century was the conservation movement, which drew on the ideals of conservation and wilderness that were promoted by the romantics. The conservation movement required the setting aside of large areas of land as wilderness reserves, and the only agency that was presumed to be able to provide for such public goods was the state. The management principles that were developed by the conservationists were appropriate in the particular context of temperate forest areas with low anthropogenic pressures. However, they were applied universally, especially by colonial foresters operating in regions where human populations were still highly dependent on forests for basic subsistence. The efficient and scientific management of resources required them to be enclosed and policed, against the so-called "rapacious" demands of local populations.

---

[3] http://www.pefc.org/forest-issues/who-owns-the-forest. Based on data from FAO (2005).

[4] In Brazil and much of Latin America, for example, many public lands have been occupied by squatters or speculators without formal deed of property.

Independence from their colonial rulers did not really change the nature of forest resource management regimes in the tropics. The external drain upon resources was replaced by the needs of the new regime as these countries embarked upon a path of planned development. Forests were seen as a national resource, to be harnessed for the wider public interest, which was usually interpreted as maximizing economic growth. Forests were most valued for their contribution to the industrial sector, and competing uses (especially FSN needs from forests) were implicitly given less importance. In a number of countries, timber concessions were auctioned for a fraction of their economic value (and even less if ecological functions are included), and there was a rapid expansion of forest-based industry, supported by state subsidy. In countries with large areas of forest, the demand was for land for agriculture and other uses, and the clearing and burning of forestland (often to promote agriculture) was actively encouraged through the use of direct and indirect policy instruments.

This situation continued until the early 1970s. The rise in environmental consciousness at this time was combined with a radical shift in development thinking, away from the growth-oriented strategies of the 1960s, to recognition of basic needs as an important factor in developmental decision-making. One of these basic needs was fuel for cooking, and it was believed that a large proportion of the world's population depended on wood for its basic cooking requirements. Given the area under forests at the time, and projections of world population growth, there was a perception of impending woodfuel scarcity and crisis. The oil price increases of the early 1970s added to this perception of a crisis in the energy sector. It was believed that there was a need for massive investment in the forestry sector, both to provide for the basic needs of the poorest populations as well as for the needs of the industrial sector. Further, it was also believed that most countries were unable to command the resources that were required for this massive investment, and there was a call for ”participation” in the forest sector led by the donor community, especially the World Bank and FAO.

The radical re-thinking of forest sector strategy in the developing world by the late 1970s led to a number of institutional reforms in this sector. Governments and state forest departments have attempted to introduce new governance practices that increase the scope for the involvement of various stakeholders in forestry. These have included regimes that have attempted to engage other actors in activity on state forestry lands, as well as institutional support from the state for initiating forestry and tree cultivation practices on private and community lands. Non-state actors have also started to transact among themselves to further their forest resource-related interests, and the state's role is, in many cases, limited to providing an enabling environment for these emergent regimes.

Participatory management implies the re-orientation of the hierarchical, control- and regulation-oriented structure of state forest management that has evolved over the last century in a number of countries. This new paradigm sees the local level forest bureaucracy as playing a supportive role, encouraging community initiative and sharing management responsibility. At the most general level, such a philosophy aims to "link the socioeconomic interests of the rural dwellers in and around forests with the sustainable management of these areas while maintaining environmental stability and ecological security" (Rastogi, 1995).

Earlier blueprint developmental strategies have been unable to deal with the complexities of forestry in an age of multiple stakeholders and multiple uses. Bureaucracies have also faced increasing pressures to justify their operations in a climate of fiscal austerity, and this has encouraged them to examine new ways of performing their core functions, including ”contracting out” some of these functions to other stakeholders. In many countries, the public (local, provincial or national) owns large areas of forestland, some of which is heavily degraded and in need of rehabilitation, but lacks the institutional and financial capacity to engage in these tasks, or to maintain existing areas of good forests. The interests of the state typically include concerns for ecological restoration and stability, creation of rural employment opportunities and poverty alleviation. A number of stakeholders can provide an input into these operations, especially private individuals and communities, with NGOs and donors performing an important supportive role.

The most common form of partnerships on state forests occur in conjunction with local communities. These regimes have been referred to as joint forest management (JFM), co-management, shared management, or collaborative management. These terms describe management partnerships 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 (Borrini-Feyerabend, 1996). While land ownership continues to rest with the state, management responsibility is shared. In particular, the involvement of the local community reduces policing and monitoring costs for the state, while local communities bring their own specialist local knowledge and skills to the task of management. Both parties need an assurance about enjoying the long-term benefits from participation in the regime. Typically, the local community is given rights over intermediate products such as grasses, as well as other NTFPs, while the final timber harvest is 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. Further, the community also usually sacrifices returns from the land set aside for protection in the short term, since a number of otherwise unproductive degraded forest areas are frequently used by communities for scrub grazing and for other low-value uses. Governance by co-management may also be an option for conflict resolution in situations where different stakeholders use land, most often for different purposes, but the legal rights belong to both stakeholders. Conflicts often occur in these situations and co-management is a way forward to solve these conflicts (Widmark, 2009).

Forests under co-management are likely to be diverse, producing a range of NTFPs and grasses, as well as the final timber harvest. The potential for employment generation is good, not just for plantation, maintenance and protection activity, but also for harvesting NTFPs and the final harvest, as well as for primary processing and value addition activities. Poverty alleviation would be addressed since the benefits from co-management would be shared among members of the local community, although issues such as gender and ethnicity may lead to conflict over benefit-sharing. Finally, ecological needs would be well served by a diverse and species-rich forest that is managed both for the yield of grasses and NTFPs as well as for the final timber value.

The evidence on the experience of such regimes suggests that there is considerable variation in field-level outcomes (Hobley, 1996; Poffenberger *et al.,* 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 25). 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).

Box 25 Local governance in Quebec and social networks in forest governance: what lessons for sustainable forestry for food security and nutrition?

In Canada, public forests are under provincial jurisdiction, and each province is able to define its own legislative and regulatory framework. In Quebec, for 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 the forest and its 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 Lecler, 2013).

The **regional round tables for integrated resource management planning** are the principal governance instrument at 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:

(i) to promote local cooperation and harmonization of uses;

(ii) to identify shared goals for the protection and development of resources and land;

(iii) to participate in the preparation of tactical and operational integrated forest management plans (PAFI) 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 partners who have a broad range of activities on and interests in public land (i) Forestry; (ii) Wildlife; (iii) Other Users with Rights; (iv) Nature; (v) Territory; and (vi) First Nations.

Regional round tables for integrated resource management planning are similar in certain aspects to social networks in forest governance. A social network is set of relations 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 *et al.* 2009). Ties and connections and levels of cohesion between different actors are important to improve governance.

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

In South Asia, problematic experience with both public and community forestry governance led to the decision to create partnerships between communities and public authorities. Such ”joint management” schemes met with considerable success in protection of remaining forest fragments on as much as possible of the public lands. Villagers agree to assist in the safeguarding of forest resources through protection from fire, grazing and illegal harvesting in exchange for which they can access and collect NTFPs and a share of the revenue from the sale of timber products. By 2005, as much as 14 million ha of public forestlands in South Asia were managed within such participatory management schemes. Similarly, in Brazil, where 135 million ha of public forestlands are under community control, the public forest law also provides for co-management of such lands by traditional communities who undertake forest product extractivism at low intensity on public lands.[12]

Partnerships between the state and individual users are often targeted at the landless and the rural unemployed, providing rights over trees in return for their efforts in plantation, care and maintenance of the resource. Land ownership continues to rest with the state, but individuals can make decisions about the type of species to be planted, enjoy all NTFPs from the trees, and also a share in the final harvest once the trees are cut. Policing costs are minimized since individuals have a private incentive to protect trees over which they have secure tenure rights; if there are economies of scale in such activity, there would be incentives for group tenure over larger areas. The state would bear the initial cost of the planting material and other equipment, would provide technical support, and would also need to pay a wage to the individuals in order to elicit their participation.

Although individuals would be interested in planting trees that yield high value, they would also be interested in the annual flow of NTFPs from the resource, and such arrangements can thus become an important source of foodstuffs to promote local food security. Employment generation is likely to be high, with individuals being given complete responsibility for the plantation, care, protection and maintenance of their trees, as well as being responsible for harvests. Poverty alleviation would also be addressed, particularly as such schemes can be targeted at the landless and the unemployed. The state, thus, could meet a range of social objectives while also rehabilitating degraded forests, lowering policing costs, and enjoying a share of the final harvest from the restored forest. In turn, individuals are given access to a reasonable source of employment and income, and this provides the basis for synergy and collaboration. One example of such schemes is in the Tree Growers’ Cooperatives model that has been promoted in parts of India (Saigal *et al.*, 2008).

Box 26 Forests and food security in the Republic of Korea – a model to follow?

The Republic of Korea is a mountainous country where the people have traditionally had a high reliance 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 food security needs resulted in severe deforestation and paradoxically became the main factor threatening food security. 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 TenYear Forest Rehabilitation Plans which achieved complete rehabilitation in merely two decades. The government perceived that restoring forests, especially in mountain watersheds, would help prevent agricultural disaster, provide

[12] http://www.florestal.gov.br/florestas-comunitarias/sobre-florestas-comunitarias/sobre-florestas-comunitarias

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. This programme demonstrates how the national Forest Rehabilitation Plans incorporated food and nutrition objectives, highlighting the important socio-economic benefits of forest rehabilitation in improving food security and sustainable livelihoods.

Forest rehabilitation in the Republic of Korea contributed to satisfying all four dimensions of food security:

- Food availability. In times of need people had always harvested forest foods such as wild edible plants, mushrooms and nuts. As part of the rehabilitation effort, planting of fruitand nut-trees, especially chestnut, was promoted to contribute to the alleviation of food shortage. • Food access. Income from harvest and sale of wood and non-wood forest products and from planting of fruit- and nut-trees (especially chestnut) enabled people to buy food. Other sources of income include participation in forest rehabilitation projects and, in more recent years, provision of services in recreational forests.
- Food utilization. Fuelwood was traditionally used for cooking, but to lessen pressure on the forests the government introduced alternatives to fuelwood for cooking and banned the use of fuelwood in 20 cities. The decline in fuelwood use allowed the conversion of existing fuelwood plantations to wood production, benefiting the economy. Restored mountain forests contribute to food utilization by supplying a naturally purified water supply for cooking and other uses. Finally, increased production of foods from the rehabilitated forests (e.g. chestnuts, pine nuts) provides energy and nutrients and diversifies diets, which during times of hunger were based mainly on carbohydrates (cereals, potatoes and pulses).
- Stability of food security. Forests provide a food safety net and sustain a healthy environment conducive to food production; they protect farmland and water supply and thus contribute to increased sustainable crop production. With the country's ongoing rapid economic development, the roles of forests in the four dimensions of food security have changed over time. Until the 1960s, during the time of absolute poverty, forests primarily had a role in food availability.
- With accelerated economic growth and the implementation of rehabilitation projects, the food access aspect of food security gained importance, as income earned from participating in rehabilitation activities greatly contributed to solving food problems. In addition, the role of forests in providing clean drinking-water supported the utilization aspect of food security.

With their complete rehabilitation, forests became more important in the stability of food security by controlling erosion and protecting watersheds for the improvement and stabilization of agricultural productivity. Today, in a prosperous society, the demand for the recreational, rest and healing functions of forests is increasing rapidly, especially among the urban population, and the demand for related services creates employment among the rural population which contributes to rural income and food security.

Source: Modified from: FAO. 2016. Integrated policy for forests, food security and sustainable livelihoods: Lessons from the Republic of Korea. Food and Agriculture Organisation of the United Nations. http://www.fao.org/3/a-i5444e.pdf

5.2.2 Forest governance on community-owned lands

Community forestry refers to forest management that has ecological sustainability and local community benefits as central goals, with some degree of responsibility and authority for forest management formally vested in the community (Charnley and Poe 2007).Conservation and development practitioners have increasingly promoted community forestry as a means to achieve multiple benefits. However, outcomes of community forestry have been mixed (Hajjar *et al.* 2016). There is a rich literature on community forestry institutional arrangements, but fewer efforts to examine the role of socioeconomic, market, and biophysical factors in shaping both land cover change dynamics, and individual and collective livelihood outcomes. There are substantial data gaps linking population dynamics, market forces, and biophysical characteristics to both environmental and livelihood outcomes. Second, most studies focus on environmental outcomes, and the majority of studies that do assess socio-economic outcomes rely on qualitative data, making it difficult to make comparisons across cases. In a systematic review of the effectiveness of community forestry Hajjar *et al.* (2016) find a heavy bias towards studies on South Asian and Latin American forests, indicating that the literature on community forestry might not be representative of decentralization policies and community forest management globally.

Community lands are often held collectively by groups for the pursuit of specific shared objectives, such as grazing and the production of tree products, as well as for spiritual and cultural purposes. These lands are often poorly maintained and inadequately stocked, or may be under *de facto* private control because of encroachment and occupation by locally powerful interests (Jodha, 1992). Pressure on such lands leads to a significant decline in their overall extent, especially in countries where land scarcity means that there is little alternative land available for state initiatives, or for redistribution to the landless (Jodha, 1986; Pasha, 1992). Recent efforts to restore lands to community control have resulted in small increases in lands owned by indigenous peoples and communities over the last two decades (RRI, 2014). Traditional management in some indigenous communities, together with decentralization policies, has resulted in the sustainable management of forests by communities, as in the case of Totonicapán in the highlands of Guatemala (Colfer and Capistrano, 2013).

Many communities have substantial knowledge and beliefs transmitted through oral traditions derived from first-hand observations about the local environment, which underpin systems of self-management that govern resource use. The practices of indigenous peoples and local communities, deriving from customary uses of biological resources, are the fundamental basis of food security systems in many forest territories. Some empirical studies in Canada (Elliot *et al.*, 2012) and central Africa on traditional knowledge and food security have shown evidence that harvesting, preparing and conserving wild forests food by indigenous peoples according to customary traditions have positive impacts on the food security system, especially at the local level.

Local and indigenous communities have managed their heterogeneous landscapes for the production of food for millennia (Padoch and Sunderland 2014), so much so that virtually all tropical forests are thought to have been heavily shaped by past human use (Anderson 2006, Heckenberger *et al.* 2007). Although there is no consensus as to whether these historical disturbances had a positive or negative impact on biodiversity, many careful and deliberate traditional management strategies have been demonstrated to maintain and enhance populations of useful species and biodiversity (Anderson 2006).

One reason for the success of customary forest use is that the relationship indigenous peoples have to food is often based on cultural practices. A case study on some First Nations in Canada used the concept of “cultural food security” to demonstrate the ability of aboriginal peoples to reliably access important traditional foods through traditional harvesting methods (Power, 2008). In Central Africa, several studies have shown evidence that when forest products are harvested for local consumption, the harvesting techniques employed by forest communities are more sustainable, and facilitate forest regeneration and biodiversity conservation (Rerkasem *et al.*, 2009). The challenge is to ensure the *in situ* protection of indigenous peoples’ local knowledge and traditional resource use in a way that continues to improve food security, and to learn from these diverse knowledge systems.

Community-managed systems have been in flux over the last few decades, with pressures on these systems from a range of competing users, but also attempts to revive and reintroduce systems, especially recognizing the important roles they can play in transitions towards more just and inclusive forms of forest governance. Arnold (1998) reviewed the state of traditional community-level forestry across Southeast Asia, South Asia, sub-Saharan Africa and South America, and found that a number of systems that were important and widespread in the past were in decline. The reasons for the decline in historical and traditional systems were attributed to a combination of economic, demographic and social factors that undermined the viability of community-based systems, as well as a negative policy environment for such regimes. The most pervasive influence of state policy was the expropriation and take-over of community forests, and their conversion to reserves and other forms of state property. There has also been an extension of government control over resources, including in the forest sector, which has replaced local systems of management. However, this extension of state authority has not always been accompanied by a matching capacity within the organs of the state to implement effective management and control.

In other circumstances, users have attempted to revive traditional forms of management and/or governance, or to introduce new and modified regimes regulating access and control of forests, in order to respond to a combination of growing shortages of forest-related goods or services, increasing pressure on existing forests from non-local users, and the identification of new challenges and needs that were more effectively dealt with under community management. A number of groups, advocating for the rights of communities or for the need for their recognition in formal governance arrangements of forests, have become important allies in these struggles for community recognition – notable among these are groups such as Survival International and the Rights and Resources Initiative. Moreover, the discourse has shifted from the functional outcomes of community management towards a rights-based perspective based on historical claims, rights recognition and a combination of strong grassroots leadership. Additionally, increases in strategic external support have led to a growing recognition of the need to harness the ability of communities and indigenous peoples to govern themselves and their forest resources.

Some of the earliest examples of community forestry can be traced to the social forestry projects of FAO in the 1960s in Ecuador, where plantations were established on a sharing investment arrangement (government provided the land, private sector provided the money, and communities provided labour) (Kenny *et al.,* 1999). One dimension of these interventions was to encourage individuals to cultivate trees (farm forestry, discussed in the last section), while the other aspect was the creation of woodlots on communal lands. Communal woodlots were promoted by the state to reduce pressures on existing natural forests, by creating locally-managed sources from which rural users could meet their needs for forest products and services, and support their needs for FSN (both directly and indirectly). Such programmes were promoted extensively throughout Asia, sub-Saharan Africa, Latin America and the Pacific Region, often with considerable funding and support from bilateral and multilateral donors. Community land was identified for tree plantation, and the activity was supported by the creation of new or modified local-level management institutions and the provision of technical and other inputs through government forestry agencies. Outcomes were mixed: 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); while 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.,* 1988). More recent experience of state-community partnerships on community lands comes from the *ejido* community forests of Mexico, in which control over forests has been transferred from the state to communities since the mid-1980s, and from the CAMPFIRE project in Zimbabwe, where communities have been given control over wildlife resources on their land and rights to benefit from harvesting these resources (these two cases are reviewed in Arnold, 1998). Also in the mid 1990s, the community concessions where formed in Petén, Guatemala and in the late 1980s, the extractivist reserves that were established in Brazil (Villalobos, 2013). Extractivist reserves (Resex) are defined as *"natural areas utilized by traditional extractivist population, where subsistence is based on extractivism (the extraction of renewable natural resources from the land) and on complementary subsistence agriculture and small animal husbandry"* (Silva Neto *et al.,* 2004). In the Brazilian Amazon, by 2004, a total of 18 extractivist reserves had been set up, totalling an area of 4 842 721 ha, with a population of around 8000 people (indicating that these extractive reserves are a low intensity operation). Reserves are managed in order to produce income (from rubber and Brazil nut) and food. Governance is guaranteed in the law, and the extractictivists are organized in different ways to directly administer the area.

In recent years, pressures on community lands and their use for forestry activity has led to a shift towards collaboration between communities and other (non-state) stakeholders for forest management. There may be scope for other stakeholders to participate in forest governance on community-owned land if there is a perceived need for inputs from outside the community to avert such institutional failures. These inputs could be organizational, financial, managerial or technical, or may relate to the engagement of the community with the outside world (access to markets, credit or to influence over the policy process). However, pressures for land for cultivation can also undermine these community-managed forest systems. For example, in some recent cases of indigenous peoples' forests in the Nicaraguan Atlantic Region (RACCN), although the local communities have rights to the territories by law, there is an increase in land invasion by displaced people from other parts of the country (which comes with the tacit support of the government). This is a case in which systems of local and territorial governance collide with national imperatives (Larson *et al.,* 2006). This situation, which was originally reported in 2006, is increasing in intensity, and the case is being heard in the

InterAmerican Court of Human Rights. This case represents a conflict over land and food security between indigenous peoples and landless people, and raises some challenges and questions about how to manage these difficult trade-offs in land-scarce contexts.

There is a need for clear demarcation of traditional land, territory and property and tenure rights as a condition not only of forest conservation but also for ensuring the availability of forest goods and services to the broader society. Serious conflicts arise when tenure rights and rights of access are not well defined or upheld. For example, in the example of the Caribbean North of Nicaragua, while indigenous peoples have rights to their territories, they lack strong legal support from the government. As a result, many local, traditional owners of collectively held land risk losing their land to migrants and settlers. Some African forest legislations such as Cameroon, Gabon and the Democratic Republic of the Congo recognize a right to access to the forest for riparian forest communities. This right to access is extended to the right to use wild forest products. Indonesia has also introduced new legislation protecting the customary ownership of forests by indigenous peoples, where certain historical and contemporary use conditions apply. These laws are enforced by national, local and community institutions such as local committees composed of representatives of local villages, municipal and state agents involved in forest management, and managers of protected areas. Such laws must include provisions for enforcement, protecting customary owners from the pressures of agricultural expansion as well as incentivizing sustainable use of forest resources. Finding ways to ensure that poor rural communities achieve economic development without losing access to the benefits of locally produced and harvested foods will require additional research and careful consideration of how landscapes are structured and how they change overtime. In particular, there is a need to “nest” community-based systems within larger systems of local and national governance to improve inclusion, accountability and transparency, and also to provide security and enforcement of legal regimes against pressure from external actors (Ojha, 2014).

5.2.3 Forest governance on individual lands

As Chapter 2 has shown, agricultural lands with over 10 percent of tree cover are found in every region of the world, and are estimated to cover over 1 billion hectares of land worldwide. Farmers have incorporated planted trees as part of their land-use systems since the establishment of settled agriculture. Boserup (1965) classified land-use systems in accordance with their degree of integration between forest and bush rotations and their gradual shift to continuous cultivation of crops in isolation from trees, as related to increased population density. In her view, density-induced intensification combined with technical innovation would stave off a Malthusian crisis. However, excessive intensification led farmers to reduce cropland integration with trees and livestock. With a decline in organic manuring and water and nutrient pump functions of tree integration came increasing soil degradation.

Box 27 Case study of the Russian Federation’s use of forest for food security and forest governance

Russian forests make the following contributions to food security:

- procurement of forest food products (berries, mushrooms);
- use of public forestland for agriculture (haymaking, pastures);
- hunting for supply of meat and other products;
- growing of forests for the purpose of agricultural land protection against natural disasters.

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)	**	**

*Source: Petrov (unpublished) * Does not include subsistence production. ** Data unavailable*

Forest governance issues

The legal framework for forest governance in Russia permits that citizens visit forests for recreation and to collect wild food resources for their own use free of charge, while commercial use of wild food resources is based on leasing agreements.

Factors that hamper development of such uses include:

1. FSN do not belong to the power of federal and regional authorities responsible for forest administration and management.
2. Forest lease holders harvesting wood have no legal rules or economic motivations to procure non-wood food resources.
3. In many regions there is no social and transport infrastructure to procure and deliver the food products to the domestic and export markets;
4. The public authorities do not support economically private business to develop the procurement of forest food products.

A significant change in policy towards on-farm tree cultivation can be traced to the 1970s, a period during which there was a widespread perception that poor populations in the developing world were facing an acute shortage of domestic fuel (Eckholm, 1975). The woodfuel crisis, as it came to be known, referred to the growing conflict between demand – as estimated by household energy surveys and population growth rates – and available supplies from natural forests. The solution – referred to by Dewees (1989), as the “woodfuel orthodoxy” – was to encourage farmers and smallholders to grow trees on private farm lands or in community-managed woodlots (“social forestry”). Farming households would thereby meet their own livelihood objectives while simultaneously reducing the pressure of subsistence demands on state forests. Thus, on-farm tree cultivation shifted from being a purely private decision made by a dwindling number of individual farmers, to an activity that was promoted and supported by a variety of actors, in the governmental, non-governmental and corporate sectors. This changing policy support for farm and agroforestry represented a fundamental shift in forest governance strategies, although at this early stage, they were not carefully integrated with continuing food and nutritional requirements.

Subsequent research has shown that the assumptions behind many early farm and social forestry interventions were deeply flawed, primarily because tree planting was not analysed as part of a household’s overall livelihood strategy, rather as a singular response to a specific scarcity (Arnold and Dewees, 1997). The literature has demonstrated that farmers will plant trees if this optimizes their use of land, labour and capital resources with respect to the options available to them both on and off the farm. Tree growing is not costless, and farmers will devote resources to this activity only if it yields superior returns to available alternatives. In some cases, trees were grown to maintain supplies of wood products as the availability of off-farm resources declined; however, in many others, households responded to scarcity by sharing cooking arrangements, increasing labour devoted to collection, substituting between fuels, migrating, or engaging in nomadism and transhumance.

Trees were often seen simply as a lucrative cash crop (not a subsistence commodity), especially since the “segmented” wood market offered higher returns on trees that could be converted to pulp, small timber and poles than to trees sold as fuelwood. This also affected the choice of species in areas where farm forestry was adopted principally as a commercial venture. In general, extension agents promoted fast-growing, commercially-valuable exotics, especially in the early phase of farm forestry and agroforestry programmes. As other stakeholders – especially NGOs – entered this sector, there was a growing recognition that these species were not always suited to the needs of local users, and sometimes were ecologically inappropriate. Recent efforts at promoting farm forestry have become more sensitive to the need to find suitable and locally valued species that are more likely to be adopted by individual smallholders, which might include fast-growing exotics where they provide a source of fuelwood, or construction timber (Mendez *et al.,* 2007).

In other cases, trees have been planted by labour-scarce households in response to an increase in off-farm employment opportunities, since they entailed lower input and supervision costs.

Trees are also planted in response to declining soil fertility and agricultural productivity, in order to produce organic mulch, provide shade, soil nutrients and energy, and to regulate local wind and water cycles. Finally, in some cases, as land use has intensified, trees are planted to fence fields and to act as boundary markers. In this sense, tree planting has become part of a broader strategy to protect and restore degraded ecosystems, directly providing food, as well as providing services that would enhance agricultural productivity and reduce pressures on pasture. As Box 28 shows, this shift is particularly important in a context of an increased "feminisation" of rural agricultural practices, and the specific roles that women play in managing household needs for FSN.

Box 28 The role of women in farming-based forestry systems for food security and nutrition

It is estimated that women produce more than 50 percent of the food grown worldwide, primarily in small-scale farming systems, in complex, multi-functional mosaics. Indeed, women tend to grow a greater diversity of products, experiment more with folk varieties and landraces (and thus agrobiodiversity) and are often reliant on broader aspects of biodiversity for their family's herbal needs. Although women comprise up to 80 percent of farmers in sub-Saharan Africa and 60 percent in Asia – ratios that are increasing due to male emigration and moves towards off-farm sources of income – their access and control over land and resources is generally inferior to that of men in the same household or community. Where women do have access to land, they will generally use it for food production and income generated from such land is more likely to be utilized for the wellbeing of the household, whether for nutritional, health or other benefits. Women are also primarily responsible for food preparation and allocation and, as such, are usually the "guardians of household food security". In times of food insecurity, maternal food deprivation can impact the long-term productivity of the wider community through childhood malnutrition and ill-health, effects that can linger long into adulthood, ultimately affecting their life-long productivity and health. Malnutrition during pregnancy can cause stunting and reduce foetal cogitative development, having direct effects upon educational attainment. Thus a vicious cycle between poor maternal nutrition and poverty develops, characterized by nutritionists as the "intergenerational transmission of malnutrition and poverty".

Evidence (Adedayo *et al.*, 2010) suggests that investment aimed at women leads to the increase of both farm and non-farm incomes at the household level. Despite this, many female farmers lack access to credit and extension services. The crucial contributions of women farmers to food security are increasingly recognized by development policy-makers and agencies. However, contemporary agricultural policies and research do not often directly address the needs of women smallholder farmers, rather, they focus more on traditionally male-dominated cropping practices. Such "gender blindness" in the context of sustainable agricultural development is a major risk to future food security.

For women and other vulnerable groups, appropriate education and training programmes can improve the understanding of healthy, nutritious foods and natural resource management practices. Furthermore, they can aid in the support of traditional rural societies to understand and incorporate necessary changes that enable gender inclusiveness in decision-making and benefit-sharing of forests and tree-based systems (Agarwal, 2010; Vira *et al.*, 2015).

A growing amount of evidence suggests that farmers adopt tree cultivation on private farm lands for diverse reasons. Other stakeholders may play a role in forestry on individual holdings if their inputs complement those of the farmers in pursuit of their own objectives. Thus, forest governance should attempt to address specific market failures or policy-related impediments that prevent farmers from adopting trees as part of their own livelihood strategies. Market failures could include: imperfections in capital markets and the availability of credit (especially in the light of the long gestation period and risks associated with tree farming); under-development of wood markets; and poor information about the availability of tree-growing options. State agencies may step in by providing credit, market support (information, as well as specific measures such as minimum procurement prices), and relevant technical advice, but there is a role for other stakeholders as well, especially the commercial sector and NGOs. Private business (including financial institutions) may enter into long-term agreements with farmers for the purchase of specific tree crops (out-grower agreements), or enter into share cropping or product supply agreements (contract farming). Companies typically provide initial credit as well as an annual flow of income to meet short-term farmer needs, utilizing the trees as collateral. NGOs may also play a role in organizing collective credit arrangements, as well as providing marketing support, especially for small farmers. Finally, farmers may enter into collaborative agreements with community-level groups, such as the establishment of tree grower cooperatives that provide support for activities such as the collective marketing of produce.

Farmers adopting tree cultivation on farmlands can simultaneously enhance biodiversity and deliver a wide range of tree foods that support FSN. In their review, Jamnadass *et al.* (2015) identify a number of examples of tree-species rich agroforests in Africa, Asia and Latin America that contribute directly to food production (Table 13).

Box 29 Gender and natural resource management: who manages?

Women often use natural resources differently than men yet frequently have minimal influence on how local resources are managed. An emerging hypothesis is that empowering more women in local resource decision-making may lead to better resource governance and conservation. However, what is the evidence that the gender composition of forest and fisheries management groups affects resource governance and conservation outcomes? Leischer *et al.* (2016) have recently published a systematic map detailing the geographic and thematic extent of the evidence base and assessing the quality of the evidence, as per a published a priori protocol (Leischer *et al.* 2015).

The majority of the studies included are in forest management and come from India and Nepal. There are several likely reasons for this concentration. India and Nepal were among the first to introduce community forest management on a systematic basis, India in 1990 and Nepal in 1993. By 2006, India had 106,482 registered Joint Forest Management groups, and guidelines on Joint Forest Management issued in 2000 recommend that the general body of Village Forest Committees consist of 50 % women members, with at least 33 % women on the executive committee. In 2011, Nepal had 17,685 Forest User Groups, with approximately 800 women-only groups, and government guidelines for community forestry recommend that women comprise 50 % of a Forest User Group's executive committee. The two countries have created a 'natural experiment' in the gender composition of forest management groups.

To answer the primary question, for some areas, such as India and Nepal, the evidence is strong enough to suggest that including women in forest and fishery management groups can result in better resource governance and conservation outcomes. The substantial gaps, however, in the evidence base and social, economic and ecological differences globally, make it problematic to generalise from this evidence to other geographies. Thus, there is a strong case for extending the research to other countries and regions, as per the more robust studies in India.

The strength of the available evidence also supports a hypothesized theory of change linking the participation of women in forestry and fisheries management groups with better nature resource governance and conservation outcomes. Identifying the likely causal pathways for this theory of change should be a research priority.

The policy and programme implications beyond South Asia are hindered because the evidence from other regions is limited. At the same time, the conceptual framework provided by existing studies provides a clear case for gathering robust evidence from a diversity of regions on the impact from varying gender compositions of resource management groups.

The results of the systematic map suggest several potential research avenues:

- Additional studies on the impact of the gender composition of forest and fishery management groups in different regions of the world, with regions selected systematically to reflect social, economic, and ecological diversity.
- Identifying the pathways through which women's inclusion in natural resource management leads to better resource governance and conservation outcomes.

Source: Leischer et al. 2015: http://www.environmentalevidencejournal.org/content/pdf/s13750-015-0039-2.pdf

Leischer et al. 2016" http://environmentalevidencejournal.biomedcentral.com/articles/10.1186/s13750-016-0057-8

Table 13 Farming systems combining tree diversity with food production

Reference	Location	Tree diversity	Tree uses
Das and Das (2005)	Barak Valley, Assam, India	87 tree species identified in agroforestry home gardens	Farmers indicated a mean of 8 species used as edible fruit per home garden, many of which were indigenous. Fruit trees were more dominant in smaller gardens. ~5 species per garden used for timber, 2 for woodfuel
Garen *et al.* (2011)	Los Santos and Rio Hato, Panama	99 tree species, $^3/_4$ indigenous, utilised, planted and/or protected on farmers' land	~ $^1/_3$ of species valued for human food. 27 mostly exotic fruits mentioned as planted. ~ $^1/_3$ of species each valued for their wood or as living fences. >60% of species were assigned multiple uses
Kehlenbeck *et al.* (2011)	Surrounding Mount Kenya, Kenya	424 woody plant species, 306 indigenous, revealed in farm plots	Farmers indicated many species used for food. 7 of the 10 most common exotic species were planted, mainly for edible fruits/nuts. The most common indigenous species were used primarily for timber/firewood
Lengkeek *et al.* (2003)	East of Mount Kenya, Kenya	297 tree species, ~ $^2/_3$ indigenous, revealed in smallholder farms	Farmers indicated that >20% of species yield fruits/nuts for human consumption. The most common exotic was coffee, then timber trees
Marjokorpi and Ruokolainen (2003)	Two areas of West Kalimantan, Indonesia	> 120 tree species identified in forest gardens, most species not planted	Farmers indicated ~30% of species used for edible fruit, latex and in other non-destructive ways, ~50% used for timber and in other destructive ways. Seedlings of unused trees removed around naturally-regenerating and intentionally-planted fruit/other useful trees
Philpott *et al.* (2008)	Bukit Barisan Selatan Park, Lampung province, Sumatra, Indonesia	92 and 90 trees species identified in coffee farm plots outside and inside the park, respectively	>50% of farmers grew a total of 17 other products in addition to coffee, including spices, timber and, most commonly, indigenous and exotic fruits. Farmers planting outside the park grew alternative tree products more often
Sambuichi and Haridasan (2007)	Southern Bahia, Brazil	293 tree species, 97% indigenous, revealed in cacao plantation plots in forest understory	Many indigenous trees used for food. Seedlings favoured for retention during weeding were those providing edible fruit or good wood. The most abundant exotics were fruit species
Sonwa *et al.* (2007)	Yaoundé, Mbalmayo and Ebolowa sub-regions, Cameroon	206 mostly indigenous tree species revealed in cacao agroforestry plots	Farmers indicated 17% of tree species used primarily for food, $^2/_3$ of which were indigenous. 22% of tree species primarily for timber, 8% for medicine. Excluding cacao, the 3 most common species (2 indigenous) were used for food. Close to urban Yaoundé, the density of food trees was higher.

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

5.2.4 Forest governance on lands owned by the corporate sector

Forestry activity on corporate-owned lands usually takes the form of small- or large-scale plantations, natural forest ownerships and concessions that produce specific products or services for the market. The corporate business sector cultivates trees that satisfy final consumer demands, or those that serve as intermediate inputs into industrial and commercial production processes. In addition to outputs from commercial plantations and concessions, these needs are met from a number of other sources, including smallholder farm forests, agroforestry ventures, community forests, state forests and imports from other countries. To the extent that corporate forests impinge upon crop or livestock production by smallholders or other producers, such plantations and native forest concessions can be a source of conflict with FSN.

Governments and policy-makers may actively seek to promote commercial forestry on private corporate lands rather than on public or community lands, so that these other types of land can be used to satisfy livelihood-related, ecological and recreational demands upon forests. It is also argued, especially by forest-based industrialists, that some commercial uses of forests, such as the production of pulp and paper products, provide a quasi-public good since they contribute to the growth of human capital and employment.

What needs to be considered more carefully are the specific circumstances in which the direct participation of other stakeholders would facilitate the management of forestry on lands owned or managed by the corporate sector. One area in which such support may be required is research and development, as well as the training of personnel for the management of commercial forestry operations. These are areas that are associated with increasing returns and scale economies, and private sector investment in such activity may be less than optimal, creating a case for state support. The state may also play an indirect role in eliminating policy-related restrictions on private sector forestry activity, such as limitations on the size of landholding, insecurity of tenure, restrictions on private cultivation, harvesting and transport of wood products, as well as impediments to trade in forest products. There is unlikely to be a strong case for direct subsidies to activities in this sector, since operations must be able to survive the market test of commercial viability. However, the state may provide other incentives, such as access to cheap credit, tax benefits and so on, in order to encourage private sector investment in this sector. The waiting period from the beginning of the support of government to industrial forestry has sense, at the beginning of the construction of the natural capital formed by plantations, since there is a long period of time (15 to 25 years), in which there are only investments and costs, until a positive cash flow is reached. That is why many developed and developing countries begun their plantation forestry activities with subsidies (Chile, United States of America, Spain, Germany, Costa Rica, etc.)

There are a number of other contexts in which forestry on corporate lands may involve collaboration with other stakeholders. These include co-management arrangements between the corporate sector and communities, with the corporate sector retaining rights to timber and giving communities rights over NTFPs in return for their participation in management. Such agreements have been made in the Brazilian Amazon, for example, in which community members in adjacent land reform areas have been able to access corporate forestlands under timber management, to extract NTFPs during the interregnum after timber operations are no longer present. NGOs and independent agencies (such as the Forest Stewardship Council, or the Round Table on Sustainable Palm Oil) are beginning to play a critical role in certifying private sector forestry, thereby providing final consumers with an assurance that their demands are being met from well-managed and sustainable sources. Such assurances often also include the provision of harvesting rights to neighbouring communities. Similar collaboration has occurred in Petén, Guatemala, where most of the concessions are communal and also a couple of private companies have been granted with concessions. A close collaboration has occurred between them to exchange expertise, services and also to create a strong defense front against thesector who want to eliminate the concessions (Orjuela, 2015; Villalobos *et al.,* 2013, de Camino *et al.,* 2007)

The emergence of markets for forestry-related services (such as their role in carbon sequestration, recognized in REDD+) has also led to a new wave of interest in private sector forestry, but often in collaboration with either state, non-state (NGO and commercial) or community-level actors. In Indonesia, Brazil, Kenya 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 (like FSC) 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 only a small proportion of income generation from forest management.

At the Global Landscapes Forum (part of the UNFCC meetings) in Paris in December 2015, restoration commitments were announced to address degraded and deforested landscapes in different parts of the world, with an ambition to cover 128 million ha (including earlier commitments under the Bonn Challenge). These initiatives require close collaboration between a range of stakeholders, including the private sector, while also ensuring that the rights of the most vulnerable or marginalized forest-dependent populations are not neglected or abrogated in this ambitious push towards scaling up restoration efforts. Stakeholders associated with these restoration efforts include major international organizations such as WRI, CIFOR, CATIE, CIAT and IUCN, which are facilitating and supporting processes that involve governments and multilateral agencies, but also the private sector, especially Impact Investment Funds, which attempt to balance returns on investment with improved social and ecological outcomes. What is promised is a change in paradigm, in which the private sector is willing to share benefits with small and medium farmers and communities. This will demand a significant shift in governance arrangements, ensuring that the voices of all stakeholders are fully and effectively represented in decision making, in order for these ambitious goals to be realized without negatively impacting those who are traditionally less well-represented in high-level policy-making and decision forums.[13] There are concerns, in particular, that a growing business interest in forests and landscapes may conflict with the rights of local and indigenous peoples, in the form of a 'green grab' (Fairhead et al 2012); adequate safeguards must be implemented in order to avoid such an eventuality.

5.3 Policy instruments and institutions for sustainable forest management and governance at national level

5.3.1 National forest policy

Regional criteria and indicators serve as a reference framework for sustainable forest management related policies in many countries. Policies approved by national public authorities provide both normative principles and a comprehensive framework for multifunctional forest management, and these can be used to promote the roles of sustainable forest management forFSN.

The purposes of national forest policies include the following:

- to set divisional and regional priorities for forest sector development;
- to increase economic, social and ecological values of forests;
- to increase the forest sector's contribution to the country's socio-economic development, including for marginal and vulnerable groups;
- to ensure ecological safety and stability to meet public demands for forest resources and services;
- to provide the framework for the development of forest legislation.

As regards the use of forests for food security and nutrition, national forest policies have to capture political support for these goals within these overarching principles.

An important conclusion is that there is a close relationship between good forest management and FSN, that a target in the countries has to be to improve forest management to optimize the contribution of forests to FSN, but another important, even vital conclusion, is that the institutions, legislation, regulation needs to eliminate many of the strong transaction costs imposed by the official systems in order to make sustainable forestry profitable for people. If this does not occur, local people will end up deforesting what they will consider an obstacle to improve their livelihoods.

5.3.2 Forest legislation

Forest legislation provides the regulations and legal framework to achieve the goals set by national forest policy.

Forest legislation establishes:

- property and tenure rights for forest land, including for indigenous groups and local communities;
- institutional organization of forest administration at federal, regional and local/municipal levels;
- institutional organization of forest management;
- the role of public–private partnership;
- economic and financial relationships in the forest sector;

[13] See http://www.wri.org/our-work/project/initiative-20x20 in order to learn about the 20 x 20 initiative of forest and soil restoration in Latin America.

- forms and methods to access forest resource for use;
- silvicultural and environment standards.

The extent to which forest legislation creates ownership structures and incentives that support the transition towards sustainable forestry for FSN varies across jurisdictions. In many cases, forest sector legislation is not well integrated into agricultural strategies, and this results in fragmented structures that create perverse incentives in different sectors. A shift towards more comprehensive legislative processes that promote nutrition-sensitive landscapes and more integrated planning would help address some of these deficiencies in existing legislation.

5.3.3 Forest Sector Outlook Studies

Forest policy goals and legal regulations serve as the foundation for long-term strategic planning in the forest sector. There is considerable international experience in forecasting long-term development of the forest sector on the basis of regional outlook studies, based on the FAO's guidance notes. The main purpose of the outlook study is to present an independent expert evaluation of the current state of the forest sector at the regional level and possible scenarios of its long-term development. There is scope, within these longer-term strategic planning exercises, to explore the role that forest use might play for FSN.

In 2012, the Russian Federation released "The Russian Federation Forest Sector Outlook Study to 2030" prepared by independent Russian and foreign experts, based on FAO guidance. The forest sector forecast is based on three scenarios: inertial, moderate and innovation. The inertial scenario is based on past trends. The moderate scenario presumes moderate economic development and represents progress form the inertial to the innovation stage. The innovation scenario represents the most favourable conditions to encourage supply and demand for forest products in domestic and export markets. Unfortunately, none of scenarios contains any goals and actions connected with forest use forFSN.

5.3.4 Forest certification.

Forest certification plays an important role in determining whether forest administration and management correspond to approved criteria and indicators and legal regulations for the use of forest resources at the national level, and in accordance with accepted international principles, such as those articulated by the FSC (Forest Stewardship Council), PEFC (Programme for the Endorsement of Forest Certification),, the Roundtable on Sustainable Palm Oil (RSPO) and the Roundtable on Sustainable Soy (RTRS), among others.

Globally, MacDicken *et al.* (2015) estimate that 1.1 billion hectares (out of a permanent estate of 2.17 billion hectares) are covered by recognised SFM management regimes. As of 2014, forest certification, however, is primarily focussed in temperate forests, with only 6% of forests in the tropical permanent estate certified (MacDicken *et al.* 2015). Thus, despite great strides in recent years there is clearly work to do on implementing more geographically-equitable sustainable forestry.

Box 30 Forest certification in the Russian Federation

At present in the Russian Federation forest certification is represented by two main systems:

- the Forest Stewardship Council, widely used in the North America and Europe;
- the Russian National Council on Forest Certification with accreditation within the International Programme for the Endorsement of Forest Certification.

The forest system (FSC) prevails now in the Russian Federation. Certified forests occupy about 30 percent of total forest area. Forest certification deals only with wood resources. Certification is used:

- to improve forest management and environmental protection;
- to improve the financial state of private business;
- to increase the competitive advantageous of forest industry in the export timber markets;
- to increase social and economical stability in the regions rich in forest.

5.4 Land rights and legal tenure over trees, forests and forest products

Many forest-adjacent rural households in developing countries generate much of their income from forests. Thus the contributions forests and trees make to direct income and livelihood diversity are potentially even more important during shocks. Typically, rural households employ diverse livelihood strategies, and so the maintenance of a variety of forest functions is very often an economic priority. Despite this, in many countries/regions forest-adjacent communities have little to no legal ownership of forests and access to forests may be insecure.

Access to forest resources depends on the land tenure and use rights systems of the forest territories. Land-tenure rights over forestland and legal access to forest resources can be, in some situations, a barrier to access of wild foods and income generating NTFPs. At the same time, non-regulated access rights can cause overexploitation of resources, thus undermining the sustainability of any FSN benefits. A principal problem of undefined tenure over forests is their treatment as open access resources, subject to the tragedy of the commons.[14] On the other hand, where forests are managed collectively based on mutually agreed rules and norms for the exclusive benefit of community members, resources such as forest fruits can often be managed and protected against encroachment (Ostrom *et al.* 1999, Agrawal 2001).

There is a need for clear demarcation of traditional land, territory and property rights as a condition not only of forest conservation but also of forest goods and services availability to the broader society. Serious conflicts arise when tenure rights and rights of access are not well-defined or upheld. For example, in the Caribbean North of Nicaragua, indigenous peoples have rights to their territories yet lack strong legal support from the government. As a result, many local, traditional owners of land risk losing their land to migrants and settlers. Some African forest legislations such as Cameroon, Gabon and the Democratic Republic of the Congo recognize a right to access to the forest for riparian forests communities. This right to access is extended to the right to use wild forest products. Indonesia has also experienced new legislation protecting the customary ownership of forests by indigenous peoples, where certain historical and contemporary use conditions apply. Such laws must include provisions for enforcement, protecting customary owners from the pressures of agricultural expansion as well as incentivizing sustainable use of forest resources. Finding ways to ensure that poor rural communities achieve economic development without losing access to the benefits of locally-produced and harvested foods will require additional research and careful consideration of how landscapes are structured and how they change over time.

5.4.1 Protecting and utilizing indigenous and cultural knowledge

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

This vital relationship that indigenous communities have with the forest took time to be recognized and formalized at the international and national levels. Even today, this recognition is limited to the principles and international declarations that have still no legal values in several states. In 1987, the Brundtland report[15] 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

[14] The tragedy of commons is an economic problem in which every individual tries to reap the greatest benefit from common pool resources (Olson, 1965; Hardin, 1968). As the demand for the resource overwhelms the supply, every individual who consumes an additional unit directly harms others who can no longer enjoy the benefits. Thus, concerning common resources as forests, the theory argues that, individuals cannot overcome their narrow self-interest. Limitation of access and uses to stop overconsumption, and private or state regulation are proposed to avoid the tragedy.

[15] http://www.un-documents.net/our-common-future.pdf

that sustain their way of life - rights they may define in terms that do not fit into standard legal systems. These groups' own institutions to regulate rights and obligations are crucial for maintaining the harmony with nature and the environmental awareness characteristic of the traditional way of life. During the Rio Summit in 1992, indigenous peoples' rights to forests were clearly recognized as a crucial component to preserve the environment and solve the global environmental crisis. The Rio Declaration launched the first international response to proclaim the "vital role of indigenous peoples in environmental management and development."

Since then, most of the international legal instruments continue to insist that sustainable development cannot be conceived without protecting and including populations, particularly indigenous peoples who must keep their specific rights according to their traditional particularity. In this sense, the United Nations Declaration on the rights of indigenous peoples (UNDRIP), adopted in 2007, states in Article 26 that: *1. Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired. 2. Indigenous peoples have the right to own, use, develop and control the lands, territories and resources that they possess by reason of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired. 3. States shall give legal recognition and protection to these lands, territories and resources. Such recognition shall be conducted with due respect to the customs, traditions and land tenure systems of the indigenous peoples concerned.* This assertion recognizes the land rights and natural resources for the indigenous community, which means the right to use, access and own forest's territories and resources. This recognition supposes the implication and the free and real participation of indigenous people in forest governance. If this requirement cannot be respected the UNDRIP states in Article 28 that*: Indigenous peoples have the right to redress, by means that can include restitution or, when this is not possible, just, fair and equitable compensation, for the lands, territories and resources which they have traditionally owned or otherwise occupied or used, and which have been confiscated, taken, occupied, used or damaged without their free, prior and informed consent. 2. Unless otherwise freely agreed upon by the peoples concerned, compensation shall take the form of lands, territories and resources equal in quality, size and legal status or of monetary compensation or other appropriate redress.* In the same way, Article 29 mentions that: *Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources. States shall establish and implement assistance programmes for indigenous peoples for such conservation and protection, without discrimination. 2. States shall take effective measures to ensure that no storage or disposal of hazardous materials shall take place in the lands or territories of indigenous peoples without their free, prior and informed consent. 3. States shall also take effective measures to ensure, as needed, that programmes for monitoring, maintaining and restoring the health of indigenous peoples, as developed and implemented by the peoples affected by such materials, are duly implemented.*

One proposed reason for the success of customary forest use is that the relationship indigenous peoples have to food is more cultural than the other community. A case study on some First Nations in Canada proposed to specify this indigenous ability by using the concept of "cultural food security" to emphasize the ability of aboriginal people to reliably access important traditional food through traditional harvesting methods (Power, 2008). In Central Africa, for example, several studies showed 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' use of local knowledge and traditional resources in a way that continues to improve food security, and to learn from their diverse knowledge systems.

5.4.2 Empowering smallholders and communities

Many policies and legal frameworks unintentionally increase transaction costs for farmers and forest owners. Complicated and confused policies and regulations, centralization of governance systems, lack of flexibility in policies, costs and time associated with reporting, and lack of access to legal expertise, all constrain the development of smallholders. Smallholders and communities could be empowered through awareness-building and education. Education plays an important role in empowering rural populations and has the potential to generate tangible and fundamental benefits for households and communities in achieving FSN, sustainable forest and landscape management, and health (Vira *et al.*, 2015). For women and other vulnerable groups, appropriate education and training programmes can improve the understanding of healthy and nutritious foods and natural resource management practices, and support traditional rural societies in understanding and incorporating necessary changes that enable gender inclusiveness in decision-making and benefit-sharing in forests and tree-based systems (Vira *et al.*, 2015).

5.5 Sustainable use of forest resource foods and NTFPs

Some wild edible plants from forests can be harvested at sustainable rates, although some plant-based NTFPs are considerably overharvested. The case of NTFPs, bushmeat on the other hand poses a major threat to species survival and forest ecosystem functioning in many areas. The importance of bushmeat in the diets of many cultures should not be underestimated, and it should be noted that attempts to ban hunting outright generally leads to increased poaching and illegal trade. Care must be taken to recognize the nutritional importance of bushmeat (as described above in Chapter 3) and to protect vulnerable communities from losing access to forest meat and fish. At the same time, alternative sources of ASFs such as livestock under silvopastural systems and bushmeat species with shorter life should be promoted over threatened species with long life. Bushmeat is an essential component of many diets; however, it should be extracted at the maximum sustainable yield in order to provide the maximum, long-term contributions to FSN.

5.5.1 Integrating gender in sustainable forestry for food security and nutrition

Women are pivotal to ensuring food security. It is estimated that women produce more than 50 percent of the food grown worldwide, primarily in small-scale farming systems, in complex, multifunctional mosaics (FAO, 2011b). Indeed, women tend to grow a greater diversity of products, experiment more with folk varieties and landraces (and thus agrobiodiversity) and are often reliant on broader aspects of biodiversity for their family's herbal needs. Although women comprise up to 80 percent of farmers in sub-Saharan Africa and 60 percent in Asia – ratios that are increasing due to male emigration and moves towards off-farm sources of income – their access to and control over land and resources is generally inferior to that of men in the same household or community (Sunderland, 2011). Where women do have access to land, they will generally use it for food production and income generated from such land is more likely to be utilized for the well-being of the household, whether for nutritional, health or other benefits. Women are also primarily responsible for food preparation and allocation and, as such, are usually the "guardians of household food security". In times of food insecurity, maternal food deprivation can impact the long-term productivity of the wider community through childhood malnutrition and ill-health, effects that can linger long into adulthood, ultimately affecting their life-long productivity and health. Malnutrition during pregnancy can cause stunting and reduce foetal cogitative development, having direct effects upon educational attainment. Thus a vicious cycle between poor maternal nutrition and poverty develops, characterized by nutritionists as the "intergenerational transmission of malnutrition and poverty".

Box 31 Gender, climate changes, sustainable forestry and food security and nutrition: how to integrate women and girls in sustainable forestry and food security and nutrition in response to climate change

Many studies have proven (Argawal, 2009, 2010) that, primarily as they represent the majority of the world's poor and are more dependent for their livelihood on natural resources that are threatened by climate change, women and girls are more vulnerable to the effects of climate change than men. In the same way, they both face social, economic and political barriers that limit their capacities. The UN policy brief identifies four key factors that account for the discrepancy between women's and men's differential exposure and vulnerability to climate change risks and their inclusion in the planning and decision-making processes:

- a global gender gap in earnings and productivity;
- the differential access in all levels of policy and decision-making processes, making women less able to influence policies, programmes and decisions;
- socio-cultural norms that limit women's acquisition of information and skills to escape or avoid hazards; and
- lack of sex-disaggregated data in all sectors that gives rise to an underestimation of women's roles and contributions.

Four dimensions can help as keys to improve the situation of the women and girls in SF and FSN and to reduce their vulnerability to the effects of climate change:

1. Empowerment of women and girls as keys of sustainable forestry for FSN: enhancing women's social status and role in forest decision-making structures and institutions that develop women social network in forest governance.
2. Develop forests technologies and mechanisms that address women's needs: women often have a strong body of knowledge and expertise that can be used in climate change mitigation, disaster reduction and adaptation strategies.
3. Integrate gender analysis and gender-sensitive tools: governments and organizations, should be encouraged to incorporate gender's FSN perspectives into their national forestry policies, action plans, management plans and other measures on sustainable development and climate change, through: carrying out systematic gender analyses; collecting and utilizing sex-disaggregated data; establishing gender-sensitive benchmarks and indicators; and developing practical tools to support increased attention to gender perspectives.
4. Financing mechanisms must be flexible enough to reflect women's priorities and needs.

Evidence (Adedayo *et al.* 2010) suggests that investment aimed at women leads to the increase of both farm and non-farm incomes at the household level. Despite this, many female farmers lack access to credit and extension services. The crucial contributions of women farmers to food security are increasingly recognized by development policy-makers and agencies. However, contemporary agricultural policies and research do not often directly address the needs of women smallholder farmers; rather, they focus more on traditionally male-dominated cropping practices. Such "gender blindness" in the context of sustainable agricultural development is a major risk to future food security.

For women and other vulnerable groups, appropriate education and training programmes can improve the understanding of healthy, nutritious foods and natural resource management practices. Furthermore, they can aid in the support of traditional rural societies to understand and incorporate necessary changes that enable gender inclusiveness in decision-making and benefit-sharing of forests and tree-based systems (Agrawal, 2010; Vira *et al.,* 2015).

Box 32 Study paints nuanced picture of gender roles in forestry

A recent global study challenges conventional notions of gender roles in forest management, showing that both men and women collect forest products, both for subsistence and for market. "Challenging perceptions about men, women and forest-product use: A global-comparative study" is one of five initial papers to emerge from the study. The others tackle themes of income generation and rural livelihoods, forests as safety nets, forest clearing and livelihoods, and land tenure and forest income.

Demystification

Traditionally, researchers assumed that men were the main contributors to family income, which made any contribution from women invisible. Beginning in the 1970s, researchers "discovered" women's contributions to household income. In so doing, however, they began to ignore men's role. Yet, contrary to this general perception (Kennedy and Peters, 1996), men actually played an important subsistence role in the households studied. The gender debate with respect to the relative roles of men and women has become engrained in the literature. That's why it was surprising that the data showed men were actually collecting firewood and water, and doing more than their bit for the household.

In other words, gender studies were equated with women's studies. Increasingly, it is also about men, and their roles at work, at home and in society. Hopefully, we get the same change in the development literature."

Nuanced view

The global study adds fuel to the gender debate, putting a new perspective on the roles of both men and women, showing that their overall contribution varies across societies. The results, when first presented, created somewhat of a stir because of the size of the dataset and the message it conveyed. It's great that conventional wisdom about how men and women interact with their natural resources was challenged.

According to the study, men and women contribute almost equally to the value of household income from unprocessed forest products such as timber, poles, fruits and mushrooms. This overall finding, however, hides regional differences. 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.

Care must be taken with generalities. In the literature, you'll often see a paper titled, 'Women contribute more to the household.' The data in the PEN analysis show it's much more nuanced and subtle, and sends a strong and compelling message backed up by substantial evidence."

Regional variations

In Latin America, the data show 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. The commonly held belief that women are the main collectors of forest products seems to hold up only in Africa. Earlier case studies weren't wrong, he said, only too narrowly focused. Findings from one site, for example, were often extrapolated to make a broad generalization. "With multi-site comparisons, we have a more expansive approach that gives us more confidence in our results. The regional differences in the study suggest the relationship of women and women to natural resources is culturally mediated. For a complete picture of the dependency of any rural society on natural resources, it's not enough to consider the role of men or women. We need both.

Markets and gender

Another common generalization is that men sell products of the highest value, whereas women — if they get to a market at all — are focused on small-scale subsistence products. In fact, there is incredible regional variation. In Africa, where the markets tend to be more subsistence-oriented, women tend to dominate. In Latin America, which have more specialized markets, men dominate. In Asia, it's a mixture of the two. Will these patterns hold, or will Africa's markets shift from subsistence to more specialized forest products? If so, will gender patterns of forest use also change? And will cultural differences in gender roles also make a difference?

Source. Sunderland *et al.* 2013: http://dx.doi.org/10.1016/j.worlddev.2014.03.003, Kennedy and Peters, 1996: http://www.sciencedirect.com/science/article/pii/0305750X9290001C

5.6 Ways forward: hybrid and cross-sectoral approaches to forest governance

Particular characteristics of forestry make it an especially interesting sector for the analysis of multistakeholder and cross-sectoral governance regimes. The ability to separate tree tenure from land tenure offers the potential to increase the number of legal stakeholders in a management regime. The bundle of rights that are embodied in trees can be allocated to different individuals and groups, as can the rights to enjoy the flow of services from the forest system as a whole. If tree tenure and land tenure are allocated to different individuals, the rights of other stakeholders over trees, their products and system-wide forest services may be seen to attenuate the ownership rights of the landowner. While this may reduce the value of landholding and the potential price that a landowner may expect to receive from land sales, it provides the forest manager (tree tenure holder) with secure returns from investment in tree cultivation or in protection of natural forest remnants. Given the long periods associated with forestry operations, such arrangements could provide strong incentives for potential resource managers to participate in shared forestry operations, even if they are not conferred any rights over land. Such arrangements may be particularly significant in facilitating the reform of state forestry operations, since states often attempt to encourage the participation of other stakeholders in forest management, but are reluctant to give up ownership rights over state forest lands.

Box 33 The right to wild foods in a world of increasing land annexation

As this report illustrates, forests and tree-based systems contribute significantly to the food security and nutritional status of millions of people worldwide. However, current global commitments to set aside up to 17% of all terrestrial land to expand the network of protected areas, often with the highest level of protection, will restrict access to yet more land. Much of the expansion in PA's is occurring in forest ecosystems; the very environments that provide both direct and indirect provisioning critical for FSN.

Rights and social justice are no longer 'sideline' issues in conservation. Indeed they are increasingly at the fore. A host of major international organisations that support conservation and natural resource management have issued public statements, organisational policies, programmatic guidance and other instruments addressing the rights and social justice implications of their work, inclduing the Conservation Initiative on Human Rights (CIHR). Such instruments reflect growing recognition that such issues must be understood and addressed as a core part of conservation.

These commitments affirm that the "right to adequate food" is as critical a human right as any other and, as we have shown, given the contribution of wild foods to human societies, restriction of access to traditional forest lands could be described as a major infringement of this basic human right.

The FAO-led "Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security" were endorsed by the CFS in 2012. These are designed to safeguard tenure rights and promote responsible governance in relation to land, fisheries and forests, with an overarching goal of achieving food security for all and supporting the realisation of the right to food.

Sources: http://www.fao.org/righttofood/right-to-food-home/en/, https://www.cbd.int/sp/targets/rationale/target-11/, http://www.fao.org/nr/tenure/voluntary-guidelines/en/

Campese *et al.* (eds) 2009. Rights Based Approaches: Exploring Issues and Opportunities for Conservation. Centre for International Forestry Research, Bogor. http://www.cifor.cgiar.org/Knowledge/Publications/Detail?pid=2800

The multiple-use character of forests refers to the joint production of a variety of goods, such as timber, firewood, forage and fodder, fruit, latex and other NTFPs, as well as the ability of standing forests to satisfy a number of ecological, aesthetic, health and well-being and recreational functions. The existence of multiple uses offers both an opportunity and a threat to the negotiation of a multistakeholder regime. For example, the recreational use of forests for exercise and for collection of mushrooms and berries in the Russian Federation may constitute greater value than other forest products. The opportunity arises because those uses that can be satisfied simultaneously are mutually compatible, and can form the basis for establishing common interests. While upholding and protecting the existing rights of indigenous peoples and local communities, there could be conditions under which multiple stakeholders can be granted legal rights over different goods and services, increasing incentives for collaboration. If the private interests of each of the potential partners can be accommodated without conflict, the costs of establishing a regime are likely to be low. In other situations, however, multiple uses conflict with each other, such as the incompatibility of a purely preservationist strategy for maintaining biodiversity with one which requires periodic harvests of forest resources to meet consumption needs. In such circumstances, agreement on a common plan may be very difficult, and this limits the extent to which regimes that involve multiple resource interests can be negotiated.

Of specific concern to the role that forestry plays in relation to FSN is the question of how effectively landscapes can deliver with respect to both conservation and food production objectives, and what sort of landscape configuration produces the most beneficial outcomes (and for whom). At one extreme is an approach that focuses on specialized production landscapes, with the most productive land used for intensive crop production, while marginal agricultural lands and those that have high biodiversity and conservation values are strictly protected to preserve these ecosystem functions (but also to produce wood under forest management, at least in some cases). This has been characterized as a "land sparing" approach, where intensification of crop production might release less productive land for conservation objectives; to be effective, the approach needs to couple the intensification of agricultural strategies with a range of regulatory (zoning) and market-related (incentive-based) interventions that ensure that the land that has been 'spared' is not diverted from conservation purposes (Phalan *et al.,* 2016). At the other end of this debate are hybrid and multifunctional landscapes that simultaneously produce crops and provide biodiversity benefits; these include agroforestry and silvopastoral systems, which are able to serve conservation ends as well as the needs of food production. The choice between these alternatives is, at one level, empirical, and depends on how the productive and protective functions of the wider landscape can best be secured. What both share is a systematic approach to landscape management, and a recognition of the hybrid and cross-sectoral contexts in which forestry and food production systems operate, attempting to balance multiple, often competing needs in a context of land scarcity.

While land management strategies have moved towards a greater recognition of these interdependencies, there remain important challenges in relation to the sectoral fragmentation of governance systems. There is often little communication and collaboration between line agencies and government departments with responsibilities for food production, water supply, forestry, the provision of environmental services, and rural development. Integration across these sectoral divides is a critical first step in harnessing the potential for forestry to address hunger and nutrition needs, and to move towards a future vision of nutrition-sensitive landscapes.

5.6.1 Integrating Food Security and Nutrition into Forest Governance

Forest managers and forest sector decision-makers have hitherto neglected the roles that forests might play in the context of FSN, focusing instead on timber values, or particular high value NTFPs and forest products, and more recently on other ecosystem services (carbon sequestration, water) for which demand has translated into potential commercial opportunities. There has, however, been a noticeable shift in this emphasis in the last few years. The International Forestry Review published a special issue in 2011 devoted to forests, biodiversity and food security (Arnold *et al.,* 2011). FAO convened a major conference on Forests for Food Security and Nutrition in May 2013, drawing attention to the potential synergies between these agendas, and building on work across a number of institutions (notably CIFOR and ICRAF) which was seeking to develop landscape-scale perspectives on forests and food production. The Collaborative Partnership on Forests then convened a Global Forest Expert Panel (GFEP) in November 2013, which produced a report on the role of forests in FSN, which was released at the United Nations Forum on Forests in May 2015 (Vira *et al.,* 2015).

Box 34 Nutrition-sensitive landscapes: A way forward for forests, trees and agriculture?

The nature of the relationships between communities, food production systems and the environment is complex and bidirectional as humans impact and are impacted by nature. People's behavior influences the capacity of landscapes to provide the multiple functions that are essential for our well-being, including multiple nutrition and health functions ranging from the variety of foods produced, the quality of, and access to water, to disease incidence and transmission. The complexity of current global challenges requires a fresh look at how people interact with their environments in order to fulfill the goals of food and nutrition security while maintaining, restoring, and securing the ecosystems upon which we are ultimately dependent.

A Nutrition-Sensitive Landscapes (NSL) approach considers the diverse interactions and interconnectivity within a given landscape to optimize the multiple goals of food and nutrition security, sustainable use of natural resources and conservation of biodiversity, both for human health, as well as environmental health. Nutrition-sensitive actions, as defined by Ruel *et al.* (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 a socio-ecosystems approach at the landscape level.

At the heart of a systems orientation is an emphasis on relationships and understanding synergies, tradeoffs and feedback loops between changing factors. The NSL approach addresses the relationship between nutrition, agriculture and the environment, and aims to identify, quantify and tackle unsustainable tradeoffs while generating synergies. The ecosystems dimension emphasizes the interaction between species and their environment, while the socio-ecosystem approach highlights the coupling between people and the environment.

The landscape adds an explicit spatial dimension. 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 the ecological, historical, economic and cultural processes and activities of the area. In practice, the landscape scale is the scale at which natural resources are managed to achieve multiple objectives in terms of crop and livestock production, income generation and support to livelihoods. Agricultural, forest and aquatic-type ecosystems are dynamic systems sharing space within a landscape. Drivers of change in agricultural systems are often highly dependent on landscape conditions, including soil type, agro-ecosystem typologies, climate, socio-economic conditions, cultural values and globalization status. It is therefore particularly at the landscape scale that key interactions among biophysical and socio-economic factors occur and can be observed over short- and long-term periods (>20 years) (Jackson *et al.*, 2005; Sachs *et al.*, 2011). In landscape ecology, the precise scope and scale within a landscape are not predetermined, but depend on the process of interest. In the case of our research theme, the process of interest is health and nutrition, therefore, nutrition-sensitive landscapes 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 the foods are sourced. A better understanding of the landscape scale interactions that affect food and nutrition security across different agro-ecological zones can provide insights on how to tackle complex issues related to achieving gains in food and nutrition security while preserving the integrity of ecosystems.

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 (DeClerck, 2013). A nutrition-sensitive landscape does not imply that the environment can produce all nutrients required for adequate human nutrition, it does however mean a focus on producing diverse sources of food within a given landscape while also managing other ecosystem functions that are critical for environmental sustainability and human well-being.

Building on ecosystem services concepts, the NSL research area seeks to build a strong knowledge-base of how nutrition and health outcomes can be improved in contexts where finite natural resources are fortified to achieve multiple and sometimes competing objectives. These include the scaling-up of landscape approaches to address multiple land use and conservation objectives including sustainability, climate-resilient food and fiber production, biodiversity conservation and improving livelihoods. The main research area focuses on how ecosystems can contribute to food availability, access and utlization, as well as the impact of food system activities on the health and sustainability of these ecosystems.

Source:
https://www.bioversityinternational.org/fileadmin/user_upload/research/research_portfolio/Diet_diversity/Nutrition__Sensitive_Landscapes_Concept_paper_March_2014.pdf

The key message from these processes is an important one, and one that has gained some resonance within the forestry community. Forests matter for FSN, both because of their direct roles, and the indirect contributions that they make to the production systems that underpin agriculture and nutrition strategies. This requires forest sector decision-makers to reimagine forests, not just as spaces for conservation, protection and/or for the production of valued timber, NTFPs and other forest products, and ecosystem services (all of which have been well recognized), but also as sources of food and nutrition. Forest governance strategies, thus, have to recognize these contributions, and take into account the interests and needs of those who depend upon forests for FSN, as well as the potential synergies and trade-offs between these needs and other demands from the forested landscape.

The UNFCCC has established as a particular priority the development of national climate adaptation programmes and policies. In the Paris Accord of 2015, the role of forests in contributing to both mitigation of GHG emissions and adaptation by provision of ecosystem services such as regional rainfall and temperature stability have been clearly identified. Financial support for such endeavours is being promoted through existing mechanisms such as the Green Climate Fund and the GEF. One example that has been implemented since 2009 is that of the GEF/FAO Kagera Transboundary Agro-ecosystem Management Project on the catchment that borders the United Republic of Tanzania, Uganda, Rwanda and Burundi. The project includes efforts to restore degraded cropland with agroforestry practices, shelterbelts and other approaches to integrated watershed management.[16]

[16] http://www.fao.org/in-action/kagera/en/

Box 35 Market information system on NTFPs (SIM-PFNL) as a key of sustainable forestry for FSN: the case of Cameroon.

Market information systems (MIS) on NTFPs are mechanisms that help to implement network actors in NTFP sectors and facilitate the marketing of products by centralizing information on the demand and supply of NTFPs.

This system is used to connect main Actors in the Supply Chain of NTFPs with information on the quantities, quality and price of the product circulated among stakeholders to better increase their activities. This system also provides information on the availability and the production sites to better guide buyers and reduce other costs of collection in villages. Direct actors work with the products, collecting them from the wild, transforming them from one form to another or moving them from one place to another. Indirect actors exert some influence over the direct actors but do not physically work with the products. In Cameroon, since 2009, the communal forest association (ACFCAM) has implemented NTFP's market information system in all the forest municipality and forest localities.

Empirical studies on the question (Awono *et al.,* 2010; Abanda, 2013) have demonstrated that the NTFPs, MIS promote a synergy of action between forest stakeholders and users. For example, in the system put in place by the ACFCAM, communities, NGOs (Giz for example), state institutions (national public radio channels, the Ministry of Forests) and municipalities join forces to make this system function well. With this collective action, communities can sometimes negotiate their access to forest areas where the right of use was restricted. Training on conservation and transformation of NTFPs is carried out by an NGO (GIZ) and helps communities to better manage the stocks and quantities collected. Evidence of the importance of the MIS on NTFPs in women's organizations occurs in some studies (Mekongo, 2011; Belibi *et al.,* 2015)

The SIM-PFNL can thus be a great mechanism for coordination and action of sustainable forestry for FSN.

CONCLUSION

Addressing the current shortfalls in the global food system, and the biological processes upon which it depends, will require coordination across different sectors at multiple scales from the local to the global and vice versa. There is another important assumption accompanying the food security issue*: "to recognize that agriculture and the rural economy are greatly influenced by policies and outcomes in the rest of the economy. Strategies include economic growth with unchanging income distribution, and growth with redistribution. The latter encourages balanced growth to create non-farm employment opportunities, while investing in rural infrastructure"* (Timer, 2000). The requirement for such global, intersectorial governance is unprecedented in agricultural development, and the siloed discourse that has characterised the sustainable agriculture debate has changed to reflect one of integration at the landscape scale to a more systems approach.

Thus while this report attempts to provide a robust evidence base for the integration of sustainable forestry and FSN, future research effort should focus on compiling the data needed for adequate decision making at the implementation (local), regional and broader geographies. For example, there is a need to measure the socio-economic benefits from forests and data collection must focus on both people and trees. As this report highlights, forestry administrations have little information on how many people benefit from forests, and the available data is often sparse, at best.

In addition, forest policies must explicitly address the role of forests in providing livelihood benefits, including FSN. 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 protected area management) and the considerable numbers of people using forests to meet their livelihood needs.

There needs to be a great recognition of the value of forest ecosystem services and if the value of these services is not measured or recognised, then economic and policy decisions affecting forests will be compromised. This is critical for the sustainable provision of essential services such as FSN, including agricultural productivity to recreation and other forest-based services.

To meet rising and changing global demands, sustainable forestry will have to embrace more efficient production. As such, demand for the many benefits derived from the consumption of forest products is likely to increase as populations increase and lifestyles change, and with the global shift to urban living. To avoid further degrading this resource, more sustainable production techniques must be adopted, notablyin the current informal sector.

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 twenty years, including incorporating sustainable forestry as a broad national goal. This has involved increasing stakeholder participation as well as great openness to voluntary and market-based approaches. Yet implementation capacity remains weak in many countries.

Main messages:

- Sustainable forest management can safeguard and deliver a wide range of social, cultural, environmental and economic benefits that support FSN and livelihoods in general.
- Linking people centred, pro-poor and landscape-focussed policy and planning approaches that integrate forests, agriculture and other land uses can enhance productivity and the provision of forest goods and ecosystem services.
- FM can play an important role in integrating forests into development strategies, FSN, poverty reduction, sustainable land use and climate change initiatives.
- Payments for Ecosystem Services and other compensation schemes can enhance the provision of such services and support sustainable forest management.

DRAFT AREAS OF RECOMMENDATIONS FOR ACTION

(This section of the report is presented now only in broad outline and will be developed further during the next steps of the work, in light of the contributions received from the open consultation).

These recommendations will be directed as appropriate to states and other stakeholders and actors, as well as to multilateral organizations

1. Increase awareness on the contributions of forests and trees to FSN through knowledge generation and training

- Improve data collection and monitoring.
- Increase attention to forest dependent populations and the role of forests in poverty alleviation.
- Educate diverse sectors of society on the importance of forests for FSN, including the current and potential importance of nutritionally important foods derived from trees and forests.
- Support appropriate extension methods for promoting wider adoption of agroforestry as a basis to reinforce the contribution of trees to FSN at the community level.

2. Address forest/agricultural land use trade-offs through valorization and market instruments

- Promote forests' contribution to local communities and national income by encouraging income generation and trade in forest foods and goods.
- Develop marketing information systems for NTFP and other forest goods and services to promote the development of small-scale social forestry enterprises
- Assess socio-cultural, economic and health implications of deforestation and forest degradation on food security and nutrition.
- Integrate FSN concerns in forest certification schemes.

3. Integrate forest and agricultural land use across the productive landscape

- Manage multi-functional landscapes that combine food production with biodiversity conservation, to incorporate both land sparing and land sharing approaches.
- Administer policies and practices for the forestry and agriculture sectors in tandem across governance scales.
- Coordinate with local producer organizations to achieve more inclusive food systems that value local forest management practices and knowledge.
- Engage the private sector using appropriate co-management and co-production initiatives in conjunction with state agencies and local community groups.

4. Address climate mitigation and adaptation by combining forest conservation and agroforestry with food security

- Make local agreements coherent with solutions at higher levels of geographic aggregation.
- Consider how the implementation of mechanisms and other initiatives that are designed to address climate mitigation and/or forest conservation (e.g., REDD+) will affect local communities' access to forest foods and how this might impact dietary quality.
- Seek means to diminish trade-offs between income / purchasing power vs. access to wild foods.
- Include adequate budgetary allocations for climate change adaptation/mitigation strategies that promote FSN.
- Promote use of "climate smart" agricultural technologies, agroecological solutions, and agroforestry practices for FSN.

- Curb the destructive use of forests for fuelwood production and prioritize sources of wood close to homes
- Invest in appropriate technologies and innovations to improve health outcomes associated with the use of fuelwood and wood stoves.

5. Recognize land and forest use rights for traditional peoples and women

- Ensure that customary tenure and land rights are formally protected, upheld, registered and reflect safeguards to enhance FSN for women and indigenous peoples, building on the UN Declaration on the Rights of Indigenous Peoples, building on the CFS Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT) and other relevant instruments in the international legal framework.
- Encourage international certification and corporate social responsibility as an integral part of forest management enterprise, as a means to respect and uphold the rights of women and indigenous peoples.
- Recognize claims to food sovereignty as a means to support local communities' efforts to gain better access to appropriate and adequate food, and to improve their diet quality and nutrition.
- Reinstate traditional nutritious foods and, through collaborative initiatives, reintroduce them to the FSN value chain while respecting and upholding the in situ protection of local and indigenous peoples' traditional knowledge and genetic resources.
- Respect and uphold the in situ protection of traditional knowledge of local and indigenous peoples and, through collaborative initiatives, incorporate it into management practices and policies to enhance the productivity and resilience of forest and tree-based systems.

6. Strengthen governance systems across scales

- Ensure that policy and regulatory frameworks allow conservation and sustainable management of natural resources and provide equitable access of the poor, women, vulnerable and marginalized groups to forests and tree-based systems for FSN, building on the CFS principles for responsible investment in agriculture and food systems (RAI) and other relevant instruments in the international legal framework.
- Ensure that regulatory arrangements recognize and uphold relevant rights to direct and indirect benefits for FSN, including wood and non-wood products taking into account the differences among social groups, as well as the specific roles of women
- Harmonize biodiversity conservation, ecosystem service provisioning and forest and agricultural production goals through a multi-functional landscape approach.
- Design appropriate and integrated responses to the complex drivers that affect the extent to which forests and tree-based systems can contribute effectively to FSN.

7. Better integrate forest–FSN interactions in policy processes

- Assess what policy incentives are in place or can be encouraged to reinforce the role of sustainable forestry in FSN.
- Get sustainable forestry onto the global food security and nutrition agenda, including through zero deforestation, Declarations on Forestry and Agriculture and SDGs.
- Better integrate FSN concerns in the creation and management of protected areas through participatory process involving all concerned populations, including indigenous peoples.

REFERENCES

Abanda, N.F. 2013. *Exploitation des produits forestiers non ligneux et développement durable des localités riveraines des forêts camerounaises: Revue internationale des Sciences humaines et sociales.* Presse de l'Université Catholique d'Afrique centrale (PUCAC).

Achard, F., Beuchle, R., Mayaux, P., Stibig, H.-J., Bodart, C., Brink, A., Donnay, F., Lupi, A., Carboni, S., Desclee, B., Donnay, F., Eva, H.D., Lupi, A., Rasi, R., Seliher, R., Simonetti. D. 2014. Determination of tropical deforestation rates and related carbon losses from 1990 to 2010. Glob. Change Biol., 20 (2014), pp. 2540–2554.Byerlee, D., J. Stevenson and N. Viloria. Does intensification slow crop land expansion or encourage deforestation? 2014. Global Food Security 3 (2014) 92-98.

Adedayo, A.G., Oyun, M.B. & Kadeba, O. 2010. Access of rural women to forest resources and its impact on rural household welfare in North Central Nigeria. For. *s*, 12(6): 439–450.

Agrawal, A., Cashore, B., Hardin, R., Shepherd, G., Benson, C. & Miller, D. 2013. Economic contributions of forests. Paper presented at 2013.

Agrawal, A. 2001. Common Property Institutions and Sustainable Governance of Resources. *World Development, 29*(10), 1649-1672, doi:http://dx.doi.org/10.1016/S0305-750X(01)00063-8.

Agarwal, B. 2009. Gender and forest conservation: The impact of women's participation in community forest governance. *Ecol. Econ.*, 68(11): 2785–2799.

Agarwal, B. 2010. Does Women's Proportional Strength Affect their Participation? Governing Local Forests in South Asia. *World Dev.*, 38(1): 98–112.

Ahsan, F. 2014. *Top 12 shade tolerant vegetables and herbs for a shady garden. Planting vegetable gardens* (avaliable at http://theselfsufficientliving.com/shade-tolerant-vegetables-herbs/).

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. & Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. Ann. Bot., 103(9): 1579–1588.

Albrecht, A. & Kandji, S.T. 2003. Carbon sequestration in tropical agroforestry systems. *Agric. Ecosyst. Environ.*, 99(1-3): 15–27.

Alig, R., Latta, G. Adams, D. & McCarl, B. 2010. Mitigating greenhouse gases: The importance of land base interactions between forests, agriculture and residential development in the face of changes in bioenergy and carbon prices. *Forest Policy and Economics*. 12: 67-75.

Anderson, J., Clément, J. & van Crowder, L. 1998. Accommodating conflicting interests in forestry-concepts emerging from pluralism. *Unasylva* p.3–10.

Anderson, J. ed. 1999. *Pluralism and Sustainable Forestry and Rural Development*. Rome,

Anderson, K. 2006. Tending the wild: Native American knowledge and the management of California's natural resources. Berkeley, CA, USA: University of California Press.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, C. & Wunder, S. 2014. Environmental income and rural livelihoods: a global-comparative analysis. *World Development,* 64(1): S12–S28.

Armesto, J.J., Smith-Ramirez, C. & Rozzi, R. 2001. Conservation strategies for biodiversity and indigenous people in Chilean forest ecosystems, Journal of the Royal Society of New Zealand, Volume 31, Issue 4. http://www.tandfonline.com/doi/abs/10.1080/03014223.2001.9517681

Arnold, J.E.M. 1998. *Managing forests as common property*. Rome.

Arnold, J.E.M. 1990. *Social forestry and communal management in India*, ODI: rural development forestry network (RDFN).

Arnold, J.E.M. 2001. *Forests and People: 25 Years of Community Forestry*. Rome.

Arnold, J.E.M. & Dewees, P.A. 1997. *Farms, trees and farmers: responses to agricultural intensification*. Earthscan.

Arnold, M., Powell, B., Shanley, P. & Sunderland, T.C.H. 2011. Special Issue: Forests, biodiversity and food security. *Int. For. Rev.*, 13(3): 259–264.

Arthur, A.D., Li, J., Henry, S. & Cunningham, S.A. 2010. Influence of woody vegetation on pollinator densities in oilseed Brassica fields in an Australian temperate landscape. *Basic Appl. Ecol.*, 11(5): 406–414.

Awono, A., Ndoye, O. & Preece, L. 2010. Empowering Women ' S Capacity for Improved Livelihoods in Non-Timber Forest Product Trade in Cameroon. *Int. J. Soc. For.*, 3(2): 151–163.

Baer, L-A. 1996. Boreal forest dwellers: the Saami in Sweden. *Unasylva* No. 186 (available at http://www.fao.org/docrep/w1033e/w1033e05.htm).

Bajželj, B., Richards, K. Allwood, J., Smith, P. Dennis, J. Curmi, E & Gilligan C. 2014. Importance of food-demand for climate mitigation. *Nature Climate Change* 4: 924-929.

Bailie, R.S., Carson, B.E. & McDonald, E.L. 2004. Water supply and sanitation in remote indigenous communities--priorities for health development. *Aust. N. Z. J. Public Health*, 28(5): 409–14.

Bailey, S., Requier, F., Nusillard, B., Roberts, S.P.M., Potts, S.G. & Bouget, C. 2014. Distance from forest edge affects bee pollinators in oilseed rape fields. *Ecol. Evol.*, 4(4): 370–380.

Bale, J.S., van Lenteren, J.C. & Bigler, F. 2008. Biological control and sustainable food production. *Philos Trans R Soc L. B Biol Sci,* 363(1492): 761–776.

Barraclough, S.L. & Ghimire, K.B. 1995. *Forests and livelihoods: the social dynamics of deforestation in developing countries*, 1st edition. Palgrave Macmillan UK.

Baudron, F. & Giller, K.E. 2014. Agriculture and nature: Trouble and strife? *Biol. Conserv.,* 170: 232–245.

Baudron, F., Mwanza, H.M., Triomphe, B. & Bwalya, M. 2007. *Conservation agriculture in Zambia: a case study of Southern Province*. Narobi, African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Beddington, J., Asaduzzaman, M., Clark, M., Fernández, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Van Bo, N., Nobre, C., Scholes, R., Sharma, R. & Wakhungu, J. 2012a. *Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark,

Beddington, J.R., Asaduzzaman, M., Clark, M.E., Fernandez Bremauntz, a., Guillou, M.D., Howlett, D.J.B., Jahn, M.M., Lin, E., Mamo, T., Negra, C., Nobre, C. a., Scholes, R.J., Van Bo, N. & Wakhungu, J. 2012b. What Next for Agriculture After Durban? *Science* (80-.)., 335(6066): 289–290.

Belibi, M.B., van Eijnatten, J., Mala, M.A. & Ingram, V. 2015. Empowering Women and Ethnic Minority Groups to Collectively Market non Timber Forest Products from Community Forests in Cameroon. *J. Life Sci.*, 9(8)

Bennett, E.L., Blencowe, E., Brandon, K., Brown, D., Burn, R.W., Cowlishaw, G., Davies, G., Dublin, H., Fa, J.E., Milner-Gulland, E.J., Robinson, J.G., Rowcliffe, J.M., Underwood, F.M. & Wilkie, D.S. 2007. Hunting for consensus: Reconciling bushmeat harvest, conservation, and development policy in West and Central Africa. *Conserv. Biol*., 21(3): 884–887.

Betts, R.A., Malhi, Y. & Roberts, J.T. 2008. The future of the Amazon: new perspectives from climate, ecosystem and social sciences. *Philos. Trans. R. Soc. London B Biol. Sci.*, 363(1498): 1729–1735.

Bharucha, Z., & Pretty, J. 2010. The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2913-2926, doi:10.1098/rstb.2010.012

Bishaw, B., Neufeldt, H., Mowo, J., Abdelkadir, A., Muriuki, J., Dalle, G., Assefa, T., Guillozet, K., Kassa, H., dawson, I.K., Luedeling, E. & Lbow, C. 2013. *Farmers' Strategies for Adapting to and Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya,* Forestry Communications Group. Corvallis, OR: Oregon State University.

Blackie, R., Baldauf, C., Gautier, D., Gumbo, D., Kassa, H., Parthasarathy, N., Paumgarten, F., Sola, P., Pulla, S., Waeber, P. & others. 2014. Tropical dry forests: The state of global knowledge and recommendations for future research. CIFOR.

Blaikie, P. & Springate-Baginski, O. 2007. *Setting up key policy issues in participatory forest management*. For. policy power Polit. Ecol. reform South Asia. Earthscan, London, : 1–23.

Blais, R. & Boucher, J.L. 2013. Les temps des régimes forestiers au Québec. *In* La gouvernance locale des forêts publiques québécoises: une avenue de développement des régions périphériques, pp.33–63. Québec, Presses de l'Université du Québec.

Blanche, K.R., Ludwig, J.A. & Cunningham, S.A. 2006. Proximity to rainforest enhances pollination and fruit set in orchards. *J. Appl. Ecol.*, 43(6): 1182–1187.

Blaney, S., Beaudry, M., & Latham, M. 2009. Contribution of natural resources to nutritional status in a protected area of Gabon. Food & Nutrition Bulletin, 30(1), 49-62. http://fnb.sagepub.com/content/30/1/49.full.pdf

Bodin, Ö. & Crona, B.I. 2009. The role of social networks in natural resource governance: What relational patterns make a difference? *Glob. Environ. Chang.*, 19(3): 366–374.

Borrini-Feyerabend, G. 1996. *Collaborative Management of Protected Areas: Tailoring the Approach to the Context*. IUCN. Switzerland.

Boserup, E. 1965. *The Conditions ofAgricultural Growth*. The Economics Agrar. Chang. Popul. Press.,

Bowyer, J.L. 2006. Forest plantations threatening or saving natural forests? *Arbro Vitae,* 31.

Boyd, J. & Banzhaf, S. 2007. What are ecosystem services? The need for standardized environmental accounting units. *Ecol. Econ.*, 63(2–3): 616–626.

Brouwer, I.D., den Hartog, A.P., Kamwendo, M.O.K. & Heldens, M.W.O. 1996. Wood quality and wood preferences in relation to food preparation and diet composition in Central Malawi. *Ecol. Food Nutr.*, 35(1): 1–13.

Bradshaw, C. J. A. Sodhi, N. S. Peh, K. S. H. Brook, B.W. 2007. Global evidence that deforestation amplifies flood and severity in the developing world. Glob. Chang. Biol. Available at: http://www.dbs.nus.edu.sg/lab/cons-lab/documents/Bradshaw_etal_Glob_Change_Biol_2007.pdf (accessed 5.24.16).

Brandt, J. Nolte, C. & Agrawal, A. 2016. Deforestation and timber prodection in Congo after implementation of sustainable forest management policy. *Land Use Policy*. 52: 15-22.

Brouwer, I.D., Hoorweg, J.C. & Van Liere, M.J. 1997. When households run out of fuel: responses of rural households to decreasing fuelwood availability, Ntcheu District, Malawi. *World Dev.*, 25(2): 255–266.

Brown, D. 1999. Principles and practice of forest co-management: evidence from west-central Africa. *Eur. Union Trop. For. Pap*. 2: 33.

Brownlow, M.J.C. 1992. Acorns and swine: historical lessons for modern agroforestry. Q J For 86(3): 181–190

Brownlow, M.J.C. 1994. Towards a framework of understanding for the integration of forestry with domestic pig (Sus scrofa domestica) and European wild boar (Sus scrofa scrofa) husbandry in the United Kingdom. For 67(3): 189–218

Byerlee, D., J. Stevenson and N. Viloria. Does intensification slow crop land expansion or encourage deforestation? 2014. Global Food Security 3 (2014) 92-98.

Byron, N. & Arnold, M. 1997. *What futures for the people of the tropical forests?* Working Paper No. 19. Centre for International Forestry Research, Bogor, Indonesia.

Calorio, C.M. & Silva, R.O. 2014. Seminário: Repactuação da Agenda do Manejo Florestal Comunitário e Familiar na Amazônia: 2015-2018. Relatório. IEB, Brasília http://www.iieb.org.br/index.php/publicacoes/livros/relatorio-do-seminario-de-repactuacao-da-agenda-do-manejo-florestal-comunitario-e-familiar-na-amazonia-2015-2018/

Campbell, B.M., P. Thornton, R. Zougmore, P. van Asten and L. Lipper. 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability 2014, 8: 39-43.

Campbell-Platt, G. 1980. African locust bean (parkia species) and its west african fermented food product, dawadawa. Ecol. Food Nutr., 9(2): 123–132.

Canadian Forest Service. 2003. *Developing non timer forest products in Canada*, Bulletin No. 28 (available at http://publications.gc.ca/collections/collection_2011/rncan-nrcan/Fo122-1-28-2003-eng.pdf).

Canadell, J.G. & Raupach, M.R. 2008. Managing forests for climate change mitigation. *Science*, 320(5882): 1456–1457.

CBD, 2009 : Secretariat of the Convention on Biological Diversity. 2009. Sustainable Forest Management, Biodiversity and Livelihoods: A Good Practice Guide. Montreal, 47 + iii pages.

CCA (Council of Canadian Academies). 2014. Aboriginal Food Security in Northern Canada: An Assessment of the State of Knowledge, Ottawa, ON. The Expert Panel on the State of Knowledge of Food Security in Northern Canada, Council of Canadian Academies. http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/food%20security/foodsecurity_fullreporten.pdf

CDB/IUCN. 2009. Sustainable Forest Management, Biodiversity And Livelihoods: A good practice guide (available for download at: https://www.cbd.int/development/doc/cbd-good-practice-guide-forestry-booklet-web-en.pdf).

Carletto, G., Ruel, M., Winters, P., & Zezza, A. 2015. Farm-Level Pathways to Improved Nutritional Status: Introduction to the Special Issue. The Journal of Development Studies, 51(8), 945-957, doi:10.1080/00220388.2015.1018908.

Ceppi, S.L. & Nielsen, M.R. 2014. A comparative study on bushmeat consumption patterns in ten tribes in Tanzania. Trop. Conserv. Sci., 7(2): 272–287.

Cesario, M. & Andrade-Morraye, M. 2008. Land-Use and Land-Cover Changes and the (Re) Emergence of Diseases in Brazil. In Towards Sustainable Global Health, p.61. Studies of the University: Research, Counsel, Education.

Chacoff, N.P. & Aizen, M.A. 2006. Edge effects on flower-visiting insects in grapefruit plantations bordering premontane subtropical forest. *J. Appl. Ecol.*, 43(1): 18–27.

Charnley, S. & Poe, M.R. 2007. Community Forestry in Theory and Practice: Where Are We Now? *Annu. Rev. Anthropol.*, 36: 301–336.

Chazdon, R.L., Brancalion, P.H.S., Laestadius, L., Bennett-Curry, A., Buckingham, K., Kumar, C., Moll-Rocek, J., Guimarães Vieira, I.C. & Wilson, S.J. 2016. When is a forest a forest? Forest concepts and definitions in the era of forest and landscape restoration. *Ambio*, DOI 10.1007/s13280-016-0772-y.

Chao, S. 2012. *Forest peoples: Numbers across the world*. Moreton-in-Marsh, United Kingdom, Forest Peoples Programme (available at www.forestpeoples.org).

Chiasson, G. & Leclerc, É. 2013. *La gouvernance locale des forêts publiques québécoises: une avenue de développement des régions périphériques*?. Puq.

Clason, T.R. 1995. Economic implications of silvipastures on southern pine plantations. Agrofor. Syst., 29(3): 227–238.

Cline, W.R. 2007 *Global warming and agriculture: impact estimates by country*. Washington, DC: Peterson Institute. http://maps.grida.no/go/graphic/projected-agriculture-in- 2080-due-to-climate-change.

Colchester, M. 1994. *Salvaging Nature: Indigenous Peoples, Protected Areas and Biodiversity Conservation.* UNRISD Discussion Paper No. DP 55, UNRISD. Geneva

Colfer, C.J.P. 1999. *The BAG: basic assessment guide for human well-being*. CIFOR.

Colfer, C.J.P., Sheil, D. & Kishi, M. 2006. *Forest and Human Health. Assessing the evidence.* CIFOR Occasional Paper no 45. http://www.cifor.org/library/2037/forests-and-human-health-assessing-the-evidence/

Colfer, C. & Capistrano, D. 2013. *The Politics of Decentralization. Forests, People and Power.* CIFOR. Rutledge.

Conforti, P.A. & Lupano, C.E. 2011. Selected properties of araucaria angustifolia and araucaria araucana seed protein. Int. J. Food Prop., 14(1): 84–91.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V. & Paruelo, J. 1998. The value of the world's ecosystem services and natural capital. *Ecol. Econ.*, 25(1): 3–15.

Cotter, J. & Tirado, R. 2008. *Food security and climate change: the answer is biodiversity*. A review of scientific publications on climate change adaptation in agriculture, Greenpeace. UK.

Crélerot, F.M. 1995. Importance of shea nuts for women's activities and young children's nutrition in Burkina Faso: The case of the Lobi. University of Wisconsin-Madison. Madison, USA.

Criotoru, L. 2007. Valuing the non-timber forest products in the Mediterranean region. *Ecological Economics.* 63: 768-775.

Crowther, T.W., Glick, H.B., Covey, K.R., Bettigole, C., Maynard, D.S., Thomas, S.M., Smith, J.R., Hintler, G., Duguid, M.C., Amatulli, G., Tuanmu, M.-N., Jetz, W., Salas, C., Stam, C., Piotto, D., Tavani, R., Green, S., Bruce, G., Williams, S.J., Wiser, S.K., Huber, M.O., Hengeveld, G.M., Nabuurs, G.-J., Tikhonova, E., Borchardt, P., Li, C.-F., Powrie, L.W., Fischer, M., Hemp, A., Homeier, J., Cho, P., Vibrans, A.C.,

Umunay, P.M., Piao, S.L., Rowe, C.W., Ashton, M.S., Crane, P.R. & Bradford, M.A. 2015. Mapping tree density at a global scale. *Nature*, 525(7568): 201–5.
Daily, G.C. 1997. *Nature's services: societal dependence on natural ecosystems*. Washington DC, Island Press.
Danley, B. & Widmark, C., 2016. Evaluating conceptual definitions of ecosystem services and their implications. Ecol. Econ. 126, 132-138. doi:10.1016/j.ecolecon.2016.04.003
Das, T. and Das, A.K. 2005. Inventorying plant biodiversity in home gardens: A case study in Barak Valley: Assam, North East India. Current Science 89:155-163.
daSilva, A., & Begossi, A. 2009. Biodiversity, food consumption and ecological niche dimension: a study case of the riverine populations from the Rio Negro, Amazonia, Brazil. Environment, Development and Sustainability, 11(3), 489-507, doi:10.1007/s10668-007-9126-z.de Camino, R; Breitling,J. & Facilitators. 2007. *El Cambio es Posible: 20 años de Experiencias Innovadoras en los Recursos Naturales en Guatemala*. Alianza para la conservación de la biodiversidad en el trópico Americano. San José Costa Rica. p.181.
de Camino, R., Morales, J., Villalobos, R., Navarro, G., Ortega, M., Henao, E. & Sage, L. 2012. *Forestería de Ingreso Sostenible (FIS): para valorar los bosques y las tierras de vocación forestal*. CATIE, UICN. IUFRO, Tercer Congreso Forestal Latinoamericano. San José. Costa Rica.
de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., ten Brink, P. & van Beukering, P. 2012. Global estimates of the value of ecosystems and their services in monetary units. *Ecosyst. Serv.,* 1(1): 50–61.
De Jing, B., Tipper, R. & Montoya, G. 2000. An economic analysis of the potential for carbonsequestration by forests: evidence from southern Mexico. *Ecological Economics,* 33: 313–327.
Deakin, E., M. Kshatriya & T. Sunderland (eds) 2016. *Agrarian change in tropical landscapes*.
DeKlerck, F., Fanzo, J. Pal, C. & Remans. R. 2011. Ecological approcahes to human nutrition. Food and Nutrition Bulletin 32(1): 541-550.
Delang, C. 2006. Not just minor products: the socio-economic rationale for the consumption of wild food plants by subsistence farmers. *Ecological Economics*. 59: 64-73.
De Marco, P. & Coelho, F.M. 2004. Services performed by the ecosystem: Forest remnants influence agricultural cultures' pollination and production. *Biodivers. Conserv.*, 13(7): 1245–1255.
Dewees, P.A. 1989. The woodfuel crisis reconsidered: observations on the dynamics of abundance and scarcity. *World Dev.,* 17(8): 1159–1172.
Dillon, A., McGee, K., & Oseni, G. 2015. Agricultural Production, Dietary Diversity and Climate Variability. The Journal of Development Studies, 51(8), 976-995, doi:10.1080/00220388.2015.1018902.
Dixon, R.K., Winjum, J.K. & Schroeder, P.E. 1993. Conservation and sequestration of carbon: the potential of forest and agroforest management practices. *Glob. Environ. Chang.*, 3(2): 159–173.
Djenontin, I., & Djoudi, H. 2015. From degraded to functional restored forest land: Smallholder farmers curbing food insecurity in central Burkina Faso. In C. Kumar, Saint-Laurent, C., Begeladze, S. and Calmon, M. (Ed.), Enhancing food security through forest landscape restoration: Lessons from Burkina Faso, Brazil, Guatemala, Viet Nam, Ghana, Ethiopia and Philippines (pp. 18-41). Gland, Switzerland: IUCN.
Doak, C.M., Adair, L.S., Bentley, M., Monteiro, C. & Popkin, B.M. 2005. The dual burden household and the nutrition transition paradox. *Int. J. Obes.* (Lond)., 29(1): 129–136.
Dounias, E. & Froment, A. 2011. From foraging to farming among present-day forest hunter-gatherers: consequences on diet and health. I*nt. For. Rev.*, 13(3): 294–304.
Dowie, M. 2009. *Conservation refugees. The hundred year old conflict between global conservation and native peoples.* MIT Press Cambridge.
Eckholm, E. 1975. *The other energy crisis: firewood.* Worldwatch instirute.
Elbehri, A. 2015. Climate change and food systems: Global assessments and implications for food security and trade. FAO of the UN, Rome, Italy. 356 p
Elliott, B., Jayatilaka, D., Brown, C., Varley, L & Corbett, K.K. 2012. "We Are Not Being Heard": Aboriginal Perspectives on Traditional Foods Access and Food Security. Journal of Environmental and Public Health Volume 2012 (2012), Article ID 130945, http://dx.doi.org/10.1155/2012/130945 http://www.hindawi.com/journals/jeph/2012/130945/
Erni, C. 2015. Shifting Cultivation, Livelihood and Food Security. New Old Challenges Indig. Peoples Asia. Ed. FAO, IWGIA, AIPP. Bankok,
Fa, J.E., Juste, J., Burn, R.W. & Broad, G. 2002. Bushmeat consumption and preferences of two ethnic groups in Bioko Island, West Africa. Hum. Ecol., 30(3): 397–416.
Fa, J.E., Olivero, J., Real, R., Farfán, M.A., Márquez, A.L., Vargas, J.M., Ziegler, S., Wegmann, M., Brown, D., Margetts, B. & Nasi, R. 2015. Disentangling the relative effects of bushmeat availability on human nutrition in central Africa. Sci. Rep., 5: 8168.
Fairhead, J., Leach, M. & Scoones, I. 2012. Green grabbing: a new appropriation of nature? J. Peasant Stud. 39(2): 237-261.
FAO. 1999. The markets for Central African non-wood forest products in Europe. In: T.C.H. Sunderland, L. Clark & P. Vantomme (eds). 1999. The Non-Wood Forest Products of Central Africa: Current Research Issues and Prospects for Conservation and Development. Food & Agriculture Organisation (FAO). Rome. pp 265-273 http://www.fao.org/docrep/x2161e/x2161e27.htm
FAO. 2006*. Forests and climate change Better forest management has a key role to play in dealing with climate change*, Rome.
FAO. 2008. *Climate change and food security: A framework document*. Rome.

FAO. 2010. G*lobal Forest Resources Assessment 2010 Main report.* FAO Forestry paper 163 http://www.fao.org/docrep/013/i1757e/i1757e.pdf
FAO. 2011a. *Biodiversity for Food and Agriculture, Contributing to food security and sustainability in a changing world*. Rome.
FAO. 2011b. *The role of women in agriculture*: ESA Working Paper No.11-02: 46.
FAO. 2012a. World agriculture towards 2030/2050. The 2012 Revision. ESA Working Paper No. 12-03, June 2012. FAO, Rome. http://www.fao.org/docrep/016/ap106e/ap106e.pdf
FAO. 2012b. *State of the World's Forests 2012*. FAO, Rome.
FAO. 2012c. *The State of Food Insecurity in the World.* Economic growth is necessary but not sufcient to accelerate reduction of hunger and malnutrition. FAO, Rome. http://www.fao.org/docrep/016/i3027e/i3027e.pdf
FAO. 2013. Forests and water. International momentum and action. FAO, Rome. http://www.fao.org/docrep/017/i3129e/i3129e.pdf
FAO. 2014a. *State of the World's Forests, Enhancing the socioeconomic benefits from forests.* FAO, Rome, http://www.fao.org/3/a-i3710e.pdf.
FAO. 2014b. *FAO Statistical Yearbook, 2014*. FAO, Rome.
FAO. 2014c. The state of the world's land and water resources for food and agriculture. Managing systems at risk, FAO, Rome.
FAO. 2015. Global Forest Resources Assessment 2015. FAO of the United Nations, Rome, 2015.
FAO/ITTO. 2015. *Making forest concessions work to sustain forests, economies and livelihoods in tropical timber producing countries,* A FAO - ITTO initiative in collaboration with SFB, CIFOR and Cirad (avaliable at http://www.fao.org/forestry/44075-08960f20f3f0a4e82224fa19b65812a22.pdf).
Fearnside, P.M. 2000. Global Warming and Tropical Land-Use Change: Greenhouse Gas Emissions From Biomass Burning, Decomposition and Soils in Forest Conversion, Shifting Cultivation and Secondary Vegetation. *Clim. Change*, 46: 115–158.
Firbank, L.G., S. Petit, S. Smart, A. Blain and R.J. Fuller. 2008. Assessing the impacts of agricultural intensification on biodiversity: a British perspective. Philosophical Transactions of the Royal Society B. Volume 363: Issue 1492.
Fisher, R.J., Srimongkontip, S, Veer, C. 1997. People and forests in Asia and the pacific: situation and prospects. FAO/RAPA. Working Paper No: APFSOS/WP/27. http://www.fao.org/3/a-w7732e.pdf
Fischer, J., Abson, D., Butsic, V., Chappell, M., Ekroos, J., Hanspach, J., Kuemmerle, T., Smith, H. & Wehrden, H. 2014. Land sparing and land sharing: moving forward. *Conservation Letters*. 7: 149-157.
Flohre, A., C. Fischer, T. Aavik, J. Bengtsson, F. Berendse, R. Bommarco, P. Ceryngier, L.W. Clement, C. Dennis, S. Eggers, M. Emmerson, F. Geiger, I. Guerrero, V. Hawo, P. Inhausti, J. Liira, M.B. Morales, J.J. Onate, T. Part, W.W. Weisser, C. Winqvist, C. Thies and T. Tscharntke. 2011. Agricultural intensification and biodiversity partitioning in European landscapes comparing plants, carabids and birds. Ecological Applications, 21(5), pp. 1772-1781.
Foli, S., Reed, J., Clendenning, J., Petrokofsky, G., Padoch, C. & Sunderland, T. 2014. To what extent does the presence of forests and trees contribute to food production in humid and dry forest landscapes?: a systematic review protocol. *Environ. Evid.*, 3(1): 15.
Food Secure Canada. 2008. *Food sovereignity in rural and remote communities*, Discussion paper 2. Montreal. Canada.
Forest Trends. 2013. *La forestería comunitaria en Honduras.* Un camino hacia una major gobernanza forestal. Information Brief 08.
Freitas, B.M., Filho, A.J.S.P., Andrade, P.B., Lemos, C.Q., Rocha, E.E.M., Pereira, N.O., Bezerra, A.D.M., Nogueira, D.S., Alencar, R.L., Rocha, R.F. & Mendonça, K.S. 2014. Forest remnants enhance wild pollinator visits to cashew flowers and mitigate pollination deficit in NE Brazil. *J. Pollinat. Ecol.*, 12(4): 22–30.
Garen, E.J., Saltonstall, K., Ashton, M.S., Slusser, J.L., Mathias, S. and Hall, J.S. 2011. The tree planting and protecting culture of cattle ranchers and small-scale agriculturalists in rural Panama: opportunities for reforestation and land restoration. Forest Ecology and Management 261: 1684–1695.
Garibaldi, L.A., Steffan-Dewenter, I., Kremen, C., Morales, J.M., Bommarco, R., Cunningham, S.A., Carvalheiro, L.G., Chacoff, N.P., Dudenh??ffer, J.H., Greenleaf, S.S., Holzschuh, A., Isaacs, R., Krewenka, K., Mandelik, Y., Mayfield, M.M., Morandin, L.A., Potts, S.G., Ricketts, T.H., Szentgy??rgyi, H., Viana, B.F., Westphal, C., Winfree, R. & Klein, A.M. 2011. Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecol. Lett., 14(10): 1062–1072.
Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., Cunningham, S.A., Kremen, C., Carvalheiro, L.G., Harder, L.D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N.P., Dudenhöffer, J.H., Freitas, B.M., Ghazoul, J., Greenleaf, S., Hipólito, J., Holzschuh, A., Howlett, B., Isaacs, R., Javorek, S.K., Kennedy, C.M., Krewenka, K.M., Krishnan, S., Mandelik, Y., Mayfield, M.M., Motzke, I., Munyuli, T., Nault, B.A., Otieno, M., Petersen, J., Pisanty, G., Potts, S.G., Rader, R., Ricketts, T.H., Rundlöf, M., Seymour, C.L., Schüepp, C., Szentgyörgyi, H., Taki, H., Tscharntke, T., Vergara, C.H., Viana, B.F., Wanger, T.C., Westphal, C., Williams, N. & Klein, A.M. 2013. Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance. Science (80-.)., 339(6127): 1608–1611.
Geist, H. & Lambin, E. 2002. Proximate causes and underlying driving forces of tropical deforestation. *BioScience*. 52: 143-144.
Gerten, D., Schaphoff, S., Haberlandt, U., Lucht, W. & Sitch, S. 2004. Terrestrial vegetation and water balance—hydrological evaluation of a dynamic global vegetation model. *J. Hydrol.*, 286(1): 249–270.

Gibbons, P., Lindenmayer, D.B., Fischer, J., Manning, A.D., Weinberg, A., Seddon, J., Ryan, P. & Barrett, G. 2008. The future of scattered trees in agricultural landscapes. *Conserv. Biol.*, 22(5): 1309–1319.

Gibson, J. & Rozelle, S. 2002. How Elastic is Calorie Demand? Parametric, Nonparametric, and Semiparametric Results for Urban Papua New Guinea. *J. Dev. Stud.*, 38(6): 23–46.

Ghimire, K. and M.P. Pimbert, 1997. *Social Change and Conservation*. *Environmental Politics and Impacts of National Parks and Protected Areas.* Routledge, London.

Godoy, C. 2010. Propuesta para elaborar planes de manejo integrados de recursos forestales no maderables en la reserva de la Biósfera Maya, Petén, Guatemala. San Carlos University.

Golden, C.D., Fernald, L.C.H., Brashares, J.S., Rasolofoniaina, B.J.R. & Kremen, C. 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proc. Natl. Acad. Sci.*, 108(49): 19653–19656.

Goulding, M. 1981. Man and fisheries on an Amazon frontier, 1st edition. Springer Netherlands.

Gray, J.A. 2002. Forest concession policies and revenue systems: Country experiences and policy changes for sustainable tropical forestry. World Bank Technical Paper, Forest Series, Washington DC.

Gram, S., Kvist, L.P. & Cáseres, a. 2001. The economic importance of products extracted from Amazonian flood plain forests. *Ambio*, 30(6): 365–368.

Green, R.E., Cornell, S.J., Scharlemann, J.P.W. & Balmford, A. 2005. Farming and the fate of wild nature. *Science*, 307(5709): 550–555.

Grieco, J.P., Achee, N.L., Andre, R.G. & Roberts, D.R. 2002. Host feeding preferences of Anopheles species collected by manual aspiration, mechanical aspiration, and from a vehicle-mounted trap in the Toledo District, Belize, Central America. *J Am Mosq Control Assoc*, 18(4): 307–315.

Grimble, R., Chan, M.-K., Aglionby, J. & Quan, J. 1995. *Trees and trade-offs: a stakeholder approach to natural resource management.* IIED London, UK.

Guil Guerrero, J.L., Giménez Martınez, J.J. & and Torija Isasa, M.E. 1998. Mineral nutrient composition of edible wild plants. *Journal of Food Composition and Analysis*, 11(4): 322–328.

Hansen, M.C., Potapov, P. V, Moore, R., Hancher, M., Turubanova, S. a, Tyukavina, a, Thau, D., Stehman, S. V, Goetz, S.J., Loveland, T.R., Kommareddy, a, Egorov, a, Chini, L., Justice, C.O. & Townshend, J.R.G. 2013. High-resolution global maps of 21st-century forest cover change. *Science*, 342(2013): 850–3.

Hardin, G. 1968. The tragedy of the commons. Science, New Series, Vol. 162, No. 3859 (Dec. 13, 1968), pp. 1243-1248

Hawkins RP. 1965. Factors affecting the yield of seed produced by different varieties of red clover. J. Agric. Sci. 1965;65:245–253.

Headey, D.D. 2013. Developmental Drivers of Nutritional Change: A Cross-Country Analysis. *World Dev.*, 42(1): 76–88.

Henao Bravo, E.I., Ordóñez,Y., Camino Velozo, R.de., Villalobos Soto, R. & Carrera Gambeta, F. 2015. *El bosque secundario en Centroamérica: un recurso potencial de uso limitado por procedimientos y normativas inadecuadas*, Serie técnica. Boletín técnico no.77 CATIE, CIFOR/FTA.

Herzog, F. 1998. Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe, Agroforestry Systems, 42, pp 61-80.

Hobley, M. 1996. *Participatory forestry: the process of change in India and Nepal* (available at: http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8144.pdf).

Holt-Gimenez, E., Shattuck, A., Altieri, M., Herren, H. & Gleissman. 2012. We already grow enough food for ten billion people… and still can't end hunger. *Journal of Sustainable Agriculture*. 6: 595-598.

Houghton, R.A., Byers, B. & Nassikas, A.A. 2015. A role for tropical forests in stabilizing atmospheric CO_2. *Nature Climate Change,* 5: 1022–1023.

Howard, A., J.A. Gray, A.H. Contreras, M.H. El-Lakany, P.W. Matakala, P.H. Pearse and S. Schinnerl. 2001. Governance principles for concessions and contracts in public forests. FAO Forestry Paper 139. Rome, Italy.

Howe, C., Suich, H. Vira, B & Mace. G. 2014. Creting win-wins from trade-offs? Ecosystem services for human well-being: A meta-analysis of ecosystem service trade-offs and synergies in the real world. *Global Environmental Change*. 28: 263-275.

Humphry, C.M., Clegg, M.S., Keen, C.L. & Grivetti, L.E. 1993. Food diversity and drought survival. The Hausa example. Int. J. Food Sci. Nutr., 44(1): 1–16.

Hyden, G., Court, J. & Mease, K. 2004. *Making sense of governance: empirical evidence from sixteen developing countries*. Lynne Rienner Publishers.

Iannotti, L., & Lesorogol, C. 2014. Dietary Intakes and Micronutrient Adequacy Related to the Changing Livelihoods of Two Pastoralist Communities in Samburu, Kenya. Current Anthropology, 55(4), 475-482, doi:10.1086/677107.

Ibarra, J. T., Barreau, A., Del Campo, C., Camacho, C. I., Martin, G. J., & McCandless, S. R. 2011. Community conservation, payments for environmental services and food sovereignty in an indigenous community of the Chinantla, Oaxaca, Mexico. International Forestry Review, 13(3), online.

Ickowitz, A., Powell, B., A. Salim M.A. & Sunderland, T. 2014. Dietary Quality and Tree Cover in Africa. *Global Environmental Change.* 24: 287–294. http://www.sciencedirect.com/science/article/pii/S0959378013002318

Ickowitz, A., Powell, B., A. Salim M.A. & Sunderland, T. 2016. The effect of tree cover on child nutrition in Indonesia: Examining the relationship between tree cover and consumption of micronutrient-rich foods. *PLoS One*. http://journals.plos.org/plosone/article/asset?id=10.1371%2Fjournal.pone.0154139.PDF

Ickowitz, A., Powell, B., Salim, M.A. & Sunderland, T.C.H. 2014. Dietary quality and tree cover in Africa. Glob. Environ. Chang. Policy Dimens., 24: 287–294.

Ickowitz, A., Rowland, D., Powell, B., Salim, M. A., & Sunderland, T. C. H. (in press). Forests, trees, and micronutrient-rich food consumption in Indonesia. PLoS ONE.

IFPRI (International Food Policy Research Institute). 2014. *Global Nutrition Report 2014: Actions and Accountability to Accelerate the World's Progress on Nutrition*. Washington DC.

IFPRI (International Food Policy Research Institute). 2015. Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development. Washington DC.*Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development*. Washington DC. https://www.ifpri.org/cdmref/p15738coll2/id/129443/filename/129654.pdf

Indufor. 2012. *Strategic review on the future of forest plantations*. Helsinki, Finland.

INPE (National Institute for Space Research). 2015. *Deforestation and degradation of the Amazon forest*. Annual statistical series. São José dos Campos, São Paulo, Brazil.

IPCC. 2014. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva, Switzerland, IPCC.

Jamnadass, R., Place, F., Torquebiau, E., Malézieux, E., Iiyama, M., Sileshi, G.W., Kehlenbeck, K., Masters, E., McMullin, S. & Dawson, I.K. 2013. Agroforestry for food and nutritional security. *Unasylva*, 64(241): 23–29.

Jamnadass, R., McMullin, S., Iiyama, M., Dawson, I., Powell, B., Termote, C., Ickowitz, A., Kehlenbeck, K., Vinceti, B. & Van Vliet, N. 2015. Understanding the roles of forests and tree-based systems in food provision. *Forest, Trees landscapes*, 25–49.

Jie, C., Chang, J., Tan., M. & Gong, Z. 2002. Soil degradation: a global problem endangering sustainable development. *Journal of Geographical Sciences* 12: 243-252.

Jodha, N.S. 1986. Common Property Resources and Rural Poor in Dry Regions of India. *Econ. Polit. Wkly.,* 21(27): 1169–1181.

Jodha, N.S. 1992. *Common property resources: a missing dimension of development strategies*. World Bank Discuss. Pap., 169

Johnson, K. B., Jacob, A., & Brown, M. E. 2013. Forest cover associated with improved child health and nutrition: evidence from the Malawi Demographic and Health Survey and satellite data. Global Health: Science and Practice, 1(2), 237-248, doi:10.9745/ghsp-d-13-00055.

Joppa, L. 2012. Population change in and around protected areas. *Journal of Ecological Anthropology*. 1: 58-64.

Jose, S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. *Agrofor. Syst.*, 76(1): 1–10.

Junk, W.J. 1984. *Ecology, fisheries and fish culture in Amazonia*. 56: 443–476. Monographiae Biologicae. Springer

Juntheikki, J. 2014. *Estimation of eucalyptus forest plantations carbon sequestration potential in Uruguay with the CO_2 fix model*. Master's thesis. Forest economic. University of Helsinki. Faculty of agriculture and forestry. Department of forest sciences.

Kapos, V., Kurz, W.A., Gardner, T., Ferreira, J., Guariguata, M., Koh, L.P., Mansourian, S., Parrotta, J.A., Sasaki, N., Schmitt, C.B., Barlow, J., Kanninen, M., Okabe, K., Pan, Y., Thompson, I.D. & Van Vliet, N. 2012. Impacts of forest and land management on biodiversity and carbon. *In* J.A. Parrotta, C. Wildburger & S. Mansourian, eds. *Understanding Relationships between Biodiversity, Carbon, Forests and People: The Key to Achieving REDD+ Objectives*. A Global Assessment Report. Prepared by the Global Forest Expert Panel on Biodiversity, Forest Management, and REDD+, p.161. Vienna, International Union of Forest Research Organizations (IUFRO).

Karjalainen, E., Sarjala, T. & Raitio, H. 2010. Promoting human health through forests: overview and major challenges. Environ. Health Prev. Med., 15(1): 1–8.

Karp, D.S., Mendenhall, C.D., Sandí, R.F., Chaumont, N., Ehrlich, P.R., Hadly, E.A. & Daily, G.C. 2013. Forest bolsters bird abundance, pest control and coffee yield. *Ecol. Lett.*, 16(11): 1339–1347.

Katz, J. 2006. Technology, Adaptation, and Exports: How Some Developing Countries Got it Right. In V. Chandra, ed. Salmon farming in Chile, pp.193–225. Washington DC, World Bank Publications.

Keenan, R.J., Reams, G.A., Achard, F., de Freitas, J. V., Grainger, A. & Lindquist, E. 2015. Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *For. Ecol. Manage.*, 352: 9–20.

Kehlenbeck, K., Kindt, R., Sinclair, F.L., Simons, A.J. and Jamnadass, R. 2011. Exotic tree species displace indigenous ones on farms at intermediate altitudes around Mount Kenya. Agroforestry Systems 83:133-147.

Keiser, J., Singer, B.H. & Utzinger, J. 2005. Reducing the burden of malaria in different eco-epidemiological settings with environmental management: a systematic review. *Lancet. Infect. Dis*., 5(11): 695–708.

Keller, G.B., Mndiga, H. and Maass, B. 2006. Diversity and genetic erosion of traditional vegetables in Tanzania from the farmer's point of view. Plant Genetic Resources 3: 400-413. http://dx.doi.org/10.1079/pgr200594

Kennedy, E. & Peters, P. 1992. Household food security and child nutrition: the interaction of income and gender of household head. *World Dev.*, 20(8): 1077–1085.

Kenny Jordan, C.B., Herz, C., Anazco, M. & Andrade, M. 1999. *Pioneering change: community forestry in the andean highlands; natural resource management by rural communities in the highlands of Bolivia, Ecuador, Peru and Colombia*. FAO, Quito (Ecuador).

Khare, A., Sarin, M., Saxena, N.C., Palit, S., Bathla, S., Vania, F. & Satyanarayana, M. 2000. *Joint forest management: Policy, practice and prospects* .J. Mayers & E. Morrison, eds. London, IIED.

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L.H. & Struik, P.C. 2014. Increasing homogeneity in global food supplies and the implications for food security, *Proc. Natl. Acad. Sci.*, 111(11): 4001–4006.
Kimble, J.M., Levine, E.R. & Stewart, B.A. 1995. *Soils and global change*. CRC Press.
Kiraz, K., Kart, L., Demir, R., Oymak, S., Gulmez, I., Unalacak, M., Ozesmi, M. 2003. Chronic pulmonary disease in rural women exposed to biomass fumes. Clin Invest Med, 2003. 26(5): p. 243-248
Kissinger, G. 2013. Linking forests and food production in the REDD+ context. *In* Behnassi, M., Pollmann, O. & Kissinger, G. *Sustainable food security in the era of local and global environmental change*, pp.41–65. Springer.
Kivinen, S., Moen, J., Berg, A. & Eriksson, ??sa. 2010. Effects of modern forest management on winter grazing resources for reindeer in Sweden. *Ambio*, 39(4): 269–278.
Klein, A.-M., Hendrix, S. D., Clough, Y., Scofield, A., & Kremen, C. 2014. Interacting effects of pollination, water and nutrients on fruit tree performance. Plant Biology, German Botanical Society and The Royal Botanical Society of the Netherlands. http://onlinelibrary.wiley.com/doi/10.1111/plb.12180/abstract
Koffi, C., Djoudi, H. & Gautier, D. 2016. Landscape diversity and associated coping strategies during food shortage periods: evidence from the Sudano-Sahelian region of Burkina Faso. *Regional Environmental Change*, http://link.springer.com/article/10.1007/s10113-016-0945-z
Kormann, U., Scherber, C., Tscharntke, T., Klein, N., Larbig, M., Valente, J.J., Hadley, A.S. & Betts, M.G. 2016. Corridors restore animal-mediated pollination in fragmented tropical forest landscapes. *Proceedings of the royal society B*. Biological sciences. DOI: 10.1098/rspb.2015.2347.
Krankina, O.N. & Dixon, R.K. 1994. Forest management options to conserve and sequester terrestrial carbon in the Russian Federation. *World Resour. Rev.*, 6(1): 88–101.
Krishwamurthy, P.K., P.K. Lewis and R.J. Choulatorn. 2013. Climate impacts on food security and nutrition: A review of existing knowledge. Met Office Hadley Centre and World Food Programme (WFP). 13 p.
Kuhnlein, H. V. & Turner, N.J. 1991. Traditional plant foods fo Canadian indigenous peoples: Nutrition, botany and use. Amsterdam, Gordon and Breach publishers.
Kumar, N., Harris, J., & Rawat, R. 2015. If They Grow It, Will They Eat and Grow? Evidence from Zambia on Agricultural Diversity and Child Undernutrition. The Journal of Development Studies, 51(8), 1060-1077, doi:10.1080/00220388.2015.1018901.
Kümpell, N. 2006. *Incentives for sustainable hunting of bushmeat in Río Muni, Equatorial Guinea*. PhD Thesis, Imperial College, London.
Lambin, E.F.M.D.A., Rounsevell, M.D.A. & Geist, H.J. 2000. Are agricultural land-use models able to predict changes in land-use intensity? *Agric. Ecosyst. Environ.*, 82(1): 321–331.
Larson, A., Pacheco, P., Toni, F. & Vallejo, M. 2006. *Exclusión e inclusión en la forestería comunitaria: ¿ hacia donde va la descentralización?*. CIFOR- IDRC. 92 pages.
Laurance, W.F., Camargo, J.L.C., Luizão, R.C.C., Laurance, S.G., Pimm, S.L., Bruna, E.M., Stouffer, P.C., Bruce Williamson, G., Benítez-Malvido, J., Vasconcelos, H.L., Van Houtan, K.S., Zartman, C.E., Boyle, S.A., Didham, R.K., Andrade, A. & Lovejoy, T.E. 2011. The fate of Amazonian forest fragments: A 32-year investigation. *Biol. Conserv.,* 144(1): 56–67.
Lebedys, A. & Li, Y. 2014. *Contribution of the forestry sector to national economies, 1990-2011.* Rome, Forest Economics, Policy and Products Division, Forestry Department. Rome.
Lee, I., Shiroma, E., Lobelo, F., Puska, F., Blair, S. & Katzmarzyk, 2012. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of the burden of disease and life expectancy. *The Lancet*. 380: 219-229.
Lengkeek, A.G., Carsan, S. and Jaenicke, H. 2003. A wealth of knowledge: how farmers in Meru, central Kenya, manage their tree nurseries. In: Diversity Makes a Difference: Farmers Managing Inter- and Intra-Specific Tree Species Diversity in Meru Kenya, edited by A.G., Lengkeek. PhD, Thesis. Wageningen: Wageningen University, 69-86.
Lescano, C.E. 1996. *Situacion actual y estrategia para el desarrollo de la produccion y el procesamiento de especies frutihorticolas Amazonicas subutilizadas*, Mesa Redonda sobre Complementariedad de la Producción Sostenible Frutihortícola Amazónica con el Desarrollo de Microempresas Agroindustriales en los Países del Tratado de Cooperación Amazónica. Pucallpa, Perú, 21-25 octubre. FAO, Rome (Italy). Dept. de Montes; Tratado de Cooperacion Amazonica, Lima (Peru). Secretaria Pro-Tempore.
Levang, P., Dounias, E. & Sitorus, S. 2005. Out of the Forest, Out of Poverty?, *Forest, Trees Livelihoods*, 15(2): 211–235.
Levang, P., Sitorus, S. & Dounias, E. 2007. City life in the midst of the forest: A Punan hunter-gatherer's vision of conservation and development. *Ecol. Soc.*, 12(1).
Lindner, M., J. Garcia-Gonzalo, M. Kolström, T. Green, R. Reguera, M. Maroschek, R. Seidl, M.J. Lexer, S. Netherer, A. Schopf, A. Kremer, S. Delzon, A. Barbati, M. Marchetti and P. Corona. 2008. *Impacts of Climate Change on European Forests and Options for Adaptation*. Report to the European Commission Directorate-General for Agriculture and Rural Development. AGRI-2007-G4-06.
Liu, Y. & Shankar, B. 2007. Will rising household incomes solve China's micronutrient deficiency problems. *Econ. Bull.*, 15(10): 1–14.
LoGiudice, K., Ostfeld, R.S., Schmidt, K.A. & Keesing, F. 2003. The ecology of infectious disease: Effects of host diversity and community composition on Lyme disease risk. *Proc. Natl. Acad. Sci.*, 100(2): 567–571.
López, C., Shanley, P. & Fantini, A.C. 2004. *Riches of the Forest: fruits, remedies and handycrafts in Latin America*. CIFOR. Indonesia.

Lorenzo, J., Carrera, F., de Camino Velozo, R., Villalobos. R. 2014. RIABM's Approach to Cross-Landscape Knowledge-Sharing: Ingredients for Success. Washington, D.C., Eco-Agriculture Partners. http://peoplefoodandnature.org/wp-content/uploads/2014/11/RIABM_LPFNCaseStudy_November25_20141.pdf
Lund H.G. 2008. Definitions of forest, deforestation, afforestation and reforestation. Forest Information Services.
Lund H.G. 2012. *National Definitions of Forest/Forestland Listed by Country*. Forest information Service (available at http://home.comcast.net/~gyde/lundpub.htm).
Lynch, O.J. & Talbott, K. 1995 Balancing acts: Community-based forest management and national law in Asia and the Pacific. World Resources Institute: Washington. http://pdf.usaid.gov/pdf_docs/PNABX171.pdf
MA. 2005. *Ecosystems and human well-being: Current State and Trends*. Vol. 5. Island Press, Washington, DC.
MacDicken, K. 2015. Introduction to the changes in Global Forest Resources from 1990-2015. *Forest Ecology and Management*. 352: 1-2.
MacDicken, K. Sola, P., Hall, J., Sabogal, C., Tadoum, M. & Wassiege C. 2015. Global progress towards sustainable forest management. *Forest Ecology and Management*. 352: 47-56.
Maier, C. & Johnsen, K. 2010. Quantifying carbon sequestration in forest plantations by modeling the dynamics of above and below ground carbon pools, *In* Stanturf, J.A., ed. *Proceedings of the 14th biennial southern silvicultural research conference*. Gen. Tech. Rep. SRS–121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 3–8.
Malhi, Y., Aragão, L.E.O.C., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., Sitch, S., McSweeney, C. & Meir, P. 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. *Proc. Natl. Acad. Sci. U. S. A.*, 106(49): 20610–20615.
Malla, Y.B., Neupane, H.R. & Branney, P.J. 2003. Why aren't poor people benefiting more from community forestry? *J. For. Livelihood*, 3(1): 78–92.
Marjokorpi, A. and Ruokolainen, K., 2003. The role of traditional forest gardens in the conservation of tree species in West Kalimantan: Indonesia. Biodiversity and Conservation 12: 799–822.
May, P., Chevez, O. & Reydon, B. 2001. Compilación y análisis sobre los productos forestales no madereros (PFNM) en el Brasil. *In:* FAO/RELAC. *Informaciones para el uso sostenible*.
Mbotiji, J. 2002. Sustainable use of wildlife resources: The bushmeat crisis. Paper presented at 2002.
Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P.A. & Kowero, G. 2014. Agroforestry solutions to address food security and climate change challenges in Africa. Current Opinion in Environmental Sustainability, 6: 61–67. *Elsevier Ltd*.
McAdam, J.H., Burgess, P.J., Graves, A.R., Rigueiro-Rodríguez, A., Mosquera-Losada, M.R. 2009. Agroforestry in Europe: Current Status and Future Prospects, in: Rigueiro-Rodróguez, A., McAdam, J., Mosquera-Losada, M.R. (Eds.), . Springer Netherlands, Dordrecht, pp. 21-41. doi:10.1007/978-1-4020-8272-6_2
McCallum, H., Barlow, N. & Hone, J. 2001. How should pathogen transmission be modelled? *Trends Ecol. Evol.,* 16(6): 295–300.
McCune, N. 2014. Peasant to peasant. The social movement form of agroecology. Farming Matters, 30(2): 36-37.
McDermott, C.L., Irland, L.C. & Pacheco, P. 2015. Forest certification and legality initiatives in the Brazilian Amazon: Lessons for effective and equitable forest governance. *For. Policy Econ.*, 50: 134–142.
McMichael, A.J., Woodruff, R.E., Hales, S. 2006. Climate change and human health: present and future risks. Lancet 367, 859–69. doi:10.1016/S0140-6736(06)68079-3
Mekongo, F. 2011. *Amélioration de la chaîne de valeur des produits forestiers non ligneux (PFNL) exploités par les organisations féminines.* Le cas des communes des Mbang et Lomié, Départements de la Kadey et du Haut Nyong, Région de l'Est, Cameroun. Yaoundé.
Melrose, W. 2001. Deforestation in Papua New Guinea: Potential impact on health care. *Rural Remote Environ. Heal*., 1: 79.
Méndez, V.E., Gliessman, S.R. & Gilbert, G.S. 2007. Tree biodiversity in farmer cooperatives of a shade coffee landscape in western El Salvador. *Agric. Ecosyst. Environ.*, 119(1): 145–159.
Menezes, F. (Coord.) 2008. Repercussões do programa Bolsa Família na segurança alimentar e nutricional das famílias beneficiadas. Rio de Janeiro: IBASE. http://www.ibase.br/userimages/ibase_bf_sintese_site.pdf
Mertz, O., Padoch, C. & Fox, J. 2009. Swidden Change in Southeast Asia: Understanding Causes and Consequences. *Human Ecology*, 37: 259–264.
Messing, K. & Östlin, P. 2006. *Gender equality, work and health: a review of the evidence*. World Health Organization, Geneva. 46 p
Mongabay. 2007. Indonesia Statistics (avaliable at http://rainforests.mongabay.com/deforestation/2000/Indonesia.htm).
Monjane, B. 2011. *The lords of the land – preliminary analysis of the land grabbing phenomenon in Mozambique* (available at http://www.cebem.org/cmsfiles/publicaciones/senhores_terra.pdf).
Nair, V.D., Haile, S.G., Michel, G.-A. & Nair, P.K. 2007. Environmental quality improvement of agricultural lands through silvopasture in southeastern United States. *Sci. Agric.*, 64(5): 513–519.
Nasi, R., Brown, D., Wilkie, D., Bennett, E., Tutin, C., Van Tol, G. & Christophersen, T. 2008. Conservation and use of wildlife-based resources: the bushmeat crisis.
Nasi, R., Taber, a. & Van Vliet, N. 2011. Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. Int. For. Rev., 13(3): 355–368.

Nåsell, I. 2005. A new look at the critical community size for childhood infections. Theor. Popul. Biol., 67(3): 203–216.

Ndembi, N., Habakkuk, Y., Takehisa, J., Takemura, T., Kobayashi, E., Ngansop, C., Songok, E., Miura, T., Ido, E., Hayami, M., Kaptue, L. & Ichimura, H. 2003. HIV type 1 infection in Pygmy hunter gatherers is from contact with Bantu rather than from nonhuman primates. *AIDS Res. Hum. Retroviruses*, 19(5): 435–9.

Neumann, C.G., Murphy, S.P., Gewa, C., Grillenberger, M. & Bwibo, N.O. 2007. Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *J. Nutr.*, 137(4): 1119–1123.

Newman, J. L. 1975. Dimensions of Sandawe diet. Ecology of Food and Nutrition, 4(1), 33-39, doi:10.1080/03670244.1975.9990404.

Nielsen, M. R. 2006. Importance, cause and effect of bushmeat hunting in the Udzungwa Mountains, Tanzania: Implications for community based wildlife management. Biological Conservation, 128, 509–516.

Nilsson, K. Sangster, M. Callis, C. Hartig, T. Vries, S. Seeland, K. Schipperijn, J. 2011. Forests, Trees and Human Health.

Noordwijk, M.V., Hoang, M.H., Neufeldt, H., Oborn, I. & Yatich, T. 2011. *How Trees And People Can Co-adapt to Climate Change. Reducing Vulnerability in Multifunctional Landscapes*. ICRAF.

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E. 2014. Tree and forest effects on air quality and human health in the United States. Environ. Pollut. 193, 119–29. doi:10.1016/j.envpol.2014.05.028

Nunes, P.C.; Rugnitz, M.T. 2011. Semeando esperança, colhendo bens e serviços ambientais; resultados do projeto Poço de Carbono Juruena. ADERJUR, Juruena, Mato Grosso, Brazil. Further information on the Juruena Project is available at: http://coopavam.org.br/

Nuttall, M., Berkes, F., Forbes, B., Kofinas, G., Vlassova, T. & Wenzel, G. 2009. *Hunting, herding, fishing and gathering: indigenous peoples and renewable resource use in the Arctic.* Ch. 11.2.2 (available at http://www.acia.uaf.edu/acia_review/acia_ch11_text_jan04.pdf).

Nyong, A., Adesina, F. & Osman Elasha, B. 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig. Adapt. Strateg. Glob. Chang., 12(5): 787–797.

Ogle, B., Hung, P., & Tuyet, H. 2001. Significance of wild vegetables in micronutrient intakes of women in Vietnam: an analysis of food variety. Asia Pacific Journal of Clinical Nutrition, 10(1), 21-30.

Oh, H.-S., Rao, Y.S., Hoskins, M.W., Vergara, N.T., Castro, C.P. & others. 1986. *Economic development and changing forest problems and policies: the case of Korea*. FAO Regional Office for Asia and the Pacific.

Ojha, H.R. 2014. Beyond the 'local community': the evolution of multi-scale politics in Nepal's community forestry regimes. *Int. For. Rev.*, 16(3): 339–353.

Oliveira, L.J.C., Costa, M.H., Soares-Filho, B.S. & Coe, M.T. 2013. Large-scale expansion of agriculture in Amazonia may be a no-win scenario. *Environ. Res. Lett.*, 8(2).

Olson, M. 1965. The logic of collective action; Public goods and the theory of groups. Harvard University Press, Cambridge.

Olson, S.H., Gangnon, R., Silveira, G.A., Patz, J.A. & others. 2010. Deforestation and malaria in Mancio Lima county, Brazil. *Emerg Infect Dis*, 16(7): 1108–1115.

Orjuela, M. 2015. Gobernanza para el Manejo Forestal Comunitario en la Reserva de la Biosfera Maya, Petén, Guatemala y la Región Autónoma de la Costa Caribe Norte de Nicaragua. Cuatro casos de estudio desde la perspectiva de los actores locales. MSc Thesis. CATIE. Turrialba, Costa Rica.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. 1999. Revisiting the Commons: Local Lessons, Global Challenges. [10.1126/science.284.5412.278]. *Science, 284*(5412), 278-282.

Padoch, C., & Sunderland, T. 2013. Managing landscapes for greater food security and improved livelihoods. Unasylva, 214(64), 3-13.

Paillard, S., Treyer, S. & Dorin, B. 2011. *Scenarios and Challenges for Feeding the World in 2050. Agrimonde.* Editions Quae. Paris: Centre de cooperation internationale en recherche agronomique pour le development at the Institut national de la recherché agronomique.

Pain, A. & Levine, S. 2012. A *Conceptual Analysis of Livelihoods and Resilience: Addressing the'insecurity of Agency'*, HPG Working Paper. Overseas Development Institute.

Parajuli. R. 2011. *Carbon Sequestration And Uneven-Aged Management Of Loblolly Pine Stands In The Southern Usa: A Joint Optimization Approach*. MSc. Thesis. School of Renewable Natural Resources. Tribhuvan University.

Parrotta, John A., Jennie Dey de Pryck, Beatrice Darko Obiri, Christine Padoch, Bronwen Powell, Chris Sandbrook, Bina Agarwal, Amy Ickowitz, Katy Jeary, Anca Serban, Terry Sunderland and Tran Nam Tu. 2015. The Historical, Environmental and Socio-Economic Context of Forests and Tree-Based Systems for Food Security and Nutrition. In: Bhaskar Vira, Christoph Wildburger & Stephanie Mansourian (eds.), Forests, Trees and Landscapes for Food Security and Nutrition. A Global Assessment Report. IUFRO World Series Volume 33. p. 51-86

Parry, L., Barlow, J., & Peres, C. A. 2009. Hunting for sustainability in tropical secondary forests. Conservation Biology, 23(5), 1270–1280.

Pasha, S.A. 1992. Common Pool Resources and the Rural Poor: A Micro Level Analysis. *Econ. Polit. Wkly.*, 27(46): 2499–2503.

Pattanayak, S., Dickinson, K., Corey, C., Murray, B., Sills, E. & Kramer, R. 2006. Deforestation, malaria, and poverty: a call for transdisciplinary research to support the design of cross-sectoral policies. *Sustain. Sci. Pract. Policy*, 2(2).

Patz, J.A., Confalonieri, U.E.C., Amerasinghe, F.P., Chua, K.B., Daszak, P., Hyatt, A.D., Molyneux, D., Thomson, M., Yameogo, L., Lazaro, M.M. & others. 2005. *Human health: ecosystem regulation of infectious diseases. In* MA, *Ecosystems and Human Well-being: Current State and Trends*, Chapter 14, 391–415.
Patz, J.A., Olson, S.H., Uejio, C.K. & Gibbs, H.K. 2008. Disease emergence from global climate and land use change. *Med. Clin. North Am*., 92(6): 1473–1491.
Payn, T., Carnus, J-M., Smith, P., Kimberley, M., Kollert, W., Liu, S., Orazio, C. Rodriguez, L. Silva., L. & Wingfield, M. 2015. Changes in planted forests and future global implications. *Forest Ecology and Management.* 352: 57-67.
Petrov, A. & Lobovikov, M. 2012. The Russian Federation Forest Sector: Outlook Study to 2030. FAO, Rome,
Phalan, B., Green, R.E., Dicks, L. V, Dotta, G., Feniuk, C., Lamb, A., Strassburg, B.B.N., Williams, D.R., Zu Ermgassen, E.K.H.J. & Balmford, A. 2016. How can higher-yield farming help to spare nature? *Science*, 351(6272): 450–451.
Phalkey, R. Arandra-Jan, C., Marx, S., Höfle, B. & Sauerborn. 2015. Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *Proceedings of the National Academy of Science.* 1073: E4522-E4529.
Philpott, S.M., Arendt, W.J., Armbrecht, I., Bichier, P., Diestch, T.V., Gordon, C., Greenberg, R., Perfecto, I., Reynoso-Santos, R., Soto-Pinto, L., Tejeda-Cruz, C., Williams-Linera, G., Valenzuelaa, J. and Zolotoff, J.M. 2008. Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. Conservation Biology 22:1093–1105.
Pimbert, M.P. and Pretty, J.N., 1997. Parks, people and professionals. Putting "participation" into protected area management. In K. Ghimire and M.P. Pimbert (eds). *Social Change and Conservation*. 34: 297-330.
Pimbert, M.P. and Pretty, J,N., 1998. *Diversity and sustainability in community based conservation.* In: Kothari, A., N. Pathak, R V Anuradha and, B. Taneja **(Eds)** Communities and Conservation: Natural Resource Management in South and Central Asia. UNESCO and Sage Publications. London and New Delhi.
Pimentel, D., McNair, M., Buck, L., Pimentel, M. & Kamil, J. 1997. The value of forests to world food security. *Hum. Ecol.*, 25(1): 91–120.
Pinstrup-Andersen, P. & Watson II, D.D. 2011. *Food policy for developing countries: The role of government in global, national, and local food systems.* Cornell University Press.
Po, J.Y.T., FitzGerald, J.M. & Carlsten, C. 2011. Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. *Thorax*, 66(3): 232–239.
Poffenberger, M., McGean, B. & others. 1996. Village voices, forest choices. *In* Tropical Forests and the Human Spirit: Journeys to the Brink of Hope, p.17–326.
Popkin, B.M. 2001. The Nutrition Transition and Obesity in the Developing World. *J. Nutr.*, 131(3): 866S–870S.
Popkin, B.M., Adair, L.S. & Ng, S.W. 2012. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr. Rev.*, 70(1): 3–21.
Powell, B., Ickowitz, A., McMullin, S., Jamnadass, R., Miguel, C.P., Vasquez, P. & Sunderland, T. 2013a. The role of forests, trees and wild biodiversity for nutrition-sensitive food systems and landscapes. FAO WHO Publ. Geneva, : 1–25.
Powell, B., Maundu, P., Kuhnlein, H. V & Johns, T. 2013b. Wild foods from farm and forest in the East Usambara Mountains, Tanzania. *Ecol Food Nutr*, 52(6): 451–478.
Powell, B., Thilsted, S.H., Ickowitz, A., Termote, C., Sunderland, T. & Herforth, A. 2015. Improving diets with wild and cultivated biodiversity from across the landscape. Food Secur., 7(3): 535–554.
Powell, B. & Timothy J. 2015. Associations between dietary quality and biodiversity are dependent on indicators used. Poster presentation at the 2nd International Conference on Global Food Security, 11-14 October 2015, Ithaca, New York, USA
Powell, B. (2012). Biodiversity and human nutrition in a landscape mosaic of farms and forests in the East Usambara Mountains, Tanzania. McGill University, Montreal, Canada.
Power, A.G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transactions of the Royal Society B. Volume 365: Issue 1554.
Power, E.M. 2008. Conceptualizing food security for aboriginal people in Canada. *Can. J. Public Heal.*, 99(2): 95–97.
Price, L. L. 1997. Wild plant food in agricultural environments: A study of occurrence, management, and gathering rights in Northeast Thailand. Human Organization, 56(2), 209-221.
Prescott-Allen, R. & Prescott-Allen, C. 1990. How many plants feed the world? *Conservation Biology,* 4 (4): 365-374.
Pretty, J. & Bharucha, Z. 2014. Sustainable intensification in agricultural systems. Annals of Botany. 114: 1571-1596.
Rademaekers, K, L. Eichler, J. Berg, M. Obersteiner and P. Havlik. 2010. Study on the evolution of some deforestation drivers and their potential impacts on the costs of an avoiding deforestation scheme. ECORYS, COWI and IIASA
Rastogi, A. 1995. Impact of culture on process of joint forest management in India. *Ambio,* 24(4): 253–255.
Rahman, S, J. Healey, J. Jacobsen & T. Sunderland. 2016. Finding alternatives to swidden agriculture: Does agroforestry improve livelihood options and reduce pressure on existing forest? *Agroforestry Systems*. http://link.springer.com/article/10.1007/s10457-016-9912-4
Reed, J., J. van Vlanen & T. Sunderland. 2015. From global complexity to local reality: Aligning implementation frameworks with Sustainable Development Goals and landscape approaches. CIFOR InfoBrief No. 129. Centre

for International Forestry Research, Bogor. http://www.cifor.org/library/5865/from-global-complexity-to-local-reality-aligning-implementation-pathways-for-the-sustainable-development-goals-and-landscape-approaches/

Reisner, Y., de Filippi, R., Herzog, F. & Palma, J. 2007. Target regions for silvoarable agroforestry in Europe. *Ecol. Eng.*, 29(4): 401–418.

Rerkasem, K., Lawrence, D., Padoch, C., Schmidt-Vogt, D., Ziegler, A.D. & Bruun, T.B. 2009. Consequences of swidden transitions for crop and fallow biodiversity in Southeast Asia. *Hum. Ecol.*, 37(3): 347–360.

Ribot, J.C. 1999. Decentralisation, participation and accountability in Sahelian forestry: legal instruments of political-administrative control. *Africa (Lond).*, 69(1): 23–65.

Richardson, R.B. 2010. Ecosystem services and food security: Economic perspectives on environmental sustainability. *Sustainability*, 2(11): 3520–3548.

Ricketts, T.H. 2004. Tropical forest fragments enhance pollinator activity in nearby coffee crops. *Conserv. Biol.*, 18(5): 1262–1271.

Ricketts,T.H., Daily, G.C., Ehrlich, P.R. & Michener, C.D. 2004. Economic value of tropical forest to coffee production. *Proc Nat. Acad. Sci.,* 101(34): 12579–12582.

Rodrigues, A.S.L., Ewers, R.M., Parry, L., Souza, C., Veríssimo, A., Balmford, A., Jr, C.S., Veríssimo, A. & Balmford, A. 2009. Boom-and-bust development patterns across the Amazon deforestation frontier. *Science*, 324(5933): 1435–7.

Rosset, P.M. & Martinez-Torres, M.E. 2012. Rural Social Movements and Agroecology: context, theory and process. Ecology and Society, 17(3): 17.

Roturier, S. & Roué, M. 2009. Of forest, snow and lichen: Sámi reindeer herders' knowledge of winter pastures in northern Sweden. *For. Ecol. Manage.*, 258(9): 1960–1967.

Rowland, D., Blackie, R.R., Powell, B., Djoudi, H., Vergles, E., Vinceti, B. & Ickowitz, A. 2015. Direct contributions of dry forests to nutrition: a review. *Int. For. Rev.*, 17(S2): 45–53.

Rowland, D, A Ickowitz, Powell, B., Nasi, R. &Sunderland, T. (in press) Contributions of forest foods to meeting recommendations for dietary intakes: A multi-country case study analysis. Environmental Conservation.

Ruel, M. T., & Alderman, H. 2013. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? The Lancet, 382, 536–551, doi:http://dx.doi.org/10.1016/S0140-6736(13)60843-0.

Ruiz-Pérez, M., Almeida, M., Dewi, S., Costa, E.M.L., Pantoja, M.C., Puntodewo, A., de Postigo, A.A. & de Andrade, A.G. 2005. Conservation and development in Amazonian extractive reserves: the case of Alto Juruá. *Ambio*, 34(3): 218–223.

Rushton, J., Viscarra, R., Viscarra, C., Basset, F., Baptista, R., Huallata, C. & Brown, D. 2004. *Captive breeding of wild species – a sceptical view of the prospects*. Wildlife policy brieding. Number 9.

Rushton, J., Viscarra, R., Viscarra, C., Basset, F., Baptista, R. & Brown, D. 2004. *How Important is Bushmeat Consumption in South America: Now and in the Future?* ODI Wildlife Policy Briefing.

Rustad, L., Campbell, J., Dukes, S.J., Huntington, T., Fallon Lambert, F.K., Mohan, J. & Rodenhouse, N. 2012. *Changing Climate, Changing Forests: The Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada*. U.S. Forest Service.

Saigal, S., Dahal, G. R. & Vira, B. 2008. Cooperation in forestry: Analysis of forestry cooperatives in Rajasthan, India. Bogor, Indonesia: Centre for International Forestry Research/Rights and Resources Initiative. http://www.cifor.org/tenure-reform/data/files/india/site_report/sr_india1.pdf

Sambuichi, R.H.R. and Haridasan, M. 2007. Recovery of species richness and conservation of native Atlantic forest trees in the cacao plantations of southern Bahia in Brazil. Biodiversity and Conservation 16: 3681–3701.

Sangioni, L.A., Horta, M.C., Vianna, M.C.B., Gennari, S.M., Soares, R.M., Galv??o, M.A.M., Schumaker, T.T.S., Ferreira, F., Vidotto, O. & Labruna, M.B. 2005. Rickettsial infection in animals and Brazilian spotted fever endemicity. *Emerg. Infect. Dis.*, 11(2): 265–270.

Sanchez, A. 2015. Análisis de la cobertura forestal de Costa Rica entre 1960 y 2013. *Ambientico 253, Editorial, p. 2–3.*

Saxena, N.C. 1997. *The saga of participatory forest management in India*.

Shackleton, C. & Shackleton, S. 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: A review of evidence from South Africa. S. Afr. J. Sci., 100(11-12): 658–664.

Schlegel, S. A., & Guthrie, H. A. 1973. Diet and the tiruray shift from swidden to plow farming. *Ecology of Food and Nutrition, 2*(3), 181-191, doi:10.1080/03670244.1973.9990335.

Schmitt, C. J.; Maluf, R.; Belik, W. 2015. Family farming, institutional markets and innovations in public policy: food and nutritional security as a driver for governmental intervention. In: Hebinck, P. *et al.* Rural Development and the Construction of New Markets. London and New York: Routledge.

Schmidt-Vogt, D., Leisz, S.J., Mertz, O., Heinimann, A., Thiha, T., Messerli, P., Epprecht, M., Cu, P. Van, Chi, V.K., Hardiono, M. & Dao, T.M. 2009. An assessment of trends in the extent of swidden in southeast asia. *Hum. Ecol.*, 37(3): 269–280.

Schroeder, P. 1993. Agroforestry systems: integrated land use to store and conserve carbon. *Clim. Res.*, 3(1): 53–60.

Schulze, M., J. Grogan and E. Vidal. 2008. Technical challenges to sustainable forest management in concessions on public lands in the Brazilian Amazon. Journal of Sustainable Forestry, Volume 26, Issue 1, pp. 61-76.

Sharrow, S.H., Buck, L.E. & Lassoie, J.P. 1999. Silvopastoralism: competition and facilitation between trees, livestock, and improved grass-clover pastures on temperate rainfed lands. Agrofor. Sustain. Agric. Syst., : 111–130.
Shilabu, M.D.T. 2008. *The contribution of agroforestry to household food security and income generation in Maswa District, Shinyanga region*. Sokoine University of Agriculture (SUA).
Shin, W.S., Yeoun, P.S., Yoo, R.W. & Shin, C.S. 2010. Forest experience and psychological health benefits: the state of the art and future prospect in Korea, *Environ Health Prev Med*., 15(1): 38–47.
Sibhatu, K. T., Krishna, V. V., & Qaim, M. 2015. Production diversity and dietary diversity in smallholder farm households. Proceedings of the National Academy of Sciences, 112(34), 10657-10662, doi:10.1073/pnas.1510982112.
Siegel, K.R., Ali, M.K., Srinivasiah, A., Nugent, R.A. & Narayan, K.M.V. 2014. Do we produce enough fruits and vegetables to meet global health need? PLoS One, 9(8).
Silva Neto, P.B., Guimaraes, J.O., De Paula, A.C. & Barquero, G. 2004. Wildlife management by forest people in the Brazilian extractivist reserve of Cazumba. *Game Wildl. Sci.*, 21(3, Sp. Iss. SI): 189–196.
Sloan S. & Sayer, J. 2015. Forest Resources Assessment of 2015 shows positive global trends but forest loss and degradation persist in poor tropical countries. *Forest Ecology and Management* 352: 134-145
Smith, J., Sabogal C., de Jong, W. & Kaimowitz, D. 1997. Bosque secundarios como recurso para el desarrollo rural y la conservación en los trópicos de América Latina. *In* Elias, E. *Memorias del taller internacional sobre el estado actual y potencial de manejo y desarrollo de bosque secundario tropical en América Latina*. Pucallpa-Péru, 2 al 6 de junio de 1997, 79–106.
Smith, D. A. 2005. Garden Game: Shifting Cultivation, Indigenous Hunting and Wildlife Ecology in Western Panama. Human Ecology, 33(4), 505-537, doi:10.1007/s10745-005-5157-Y.
Soini, E. & Coe, R. 2014. Principles for design of projects introducing improved wood-burning cooking stoves. Development in Practice, 24:7, 908-920, DOI:10.1080/09614524.2014.952274
Soto. D., Jara, F. & Moreno, C. 2001. Escaped salmon in the inner seas, southern Chile: facing ecological and social conflicts. *Ecological Applications,* 11(6): 1750–1762.
Sonntag-Öström, E., Nordin, M., Slunga Järvholm, L., Lundell, Y., Brännström, R., Dolling, A. 2011. Can the boreal forest be used for rehabilitation and recovery from stress-related exhaustion? A pilot study. Scand. J. For. Res. 26, 245–256. doi:10.1080/02827581.2011.558521
Sonntag-Öström, E. Nordin, M. Dolling, A. Lundell, Y. Nilsson, L. Slunga Järvholm, L. 2015. Can rehabilitation in boreal forests help recovery from exhaustion disorder? The randomised clinical trial ForRest, Scandinavian Journal of Forest Research, 30:8, 732-748, DOI: 10.1080/02827581.2015.1046482
Sonwa, D.S., Nkongmeneck, B.A., Weise, S.F., Tchatat, M., Adesina, A.A. and Janssens, M.J.J. 2007. Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. Biodiversity Conservation 16: 2385–2400. doi: 10.1007/s10531-007-9187-1
Spijkers, M.A. 2010. Implications of Climate Change on Agriculture and Food Security in South Asia. In Climate Change and Food Security in South Asia, pp.217–227. Springer
Spracklen, D. V., Arnold, S.R. & Taylor, C.M. 2012. Observations of increased tropical rainfall preceded by air passage over forests. *Nature*, 489: 282–285.
Statista. 2015. *Global fruit production in 2013, by variety (in million metric tons)* (available at http://www.statista.com/statistics/264001/worldwide-production-of-fruit-by-variety/).
Stephens, C., Porter, J., Nettleton, C. & Willis, R. 2006. Disappearing, displaced, and undervalued: a call to action for Indigenous health worldwide. *Lancet*, 367(9527): 2019–2028.
Stephensen, C.B. 1999. Burden of infection on growth failure. *J. Nutr.,* 129: 534S–538S.
Stern, N. 2007. The economics of climate change: the Stern review. Cambridge University press.
Subramanyam, M.A., Kawachi, I., Berkman, L.F. & Subramanian, S. V. 2011. Is economic growth associated with reduction in child undernutrition in India? *PLoS Med.*, 8(3): e1000424.
Sundar, N., Jeffery, R., Thin, N. & others. 2001. *Branching out: joint forest management in India*. Oxford University Press.
Sunderland, T.C.H. 2011. Food security: why is biodiversity important? *International Forestry Review,* 13(3).
Sunderland, T.C.H., B. Powell, A. Ickowitz, S. Foli, M. Pinedo-Vasquez, R. Nasi and C. Padoch. 2013. *Food security and nutrition: the role of forests*. Discussion Paper. CIFOR. Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/WPapers/DPSunderland1301.pdf
Sunderland, T., Achdiawan, R., Angelsen, A., Babigumira, R., Ickowitz, A., Paumgarten, F., Reyes-García, V. & Shively, G. 2014. Challenging perceptions about men, women, and forest product use: a global comparative study. *World Dev.*, 64: S56–S66.
Sunderland, T., D. Apgaua, C. Baldauf, R. Blackie, C. Colfer, A.B. Cunningham, K. Dexter, H. Djoudi, D. Gautier, D. Gumbo, A. Ickowitz, H. Kassa, N. Parthasarathy, R.T. Pennington, F. Paumgarten, S. Pulla, P. Sola, D. Tng, P. Waeber & L.Wilmé. 2015. Global dry forests: A prologue. *International Forestry Review* 17 (Supplement 2): 1-9 http://www.cifor.org/library/5687/global-dry-forests-a-prologue/
Sutherst, R.W. 2004. Global change and human vulnerability to vector-borne diseases. *Clin. Microbiol. Rev.,* 17(1): 136–173.
Swinton, S.M., Lupi, F., Robertson, G.P. & Hamilton, S.K. 2007. Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecol. Econ.*, 64(2): 245–252.
Sylvester, O., & Segura, A. G. 2016. Landscape Ethnoecology of Forest Food Harvesting in the Talamanca Bribri Indigenous Territory, Costa Rica. Journal of Ethnobiology, 36(1), 215-233, doi:10.2993/0278-0771-36.1.215.

Taki, H., Kevan, P.G. & Ascher, J.S. 2007. Landscape effects of forest loss in a pollination system. *Landsc. Ecol.*, 22(10): 1575–1587.

Tanksley, S.D. & McCouch, S.R. 1997. Seed banks and molecular maps: unlocking genetic potential from the wild. *Science*, 277(5329): 1063–1066.

TEEB (The Economics of Ecosystems and Biodiversity). 2010. *Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB*. By: P. Sukhdev, H. Wittmer, C. Schröter-Schlaack, C. Nesshöver, J. Bishop, P. ten Brink, H. Gundimeda, P. Kumar & B. Simmons.

Ten Kate, K. & Laird, S.A. 1999. The commercial use of biodiversity. Earthscan, London. 398 p.

Tesorio, J. 2003. *Indonesia's Palm Oil Plantations: Fueling Disaster* (available at http://www.seapabkk.org/fellowships/2003/jofelle.htm).

The PLOS Medicine Editors. 2014. PLOS Medicine and Water, Sanitation, and Hygiene: A Committed Relationship. *PLoS Med* 11(3): e1001614. doi:10.1371/journal.pmed.1001614.

Thorlakson, T. & Neufeldt, H. 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agric Food Security* 1(15):1–13.

Tilman, D., C. Balzer, J. Hill and B. Befort. 2011. Global food demand and the sustainable intensification of agriculture. PNAS 108: 20260-20264.

Tilman., D & Clark., M. 2014. Global diets link environmental sustainability and human health. *Nature*. 515: 518–522

Timer, P. 2000. The macro dimensions of food security: economic growth, equitable distribution, and food price stability. *Food Policy*, 25(3); 283–295.

Turner, N., Luczaj, L., Migliorini, P., Pieroni, A., Dreon, A., Sacchetti, L., *et al.* 2011. Edible and tended wild plants, traditional ecological knowledge and agroecology. Crit Rev Plant Sci, 30, 198 - 225.

Ullstrup, A.J. 1978. *Corn diseases in the United States and their control*. Agric. Handbook-US Dept. Agric. (USA). no. 199.

UN. 2014. *World Urbanization Prospects: The 2014 revision, highlights.* Department of Economic and Social Affairs, Population Division (available at http://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf).

UNEP. 2014. Building Natural Capital: How REDD+ can Support a Green Economy, Report of the International Resource Panel,United Nations Environment Programme, Nairobi, Kenya. http://www.unep.org/resourcepanel/Portals/50244/publications/-Building_national_capital_%20how_REDD_can_support_a_Green_Economy-2014REDD-Summary-en.pdf

UNEP, FAO, UNFF. 2009. *Vital Forest Graphics*. UNEP/GRID-Arendal (available at http://www.unep.org/vitalforest/Report/VFG_full_report.pdf).

van Minnen, J.G., Strengers, B.j., Eickhout, B., Swart, R.J. & Leemans, R. 2008. Quantifying the effectiveness of climate change mitigation through forest plantations and carbon sequestration with an integrated land-use model. *Carbon Balance Management* 3:3 doi:10.1186/1750-0680-3-3.

van der Werf, G.R., Morton, D.C., DeFries, R.S., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J. & Randerson, J.T. 2009. CO_2 emissions from forest loss. *Nature geoscience,* 2(11): 737–738.

Van Vliet, N. Nasi, R., Abernethy, K., Farguot, C., Kümpell, N., Obian, A.-M. & Ringuet, S. 2010. The role of wildlife for food security in Central Africa: a threat to biodiversity? Chapter 6 In: *The Forests of the Congo Basin: State of the forests 2010*. CARPE. pp 123-135. http://carpe.umd.edu/Documents/2010/SOF_2010_EN_Intro.pdf

van Vliet, N., Mesa, M.P.Q., Antia, D.C., Morsello, C., Adams, C., Mori, F., Yagüe, B., Hernandez, S., Bonilla, T., Tellez, L. & others. 2014. Bushmeat in the tri-frontier region of Brazil, Peru and Colombia: Demise or persistence?. CIFOR.

van Vliet, N., Fa, J.E. & Nasi, R. 2015. Managing hunting under uncertainty: from one-off ecological indicators to resilience approaches in assessing the sustainability of bushmeat hunting. Ecol. Soc., 20(3).

Vega García, H. 2014a. *El rescate de la cultura y las prácticas ambientales para el buen vivir en el siglo xxi: los alimentos ancestrales en el caso de la nuez de Ramon en la reserva de la biosfera maya, Guatemala*. Centro de Estudios Generales Universidad Nacional Costa Rica.

Vega García, H. 2014b. Identidad cultural y patrimonio ambiental: resistencia,reivindicación, apropiación e innovación de las mujeres en la reserva de la biosfera maya. *Revista Latinoamericana de Derechos Humanos,* 25 (2), II Semestre.

Verdade, L.M. & Ferraz, K.M.P.M.B. 2006. Capybaras in an anthropogenic habitat in Southeastern Brazil. *Braz. J. Biol.*, 66(1B): 371–378.

Villalobos, R. Carrera, F., de Camino, R., Morales, J. & Flores, W. 2013. Construcción de cultura forestal para el desarrollo. CATIE/UFAC, *In* A. Paz, M. Montoya, R. Asensio, IEP; IDRC-CRDI; FIDA, *Escalando innovaciones rurales*. (Estudios de la Sociedad Rural, 43).

Vinceti, B., Eyzaguirre, P. & Johns, T. 2008. The nutritional role of forest plant foods for rural communities. In C.J.P. Colfer, ed. Human health and forests: a global overview of issues, practice and policy, London, UK, Earthscan.

Vira, B., Wildburger, C. & Mansourian, S. 2015. Forests, Trees and Landscapes for Food Security and Nutrition. *IUFRO World Series*, 33.

Vittor, A.Y., Gilman, R.H., Tielsch, J., Glass, G., Shields, T., Lozano, W.S., Pinedo-Cancino, V. & Patz, J.A. 2006. The effect of deforestation on the human-biting rate of Anopheles darlingi, the primary vector of falciparum malaria in the Peruvian Amazon. *The American Society of Tropical Medicine and Hygiene*, 74: 3–11.

von Maydell H-J. 1994. Agroforestry in Central, Northern and Eastern Europe. In: Welte E, Szabolcs I and Huettl RF (eds) Agroforestry and Land Use Change in Industrialized Nations. Proc 7th CIEC Symposium, pp 65–74. Berlin, Germany

Vors, L.S. & Boyce, M.S. 2009. Global declines of caribou and reindeer. *Glob. Chang. Biol.*, 15(11): 2626–2633.

Wakker, E., Watch, S. & Rozario, J. de. 2004. Greasy palms: the social and ecological impacts of large-scale oil palm plantation development in Southeast Asia. CABI. AIDEnvironment.

Wan, M., Colfer, C.J.P. & Powell, B. 2011. Forests, women and health: opportunities and challenges for conservation. *Int. For. Rev.,* 13(3): 369–387.

Watson, J.C., Wolf, A.T. & Ascher, J.S. 2011. Forested landscapes promote richness and abundance of native bees (Hymenoptera: Apoidea: Anthophila) in Wisconsin apple orchards. *Environ. Entomol.*, 40(3): 621–632.

WCFSD. 1999. Summary Report World Commission on Forests and Sustainable Development.A. Krishnaswamy & A. Hanson, eds. World Commission on Forests and Sustainable Development. https://www.iisd.org/pdf/wcfsdsummary.pdf

White, A. & Martin, A. 2002. *Who owns the worlds forests? Forest tenure and public forest in transition*. Forest Trends. Washington, D.C.

Whiteman, A., Wickramasinghe, A. & Piña, L. 2015. Global trends in forest ownership, public income and expenditure on forestry and forestry employment, *Forest Ecology and Management,* 352: 99–108.

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A.G., de Souza Dias, B.F., Ezeh, A., Frumkin, H., Gong, P., Head, P. & others. 2015. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation--Lancet Commission on planetary health. Lancet, 386(10007): 1973–2028.

WHO. 2015. *Global Health Observatory data repository* (available at http://apps.who.int/gho/data/node.main.CODREG6?lang=en).

WHO & CBD. 2015. *Connecting Global Priorities: Biodiversity and Human Health: A State of Knowledge Review*. WHO press (available at https://www.cbd.int/health/SOK-biodiversity-en.pdf).

WHO/FAO. 2004. Fruit and Vegetables for Health. Report of a joint FAO/WHO workshop. 1-3 Sept 2004, Kobe, Japan

Widmark, C., Bostedt, G., Andersson, M., Sandström, C. 2011. Measuring Transaction Costs Incurred by Landowners in Multiple-use Situations (No. 376). Umeå.

Widmark, C. 2009. Management of multiple-use commons- focusing on land use for forestry and reindeer husbandry in northern Sweden. Swedish University of Agricultural Sciences, Umeå.

Wiens, V., Kyngäs, H., Pölkki, T. 2016. The meaning of seasonal changes, nature, and animals for adolescent girls' wellbeing in northern Finland: A qualitative descriptive study. Int. J. Qual. Stud. Health Well-being 11, 30160. doi:10.3402/qhw.v11.30160

Winjum, J.K., Dixon, R.K. & Schroeder, P.E. 1992. Estimating the global potential of forest and agroforest management practices to sequester carbon. *In* Natural Sinks of CO_2, pp.213–227. Springer.

Winfree, R., Bartomeus, I. & Cariveau, D.P. 2011. Native pollinators in anthropogenic habitats, *Annu. Rev. Ecol. Evol. Syst.*, 42(1): 1.

Wollenberg, E.A., Anderson, J.B. & Edmunds, D.C. 2001. Pluralism and the less powerful: Accommodating multiple interests in local forest management. I*nt. J. Agric. Resour. Gov. Ecol.*, 1(3-4): 199–222.

World Cancer Research Fund / American Institute for Cancer Research. 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective.* Washington DC: AICR.

WRI (World Resources Institute). Undated. *Biodiversity and protected areas: Brazil*. Earthtrends: The Environmental Information Portal.

Wunder, S., Börner, J., Shively, G. & Wyman, M. 2014. Safety Nets, Gap Filling and Forests: A Global-Comparative Perspective. *World Dev.*, 64(S1): S29–S42.

Yasuoka, J. & Levins, R. 2007. Impact of deforestation and agricultural development on anopheline ecology and malaria epidemiology. *Am. J. Trop. Med. Hyg.*, 76(3): 450–460.

Zhang, W., Ricketts, T.H., Kremen, C., Carney, K. & Swinton, S.M. 2007. Ecosystem services and dis-services to agriculture. *Ecol. Econ*., 64(2): 253–260.

Zomer, R.J., Trabucco, A., Coe, R., Place, F., van Noordwijk, M. & Xu, J.C. 2014. Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics. World Agrofor. Cent. Work. Pap., 179.

Zomer, R.J., Xu, J., Wang, M., Trabucco, A. & Li, Z. 2015. Projected impact of climate change on the effectiveness of the existing protected area network for biodiversity conservation within Yunnan Province, China. Biol. Conserv., 184: 335–345.