Chapter 2
Understanding the Roles of Forests and Tree-based Systems in Food Provision

Coordinating lead authors: Ramni Jamnadass and Stepha McMullin
Lead authors: Miyuki Iiyama and Ian K. Dawson
Contributing authors: Bronwen Powell, Celine Termote, Amy Ickowitz, Katja Kehlenbeck, Barbara Vinceti, Nathalie van Vliet, Gudrun Keding, Barbara Stadlmayr, Patrick Van Damme, Sammy Carsan, Terry Sunderland, Mary Njenga, Amos Gyau, Paolo Cerutti, Jolien Schure, Christophe Kouame, Beatrice Darko Obiri, Daniel Ofori, Bina Agarwal, Henry Neufeldt, Ann Degrande and Anca Serban

CONTENTS

Abstract: Forests and other tree-based systems such as agroforestry contribute to food and nutritional security in myriad ways. Directly, trees provide a variety of healthy foods including fruits, leafy vegetables, nuts, seeds and edible oils that can diversify diets and address seasonal food and nutritional gaps. Forests are also sources of a wider range of edible plants and fungi, as well as bushmeat, fish and insects. Tree-based systems also support the provision of fodder for meat and dairy animals, of "green fertiliser" to support crop production and of woodfuel, crucial in many communities for cooking food. Indirectly, forests and tree-based systems are a source of income to support communities to purchase foods and they also provide environmental services that support crop production. There are, however, complexities in quantifying the relative benefits and costs of tree-based systems in food provision. These complexities mean that the roles of tree-based systems are often not well understood. A greater understanding focuses on systematic methods for characterising effects across different landscapes and on key indicators, such as dietary diversity measures. This chapter provides a number of case studies to highlight the relevance of forests and tree-based systems for food security and nutrition, and indicates where there is a need to further quantify the roles of these systems, allowing proper integration of their contribution into national and international developmental policies.

2.1 Introduction

The role played by *forests*[1] and trees in the lives of many people appears obvious through the many uses made of tree products, including foods, medicines, fodder, fibres and fuels, and for construction, fencing and furniture (FAO, 2010). Indeed, forests and other tree-based production systems such as agroforests have been estimated to contribute to the *livelihoods* of more than 1.6 billion people worldwide (World Bank, 2008), but just how they contribute – and the varying levels of dependency of different communities on tree products and services and how these change over time – has often not been well defined (Byron and Arnold, 1997). Complications arise for reasons that include the vast diversity and ubiquity of products and services these systems can supply, complexities of *tenure*, land-use-change dynamics, and the different routes by which products reach subsistence users and other consumers (FAO, 2010). At least until recently, this has been compounded by the inadequate attention that has been given to the characterisation of these systems, and the benefits and costs that are associated with them among different portions of the community (Dawson et al., 2014b; Turner et al., 2012).

Complexities in quantification and a general lack of proper appreciation of relative benefits help explain why the positive roles and limitations of tree-based production systems in supporting local peoples' livelihoods have frequently been neglected by policymakers, and why rural development interventions concerned with managing *forests and tree-based systems* have sometimes been poorly targeted (Belcher et al., 2005; Belcher and Schreckenberg, 2007; World Bank, 2008). The vast diversity of forest products available includes not only those derived from trees, but a wide range of (often) "less visible" products from other plants, fungi, animals and insects. "Natural" forests, agroforests and other tree-based production systems not only provide such direct products, but contribute indirectly to support people's livelihoods through the provision of a wide range of *ecosystem services* (FAO, 2010 and Figure 2.1).

In this chapter, we are concerned with describing the direct and indirect roles of forests and tree-based production systems (such as those based on commodity tree crops) in supporting the food and nutritional security of human communities. Our emphasis is on the tropics, where this role is often the greatest and where development interventions have been widely targeted in this regard (FAO, 2010). With the world food price "spikes" of the last decade, the political unrest and suffering caused by the lack of an adequate diet for many people, and the recognition of the threats of anthropogenic *climate change* and other global challenges to agricultural production, the importance of both food and nutritional security, and the roles of forests and farms in securing them, have come to the forefront politically (FAO, 2013c; Box 2.1). As a result, a greater understanding of how forests and tree-based production systems support *food security* and *nutrition*, both directly and indirectly is needed (Jamnadass et al., 2013; Padoch and Sunderland, 2013; Powell et al., 2013; Vinceti et al., 2013).

In the following sections of this chapter, we first introduce key concepts related to food security and nutrition. Both the direct and indirect roles of forests and tree-based production systems in food provision (depicted in Figure 2.1), including threats to these roles, and gender aspects that determine value and usage, are then discussed. Although our emphasis is primarily on tree products and services because of their high importance and to illustrate the concepts involved, we also consider other, mostly forest, products. In the concluding section, we provide indications where further work is required to optimise the use of forests and tree-based production systems to support food and nutritional security.

[1] All terms that are defined in the glossary (Appendix 1), appear for the first time in italics in a chapter.

2.2 Food Security and Nutrition

Food security exists when communities "have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life" (Pinstrup-Andersen, 2009). Well-nourished individuals are healthier, can work harder and have greater physical reserves, with households that are food- and nutrition-secure being better able to withstand and recover from external shocks. Despite advances in agricultural production globally, approximately one billion people are still chronically hungry, two billion people regularly experience periods of *food insecurity* and just over a third of humans are affected by micronutrient deficiencies (FAO et al., 2012; UN-SCN, 2010; Webb Girard et al., 2012). Most of the countries with "alarming" Global Hunger Index scores are in sub-Saharan Africa and this region therefore is a particular target for intervention (von Grebmer et al., 2014).

While rates of hunger (insufficient access to energy) have been falling in many parts of the world, there has been little change in the rates of micronutrient deficiencies (FAO et al., 2013). In particular, deficiencies of iron, vitamin A, iodine and zinc, are associated with poor growth and cognitive development in children, and increased mortality and morbidity in both adults and children (Black et al., 2013). Micronutrient deficiencies are often referred to as "*hidden hunger*", as they can occur within the context of adequate energy intake, and can be overlooked using traditional measures of food security (FAO et al., 2012). *Malnutrition*, including under-nutrition, micronutrient deficiency and over-nutrition (obesity and over-weight, with the concomitant cardiovascular and chronic respiratory diseases, and diabetes) are key developmental challenges. Rates of obesity are increasing in virtually all regions of the world, affecting 1.4 billion adults globally (FAO et al., 2012) and obesity can no longer be viewed only as a disease of affluence. The burden of double (over- and under-) nutrition on the well-being of people in low-income nations is immense. As such, there have been calls for greater attention to "nutrition-sensitive" agriculture and *food systems* (Herforth and Dufour, 2013).

There has been growing recognition in the nutrition community that dietary behaviour is shaped by a broad range of psychological, cultural, economic and environmental factors (Fischler, 1988; Khare, 1980; Kuhnlein and Receveur, 1996; Sobal et al., 2014). This complexity indicates that to address food and nutritional security a multi-dimensional response is required (Bryce et al., 2008). Such a response must consider the production of sufficient food as well as its availability, affordability and utilisation, and the *resilience* of its production, among other factors (Ecker et al., 2011; FAO 2009). Nutrition-sensitive approaches across disciplines, including health, education, agriculture and the environment, are needed (Bhutta et al., 2013; Pinstrup-Andersen, 2013; Ruel and Alderman, 2013).

On the production side, nutritionists agree on the importance of bio-fortification of staple crops through breeding, as well as on the need for greater use of a more biodiverse range of nutritionally-higher-quality plants for more varied diets (i.e., not just enough food, but the right food), rather than just relying on a few "Green Revolution" staples (Keatinge et al., 2010). This diversity of plants can include locally-available and often little-researched species, including forest or once-forest taxa (Burlingame and Dernini, 2012; Frison, et al., 2011; Jamnadass et al., 2011; see Box 2.1.).

Many nutritionists now accept evidence of changes in intake of certain nutritious foods and a more diverse diet (*dietary diversity* being defined as the number of different foods or food groups consumed over a given reference period (Ruel, 2003)) as enough to determine impacts on nutrition and health, since the links between dietary diversity and energy and micronutrient adequacy, and child growth, are now well established (Arimond et al., 2010; Johns and Eyzaguirre, 2006; Kennedy et al., 2007; Kennedy et al., 2011; Ogle et al., 2001). Dietary diversity of individuals or households is thus recommended as a reliable indicator to assess if nutrition is adequate, and it is a useful measure of impact following project interventions.

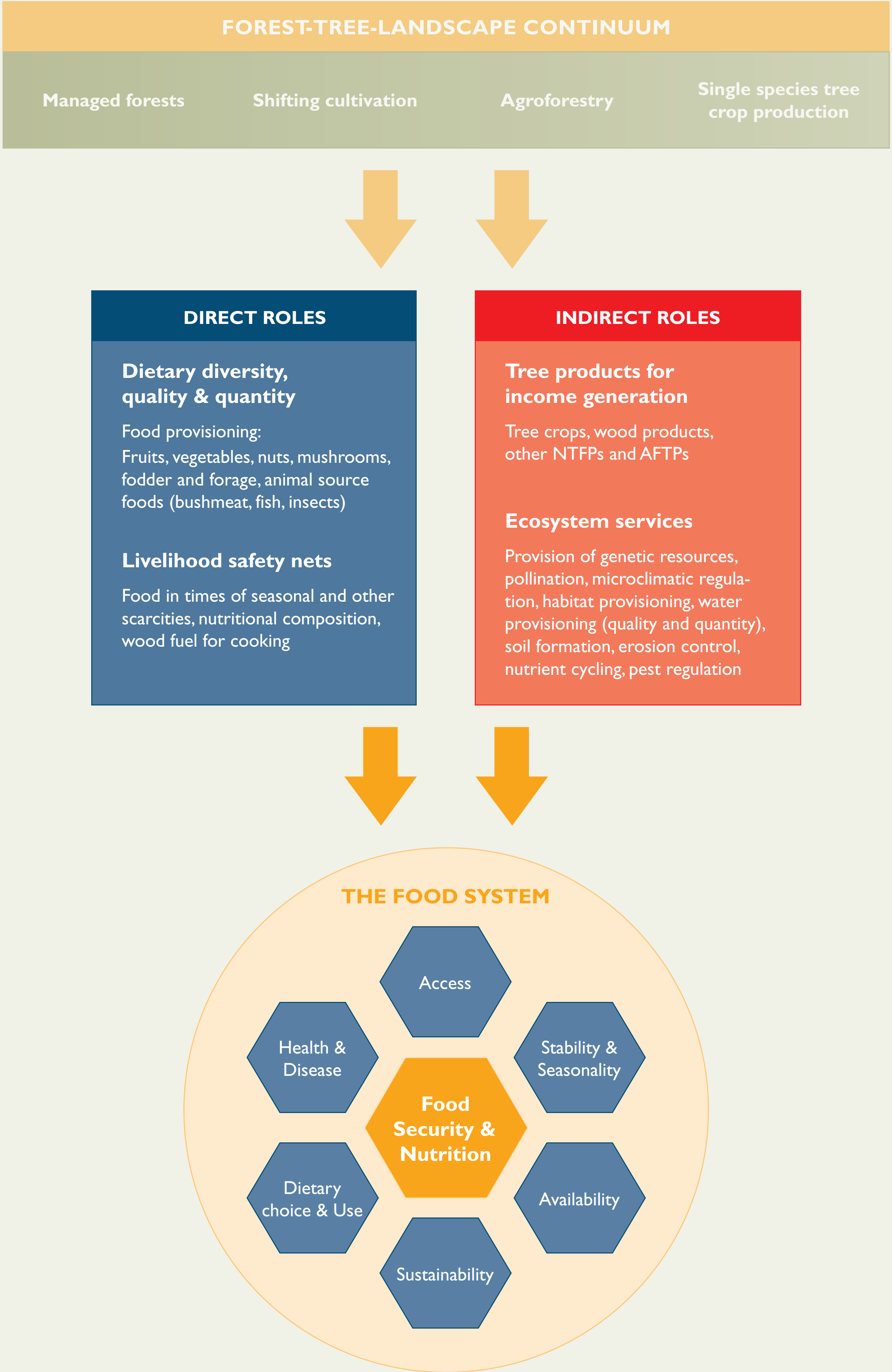
Box 2.1

Fruit and vegetable consumption in sub-Saharan Africa

A good example where changes to a healthier and more diverse diet would be beneficial is illustrated by figures on fruit and vegetable consumption in sub-Saharan Africa, where consumption is on average low with mean daily intake, respectively, of between 36 g and 123 g in surveyed East African countries; 70 g and 130 g in Southern Africa; and 90 g and 110 g in West and Central Africa (Lock et al., 2005; Ruel et al., 2005). These figures add up to considerably less than the international recommendation of 400 g in total per day to reduce micronutrient deficiencies and chronic disease (Boeing et al., 2012; FAO, 2012; WHO, 2004; see also Siegel et al., 2014). In response, initiatives are underway to bring "wild" foods in Africa into cultivation (e.g., see Jamnadass et al., 2011 for the case of fruit trees) and such approaches are receiving increased attention globally (CGIAR, 2014). This is exemplified by a recent *State of Food and Agriculture* report by the Food and Agriculture Organization of the United Nations (FAO), titled *Food Systems for Better Nutrition*, which states that "greater efforts must be directed towards interventions that diversify smallholder production such as integrated farming systems, including fisheries and forestry" (FAO, 2013c). Similarly, the World Health Organization (WHO) has recently agreed on criteria for a healthy diet that include: balanced energy intake and expenditure; the consumption of fruits, vegetables, legumes, nuts and whole grains; and the low intake of free sugars, fats and salt (WHO, 2014).

Figure 2.1

A framework depicting the direct and indirect roles of forests and tree-based production systems in food provision. Components indicated in this framework are addressed in this chapter

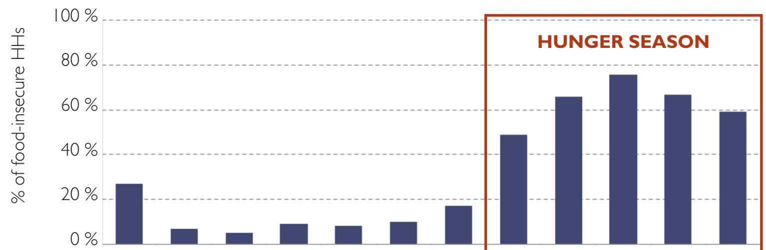


2.3 The Direct Roles of Forests and Tree-based Systems

2.3.1 Foods Provided by Forests and Tree-based Systems

Access to forests and tree-based systems has been associated with increased fruit and vegetable consumption and increased dietary diversity. Powell et al. (2011), for example, found that in the East Usambara Mountains of Tanzania, children and mothers in households who ate more foods from forests, and who had more tree cover close to their homes, had more diverse diets. In another African example, Johnson et al. (2013) found that children in Malawi who lived in communities that experienced *deforestation* had less diverse diets than children in communities where there was no deforestation. Using data from 21 countries across Africa, Ickowitz et al. (2014) found a statistically significant positive association between the dietary diversity of children under five and tree cover in their communities. While the communities globally that depend completely on forest foods for their diets are relatively modest in number and size (Colfer, 2008), the above African examples illustrate that forest foods often play an important role as nutritious supplements in otherwise monotonous diets (Grivetti and Ogle, 2000). Since the productivity of trees is often more resilient to adverse weather conditions than that of annual crops, forest foods often provide a "safety net" during periods of other food shortages caused by crop failure, as well as making important contributions during seasonal crop production gaps (Blackie et al., 2014; Keller et al., 2006; Shackleton and Shackleton, 2004). Since different tree foods in the *landscape* have different fruiting phenologies (as well as different timings for the production of other edible products), particular nutrients such as vitamins can often be made available year-round (Figure 2.2), by switching from harvesting one species (or even variety) to another over the seasons (the "portfolio" approach; Jamnadass et al., 2011).

Fruit tree portfolio for year-round vitamin C and A supply — Figure 2.2



English name	Species name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dez	Vit C	Vit A
Pawpaw	Carica papaya	■	■	■	■	■	■				■	■	■	+	+++
Mango	Mangifera indica	■	■	■									■	+	+++
Banana	Musa x paradisiaca	□	□			□					□				
Loquat	Eriobotrya japonica		■												+++
Mulberry	Morus alba		■	■										●	
Tamarind	Tamarindus indica		□	□											
Waterberry	Syzygium spp.			■					■	■					+++
Custard apple	Annona reticulata			■	■									●	
Guava	Psidium guajava			■	■	■	■							+++	+
White sapote	Casimiroa edulis				■					■				●	
Wild medlar	Vangueria madagascariensis				□	□	□								
Lemon	Citrus limon					■	■	■						+	
Orange	Citrus sinensis					■	■	■						+	
Chocolate berry	Vitex payos					■	■	■							+++
Avocado	Persea americana					□	□	□	□	□	□				
Passionfruit	Passiflora edulis							■				■			+
Jacket plum	Pappea capensis								□	□					
Desert date	Balanites aegyptiaca								■	■				●	
Bush plum	Carissa edulis											□			
Available vitamin C and A-rich fruit species		2	4	6	4	4	5	4	2	3	1	2	2		

■ Harvest time of vitamin C- and provitamin A-rich fruits (species given in red type)

□ Harvest time of vitamin C- and provitamin A-poor fruits (species given in black type)

Vitamin content levels:

+++ = very high + = intermediate ● = moderate

Food security levels of smallholders' households and the harvest periods for the most important exotic and indigenous (in italics) fruits, for 300 households in Machakos County, Eastern Kenya. Fruit harvest periods are according to household respondents and the given ratings of vitamin C and provitamin A (a precursor of vitamin A) content are according to chemical analysis (several sources, including Tanzania Food Composition Tables and the USDA National Nutrient Database) Source: Katja Kehlenbeck (personal, previously unpublished observations).

Human foods from trees

Globally, it is estimated that 50 percent of all fruit consumed by humans originate from trees (Powell et al., 2013), most of which come from cultivated sources. Many of these planted trees still have "wild" or "semi-wild" stands in "native" forest that are also harvested and which form important genetic resources for the improvement of planted stock (Dawson et al., 2014b). Although apparently wild, some forest fruit tree species have undergone a degree of domestication to support more efficient production (see for example Box 2.2), by increasing yields and quality, and by "clumping" trees together in forests to increase their density at particular sites and thus ease their harvesting. The classic case is in the Amazon, where ancient harvesting, managed regeneration and cultivation have led to genetic changes and high density aggregations, for example close to ancient anthropogenic "dark earth" soils (Clement and Junqueira, 2010) of several food tree species such as peach palm (*Bactris gasipaes*) and Brazil nut (*Bertholletia excelsa*) (Clement, 1989; Clement, 1999; Shepard and Ramirez, 2011).

Box 2.2

The case of allanblackia: integrating markets and cultivation to support the sustainable development of a new tree commodity crop

The seed of allanblackia *(Allanblackia spp.)*, found wild in the humid forests of Central, East and West Africa, yields edible oil with a significant potential in the global food market, especially as a "hardstock" for the production of healthy spreads that are low in trans-fats.

The tree is being brought into cultivation by improving seed handling and developing vegetative propagation methods, and through the selection of markedly superior genotypes. Tens of thousands of seedlings and clones have so far been distributed to smallholders.

The development of an allanblackia market has potential to improve smallholders' livelihoods and support global health. A private–public partnership known as Novella Africa is developing a sustainable allanblackia oil business that could be worth USD hundreds of millions annually for local farmers. The partnership allows different stakeholders with different interests and organisational capacities to work together.

A supply chain for seed has been established based on harvesting by local communities in natural forests and from trees remaining in farmland after forest clearance. The integration of allanblackia into small-scale cocoa farms is being promoted in West Africa to support more biodiverse and resilient agricultural landscapes. As allanblackia trees grow, cocoa trees provide the shade they need; when they are grown, they in turn will act as shade for cocoa. Cocoa and allanblackia provide harvests at different times of the year and – when the allanblackia trees have matured – will spread farmers' incomes.

Adapted from Jamnadass et al. (2010, 2014).

Traditional *agroforestry* systems often harbour high *biodiversity* and can deliver a wide array of tree foods including fruits and leafy vegetables that are both cultivated and are remnants of natural forest (Table 2.1). When established in agroforestry systems with shade trees, food diversity and sustainability of tree crop systems increase. In Ethiopia, for example, the inclusion of fruit-bearing trees as shade in coffee plantations provides farmers with access to additional foods, such as mangoes, oranges, bananas and avocados, as well as firewood and timber (Muleta, 2007).

A small number of tropical food trees is widely cultivated globally as commodity crops (e.g., cocoa [*Theobroma cacao*], coffee [*Coffea* spp.] and oil palm [*Elaeis guineensis*]; Dawson et al., 2013; Dawson et al., 2014b) in a variety of production systems, some of which harbour high levels of tree diversity, especially smallholdings (Table 2.1). Tree foods are often rich sources of vitamins, minerals, proteins, fats and other nutrients (FAO, 1992; Ho et al., 2012; Leakey, 1999), although for many traditional and wild species such information is lacking or not reliable. A recent literature review on selected African indigenous fruit trees conducted by Stadlmayr et al. (2013), for example, clearly showed their high nutritional value, but also highlighted the huge variability and low quality of some of the data reported in the literature. Edible leaves of wild African trees such as baobab (*Adansonia digitata*) and tamarind (*Tamarindus indica*) are high in calcium and are sources of protein and iron (Kehlenbeck and Jamnadass, 2014). Fruits from trees such as mango (*Mangifera indica*, native to Asia, but widely introduced through the tropics) are high in provitamin A, but there is a huge variability of almost 12-fold among different cultivars, as indicated by the colour of the fruit pulp (Shaheen et al., 2013). A child's daily requirement for vitamin A can thus be met by around 25 g of a deep orange-fleshed mango variety, while 300 g of a yellow-fleshed variety would be required. As another example, the iron contents of dried seeds of the African locust bean (*Parkia biglobosa*) and raw cashew nut (*Anacardium occidentale*) are comparable with, or even higher than, that of chicken meat (FAO, 2012), although absorption of non-haem iron from plant sources is lower than from animal sources. Iron absorption is enhanced by the intake of vitamin C, which is found in high amounts in many tree fruits (WHO/FAO, 2004). Consumption of only 10 to 20 g of baobab fruit pulp (or a glass of its juice), for example, covers a child's daily vitamin C requirement. Increasing knowledge on the biochemical components of indigenous tree species that are not widely used in agriculture internationally remains an important area of research (Slavin and Lloyd, 2012; WHO/FAO, 2004).

Human foods from other (forest) sources

Bushmeat (wild meat), fish and insects can all be important food sources. Bushmeat is often the main source of animal protein available to forest and forest-boundary communities, serving as an important source of iron and fat, and diversifying diets (Golden et al., 2011; Wilkie et al., 2005). It plays a particularly important role in diet where livestock husbandry is not a feasible option

Table 2.1

Examples of tree-species-rich agroforests in Africa, Asia and Latin America, with information on tree uses and with particular reference to possible human food use. These case studies indicate that dozens and sometimes hundreds of tree species can be found in agroforestry landscapes in the tropics, with a wide range of species contributing directly to food production *(adapted from Dawson et al., 2014b)*

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.

and where wild fish are not available (Brashares et al., 2011; Elliott et al., 2002). The hunting of animals and eating of bushmeat also play special roles in the cultural and spiritual identity of indigenous peoples (Nasi et al., 2008; Sirén, 2012). For example, more than 580 animal species, distributed in 13 taxonomic categories, are used in traditional medicine in the Amazon region (Alves and Alves, 2011).

Consumption patterns for bushmeat can vary widely (Chardonnet, 1996; Fargeot and Dieval, 2000; Wilkie et al., 2005), but hunting has been estimated to provide 30 to 80 percent of the overall protein intake of rural households in parts of Central Africa and nearly 100 percent of animal protein (Koppert et al., 1996). Numerous studies in Latin America have shown the importance of bushmeat (Iwamura et al., 2014; Peres, 2001; 2012; Van Vliet et al., 2014; Zapata-Rios et al., 2009). In the Amazon, for example, rural consumption is believed to equal ~150,000 tonnes annually, equivalent to ~ 60 kg per person (Nasi et al., 2011).

In China, increasing affluence in major consumer markets has led to spiralling demand for many wild animals, a demand that is supported by improvements in transport infrastructure. Pangolins and turtles used for meat and in traditional Chinese medicine are the most frequently encountered mammals seized from illegal traders (TRAFFIC, 2008), with major markets also in Singapore and Malaysia. Bushmeat sales can constitute a significant source of revenue for rural communities, particularly where trade is driven by increased consumption in urban areas (Milner-Gulland and Bennett, 2003). Urban consumers may have a choice of several sources of animal protein but opt for bushmeat for reasons of preference or cost relative to alternatives (Wilkie et al., 2005). Surveys of bushmeat markets are a useful way to estimate the state of fauna and to infer the sustainability of hunting activities (Fa et al., 2015).

The value of fish as a nutritious food is well established (Kawarazuka and Béné, 2011). In many tropical forests, wild fish represent the main source of animal protein in the diet, outweighing the importance of bushmeat (cf. daSilva and Begossi, 2009 for the Amazon; Powell et al., 2010 for Laos; Wilkie et al., 2005 for Gabon). In the Rio Negro region of the Brazilian Amazon, for example, da Silva and Begossi (2009) found that fish caught in flooded forests and in forest rivers accounted for 70 percent of animal protein in the diet, excluding other aquatic species such as turtles. The importance of insects as a source of food has recently regained attention (FAO, 2013b). Insects are a cheap, available source of protein and fat, and to a lesser degree carbohydrate. Some species are also considered good sources of vitamins and minerals (Dunkel, 1996; FAO, 2013b; Schabel, 2010). Many forests and agroforests are managed by local communities to enhance edible insect supply (Johnson, 2010). For example, sago palms (*Metroxylon* spp.) are managed in forest-agriculture landscape mosaics in Papua New Guinea and eastern Indonesia to support grub production (Mercer, 1997). The global importance of insects as a food source is difficult to evaluate, as statistics are mostly restricted to a few specific studies. For example, a study of the Centre for Indigenous Peoples' Nutrition and Environment and FAO evaluated the nutritional and cultural importance of various traditional food items of 12 indigenous communities from different parts of the world, and found that leaf-eating and litter-feeding invertebrates provide many Amerindian groups with important foods that can be collected year-round (Kuhnlein et al., 2009).

Tree products that support human food production and consumption

Trees provide animal fodder, enabling communities to keep livestock that provide them with nutritionally important milk and meat. They also provide green manure that replenishes soil fertility and supports annual crop production, as well as woodfuel that provides energy (Jamnadass et al., 2013). In the case of fodder production, for example, a recent initiative in East Africa involved more than 200,000 smallholder dairy farmers growing mostly introduced fodder shrubs (especially calliandra, *Calliandra calothyrsus*) as supplementary feed for their animals (Franzel et al., 2014). The typical increase in milk yield achieved enabled smallholders to raise extra revenue from milk sales of more than USD 100 per cow per year and allowed them to provide more milk more efficiently to urban consumers (Place et al., 2009). Such tree-and shrub-based practices for animal fodder production increase farmers' resilience to climate change (Dawson et al., 2014a). Many tree and other forest products are also used in ethnoveterinary treatments that support animal health and hence human food production (Dharani et al., 2014).

Boy spear-fishing in riverine forest outside of Luang Prabang, Laos.Photo © Terry Sunderland

In the case of soil fertility replenishment, an analysis of more than 90 peer-reviewed studies found consistent evidence of higher maize yields in Africa from planting nitrogen-fixing green fertilisers, including trees and shrubs, to substitute for (or enhance) mineral fertiliser application, although the level of response varied by soil type and the particular management applied (Sileshi et al., 2008). A recent project in Malawi, for example, encouraged more than 180,000 farmers to plant fertiliser trees, leading to improvements in maize yields, more food secure months per year and greater dietary diversity (CIE, 2011). As well as increasing average yields, the planting of trees as green fertilisers in Southern Africa stabilised crop production in drought years and during other extreme weather events, and improved crop rain use efficiency (Sileshi et al., 2011; Sileshi et al., 2012), contributing to food security in the context of climate change in the region. Supporting the regeneration of natural vegetation in agroforestry systems also provides significant benefits for the production of staple crops, with farmer-managed natural regeneration (FMNR) of faidherbia (*Faidherbia albida*) and other leguminous trees in dryland agroforests (parklands) in semi-arid and sub-humid Africa being a good example. Supported in Niger by a policy shift that has awarded tree tenure to farmers, as well as by more favourable wetter weather, since 1986 FMNR is reputed to have led to the "regreening" of approximately 5 million hectares (Sendzimir et al., 2011). Improvements in sorghum and millet yields, and higher dietary diversity and household incomes, have resulted in some Sahelian locations (Place and Binam, 2013).

Traditional energy sources have received little attention in current energy debates, but firewood and charcoal are crucial for the survival and well-being of as many as two billion people, enabling them to cook food to make it safe for consumption and palatable, and to release the energy within it (Owen et al., 2013; Wrangham, 2009). In sub-Saharan Africa, for example, where perhaps 90 percent of the population relies on woodfuels for cooking (GEF 2013; IEA, 2006), the use of charcoal as a cooking fuel is still increasing rapidly, with the value of the charcoal industry there estimated at USD 8 billion in 2007 (World Bank, 2011). In Asia, even better-off rural households have often been observed to be highly dependent on woodfuels, as found by Narain et al. (2005) for India, the Government of Nepal (GN, 2004) for Nepal, and Chaudhuri and Pfaff (2002) for Pakistan. With the volatile and often high price of "modern" energy sources, this situation is unlikely to change for some time, a fact often neglected in policy discussions on "energy futures" in low-income nations, which place unrealistic emphasis on "more modern" energy sources, rather than attempting to make woodfuel production and use more efficient and sustainable (Iiyama et al., 2014a; Schure et al., 2013). Access to cooking fuel provides people with more flexibility in what they can eat, including foods with better nutritional profiles that require more energy to cook (Njenga et al., 2013). The cultivation of woodlots allows the production of wood that is less harmful when burnt (Tabuti et al., 2003), has higher energy content and requires less time for collection (freeing time for other activities; Thorlakson and Neufeldt, 2012). This is particularly beneficial for women, who do most of the woodfuel collection and the cooking, and whose health suffers most from cooking-smoke-related diseases (Bailis et al., 2005). Previously collected sources of fuel can then be used for other more beneficial purposes that support food production (e.g., not cutting fruit trees for fuel; Brouwer et al., 1997; Köhlin et al., 2011; Wan et al., 2011).

2.3.2 Dietary Choices, Access to Resources and Behavioural Change

Although trees and other forest plants can provide edible fruit, nuts and leaves, etc. that are often good potential sources of nutrients and are sometimes used in this regard (see examples earlier in this chapter), it does not follow that they are used by humans for food. In this sense, long lists of edible *non-timber forest products* (NTFPs) (Bharucha and Pretty, 2010) can sometimes be misleading, as the presence of wild food species in local forest and woodland landscapes does not necessarily mean that these are consumed. Termote et al. (2012) illustrated this point with a survey around the city of Kisangani in the Democratic Republic of the Congo, where a wide variety of wild food plants were found, but few contributed significantly to human diets, despite significant local dietary deficiencies. The real contribution of these foods to diets therefore needs to be assessed by measurements of intake (as noted in Section 2.2).

When there is availability but relatively low NTFP-food use in areas of dietary need, reasons can include the high labour costs involved in collection and processing, low yields, high phenotypic variability (with large proportions of non-preferred produce), and lack of knowledge in the community. Regarding the last point, in eastern Niger and northern Burkina Faso, for example, women prepare protein-rich condiments from the seeds of wild prosopis (*Prosopis africana*) and zanmné (*Acacia macrostachya*) trees, respectively, but women in other parts of the Sahel (where the same trees are found) are not aware of these food values and do not harvest or manage woodlands for them (Faye et al., 2011). Research suggests that knowledge on the use of such products is often higher among indigenous peoples than among immigrant communities, with knowledge being lost due to social change and "modernisation" (Kuhnlein et al., 2009; Moran, 1993). Within communities, cultural perceptions on who should eat particular foods, and when, are also important (Balée, 2013; Hladik et al., 1993; Keller et al., 2006; Lykke et al., 2002). Differences arise between genders and age groups with respect to specialised knowledge and preferences in tree use (Daniggelis, 2003). This is illustrated by the different relative use values assigned to plant products by different-aged respondents in the Yuracaré and Trinitario communities in the Bolivian Amazon, where older people generally had more recall on uses for particular categories of plant, but both young and old people assigned high use values to food products (higher than respondents in their mid-years; Thomas, 2008).

From the above discussion it is evident that the relationship between the availability of food and its consumption is often complex, and simple surveys of absence/presence are therefore not in themselves adequate for understanding diets (Webb and Kennedy, 2012). When collection costs, low yields and high proportions of non-preferred produce are factors inhibiting the use of wild sources, domestication to increase productivity, quality and access can play an important role (Dawson et al., 2014b). This is exemplified by improvements in the performance of wild African fruit trees being brought into cultivation in participatory domestication programmes in the Central African region (Jamnadass et al., 2011; Tchoundjeu et al., 2010). The option of cultivation also helps address the complex threats to the use of wild stands through a combination of over-harvesting, deforestation, the conflicting use of resources and restricted (or uncontrolled) access to forests (Dawson et al., 2013; FAO, 2010; Vinceti et al., 2013). The conventional wisdom that cultivation will support the maintenance of wild stands for conservation purposes and provide sustainable access for wild harvesters (rather than cultivators) is, however, not widely supported (Dawson et al., 2013).

When bringing trees from the wild into cultivation, an important aspect is to increase yields: if indigenous trees are perceived as relatively unproductive and can only be produced inefficiently, agricultural landscapes are likely to be dominated by staple crops, with agro-biodiversity (and hence, likely, dietary diversity) reduced (Sunderland, 2011). Since many tree species are essentially undomesticated, large increases in yield and quality are often available through selection, supporting cultivation; for example, this is the case for allanblackia (*Allanblackia* spp.), described further in Box 2.2 (Jamnadass et al., 2010). Lack of knowledge on appropriate tree management, however, can be a major limitation (Jamnadass et al., 2011). Increases in efficiency are important for markets, since price to the consumer is a significant factor influencing diet (Glanz et al., 2005; Ruel et al., 2005; Story et al., 2008). Where limited access to extant forest foods is a major issue, approaches that support access such as the development of community-based *forest management* plans can be beneficial (Schreckenberg and Luttrell, 2009), but wider efforts are required to include all significant stakeholders, and in particular women (Agarwal, 2001; Mitra and Mishra, 2011).

Household decision-making regarding food use and practice, mostly made by women, is influenced by levels of knowledge on nutrition (FAO, 1997; Jamnadass et al., 2011). Translating the harvest and cultivation of tree and other forest foods into improved dietary intakes therefore involves making nutrition education and behavioural-change communication to women a high priority (McCullough et al., 2004). There is, for example, a need to understand how best to educate on the benefits of eating fruit, how to prepare nutritious foods, and how to access them (Hawkes, 2013; Jamnadass et al., 2011). Children can also be effective agents of change in societies, so teaching them about agriculture and nutrition is a wise investment (Sherman, 2003). In Kenya, for example, the “Education for Sustainable Development” initiative included a “Healthy Learning” programme targeted at school children that resulted in attitudinal and behavioural changes in communities (Vandenbosch et al., 2009). Counselling to change feeding behaviours is important (Waswa et al., 2014), within the appropriate context of culture and knowledge (Bisseleua and Niang, 2013; Smith, 2013). The education of men should also not be neglected, since they often have most control over household incomes, and need to be aware of the importance of diverse cropping systems and the spending of income on healthy foods (Fon and Edokat, 2012).

2.4 The Indirect Roles of Forests and Tree-based Systems

2.4.1 Income and other Livelihood Opportunities

Income from non-timber forest products

Local communities derive income from timber and non-timber products in forests. In this subsection, the focus is on the latter, although research in the countries of the Congo Basin, as well as in Indonesia, Ecuador and elsewhere, shows that there is a large and vibrant – and largely informal – domestic timber sector that supports the livelihoods of hundreds of thousands of local forest users (Cerutti and Lescuyer, 2011; Lescuyer et al., 2011). In many countries, however, laws for timber extraction were designed largely around large-scale export-oriented forestry operations rather than to sustain healthy small-scale domestic markets, which can be criminalised, generating large revenues in bribes for unscrupulous state officials (Cerutti et al., 2013). There are in turn, some encouraging efforts to change forest and resource *governance* rules to favour strengthened local rights (Campese et al., 2009).

In addition to providing food directly, a multitude of NTFPs harvested from natural, incipiently- and/or semi-domesticated forests and woodlands provide a range of resources that are used by harvesters directly for other purposes, or are sold for income that can be used to purchase a variety of products, including food. The increased demand for forest products in low-income nations, prompted by population growth and urbanisation, provides particular opportunities to enhance rural livelihoods (Arnold et al., 2006). Difficulties in adequately quantifying NTFP value, however, include the multiplicity of products, informal trade and bartering that occur in unmonitored local markets, direct household provisioning without products entering markets at all, and the fact that wild-harvested resources have been excluded from many large-scale rural household surveys (Angelsen et al., 2011; Shackleton et al., 2007; Shackleton et al., 2011). The heterogeneity of challenges to harness the income- and livelihood-generating opportunities from these tree products include the diversity of markets and of market structures of which they are part (Jamnadass et al., 2014).

Despite difficulties in quantification, some overall estimates of value have been attempted. Pimentel et al. (1997), for example, estimated very approximately that USD 90 billion worth of food and other NTFPs were harvested annually from forests and trees in developing countries. FAO’s latest (2010) Global Forest Resources Assessment (FRA) provided more recent estimates (based on 2005 figures), with worldwide values given of USD 19 billion and 17 billion annually for non-wood forest product- and woodfuel-removals, respectively. The data compiled for the FRA were, however, acknowledged to be far from complete (one problem is that, when they do report value for NTFPs, many countries only do so for the “top” few species of commercial importance; FAO, 2010). A good illustration of the discrepancy between current estimates of importance comes from comparing the value of woodfuel reported for Africa (most woodfuel is harvested from naturally-regenerating rather than planted sources in the continent) in the 2010 FRA (USD 1.4 billion annually) with the World Bank’s (2011) much higher estimate of the value of the charcoal industry in the sub-Saharan region (USD 8 billion annually; quoted in Section 2.3; see also FAO, 2014). There is also some confusion regarding the meaning of the term “income” in estimates: some studies use it to mean the cash made from selling products; perhaps more commonly, however, the term is used in the sense of the “environmental

Carrying bushmeat in Vietnam.
Photo © Terry Sunderland

income" from the diversity of goods provided "freely" by the environment, which includes the often higher value of subsistence extraction (Angelsen et al., 2014).

In recent years, more appropriate and systematic methods have been used to quantify the value of such products, including by the Poverty Environment Network (PEN), which compiled a comparative socio-economic data set from 8,000 households in 24 low-income tropical nations, focusing on tropical forest use and poverty alleviation (PEN, 2015; Wunder et al., 2014). The results of PEN revealed that, for the surveyed communities, environmental income constituted 28 percent of total household income, around three-quarters of which came from forests (with the highest proportion coming from forests in Latin America; Angelsen et al., 2014). According to the PEN analysis, across all sampled communities the major products and their contributions to forest income were woodfuel (firewood and charcoal, 35 percent), food (30 percent) and structure/fibre products (25 percent). There is variation between geographic regions in the importance of particular products to surveyed communities, with foods for example, being more important from forest sources in Latin America than in Africa, and the reverse being true for woodfuel. The PEN data also indicated that lower income classes were proportionally more dependent on NTFPs, partly because they have less access to private resources, although better-off households earned more in absolute terms (Angelsen et al., 2014; Wunder et al., 2014).

A wide range of other studies have also indicated an important role for NTFPs in supporting rural peoples' livelihoods (Table 2.2). NTFPs are a common "safety net" for rural households in response to shocks and as gap-filling to seasonal shortfalls, and in some instances allow asset accumulation and provide a pathway out of poverty (Angelsen and Wunder, 2003; Mulenga et al., 2012; Shackleton and Shackleton, 2004). The involvement of women, who have limited access to land and capital resources, in NTFP trade can have positive effects on intra-household equity (e.g., Kusters et al., 2006; Marshall et al., 2006). However, connecting such data with food consumption – through direct provisioning or through sales that are used to support food purchase and dietary diversity – is a different matter, and much less information is available (Ahmed, 2013). Given that much of the collection of NTFPs is done by women and children, they suffer more when access to resources is restricted or if resources are depleted (Agarwal, 2013).

As noted above and as is evident from Table 2.2, woodfuel is an important NTFP in many locations, which allows the preparation of food (Section 2.3). In contrast to subsistence firewood collection, traditionally handled by women and children, charcoal production is mainly an activity undertaken by men (Ingram et al., 2014), although the growing participation of women has been reported in some locations, such as in Zambia and northern Tanzania (Butz, 2013; Gumbo et al., 2013). Who benefits most from production depends on the specific context (Butz, 2013; Khundi et al., 2011; Schure et al., 2014; Zulu and Richardson, 2013). Charcoal production provides a good illustration of some of the dilemmas for intervention in NTFP harvest and trade since it is often based on unsustainable practices that are sometimes illegal (Mwampamba et al., 2013). Its value chain is generally affected by a complex and multi-layered regulatory context that is unclear for stakeholders (Iiyama et al., 2014b; Sepp, 2008). Interventions have rarely been effective, with economic rents accruing to the transport/wholesale stages of the value chain, as well as in bribes to those engaged in the illicit licence trade (Naughton-Treves et al., 2007). Partly as a result, producer margins are often low (Mwampamba et al., 2013).

Commercialising the wild harvest of NTFPs has been widely promoted as a conservation measure, based on the assumption that an increase in resource value is an incentive for collectors to manage forests and woodlands more sustainably (FAO, 2010). Experience shows, however, that the concept of commercialisation and conservation proceeding in tandem is often illusory (Belcher and Schreckenberg, 2007), as more beneficial livelihood outcomes are generally associated with more detrimental environmental outcomes (Kusters et al., 2006). The harvest of fruit from the argan tree (*Argania spinosa*), endemic to Morocco, is a good illustration of the dilemmas involved. The oil extracted from the kernels of argan fruit is one of the most expensive edible oils (as well as being used for cosmetic purposes) in the world and development agencies have widely promoted a "win-win" scenario for rural livelihoods and argan forest health based on further commercialisation (Lybbert et al., 2011). As Lybbert et al., showed, however, while the booming oil export market has benefited the local economy, it has also contributed to forest *degradation*. Thus, although the commercialisation of NTFP harvesting can contribute to livelihoods, not too much should be expected from it in terms of supporting sustainability, even if measures to engage in cultivation are taken (see Section 2.3; Dawson et al., 2013).

Table 2.2

Case studies indicating the proportional contribution of non-timber forest products to household budgets. The examples given show that the scale of the contribution varies widely, depending on context and wealth group, with often higher proportional contributions to poorer households

Reference	Location	Land use type	% household income**	Further information
Shackleton et al. (2007)	South Africa	Natural forest	20	
Appiah et al. (2007)	Ghana	Natural forest	38	
Kamanga et al. (2009)	Malawi	Forest, farmland	15 (17 P, 7 W)	Woodfuel, fodder, etc.
Babulo et al. (2009)	Northern Ethiopia	Natural forest	27	Woodfuel, farm implements, construction materials, wild foods, medicines
Yemiru et al. (2010)*	Southern Ethiopia	Forests (participatory management)	(53 P, 23 W)	
FAO (2011)	Mozambique	Natural forest	30	Woodfuel, fruit, mushrooms, insects, honey, medicines
FAO (2011)	Sahel	Parkland, savannah woodland	80	Shea nut
Mulenga et al. 2011	Zambia	Natural forest	32	Woodfuel, wild honey, mushrooms, ants, caterpillars
Heubach et al. (2011)	Northern Benin	Natural forest	39	
Adam and Pretzsch (2010)	Sudan	Savannah woodland	54	Ziziphus fruits
Ingram et al. (2012)	Congo Basin	Natural forest	47	
Pouliot (2012)	Burkina Faso	Parkland, forest	28 (43 P, 18 W)	Shea nut, woodfuel, locust bean pod, baobab fruit and leaves, fodder, thatching grass
Pouliot and Treue (2013)*	Ghana, Burkina Faso	Grassland, bushland, farmland, forest	Ghana (45 P, 20 W); Burkina Faso (42 P, 17 W)	Woodfuel, wild foods, fodder, construction materials, medicines
Bwalya (2013)	Zambia	Natural forest, woodland	30	Honey, mushrooms, tubers, berries, woodfuel, construction poles
Kar and Jacobson (2012)	Bangladesh	Forest-adjacent hilly areas	(16 P, 9 W)	Bamboo, wild vegetables, broom grass
Vedeld et al. (2004)	Review of 54 studies in 17 countries		20, ~ half as cash income	Woodfuel, wild foods, animal fodder, etc.

* Studies conducted under the Poverty Environment Network (PEN).

** Average for the sample, and/or (in parentheses) the range of contribution between poorer (P) and wealthier (W) groups. Values normally expressed in terms of environmental income.

Income from cultivated tree crops

Examples from Africa of widely-traded agroforestry tree foods that support farmers' incomes and consumers' choices include the indigenous semi-domesticated and widely cultivated fruit safou (*Dacryodes edulis*, Schreckenberg et al., 2006), the indigenous incipient domesticated njansang (*Ricinodendron heudelotii*, Ndoye et al., 1998) and exotic mango. New domestic markets for fruit are developing in Africa as a result of recent investments by Coca Cola, Del Monte and others to source produce locally for juice manufacture, and also to meet growing demand from population growth and increased urbanisation (Ferris et al., 2014). Worldwide, products supplied from tree-crop systems are fundamental raw materials underpinning the development of small scale to multibillion dollar industries. Coffee and cocoa are the most demanded tree crop commodities, particularly in the developed world, by beverage- and confectionery-producing giants such as Mars Inc., Nestlé and Cadbury, among others.

Women have particular opportunities to earn income from fruit and vegetable production because of their traditional involvement in harvesting and processing (Kiptot and Franzel, 2011), thereby supporting the expenditure of a greater proportion of the family income on food, although men may "co-opt" tree-based enterprises when they become more profitable (Jamnadass et al., 2011). Women are also more likely to grow a wider range of trees in the farm plots they control, including food trees (FAO, 1999).

There are still glaring gaps in the knowledge and efforts to realise the full potential of indigenous food trees, specifically in terms of production and trade status, and in the operation of value chains (Jamnadass et al., 2011). Big challenges to market engagement are the perishability of many fruits, combined with the geographic distance to larger market centres and the lack of suitable infrastructure, lack of market information, and value chains biased against small producers (Gyau et al., 2012). In addition to foods, the production of timber and other agroforestry tree products (AFTPs) for markets also provide incomes for food purchase. The high commercial value of timber planting in smallholdings pan-tropically is confirmed by the partial economic data available for the sector (e.g., for teak [*Tectona grandis*] in Indonesia see Roshetko et al., 2013; for acacia in Vietnam [*Acacia mangium* and *A. auriculiformis*] see Fisher and Gordon, 2007; Harwood and Nambiar, 2014). Many trees are also cultivated to provide medicines from bark, leaves, roots, etc., which are sold to support incomes and are used for self-treatment, supporting the health of communities along with the provision of healthy foods (Muriuki et al., 2012); however markets remain largely informal (McMullin et al., 2012; McMullin et al., 2014).

Market data recorded for agroforestry tree products are relatively sparse, but information on export value globally is quantified for major tree commodity crops such as palm oil, coffee, rubber (from *Hevea brasiliensis*), cocoa and tea (primarily from *Camellia sinensis*). Each of these crops is grown to a significant extent by smallholders, as illustrated in Indonesia where, in 2011, small farms were estimated to contribute 42 percent, 96 percent, 85 percent, 94 percent and 46 percent of the country's total production area for palm oil, coffee, rubber, cocoa and tea, respectively (GI, 2015). Unlike Indonesia, many countries do not formally differentiate between smallholder and larger-scale plantation production, but more than 67 percent of coffee produced worldwide is estimated to be from smallholdings (ICO, 2015), while the figure is 90 percent for cocoa (ICCO, 2015). Although in the 20th century there was a general transition from plantations to smallholder production for a number of tree crops, in some regions this may now be being reversed (Byerlee, 2014).

Moabi seeds contain highly valuable oil which is used for cooking, traditional healing and cosmetics.
Photo © Terry Sunderland

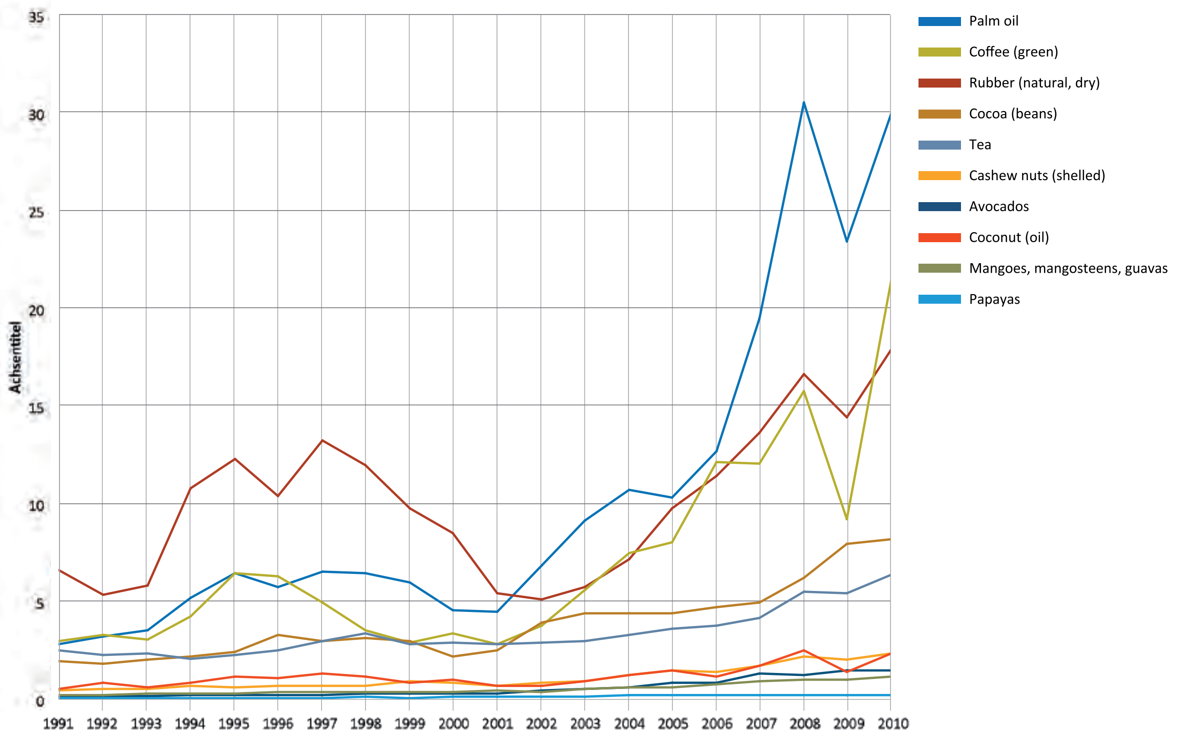
Taken together, the current annual export value of the above five tree commodity crops is tens of billions of USD, while other cultivated tree crops (such as avocados, cashews, coconuts, mangoes and papayas) also provide additional valuable contributions (Figure 2.3; FAO, 2015). Total production of these crops and their export value have grown in recent decades, with FAOSTAT data showing that export values have increased at a rate roughly four times faster than that of production. Less clear is the proportion of the export value that accrues to smallholder producers, but often production constitutes a considerable proportion of farm takings. It is estimated that cocoa accounts for 80 percent of smallholders' incomes in Bolivia, while in Ghana it provides livelihoods for over 700,000 farmers (Kolavalli and Vigneri, 2011).

There is a danger that the planting of some tree commodities will result in the conversion of natural forest – which contains important local foods – to agricultural land, and a risk that food crops will be displaced from farmland in a trend towards the growing of monocultures (e.g., oil palm, the cultivation of which has led to the wide-scale loss of forest and *agrobiodiversity*; Danielsen et al., 2009). Although it has often been suggested that intensive monocultures raise productivity and therefore reduce the amount of forested land that needs to be cut for crop cultivation (leaving forest food sources intact), there are few quantitative data to support the notion that "*land sparing*" is more effective than "*land sharing*" as a conservation strategy (Balmford et al., 2012; Tscharntke et al., 2012; see discussion in Chapter 5).

There is an important opportunity to diversify risks associated with the reliance on a few cash tree crops into other tree crops whose domestic production and export

Global export values of a range of tree commodity crops over a twenty year period, 1991 to 2010

Figure 2.3



Data were extracted from FAO (2015) and are combined figures for all nations providing information. Data for mangoes, mangosteens and guava are reported together. Given values include re-exports (i.e., import into one nation followed by export to another). Some commodities, such as coffee, cocoa and coconut, are exported in more than one form and total export values are therefore higher than those shown here (for each of these crops only the most important form by export value is given). The graph shows that there was a significant increase in export value for crops during the decade leading up to 2010, but that value was volatile. The most notable feature over the period was a sharp rise in palm oil export value. Note that local trade can also be significant for many of these products

markets are growing steadily and rapidly, while also meeting food security and nutritional needs of the growing population. For example, currently, the global supply of fruits and vegetables falls, on average, 22 percent short of population need according to nutrition recommendations, while low income countries fall on average 58 percent short of need (Siegel et al., 2014). Although tree crop cultivation provides opportunities for farmers to diversify and minimise risk, especially for products that can be consumed by the family as well as sold (Jamnadass et al., 2011), buying food using the income received from a single commodity cash crop can lead to food insecurity for individual farm households when payments are one-off, delayed or volatile in value. Similarly, individual countries can become too dependent on one or a few commodities, with significant fluctuations in GDP, dependent on unpredictable world prices (Jamnadass et al., 2014). Monocultures of tree commodities also reduce resilience to shocks such as drought, flood and, often (although not always), the outbreak of pests and diseases. As a result, tree commodity crops are sometimes viewed sceptically within agricultural production-based strategies to improve nutrition (FAO, 2013a). For farmers who have too little land to cultivate enough food to directly meet their needs, however, income from tree commodity crops may be the only way to obtain sufficient food (Arnold, 1990).

2.4.2 Provision of Ecosystem Services

The Millennium Ecosystem Assessment (MA, 2005) provided a comprehensive overview of ecosystem services and much literature has been written on the subject. Here we provide a brief overview of key ecosystem services from forests and tree-based systems, and their roles in food security and nutrition.

Forests, agroforests and – to a certain extent – plantations, provide important ecosystem services including: soil, spring, stream and watershed protection; microclimate regulation; biodiversity conservation; and pollination, all of which ultimately affect food and nutritional security (Garrity, 2004; Zhang et al., 2007). Multiple ecosystem service scan generally be fund in any single forest fragment (see Box 2.3). Forest users and farmers can be encouraged to preserve and reinforce these functions by payments for ecosystem services (PES), but more important in determining their behaviour is the direct products and services they receive from trees (Roshetko et al., 2007). Neglect of this fact by PES schemes has led to sub-optimal results (Roshetko et al., 2015). Opportunities for ecological intensification (see Chapter 5) and for the better provision of environmental services to support food security vary by stage of the forest-tree landscape continuum (van Noordwijk et al., 2014 and see Chapter 3).

Forests, woodlands and trees elsewhere in landscapes play a vital role in controlling water flows, and preventing soil erosion and nutrient leaching, all of which are critical functions for food production systems (Bruinsma, 2003). At the same time, green manures in agroforestry systems maintain and enhance soil fertility, supporting crop yields when external fertiliser inputs are not available or are unaffordable (see Section 2.3; Garrity et al., 2010; Sanchez, 2002). Nitrogen-fixing trees have in particular received considerable attention for their ability to cycle atmospheric nitrogen in cropping systems (Sileshi et al., 2008; Sileshi et al., 2011; Sileshi et al., 2012). Microclimate regulation by trees in agroforestry systems, such as through the provision of a canopy that protects crops from direct exposure to the sun (reducing evapotranspiration), from extreme rainfall events and from high temperatures, can also promote more resilient and productive food-cropping systems (Pramova et al., 2012). In Sahelian zones with long dry seasons, for example, trees provide an environment for the cultivation of nutritious leafy vegetables and pulses (Sendzimir et al., 2011).

Box 2.3

Forest fragments modulate ecosystem services

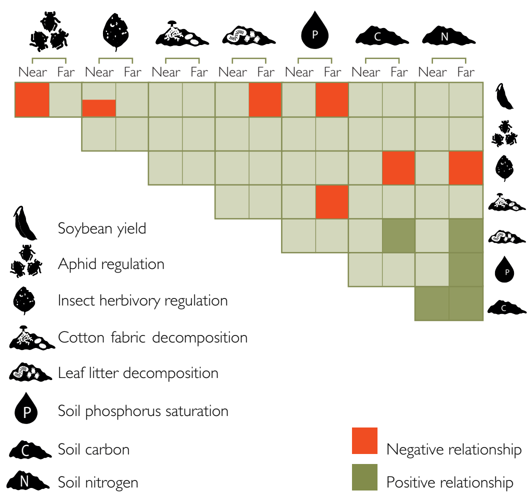
Mitchell et al. (2014) provide empirical evidence that forest fragments influence the provision of multiple ecosystem service indicators in adjacent agricultural fields. Their study looked simultaneously at six ecosystem services (crop production, pest regulation, decomposition, carbon storage, soil fertility and water quality regulation) in soya bean fields at different distances from adjacent forest fragments that differed in isolation and size across an agricultural landscape in Quebec, Canada. The study showed significant effects of distance-from-forest, fragment isolation and fragment size on crop production, insect pest regulation, and decomposition. Distance-from-forest and fragment isolation had unique influences on service provision for each of the ecosystem services measured. For example, pest regulation was maximised adjacent to forest fragments (within 100 m), while crop production was maximised at intermediate distances from forest (150 m to 300 m). As a consequence, landscape multifunctionality depended on landscape heterogeneity: the range of field and forest fragment types present. The study also observed strong negative and positive relationships between ecosystem services that were more prevalent at greater distances from forest.

Forests, and frequently agroforests, are centres of plant and animal biodiversity, protecting species and the genetic variation that is found with them, which may be essential for future human food security (Dawson et al., 2013). As already noted in Section 2.3, as well as being sources of existing and "new" foods, many already cultivated tree species have their centres of genetic diversity within forests, and these resources may be crucial for future crop improvement. A good example is coffee, an important beverage globally, which is found wild in Ethiopian montane forests. These forests are under significant threat from agricultural expansion (Labouisse et al., 2008) and climate change (Davis et al., 2012). Economic "option value" analysis of wild coffee stands for breeding purposes – to increase yields, improve disease resistances and for a lower caffeine content in the cultivated crop – shows just how important it is to implement more effective conservation strategies for Ethiopian forests (Hein and Gatzweiler, 2006; Reichhuber and Requate, 2007).

Pollination is one of the most studied ecosystem services, with perhaps the most comprehensive reviews of animal pollination and how it underpins global food production being that of Klein et al. (2007). A diversity of trees in forests and in farmland can support populations of pollinator species such as insects and birds that are essential for the production of important human foods, including fruits in both forest and farmland, and a range of other important crops in farmland (Garibaldi et al., 2013; Hagen and Kraemer, 2010; for the specific case of coffee, see Ricketts et al., 2004; Priess et al., 2007). For communities living in or around forests, pollination is therefore a crucial ecosystem service (Adams, 2012). Of course, forests and trees in agroforests provide important habitat for a range of other fauna that include the natural predators of crop pests (as well as sometimes being hosts for the crop pests themselves; Tscharntke et al., 2005).

Figure 2.4

Effects of distance-from-forest on pair-wise Spearman rank relationships between ecosystem service indicators



Source: Mitchell et al., 2014.

2.5 Conclusions

Foods provided by forests and tree-based systems

There is increasing evidence of the importance of forests and tree-based systems for supporting food production and contributing to dietary diversity and quality, addressing nutritional shortfalls. By targeting particular species for improved harvest and/or cultivation, more optimal "portfolios" of species could be devised that best support communities' nutrition year-round. An overall increase in the production through cultivation of a wide range of foods, including tree fruits and vegetables, is required to bridge consumption shortfalls. There is much further potential for the domestication of currently little-researched indigenous fruit trees to bring about large production gains, although more information is needed on the nutritional value of many of these species. Trees also provide other important products (e.g., fodder, green fertiliser, fuel) that support food production and use.

Dietary choices, access to resources and behavioural change

Dietary choices are complex and depend on more than just what potential foods are available to communities in their environments. Rather than assumptions based on availability, assessments of actual diet through dietary diversity studies and other related estimators are therefore crucial. Then, the reasons behind current limitations in usage can be explored and possibly addressed. There are multiple targets to improve food choices, with women and children being key targets for education.

Income and other livelihood opportunities

NTFPs and AFTPs, including tree commodity crops within agroforestry systems, are important sources of revenue to local people and governments, which can support food supply. More is known about the economic value of tree commodity crops than of other products, but recent initiatives have provided a clearer picture of the "environmental income" from NTFPs (though not necessarily for AFTPs). Only limited information is available on how cash incomes from these resources are spent with regard to promoting food and nutritional security, and there are clear dangers in relying on cash incomes from single commodity crops.

Provision of ecosystem services

Forests and tree-based production systems provide valuable ecosystem services that support staple crop production and that of a wider range of edible plants. Many tree species that are important crops globally require pollinators to produce fruit. The presence of these pollinators is supported by forests and diverse cropping systems. More is known about the environmental service provisioning of tropical humid forests than of dry forests (Blackie et al., 2014).

Pineapple – here in a homegarden in Cuba – is rich in manganese and vitamin C.
Photo © Stephanie Mansourian

Outstanding gaps

The value of the "hidden harvest" of edible forest foods, and the cultivation of trees by smallholders, is evident from this chapter. To maximise future potential, greater attention from both the scientific and the development communities is required. In particular, the development of a supportive policy framework requires proper attention to both the forestry and agriculture sectors in tandem. For this to take place, a better quantification of the relative benefits received by rural communities from different tree production categories is required, supported by an appropriate typology for characterisation (de Foresta et al., 2013). Despite recent advances such as PEN (2015), data are still required to quantify roles in supporting food and nutritional security that include dietary diversity measurements.

Policies that support communities' access to forest and that encourage the cultivation of tree products are required. Required reforms include more favourable land tenure arrangements for smallholders, in how farmers obtain tree planting material, and in the recognition of agroforestry as a viable investment option for food production (Jamnadass et al., 2013). Research should support food tree domestication options appropriate for meeting smallholders' needs. Emphasis should be placed on mixed agroforestry production regimes that can help to avoid many of the negative effects described in Section 2.4, by combining tree commodities in diverse production systems with locally-important food trees, staple crops, vegetables and edible fungi. Such regimes include shade coffee and shade cocoa systems (Jagoret et al., 2011; Jagoret et al., 2012; SCI, 2015), which increase or at least do not decrease commodity yields and profitability (Clough et al., 2011). Such systems have often been practised traditionally, but are now being actively encouraged through schemes such as certification by some international purchasers of tree commodity crops (Millard, 2011).

To support diverse production systems, genetic selection for commodity crop cultivars that do well under shade may be of particular importance (Mohan Jain and Priyadarshan, 2009). This may require returning to wild genetic resources still found in shaded, mixed-species forest habitats, reinforcing the value of their conservation. Not all tree commodities are, however, amenable to production in diversified systems; for example, oil palm is not well suited (Donald, 2004). There are also opportunities to develop valuable new tree commodities that are compatible with other crops and that therefore support more agro-biodiversity. Further research is also required to assess the complementarity and resilience of different crops in agroforestry systems under climate change, in the context also of other global challenges to food and nutritional security.

The development of "nutrient-sensitive" value chains is also needed, which means improving nutritional knowledge and awareness among value-chain actors and consumers, focusing on promoting the involvement of women, and considering markets for a wider range of tree foods. By promoting tree food processing and other value additions, the non-farm rural economy can also be stimulated. As highlighted elsewhere in this publication, however, more research is required to understand the economic, environmental and other trade-offs for the different sectors of rural societies when the harvesting of NTFPs is commercialised or they are planted (and perhaps are converted to new commodity crops; Dawson et al., 2014b), as the benefits and costs for different members of society vary. For example, wild harvesters without access to farmland can be disadvantaged when NTFPs become cultivated as AFTPs (Page, 2003). More work is therefore needed to ensure equitable relationships between the different participants in market supply chains (Marshall et al., 2006).

References

Adam, Y.O. and Pretzsch, J., 2010. Contribution of local trade in Ziziphusspina-christi L. fruits to rural household's economy in Rashad Locality: Sudan. *Forestry Ideas* 1: 19-27.

Adams, W.M., 2012. Feeding the next billion: hunger and conservation. *Oryx* 46: 157-158.

Agarwal, B., 2001. Participatory exclusions, community forestry, and gender: an analysis for South Asia and a conceptual framework. *World Development* 29: 1623–1648.

Agarwal, B., 2013. *Gender and Green Governance: The Political Economy of Women's Inclusion in Community Forestry Institutions.* Oxford: Oxford University Press.

Appiah, M., Blay, D., Damnyag, L., Dwomoh, F.K., Pappinen, A. and Luukkanen, O., 2007. Dependence on forest resources and tropical deforestation in Ghana. *Environment, Development and Sustainability* 11: 471-487.

Ahmed, M. A., 2013. Contribution of non-timber forest products to household food security: the case of Yabelo Woreda, Borana Zone, Ethiopia. *Food Science and Quality Management* 20.

Alves, R.N. and Alves, H.N., 2011. The faunal drugstore: animal-based remedies used in traditional medicines in Latin America. *Journal of Ethnobiology and Ethnomedicine* 7:9.

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

Angelsen, A. and Wunder, S., 2003. *Exploring the forest-poverty link: key concepts, issues and research implications*. Occasional Paper no. 40. Bogor: Center for International Forestry Research (CIFOR). Available at: http://www.cifor.org/nc/online-library/browse/view publication/publication/1211.html. [Accessed on 15 January 2015].

Angelsen, A., Wunder, S., Babigumira, R., Belcher, B., Börner, J. and Smith-Hall, C., 2011. *Environmental incomes and rural livelihoods: a global-comparative assessment.* Occasional Paper. 4th Wye Global Conference, Rio de Janeiro, 9 to 11 November 2011. Wye City Group on statistics on rural development and agriculture household income. Rio de Janeiro and Rome: The Brazilian Institute of Geography and Statistics and FAO. Available at: http://www.fao.org/fileadmin/templates/ess/pages/rural/wye_city_group/2011/documents/session4/Angelsen_Wunder_Babigumira_Belcher_Birner__Smith-Hall-Paper.pdf. [Accessed on 15 January 2015].

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M. C., Deitchler, Fanou-Fogny, N., Joseph, N.J., Kennedy, G., Martin-Prevel, Y. and Torheim, L., 2010. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse: resource-poor settings. *Journal of Nutrition* 140: 2059S-2069S.

Arnold, J.E.M., 1990. Tree components in farming systems. *Unasylva* 160: 35–42.

Arnold, J.E.M., Kohlin, G. and Persson, R., 2006. Woodfuels, livelihoods, and policy interventions: changing perspectives. *World Developmen*t 34: 596–611.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Dekkers, J. and Mathijs, E., 2009. The economic contribution of forest resources to rural livelihoods in Tigray, Northern Ethiopia. *Forest Policy and Economics* 11: 109-117.

Balée, W., 2013. *Cultural forests of the Amazon: A historical ecology of people and their landscapes*. Tuscaloosa: University of Alabama Press.

Bailis, R., Ezzati, M. and Kammen, D.M., 2005. Mortality and greenhouse gas impacts and petroleum energy futures in Africa. *Science* 308(5718): 98-103.

Balmford, A., Green, R. and Phalan, B., 2012. What conservationists need to know about farming. *Proceedings of the Royal College of London* 279: 2714–2724. doi:10.1098/rspb.2012.051.

Belcher, B. and Schreckenberg, K., 2007. Commercialisation of non-timber forest products: a reality check. *Development Policy Review* 25: 355-377.

Belcher, B., Ruiz Pérez, M. and Achdiawan, R., 2005. Global patterns and trends in the use and management of commercial NTFPs: implications for livelihoods and conservation. *World Development* 9: 1435–1452.

Bharucha, Z. and 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.2010.0123.

Bhutta, Z.A., Das, J.K., Rizvi, A., Gaffey, M.F., Walker, N., Horton, S., Webb, P., Lartey, A. and Black, R.E., 2013. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet* 382(9890): 452-477.

Bisseleua, H. B. D. and Niang, A. I., 2013. Lessons from Sub-Saharan Africa. Delivery Mechanisms for Mobilizing Agricultural Biodiversity for Improved Food and Nutrition Security. In: *Diversifying Food and Diets: Using agricultural biodiversity to improve nutrition and health,* edited by J. Fanzo, D. Hunter, T. Borelli, and F. Mattei. Oxford and New York: Routledge, 111-121.

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R. and Uauy, R., 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet* 382: 427-451.

Blackie, R., Baldauf, C., Gautier, D., Gumbo, D., Kassa, H., Parthasarathy, N., Paumgarten, F., Sola, P., Pulla, S., Waeber, P. and Sunderland, T., 2014. *Tropical dry forests: the state of global knowledge and recommendations for future research.* Discussion Paper 2. Bogor: CIFOR.

Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., Kroke, A., Leschik-Bonnet, E., Müller, M.J., Oberritter, H., Schulze, M.S., Stehle, P., and Watzl, B., 2012. Critical review: vegetables and fruit in the prevention of chronic diseases. *European Journal of Nutrition* 51: 637-663.

Brashares, J., Goldena, C., Weinbauma, K., Barrett, C. and Okello, G., 2011. Economic and geographic drivers of wildlife consumption in rural Africa. *Proceedings of the National Academy of Sciences of the USA* 108: 13931-13936.

Brouwer, I.D., Hoorweg, J.C. and van Liere, M.J., 1997. When households run out of fuel: responses of rural households to decreasing fuelwood availability, Ntcheu District, Malawi. *World Development* 25: 255–266.

Bruinsma, J., 2003. *World agriculture: towards 2015/2030. An FAO perspective.* London: Earthscan Publications Ltd.

Bryce J., Coitinho, D., Darnton-Hill I., Pelletier, D. and Pinstrup-Andersen, P., 2008. Maternal and child under-nutrition: effective action at national level. *The Lancet* 371: 510–526.

Burlingame, B. and Dernini, D., 2012. *Sustainable diets and biodiversity directions and solutions for policy, research and action.* FAO Nutrition and Consumer Protection Division Proceedings of the International Scientific Symposium Biodiversity and Sustainable Diets United Against Hunger 3–5 November 2010, Rome: FAO.

Butz, R.J., 2013. Changing land management: a case study of charcoal production among a group of pastoral women in northern Tanzania. *Energy for Sustainable Development* 17: 138-145.

Bwalya, S.M., 2013. Household dependence on forest income in rural Zambia. *Zambia Social Science Journal* 2:6.

Byerlee, D., 2014. The fall and rise again of plantations in tropical Asia: history repeated? *Land* 3: 574-597.

Byron, N. and Arnold, J.E.M., 1997. *What Futures for the People of the Tropical Forests*. CIFOR Working Paper 19. Bogor: CIFOR.

Campese, J., Sunderland, T.C.H., Greiber, T. and Oviedo, G., 2009. *Rights Based Approaches: Exploring Issues and Opportunities for Conservation*. Bogor: CIFOR.

Cerutti, P.O. and Lescuyer, G., 2011. *The domestic market for small-scale chainsaw milling in Cameroon - present situation, opportunities and challenges.* CIFOR Occasional Paper 61. Bogor: CIFOR.

Cerutti, P.O., Tacconi, L., Lescuyer, G. and Nasi, R., 2013. Cameroon's hidden harvest: commercial chainsaw logging, corruption and livelihoods. *Society and Natural Resources* 26: 539-553.

CGIAR, 2014. *Research Program on Agriculture for Nutrition and Health.* Available at: http://www.a4nh.cgiar.org/ [Accessed on January 2015].

Chardonnet P., (ed.) 1996. *Faune sauvage africaine : la ressource oubliée.* Luxembourg: Commission européenne.

Chaudhuri, S. and Pfaff, A., 2002. *Economic growth and the environment: what can we learn from household data?* Working Paper 2002, Department of Economics, Columbia University, USA.

CIE, 2011. *Evaluation of ICRAF's agroforestry food security programme (AFSP) 2007-2011*. Final report submitted to IRISH AID. Lilongwe: Center for Independent Evaluations.

Clement, C.R. and Junqueira, A.B., 2010. Between a pristine myth and an impoverished Future. *Biotropica* 42: 534–536.

Clement, C.R., 1989. A center of crop genetic diversity in western Amazonia. *BioScience* 39: 624-631.

Clement, C.R., 1999. 1492 and the loss of Amazonian crop genetic resources. I. The relation between domestication and human population decline. *Economic Botany* 52 (2): 188-202.

Colfer, C.J.P., 2008. *Human health and forests: global overview of issues, practice and policy* London: Earthscan Publications Ltd.

Clough, Y., Barkmann, J., Juhrbandt, J., Kessler, M., Wanger, T.C., Anshary, A., Buchori, D., Cicuzza, D., Darras, D., Dwi Putra, D., Erasmi, S., Pitopang, R., Schmidt, C.,Schulze, C.H., Seidel, D., Steffan-Dewenter, I., Stenchly, K., Vidal, S., Weist, M.,Wielgoss, A.C. and Tscharntke, T., 2011. Combining high biodiversity with high yields in tropical agroforests. *Proceedings of the National Academy of Sciences of the USA* 108: 8311–8316.

Danielsen, F., Beukema, H., Burgess, N.D., Parish, F., Brühl, C.A., Donald, P.F., Murdiyarso, D., Phalan, B., Reijnders, L., Struebig, M. and Fitzherbet, E.B., 2009. Biofuel plantations on forested lands: double jeopardy for biodiversity and climate. *Conservation Biology* 23: 348–358.

Daniggelis, E., 2003. Women and 'Wild' Foods: Nutrition and Household Security among Rai and Sherpa Forager Farmers in Eastern Nepal. In: *Women and Plants: relations in biodiversity management and conservation*, edited by P.L. Howard. New York and London: Zed Books and St. Martin's Press.

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. and 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* 11:489-507.

Davis, A.P., Gole, T.W., Baena, S. and Moat, J., 2012. The impact of climate change on indigenous arabica coffee (*Coffea arabica*): predicting future trends and identifying priorities. *Public Library of Science One* 7: e47981.

Dawson, I., Carsan, S., Franzel, S., Kindt, R., van Breugel, P., Graudal, L., Lillesø, J.P., Orwa, C. and Jamnadass, R., 2014a. *Agroforestry, fodder production and climate change adaptation and mitigation in East Africa: issues and options*. ICRAF Working Paper No. 178. Nairobi: ICRAF.

Dawson, I.K., Leakey, R., Clement, C.R., Weber, J., Cornelius, J.P., Roshetko, J.M., Vinceti, B., Kalinganire, A., Tchoundjeu, Z., Masters, E. and Jamnadass, R., 2014b. The management of tree genetic resources and the livelihoods of rural communities in the tropics: non-timber forest products, smallholder agroforestry practices and tree commodity crops. *Forest Ecology and Management* 333: 9-21.

Dawson, I.K., Guariguata, M.R., Loo, J., Weber, J.C., Lengkeek, A., Bush, D., Cornelius. J., Guarino, L., Kindt, R., Orwa, C., Russell, J. and Jamnadass, R., 2013. What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings: a review. *Biodiversity and Conservation* 22: 301-324.

de Foresta, H., Somarriba, E., Temu, A., Boulanger, D., Feuilly, H. and Gauthier, M., 2013. *Towards the assessment of trees outside forests*. FAO Resources Assessment Working Paper No. 183. Rome: FAO.

Dharani, N., Yenesew, A., Ermais, B., Tuei, B. and Jamnadass, R., 2014. *Traditional Ethnoveterinary Medicine in East Africa: a manual on the use of medicinal plants,* edited by I.K. Dawson. Nairobi: ICRAF.

Donald, P.F., 2004. Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology* 18: 17–38.

Dunkel, D., 1996. Nutritional values of various insects per 100 grams: *The Food Insect Newsletter.* 9: 1-8.

Ecker, O., Breisinger, C. and Pauw, K., 2011. *Growth is good but is not enough for improving nutrition.* Paper prepared for the 2020 Conference: Leveraging Agriculture for Improving Nutrition and Health: New Delhi, India, February 10–12.

Elliott, J., Grahn, R., Sriskanthan, G. and Arnold, C., 2002. *Wildlife and poverty study.* London: Department for International Development.

Fa, J. E., Olivero, J., Farfán, M. Á., Márquez, A. L., Duarte, J., Nackoney, J., Hall, A., Dupain, J., Seymour, S., Johnson, P. J., Macdonald, D. W., Real, R. and Vargas, J. M. 2015. Correlates of bushmeat in markets and depletion of wildlife. *Conservation Biology* doi: 10.1111/cobi.12441.

FAO, 2015. FAOSTAT Statistical Database, 2015. Available at: http://faostat.fao.org [Accessed on 23 January 2015].

FAO, 2014. *State of the world's forests: enhancing the socioeconomic benefits from the forests*. Rome: FAO.

FAO, 2013a. *Synthesis of guiding principles on agriculture programming for nutrition*. Rome: FAO.

FAO, 2013b. *Edible insects: future prospects for food and feed security*. FAO Forestry Paper. Rome: FAO.

FAO, 2013c. *The state of food and agriculture: better food systems for better nutrition.* Rome: FAO Available at: http://www.fao.org/docrep/018/i3300e/i3300e00.htm. [Accessed on 15 January 2015].

FAO, 2012. *The West African Food Composition Table.* Rome: FAO. Available at: http://www.fao.org/infoods/infoods/tables-and-databases/africa/en/ [Accessed on 15 January 2015].

FAO, 2011. *Forests for improved food security and nutrition report.* Rome: FAO. Available at: http://www.fao.org/docrep/014/i2011e/i2011e00.pdf. [Accessed on 27 January 2015].

FAO, 2010. *Global forest resources assessment: progress towards sustainable forest management.* Rome: FAO.

FAO, 2009. *Declaration of the World Summit on Food Security*. WSFS 2009/2. Rome: FAO.

FAO, 1999. *Agroforestry parklands in sub-Saharan Africa.* FAO Conservation Guide No. 34. Rome: FAO.

FAO, 1997. *Agriculture Food and Nutrition for Africa: A resource book for teachers of agriculture.* Food and Nutrition Division. Rome: FAO.

FAO, 1992. *Forest, trees and food*. Rome: FAO.

FAO, IFAD and WFP, 2013. *The state of food insecurity in the world 2013. The multiple dimensions of food security.* Rome: FAO. Available at: http://www.fao.org/docrep/018/i3434e/i3434e.pdf [Accessed on 15 January 2015].

FAO, WFP and IFAD, 2012. *The state of food insecurity in the world 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition.* Rome: FAO. Available at: http://www.fao.org/docrep/016/i3027e/i3027e.pdf. [Accessed 15 January 2015].

Fargeot, C. and Dieval, S., 2000. La consommation de gibier à Bangui, quelques données économiques et biologiques. *Canopée* 18: 5–7.

Faye, M.D., Weber, J.C., Abasse, T.A., Boureima, M., Larwanou, M., Bationo, A.B., Diallo, B.O., Sigué, H., Dakouo, J.M., Samaké, O. and Diaté, D.S., 2011. Farmers' preferences for tree functions and species in the West African Sahel forests. *Trees and Livelihoods* 20: 113–136.

Ferris, S., Robbins, P., Best, R., Seville, D., Buxton, A., Shriver, J. and Wei, E., 2014. *Linking smallholder farmers to markets and the implications for extension and advisory services.* MEAS Discussion Paper 4. Washington DC: CRS and USAID.

Fischler, C., 1988. Food, self and identity. *Social Science Information* 27: 275-92.

Fisher, H. and Gordon, J., 2007. *Improved Australian tree species for Vietnam*. ACIAR Impact Assessment Series Report No.47. Canberra: Australian Centre for International Agricultural Research.

Fon, D. and Edokat, T., 2012. Marginalization of women's role in sub-Saharan Africa towards crop production: a review. *Agricultural Science Research Journal* 2(9): 499-505.

Franzel, S., Carsan, S., Lukuyu, B., Sinja, J. and Wambugu, C., 2014. Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. *Current Opinion in Environmental Sustainability* 6: 98-103.

Frison, E.A., Cherfas, J. and Hodgkin, T., 2011. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability* 3: 238–253.

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., Winfree, R., Aizen, M.A., Bommarco, R. and 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, CL., Schüepp, C., Szentgyörgyi, H., Taki H, Tscharntke, T., Vergara, C.H., Viana, BF., Wanger, T.C., Westphal, C., Williams, N. and Klein, A.M., 2013. Wild pollinators enhance fruit set of crops regardless of honeybee abundance. *Science* 339(6127): 1608-1611. doi: 10.1126/science.1230200.

Garrity, D., Akinnifesi, F., Ajayi, O., Weldesemayat, S., Mowo, J., Kalinganire, A. and Bayala, J., 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* 2: 197-214.

Garrity, D.P., 2004. Agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems* 61: 5–17.

GEF, 2013. *Africa will import – not export – wood*. Washington DC: Global Environment Facility.

GI, 2015.Government of Indonesia. http://www.deptan.go.id/ [Accessed on 15 January 2015].

Glanz, K., Sallis, J.F., Saelens, B.E. and Frank, L.D., 2005. Healthy nutrition environments: concepts and measures. *American Journal of Health Promotion* 19: 330-333.

GN (Government of Nepal), 2004. *Nepal living standards survey 2003–2004*. Statistical Report. Kathmandu: CBS, National Planning Commission Secretariat, Government of Nepal.

Golden, C.D., Fernald, L.C.H, Brashares, J.S., Rasolofoniaina, B.J.R. and Kremen, C., 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proceedings of the National Academy of Sciences of the USA* 108: 19653–19656.

Grivetti, L.E. and Ogle, B.M., 2000. Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. *Nutrition Research* Reviews 13:31–46.

Gumbo, D.J., Moombe, K.B., Kandulu, M.M., Kabwe, G., Ojanen, M., Ndhlovu, E. and Sunderland, T.C.H., 2013. *Dynamics of the Charcoal and Indigenous Timber Trade in Zambia: A Scoping Study in Eastern, Northern and Northwestern Provinces'* Occasional Paper. Bogor: CIFOR.

Gyau, A., Takoutsing, B., De Grande, A. and Franzel, S., 2012. Farmers 'motivation for collective action in the production and marketing of kola in Cameroon. *Journal of Agriculture and Rural Development in the Tropics and Sub Tropics* 113: 43-50.

Hagen, M. and Kraemer, M., 2010. Agricultural surroundings support flower-visitor networks in an Afrotropical rain forest. *Biological Conservation* 143: 54–63.

Harwood, C.E. and Nambiar, E.K.S., 2014. Productivity of acacia and eucalypt plantations in South East Asia: trends and variations. *International Forestry Review* 16: 249-260.

Hawkes, C., 2013. *Promoting healthy diets through nutrition education and changes in the food environment: an international review of actions and their effectiveness.* Nutrition Education and Consumer Awareness Group, Rome: FAO. Available at: www.fao.org/ag/humannutrition/nutritioneducation/69725/en/.

Hein, L. and Gatzweiler, F., 2006. The economic value of coffee (*Coffea arabica*) genetic resources. *Ecological Economics* 60: 176-185.

Herforth, A. and Dufour, C., 2013. *Key recommendations for improving nutrition through agriculture: establishing a global consensus SCN News*. Rome: FAO.

Heubach, K., Wittig, R., Nuppenau, E. and Hahn, K., 2011. The economic importance of non-timber forest products for livelihood maintenance of rural West African communities: a case study from northern Benin. *Ecological Economics* 70: 1991-2001.

Hladik, C. M., Hladik, A., Linares, O., Pagezy, H., Semple, A. and Hadley, M. (Eds.), 1993. Tropical forests, people and food: biocultural interactions and applications to development. Carnforth, UK: Parthenon Publishing Group.

Ho, S-T., Tung, Y-T., Chen, Y-L., Zhao, Y-Y., Chung, M-J. and Wu, J-H., 2012. Antioxidant Activities and Phytochemical Study of Leaf Extracts from 18 Indigenous Tree Species in Taiwan. *Evidence-Based Complementary and Alternative Medicine.* Article ID 215959: 8. doi:10.1155/2012/215959.

ICCO, 2015. International Cacao Organization. Available at: www.icco.org/. [Accessed on 15 January 2015].

Ickowitz, A., Powell, B., Salim, M.A. and Sunderland, T.C.H., 2014. Dietary quality and tree cover in Africa. *Global Environmental Change* 24: 287. 294.

ICO, 2015. International Coffee Organization. Available from: www.ico.org/ [Accessed on 15 January 2015].

IEA, 2006.*World Energy Outlook*. Paris: IEA/OECD.

Iiyama, M., Neufeldt, H., Dobie, P., Jamnadass, R., Njenga, M. and Ndegwa, G., 2014a. The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability* 6:138-147.

Iiyama, M., Chenevoy, A., Otieno, E., Kinyanjui, T., Ndegwa, G., Vandenabeele, J. and Johnson, O., 2014b. *Achieving sustainable charcoal in Kenya: harnessing the opportunities for crosssectoral integration.* Nairobi, Kenya: ICRAF-SEI Technical Brief. Available at: http://www.sei-international.org/mediamanager/documents/Publications/ICRAF-SEI-2014-techbrief-Sustainable-charcoal.pdf [Accessed on 25 February 2015].

Ingram, V., NdumbeNjie, L. and EwaneElah, M., 2012. Small scale, high value: Gnetumafricanum and buchholzianum value chains in Cameroon. *Small-scale Forestry* 11(4): 539-566.

Ingram, V., Schure, J., Tieguhong, J. C., Ndoye, O., Awono, A. and Iponga, D. M., 2014. Gender implications of forest product value chains in the Congo Basin. *Forest, Trees and Livelihoods* 23(1-2): 67-86.

Iwamura, T., Lambin, E. F., Silvius, K. M., Luzar, J. B. and Fragoso, J. M. V., 2014. Agent-based modeling of hunting and subsistence agriculture on indigenous lands: understanding interactions between social and ecological systems. *Environmental Modelling & Software*, 58(0): 109–127. doi:http://dx.doi.org/10.1016/j.envsoft.2014.03.008.

Jagoret, P., Michel-Dounias, I. and Malézieux, E., 2011. Long-term dynamics of cocoa agroforests: a case study in central Cameroon. *Agroforestry Systems* 81: 267–278.

Jagoret, P., Michel-Dounias, I., Snoeck, D., Todem Ngnogué, H. and Malézieux, E., 2012. Afforestation of savannah with cocoa agroforestry systems: a small-farm innovation in central Cameroon. *Agroforestry Systems* 86: 493–504.

Jamnadass, R., Langford, K., Anjarwalla, P. and Mithöfer, D., 2014. Public–Private Partnerships in Agroforestry. In: *Encyclopedia of Agriculture and Food Systems*, edited by N. Van Alfen Vol. 4, San Diego: Elsevier, 544-564.

Jamnadass, R., Dawson, I.K., Anegbeh, P., Asaah, E., Atangana, A., Cordeiro, N., Hendrickx, H., Henneh, S., Kadu, C.A.C., Kattah, C., Misbah, M., Muchugi, A., Munjuga, M., Mwaura, L., Ndangalasi, H.J., Sirito Njau, C., Kofi Nyame, S., Ofori, D., Peprah, T., Russell, J., Rutatina, F., Sawe, C., Schmidt, L., Tchoundjeu, Z. and Simons, T., 2010. Allanblackia, a new tree crop in Africa for the global food industry: market development, smallholder cultivation and biodiversity management. *Forests, Trees and Livelihoods* 19: 251–268.

Jamnadass, R., Place, F., Torquebiau, E., Malézieux, E., Iiyama, M., Sileshi, G.W., Kehlenbeck, K., Masters, E., McMullin, S. and Dawson, I.K., 2013. Agroforestry for food and nutritional security. *Unasylva* 241(64): 2.

Jamnadass, R.H., Dawson, I.K., Franzel, S., Leakey, R.R.B., Mithöfer, D., Akinnifesi, F.K. and Tchoundjeu, Z., 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders 'agroforestry systems: a review. *International Forest Review* 13: 338–354.

Johns, T. and Eyzaguirre, P., 2006. Linking biodiversity: diet and health in policy and practice. *Proceedings of the Nutrition Society* 65: 182-189.

Johnson, D.V., 2010. The contribution of edible forest insects to human nutrition and to forest management: Current status and future potential. In: *Forest insects as food: Humans bite back*, edited by P.B. Durst, D.V. Johnson, R.N. Leslie and K. Shono. Proceedings of a workshop on Asia-Pacific resources and their potential for development, February 2008. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Chiang Mai, Thailand.

Johnson, K.B., Jacob, A. and Brown, M.W., 2013. Forest cover associated with improved child health and nutrition: evidence from Malawi demographic and health survey and satellite data. *Global Health: Science and Practice* 1: 237- 248.

Kamanga, P., Vedeld, P. and Sjaastad, E., 2009. Forest incomes and rural livelihoods in Chiradzulu District, Malawi. *Ecological Economics* 68: 613-624.

Kar, S.P. and Jacobson, M.G., 2012. NTFP income contribution to household economy and related socio-economic factors: lessons from Bangladesh. *Forest Policy and Economics* 14:136–142.

Kawarazuka, N. and Béné, C., 2011. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. *Public Health Nutrition* 14:1927-1938.

Keatinge, J.D.H., Waliyar, F., Jamnadass, R.H., Moustafa, A., Andrade, M., Drechsel, P., Hughes, J.A., Kadirvel, P. and Luther, K., 2010. Relearning old lessons for the future of food: by bread alone no longer: diversifying diets with fruit and vegetables. *Crop Science* 50: S51–S62.

Kehlenbeck, K. and Jamnadass R., 2014. Chapter 6.2.1 Food and Nutrition – Fruits, Nuts, Vegetables and Staples from Trees. In: *Treesilience: An Assessment of the Resilience Provided by Trees in the Drylands of Eastern Africa*, edited by J. De Leeuw, M. Njenga, B. Wagner, M., Iiyama. Nairobi, Kenya: ICRAF, 166. Available from: http://www.worldagroforestry.org/knowfordocs/Treesilience_Book_2014.pdf.

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.

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.

Kennedy, G.L., Pedro, M. R., Sehieri, C., Nantel, G. and Brouwer, I., 2007. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. *Journal of Nutrition* 137: 472-477.

Khare, R.S., 1980. Food as nutrition and culture: notes towards an anthropological methodology. *Social Science Information* 19: 519-542.

Khundi, F., Jagger, P., Shively, G. and Sserunkuuma, D., 2011. Income, poverty and charcoal production in Uganda. *Forest Policy and Economics* 13: 199–205.

Kiptot, E. and Franzel, S., 2011. *Gender and agroforestry in Africa: are women participating.* ICRAF Occasional Paper No. 13. Nairobi: ICRAF.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. and Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* 274: 303-313.

Köhlin, G., Sills, E. O., Pattanayak, S. K. and Wilfong, C., 2011. *Energy, gender and development. What are the linkages? Where is the evidence?* Social Development World Bank Policy Research Working Paper 1–63.

Kolavalli, S. and Vigneri, M., 2011. Cocoa in Ghana: Shaping the success of an economy. In: *Yes Africa can: Success stories from a dynamic continent*, edited by P. Chuhan-Pole and M. Angwafo. Washington DC: The World Bank.

Koppert, G.J.A, Dounias. E., Froment, A. and Pasquet, P., 1996. Consommation alimentaire dans trois populations forestières de la région côtière du Cameroun: Yassa, Mvae et Bakola. In: *L'alimentation en forêt tropicale. Interactions bioculturelles et perspectives de développement*, edited by C.M. Hladik, A. Hladik and H. Pagezy. Paris: UNESCO, 477–496.

Kuhnlein, H., Erasmus, B. and Spigelski, D., 2009. *Indigenous peoples' food systems: the many dimensions of culture, diversity and environment for nutrition and health*. Rome: FAO.

Kuhnlein, H.V. and Receveur, O., 1996. Dietary change and traditional food systems of Indigenous Peoples. *Annual Review of Nutrition* 16: 417-442.

Kusters, K., Achdiawan, R., Belcher, B. and Ruiz Pérez, M., 2006. Balancing development and conservation? An assessment of livelihood and environmental outcomes of nontimber forest product trade in Asia, Africa, and Latin America. *Ecology and Society* 11(2):20.

Labouisse, J., Bellachew, B., Kotecha, S. and Bertrand, B., 2008. Current status of coffee (*Coffea arabica* L.) genetic resources in Ethiopia: implications for conservation. *Genetic Resources and Crop Evolution* 55: 1079-1093.

Leakey, R.R., 1999. Potential for novel food products from agroforestry trees: a review. *Food Chemistry* 66: 1–14.

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.

Lescuyer, G., Cerutti, P.O., Ndotit Manguiengha, S. and Bilogo bi Ndong, L., 2011. *The domestic market for small-scale chainsaw milling in Gabon Present situation, opportunities and challenges*. Occasional Paper 65. Bogor: CIFOR.

Lock, J., Agras, W.S., Bryson, S. and Kraemer, H., 2005. A comparison of short- and long-term family therapy for adolescent anorexia nervosa. *Journal of the American Academy of Child and Adolescent Psychiatry* 44:632–639.

Lybbert, T.J., Aboudrare, A., Chaloud, D., Magnan, N. and Nash, M., 2011. Booming markets for Moroccan argan oil appear to benefit some rural households while threatening the endemic argan forest. *Proceedings of the National Academy of Sciences USA*. 108: 13963–13968.

Lykke, A.M., Mertz, O. and Ganaba, S., 2002. Food consumption in rural Burkina Faso. *Ecology of Food Nutrition* 41:119–153.

MA (Millennium Ecosystem Assessment), 2005. *Ecosystems and human well-being: synthesis*. Washington DC: Island Press.

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.

Marshall, D., Schreckenberg, K. and Newton, A.C., 2006. *Commercialization of non-timber forest products: factors influencing success.* Lessons learned from Mexico and Bolivia and policy implications for decision-makers. Cambridge: UNEP World Conservation Monitoring Centre.

McCullough, F.S.W., Yoo, S. and Ainsworth, P., 2004. Food choice: nutrition education and parental influence on British and Korean primary school children. *International Journal of Consumer Studies* 28: 235-244.

McMullin, S., Phelan, J., Jamnadass, R., Iiyama, M., Franzel, S. and Nieuwenhuis, M., 2012. Trade in medicinal tree and shrub products in three urban centres in Kenya. *Forests, Trees and Livelihoods* 21(3): 188-206.

McMullin, S., Nieuwenhuis, M. and Jamnadass. R., 2014. Strategies for sustainable supply of and trade in threatened medicinal tree species: a case study of Genus Warburgia. *Ethnobotany Research and Applications* 12: 671-683.

Mercer, C.W.L., 1997. Sustainable production of insects for food and income by New Guinea villagers. *Ecology of Food and Nutrition* 36:151-157.

Millard, E., 2011. Incorporating agroforestry approaches into commodity value chains. *Environmental Management* 48: 365-377.

Milner-Gulland, E.J. and Bennett, E.L., 2003. Wild meat: the bigger picture. *Trends in Ecology and Evolution* 18: 351–357.

Mitra, A. and Mishra, D.K., 2011. Environmental resource consumption pattern in rural Arunachal Pradesh. *Forest Policy and Economics* 13: 166-170.

Mitchell, M.G.E., Bennett, E.M. and Gonzalez, A., 2014. Forest fragments modulate the provision of multiple ecosystem services. *Journal of Applied Ecology* 51: 909–918.

Mohan Jain, S. and Priyadarshan, P.M., 2009. Breeding Plantation Tree Crops: Tropical Species. New York: *Springer Science & Business Media.*

Moran, E. F., 1993. Managing Amazonian Variability with Indigenous Knowledge. In: *Tropical Forests, People and Food. Biocultural Interactions and Applications to Development*, edited by C.M. Hadlik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple and M. Hadley. Vol. 765: 753–766. Indiana: Anthropological Centre for Training and Research on Global Environmental Change Indiana University.

Mulenga, B.P., Richardson, R.B. and Tembo, G., 2012. *Non-timber forest products and rural poverty alleviation in Zambia*. Working Paper No. 62.

Mulenga, B.P., Richardson, R.B., Mapemba, L. and Tembo, G., 2011. *The contribution of non-timber forest products to rural household income in Zambia*. Food Security Research Project Lusaka, Zambia. Working Paper No 54.

Muleta, D., 2007. *Microbial inputs in coffee (Coffea arabica L.) production systems, southwestern Ethiopia - implications for promotion of biofertilizers and biocontrol agents*. Doctoral thesis. Swedish University of Agricultural Sciences/Uppsala.

Muriuki, J., Franzel, F., Mowo, J., Kariuki P. and Jamnadass, R., 2012. Formalisation of local herbal product markets has potential to stimulate cultivation of medicinal plants by smallholder farmers in Kenya. *Forests, Trees and Livelihoods* 21: 114–127.

Mwampamba, T.H., Ghilardi, A., Sander, K. and Chaix, K.J., 2013. Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries. *Energy for Sustainable Development* 17:158-170.

Narain, U. S., Gupta, S. and Veld. K.V., 2005. *Poverty and the environment: exploring the relationship between household incomes, private assets and natural assets.* Discussion Paper 05-18. Washington DC: Resources for the Future.

Nasi, R., Taber, A. and Van Vliet, N., 2011. Empty forests, empty stomachs: bushmeat and livelihoods in the Congo and Amazon Basins. *International Forestry Review* 13(3):355-368. doi: http://dx.doi.org/10.1505/146554811798293872.

Nasi, R., Brown, D., Wilkie, D., Bennett, E., Tutin, C., van Tol, G. and Christophersen, T., 2008. *Conservation and use of wildlife-based resources: the bushmeat crisis.* Technical Series No.33. Secretariat of the Convention on Biological Diversity: Montreal, and Centre for International Forestry Research: Bogor, Indonesia.

Naughton-Treves, L., Kammen, D.M. and Chapman, C., 2007. Burning biodiversity: Woody biomass use by commercial and subsistence groups in western Uganda's forests. *Biological Conservation* 134: 232-241.

Ndoye, O., Ruiz Pérez, M. and Eyebe, A., 1998. *The markets of non-timber forest products in the humid forest zone of Cameroon*. Paper 22c. London: Rural Development Forestry Network.

Njenga. M., Yonemitsu, A., Karanja, N., Iiyama, M., Kithinji, J., Dubbeling M., Sundberg, C. and Jamnadass, R., 2013. Implications of charcoal briquette produced by local communities on livelihoods and environment in Nairobi, Kenya. *International Journal of Renewable Energy Development* 2(1):19-29.

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

Owen, M., Van der Plas, R. and Sepp, S., 2013. Can there be energy policy in Sub-Saharan Africa without biomass? *Energy Sustainable Development* 17:146-152.

Padoch, C. and Sunderland T., 2013. Managing landscapes for greater food security and livelihoods. *Unasylva* 241(64): 3-13.

Page, B., 2003. The political ecology of *Prunus africana* in Cameroon. *Area* 35: 357-370.

PEN, 2015. Poverty Environment Network. *A comprehensive global analysis of tropical forests and poverty.* Available at: http://www1.cifor.org/pen [Accessed on 22 February 2015].

Peres, C.A., 2001. Synergistic effects of subsistence hunting and habitat fragmentation on Amazonian forest vertebrates. *Conservation Biology* 15:1490-1505.

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.

Pimentel, D., McNair, M., Buck, L., Pimentel, M. and Kamil, J., 1997. The value of forests to world food security. *Human Ecology* 25: 91–120.

Pinstrup-Andersen, P., 2013. Special Debate Section, Can Agriculture Meet Future Nutrition Challenges? *European Journal of Development Research* 25 (1): 5–12.

Pinstrup-Andersen, P., 2009. Food Security: Definition and Measurement. *Food Security* 1:5-7.

Place, F. and Binam, J.N., 2013. *Economic impacts of farmer managed natural regeneration in the Sahel.* End of Project Technical Report for the Free University Amsterdam and IFAD. Nairobi: ICRAF.

Place, F., Roothaert, R., Maina, L., Franzel, S., Sinja, J. and Wanjiku, J., 2009. *The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research*. ICRAF Occasional Paper No. 12. Nairobi: ICRAF.

Pouliot, M., 2012. Contribution of "Women's Gold" to West African livelihoods: the case of Shea (Vitellaria paradoxa) in Burkina Faso. *Economic Botany* 66(3): 237–248.

Pouliot, M. and Treue, T., 2013. Rural People's Reliance on Forests and the Non-Forest Environment in West Africa: Evidence from Ghana and Burkina Faso. *World Development* 43: 180-193.

Powell, B., Ickowitz, A., McMullin, S., Jamnadass, R., Padoch, C., Pinedo-Vasquez, M. and Sunderland, T., 2013. *The role of forests, trees and wild biodiversity for improved nutrition: sensitivity of food and agriculture systems*. Expert background paper for the International Conference on Nutrition 2. FAO: Rome.

Powell, B., Watts, J., Boucard, A., Urech, Z., Feintrenie, L., Lyimo, E., Asaha, S. and Sunderland-Groves, J., 2010. The role of wild species in the governance of tropical forested landscapes. In: *Collaborative Governance of Tropical Landscapes*, edited by C.J.P. Colfer and J.L. Pfund. London: Earthscan Publications Ltd. Chapter 7.

Powell, L.M., Schermbeck, R.M., Szczypka, G., Chaloupka, F.J. and Braunschweig, C.L., 2011. Trends in the nutritional content of television food advertisements seen by children in the United States: analyses by age, food categories, and companies. *Arch Pediatrics* and *Adolescent Medicine* 257–269.

Pramova, E., Locatelli, B., Djoudi, H. and Somorin, O.A., 2012. Forests and trees for social adaptation to climate variability and change. *Wiley Interdisciplinary Reviews: Climate Change* 3(6): 581-596.

Priess, J.A., Mimler, M., Klein, A.M., Schwarze, S., Tscharntke, T. and Steffan-Dewenter, I., 2007. Linking deforestation scenarios to pollination services and economic returns in coffee agroforestry systems. *Ecological Applications* 17: 407-417.

Reichhuber, A. and Requate, T., 2007. *Alternative use systems for the remaining cloud forest in Ethiopia and the role of Arabica coffee: A cost-benefit analysis.* Economics Working Paper No. 7, 2007. Kiel: Department of Economics, Christian-Albrechts-Universität.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R. and Michener, C.D., 2004. Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences of the USA* 101: 12579-12582.

Roshetko, J., Dawson, I.K., Urquiola, J., Lasco, R., Leimona, B., Graudal, L., Bozzano, M., Weber, J.C. and Jamnadass, R., 2015. Tree planting for environmental services: considering source to improve outcomes (in preparation).

Roshetko, JM., Rohadi, D., Perdana, A., Sabastian, G., Nuryartono, N., Pramono, A.A., Widyani, N., Manalu, P., Fauzi, MA., Sumardamto, P. and Kusumowardhani, N., 2013. Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation. *Forests, Trees, and Livelihoods* 22(4) Available at: http://www.tandfonline.com/doi/full/10.1080/14728028.2013.855150.

Roshetko, J.M., Lasco, R.D. and Delos Angeles, M.S., 2007. Smallholder agroforestry systems for carbon storage. *Mitigation and Adaptation Strategies for Global Climate Change* 12: 219–242.

Ruel, M.T. and 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.

Ruel, M.T., 2003. Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities. *Journal of Nutrition* 133: 3911S- 3926S.

Ruel, M.T., Minot, N. and Smith, L., 2005. *Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa: a multi-country comparison.* Geneva: World Health Organization and Washington: IFPRI.

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.

Sanchez, P.A., 2002. Soil fertility and hunger in Africa. *Science* 295: 2019-2020.

Schabel, H.G., 2010. Forests insects as food: A global review. In: *Forest Insects as Food: Humans Bite Back,* edited by P.B. Durst, D.V. Johnson, R.N. Leslie and K. Shono. Proceedings of a workshop on asia-pacific resources and their potential for development, 19-21 February 2008. 37-64.

Schreckenberg, K. and Luttrell, C., 2009. Participatory forest management: a route to poverty reduction? *International Forestry Review* 11: 221-238.

Schreckenberg, K., Awono, A., Degrande, A., Mbosso, C., Ndoye, O. and Tchoundjeu, Z., 2006. Domesticating indigenous fruit trees as a contribution to poverty reduction. *Forests, Trees and Livelihoods* 16: 35–51.

Schure, J., Ingram, V., Assembe-Mvondo, S., Mvula-Mampasi, E., Inzamba, J. and Levang, P. 2013. La Filière Bois Énergie des Villes de Kinshasa et Kisangani. In: *Quand la ville mange la forêt* edited by J.-N. Marien, E. Dubiez, D. Louppe and A. Larzilliere. Versailles: Editions QUAE, 27-44.

Schure, J., Levang, P. and Wiersum, K.F., 2014. Producing woodfuel for urban centres in the Democratic Republic of Congo: a path out of poverty for rural households. *World Development* 64: 80-90.

SCI, 2015. Sustainable Cocoa Initiative. Available at: http://cocoasustainability.com. [Accessed on 15 January 2015].

Sendzimir, J., Reij, C.P. and Magnuszewski, P., 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. *Ecology and Society* 16(3): 1.

Sepp, S., 2008. *Shaping charcoal policies: context, process and instruments as exemplified by country cases.* Bonn: GTZ.

Shackleton, C. and 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. *Southern Africa Journal of Science* 100: 658–664.

Shackleton, C.M., Shackleton, S.E., Buitenb, E. and Bird, N., 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy and Economics* 9(5): 558–577 doi:10.1016/j.forpol.2006.03.004.

Shackleton, S., Paumgarten, F., Kassa, H., Husseelman, M. and Zida, M., 2011.Opportunities for enhancing women's economic empowerment in the value chains of three African non timber forest products. *International Forestry Review* special issue 13.

Shaheen, N., Rahim, A.T., Abu Torab, M.A.R., Mohiduzzaman, MD., Banu, CP., Bari, MD.L., Tukan, AB., Mannan, MA., Bhattacharjee, L., and Stadlmayr, B., 2013. *Food Composition Table for Bangladesh.* Dhaka: University of Dhaka, Bangladesh.

Shepard, G.H. and Ramirez, H., 2011. Made in Brazil: human dispersal of the Brazil nut (*Bertholletiaexcelsa*, Lecythidaceae) in ancient Amazonia. *Economic Botany* 65: 44-65.

Sherman, J., 2003. From nutritional needs to classroom lessons: can we make a difference? *Food, Nutrition and Agriculture* 33: 45–51.

Siegel, K.R., Ali, M.K., Srinivasiah, A., Nugent, R.A. and Narayan, K.M.V., 2014. Do we produce enough fruits and vegetables to meet global health need? *PLoS ONE* 9(8): e104059.

Sileshi, G., Akinnifesi, F.K., Ajayi, O.C. and Place, F., 2008. Meta-analysis of maize yield response to planted fallow and green manure legumes in sub-Saharan Africa. *Plant and Soil* 307: 1-19.

Sileshi, G.W., Akinnifesi, F.K., Ajayi, O.C. and Muys B., 2011. Integration of legume trees in maize-based cropping systems improves rain-use efficiency and yield stability under rain-fed agriculture. *Agricultural Water Management* 98: 1364–1372.

Sileshi, G.W., Debusho, L.K. and Akinnifesi, F.K., 2012. Can integration of legume trees increase yield stability in rainfed maize cropping systems in Southern Africa? *Agronomy Journal* 104: 1392-1398.

Sirén, A., 2012. Festival hunting by the kichwa people in the Ecuadorian amazon. *Journal of Ethnobiology* 32: 30–50.

Slavin, J. L. and Lloyd, B., 2012. Health benefits of fruits and vegetables. *Advances in Nutrition* 3(4): 506–16. doi:10.3945/an.112.002154.

Smith, I.F. 2013. Sustained and integrated promotion of local, traditional food systems for nutrition security. In: *Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health Issues in Agricultural Biodiversity*, edited by J. Fanzo, D. Hunter, T. Borelli and F. Mattei. London: Earthscan Publications Ltd. 122–139.

Sobal, J., Bisogni, C.A., and Jastran, M., 2014. Food choice is multifaceted: contextual, dynamic, multilevel, integrated, and diverse. *Mind, Brain, and Education* 8: 6-12.

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

Stadlmayr, B., Charrondière, U.R., Eisenwagen, S., Jamnadass, R. and Kehlenbeck, K., 2013. Review: Nutrient composition of selected indigenous fruits from sub-Saharan Africa. *Journal of the Science of Food and Agriculture* 93: 2627–2636.

Story, M., Kaphingst, K.M., Robinson-O'Brien, R. and Glanz, K., 2008. Creating healthy food and eating environments: policy and environmental approaches. *Annual Review of Public Health* 29: 253-272.

Sunderland, T.C.H., 2011. Food security: why is biodiversity important? *International Forestry Review* 13: 265–274.

Tabuti, J.R.S., Dhillion, S.S. and Lye, K.A., 2003. Firewood use in Bulamogi County, Uganda: species selection, harvesting and consumption patterns. *Biomass and Bioenergy* 25: 581 – 596.

Tchoundjeu, Z., Degrande, A., Leakey, R.R.B., Nimino, G., Kemajou, E., Asaah, E., Facheux, C., Mbile, P., Mbosso, C., Sado, T., and Tsobeng, A., 2010. Impacts of participatory tree domestication on farmer livelihoods in West and Central Africa. *Forests, Trees and Livelihoods* 19: 217–234.

Termote, C., BwamaMeyi, M., Dhed'aDjailo, B., Huybregts, L., Lachat, C., Kolsteren, P. and Van Damme, P., 2012. A biodiverse rich environment does not contribute to better diets. A case study from DR Congo. *Plos One* 7: e30533.

Thomas, E., 2008. *Quantitative ethnobotanical research on knowledge and use of plants for livelihood among Quechua: Yuracaré and Trinitario communities in the Andes and Amazon regions of Bolivia.* PhD thesis, Ghent University: Ghent, Belgium.

Thorlakson, T. and Neufeldt, H., 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture and Food Security* 1: 15

TRAFFIC, 2008. *What is driving the wildlife trade: a review of expert opinion on economic and social drivers of the wildlife trade and trade control efforts in Cambodia, Indonesia, Lao PDR and Vietnam.* East Asia and Pacific Region Sustainable Development Discussion Papers. Washington, DC: World Bank.

Tscharntke, T., Clough, Y., Wanger, T.C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., and Whitbread, A., 2012. Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation* 53–59.

Tscharntke,T., Klein, A., Kruess, M., Steffan-Dewenter, A. and Thies, C., 2005. Landscape perspectives on agricultural intensification and biodiversity: ecosystem service management. *Ecology Letters* 8: 857-874.

Turner, W.R., Brandon, K., Brooks, T.M., Gascon, C., Gibbs, H.K., Lawrence, K., Mittermeier, R.A. and Selig, E.R., 2012. Global Biodiversity Conservation and the Alleviation of Poverty. *BioScience* 62: 85-92.

UN-SCN., 2010. *Sixth report on the world nutrition situation: progress in nutrition*. Geneva, Switzerland: United Nations, Standing Committee on Nutrition and International Food Policy Research Institute.

Van Noordwijk, M., Bizard, V., Wangpakapattanawong, P., Tata, H.L., Villamor, G.B. and Leimona, B., 2014.Tree cover transitions and food security in Southeast Asia. *Global Food Security* 3: 200-208.

van Vliet, N., Quiceno-Mesa, MP., Cruz-Antia, D., Johnson Neves de Aquino, L., Moreno, J. and Nasi, R., 2014. The uncovered volumes of bushmeat commercialized in the Amazonian trifrontier between Colombia, Peru & Brazil. *Ethnobiology Conservation* 3:7.

Vandenbosch T., Ouko B.A., Guleid N.J., Were R.A., Mungai P.P., Mbithe D.D., Ndanyi M., Chesumo. J., Laenen-Fox L., Smets K., Kosgei C.K. and Walema B., 2009. Integrating food and nutrition: health, agricultural and environmental education towards education for sustainable development: lessons learned from the Healthy Learning Programme in Kenya. In: *Sustainable initiatives in the decade of education for sustainable development: where are we?* Proceedings of the July 2009 Environmental Education Association of Southern Africa (EEASA) conference.

Vedeld, P., Angelsen, A., Sjaastad, E. and Kobugabe Berg, G., 2004. *Counting on the environment: forest incomes and the rural poor.* Environment Economics Series No. 98. World Bank, Washington D.C., USA.

Vinceti, B., Termote, C., Ickowitz, A., Powell, B., Kehlenbeck, K. and Hunter, D., 2013. Strengthening the contribution of forests and trees to sustainable diets: challenges and opportunities. *Sustainability* 5: 4797-4824.

Von Grebmer, Saltzman, K., Birol, A., Wiesmann, E., Prasai, D., Yin, N., Yohannes, S., Menon, Y., Thompson, P. and Sonntag, A., 2014. *2014 Global hunger index: the challenge of hidden hunger.* Bonn, Washington, D.C. and Dublin: Welthungerhilfe, International Food Policy Research Institute and Concern Worldwide.

Wan, M., Colfer, C.J.P. and Powell, B., 2011. Forests, women and health: opportunities and challenges for conservation. *International Forestry Review* special issue, 13.

Waswa, F., Kilalo, C. R. S. and Mwasaru, D. M., 2014. *Sustainable Community Development: Dilemma of Options in Kenya*. Basingstoke: Palgrave Macmillan.

Webb, P. and Kennedy, E., 2012. *Impacts of agriculture on nutrition: nature of the evidence and research gaps.* Nutrition CRSP Research Brief No. 4. Boston: Tufts University.

Webb Girard, A., Self, J.L., McAuliffe, C. and Oludea, O., 2012. The Effects of Household Food Production Strategies on the Health and Nutrition Outcomes of Women and Young Children: A Systematic Review. Paediatric and Perinatal Epidemiology 26 (Suppl. 1): 205–222

WHO, 2004. *Global Strategy on Diet, Physical Activity and Health.* Geneva: WHO.

WHO, 2014. *Healthy Diet*. WHO Fact Sheets. Available at: http://www.who.int/mediacentre/factsheets/fs394/en/.

WHO/FAO, 2004. *WHO/FAO Expert consultation on vitamin and mineral requirements in human nutrition* (Second edition). Geneva: WHO.

Wilkie, D., Starkey, M., Abernethy, K., Nstame, E., Telfer, P. and Godoy, R., 2005. Role of prices and wealth in consumer demand for bushmeat in Gabon: Central Africa. *Conservation Biology* 19: 268-274.

World Bank, 2008. *Implementation, Completion and Results Report (TF-50612) on a grant in the amount of SDR 3.7 million equivalent (US $ 4.5 million) to Centro Agronomico Tropical De Investigacion Y Ensenanza (CATIE) for the Integrated Silvopastoral Approaches to Ecosystem Management Project in Columbia, Costa Rica, and Nicaragua.* Washington DC: World Bank.

World Bank, 2011. *Wood-based biomass energy development for Sub-Saharan Africa: issues and approaches.* Washington, DC 20433, USA: The International Bank for Reconstruction and Development.

Wrangham, E., 2009. *Catching Fire: How Cooking Made us Human.* New York: Basic Books.

Wunder, S., Borner, J., Shively, J. and Wyman, M., 2014. Safety nets, gap filling and forests: a global- comparative perspective. *World Development* 64(1): S29-S42.

Yemiru, T., Roos, A., Campbell, B.M. and Bohlin, F., 2010. Forest incomes and poverty alleviation under participatory forest management in the Bale highlands, Southern Ethiopia. *International Forestry Review* 12(1): 66-77. doi: http://dx.doi.org/10.1505/ifor.12.1.66.

Zapata-Rios, G., Urgiles, C. and Suarez, E., 2009. Mammal hunting by the Shuar of the Ecuadorian Amazon: is it sustainable? *Oryx* 43: 357-385.

Zhang, W., Ricketts, T.H., Kremen, C., Carney, K. and Swinton, S.M., 2007. Ecosystem services and dis-services to agriculture. *Ecological Economics* 64: 253-260.

Zulu, L.C. and Richardson R.B., 2013. Charcoal: livelihoods and poverty reduction: evidence from sub-Saharan Africa. *Energy for Sustainable Development* 17:127–137.