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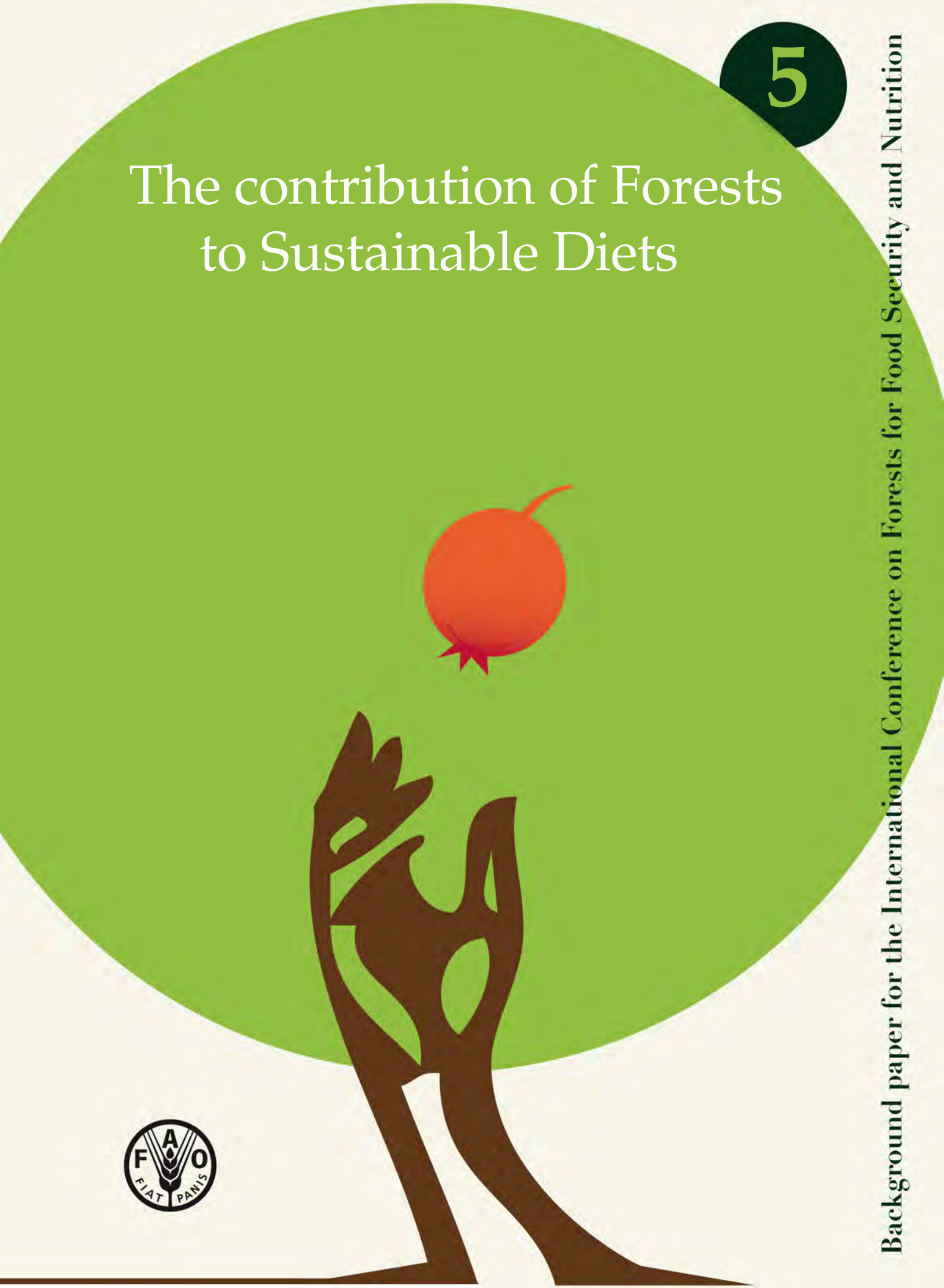
The contribution of Forests to Sustainable Diets



Background paper for the International Conference on Forests for Food Security and Nutrition

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Background paper for the International Conference on Forests for Food Security and Nutrition, FAO, Rome, 13–15 May 2013

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Key points

1. The potential for forest foods to contribute to food security and better nutrition as elements of sustainable diets is largely untapped. Forest foods represent an affordable source of food, especially for those with limited livelihood options, supplying micronutrients, fibres and other key food components most commonly lacking from diets.

2. Full realization of the contribution of forest and tree foods to sustainable diets faces a number of constraints. Key among these are knowledge gaps, issues related to tenure and access, aspects of sustainability of extraction, and rapidly evolving social and cultural contexts, which have a significant impact on diets. Research is needed on all these topics.

3. There is a need to promote better integration of information and knowledge on nutritious forest and tree foods into national nutrition strategies and programmes. The establishment of cross-sectoral policy platforms that bring together nutrition, food security, environment, agriculture, health, development, conservation and land-use planning would help achieve this.

Background

Introduction

It is unclear how the current global food system will meet the growing demands of a population expected to reach 9 billion people by 2050. In the present context of climate change, ongoing loss of species and genetic diversity, soil degradation, increasing urbanization, social conflict and extreme poverty, there is an urgent need for collective action to address food and nutrition security at the global level (Hunter and Fanzo, 2013).

Energy-rich staple crops assure caloric adequacy and policy makers have thus made them a focus in the quest for global food security. However, they generally contain low amounts of limiting nutrients, including micronutrients per unit of energy, and by themselves are not sufficient to address the problem of "hidden hunger" or micronutrient deficiency (Tontisirin *et al*., 2002; Stephenson *et al*., 2010). Increasing consumption of micronutrient-dense foods (such as a diversity of fruit, pulses, vegetables and some animal source foods) is seen as a sustainable way to improve nutrient quality (Tontisirin *et al*., 2002; Johns and Sthapit, 2004; Stephenson *et al*., 2010). In this context, the challenges are to make food systems simultaneously productive, nutrition-sensitive, culturally acceptable and sustainable (Johns *et al*., submitted) and to ensure that consumers and producers have the necessary information to make the best choices to meet their dietary and life choices.

Forest ecosystems

Forests play an important role in many food systems, either through direct and indirect provisioning for human nutrition, particularly in developing countries (Hladik *et al*., 1993; Vinceti *et al*., 2008; Arnold *et al*., 2011; Jamnadass *et al*., 2011; Sunderland, 2011), or through ecosystem services essential for both near and distant agro-ecological systems (Millennium Ecosystem Assessment, 2005). Forests and trees-outside-forests contribute to the livelihoods of more than 1.6 billion people (FAO, 2010).

Forests, tree cover and/or agroforestry[1] systems are characterized by substantial worldwide variation. Forests range from closed to open formations and cover 31 percent (4 billion hectares) of total land area (FAO, 2010).[2] The forest category also includes small patches of land with trees (often not much larger than 0.5 hectares) scattered across densely populated agricultural landscapes, and referred to as agroforestry systems. Identification and monitoring of such areas is challenging and in most countries trees outside forests are still poorly reported in official statistics.

Around 30 percent of the world's forests are used primarily for production of wood and non-wood forest products. Information on non-timber forest products (NTFPs)[3] is not available for many countries and their true value for subsistence is not captured by available statistics. However, according to the most recent Global Forest Resource Assessment (FAO, 2010), the estimated value of non-wood forest products

[1] For a description of agroforestry, see the background paper on "Agroforestry, food and nutritional security".

[2] This calculation is based on FAO's definition of forest defined as a piece of land with tree crown cover (or equivalent stocking level) of more than 10 percent and an area of more than 0.5 hectares, with trees reaching a minimum height of 5 metres at maturity *in situ* (FAO, 2000).

[3] Non-timber forest products consist of goods of biological origin other than timber, derived from forests, other wooded land and trees outside forests, including fuelwood and small woods.

(NWFPs)[4] extracted in 2005, based on country reports, amounts to approximately US$18.5 billion, and this is most likely an underestimate. According to some authors, the value of the trade of NTFPs harvested from the wild for nutrition and income is much higher, reaching around US$90 billion/year (Pimentel *et al*., 1997). The Global Forest Resource Assessment (FAO, 2010) also states that food represents, by far, the most valuable category of NWFPs removed globally, followed by other plant products, wild honey and beeswax, ornamental plants and exudates (Table 1).

Table 1. Value of NWFPs extracted by category and region, 2005.

PFNM categorías	**Total (millon US $)**	**Share of each category in total value (%)**					
		World	**Europe**	**Asia**	**Americas**	**Oceania**	**Africa**
Food	8 614	51	48	67	23	47	39
Other plant products	2 792	17	3	22	61	3	7
Wild honey and beeswax	1 805	11	21	n.s.	n.s.	12	n.s.
Ornamental plants	984	6	10	1	3	4	0
Exudates	631	4	1	7	5	0	25
Plant materials for medicine, etc.	628	4	5	2	1	9	18
Wild meat	577	3	7	n.s.	n.s.	1	2
Materials for utensils, construction, etc.	427	3	3	1	3	18	n.s.
Hides, skins and trophies	183	1	1	n.s.	3	7	n.s.
Living animals	154	1	2	n.s.	n.s.	0	7
Fodder	21	n.s.	n.s.	n.s.	n.s.	0	2
Colorants and dyes	18	n.s.	n.s.	n.s.	n.s.	0	n.s.
Other non-edible animal products	6	n.s.	0	n.s.	0	0	n.s.
Other edible animal products	1	n.s.	n.s.		0	0	n.s.
Raw animal material for medicine	0	n.s.	n.s.		0	0	0
Total value (millon US $)	**16 839**	**16 839**	**8 389**	**5 655**	**2 132**	**402**	**261**

Note: n.s = 'non-significant' (i.e less than one percent of the total)
Source: FAO, 2010.

[4] While the text refers throughout to NTFPs, this section makes reference to FAO statistics from the *Global Forest Resource Assessment*, which reports values for NWFPs. These correspond to NTFPs with the exclusion of fuelwood.

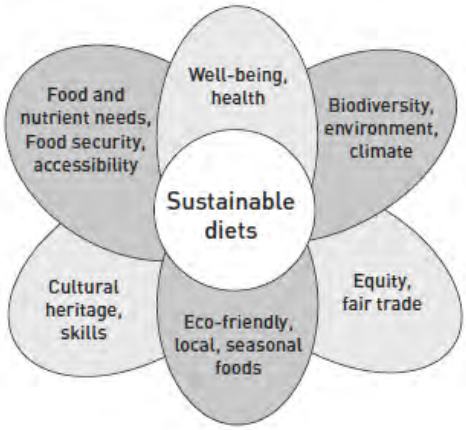
Sustainable diets

The first International Scientific Symposium on Biodiversity and Sustainable Diets, held at FAO in 2010, defined sustainable diets as:

> Those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources (Burlingame and Dernini, 2012).

This symposium also drafted a "platform for action" as well as a "code of conduct" (Burlingame and Dernini, 2012). Work on what constitutes a sustainable diet and how to promote it is still at an early stage and more research is needed to fully capture its many dimensions (Figure 1). The development of a "score card" or "index", however, might aid operationalization of the concept of sustainable diets into measurable, robust and useful metrics or indicators. This could allow for comparison of diets across regions and countries and guide future policies and programmes (Fanzo *et al*., 2012).

Figure 1. The many dimensions of a sustainable diet



Source: FAO/Bioversity International 2012.

This paper makes a first attempt to examine the contribution of forests and trees to some of the dimensions of sustainable diets presented here (Figure 2). Future work on sustainable diets should include the role and contribution of forests and trees.

Forests and sustainable diets

This section reviews the main characteristics of forest foods and the ways in which they relate to the main dimensions of the sustainable diet framework.

Availability of local, affordable, nutritious forest foods

Forest foods, including products from trees, herbs, mushrooms and animals, contribute in many ways to improving food security by providing ready accessibility to affordable and often highly nutritious food (Chweya and Eyzaguirre, 1999; Dansi *et al*., 2008; Vinceti *et al*., 2008; Powell *et al*., 2011). While there are very few communities in the world that currently rely on forest foods to provide a complete diet (Bailey *et al*., 1989; Mercader, 2002; Colfer, 2008), forest foods can help maintain household nutrition during the lean season (complementing for example the seasonality of staple agricultural crops) and at times of low agricultural production, periods of climate-induced vulnerability and food gaps due to other cyclical events (Humphry *et al*., 1993; Moreno-Black *et al*., 2000; Angelsen and Wunder, 2003; Faye *et al*., 2010a; Karjalainen *et al*., 2010). For examples, see the seasonal calendar of indigenous fruit tree species in the background paper on "Agroforestry, food and nutritional security" (Jamnadass *et al*., 2011).

Despite their value and contribution to the "global food basket", wild foods only recently made an appearance in official statistics on the economic value of natural resources (Bharucha and Pretty, 2010), although there remain questions about the reliability of these data, which come mainly from the informal sector. A recent survey by these authors, summarizing information from 36 studies in 22 countries, highlights the important role still played by wild biodiversity in local contexts with around 90–100 wild species known per location. In some instances, estimates for level of utilization can reach 300–800 species (e.g. Ethiopia, India, Kenya). However, such studies include data from very different contexts, collected using different methodological approaches; therefore global estimates need to be considered with caution (Peñafiel *et al*., 2011). In addition, absolute numbers of species known/used are not very informative *per se*, and should be considered in relation to the richness of the local flora. Moreover, knowledge about the usefulness of a large number of plant species does not mean necessarily that they are consumed or collected with high frequency (Termote, 2012a). Thus, there is a large margin for improvement in the process of documenting consumption of wild foods.

As discussed above, forest foods cannot be a panacea for global issues related to food security and nutrition, but in some specific geographic contexts they can have a significant role. A study conducted over five districts of the Orissa State in eastern India (a state with the second largest tribal population in the country, ca. 6.82 million) showed that tribal communities derive, on average, 15 percent of their gross family income from selling fruits, and that indigenous tribal families living within a 5–7 km radius of forests consume on average 82 kg yr−1 household−1 of wild fruits, with about a quarter of households collecting regularly (Mahapatra and Panda, 2012). This has been observed for the majority of tribal populations in India, living within or near the forest (Bahuguna, 2000; Mohapatra and Sahoo, 2010).

Forest foods are mostly consumed locally or traded in local/regional markets, with transportation distances highly limited by perishability of products and pest infestation (Akinnifesi *et al*., 2006). The collection and sale of wild foods can provide considerable support to local livelihoods, especially for those who lack the capital to engage in other livelihood activities (women and the most disadvantaged members of a

community) (Delang, 2006). Forest products can also be sold in time of crisis to earn the income needed to ensure food security (Fisher, 2004; Arnold, 2008).

Nutritional quality of forest foods

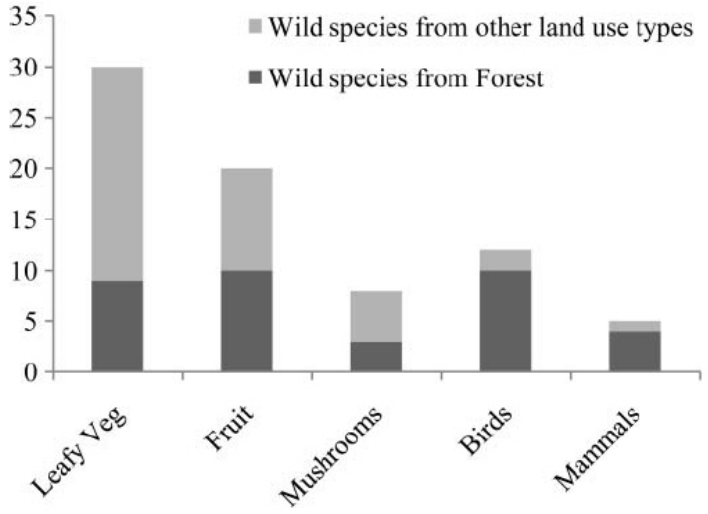
The contribution of forests and trees is not limited to periods of scarcity or shortage; even during periods of less difficulty, forests play a critical role in supplying crucial nutrients and other components not provided by staple foods alone. From a nutritional perspective, forest environments offer sources of animal foods (vertebrate and invertebrate) rich in highly bio-available iron, zinc and vitamin B_{12} (a well as protein and fat) and diverse options for obtaining leafy vegetables, fruits, nuts and other plant foods important for intake of vitamin A, iron, folate, niacin and calcium (Johns and Maundu, 2006; Vinceti *et al*., 2008; Powell *et al*., 2011).

Many of the micronutrients provided by forest foods are those most commonly lacking from diets and which have important health and developmental functions (UNSCN, 2004). For example, vitamin A deficiency causes blindness in up to 500 000 children every year and is also associated with higher rates of infection (diarrhea, measles, respiratory tract infections, etc.) because of its importance to proper immune function (Black *et al*., 2003; Kennedy *et al*., 2003). Good dietary sources of vitamin A are green leafy vegetables and orange-coloured fruits and vegetables (Underwood, 2004). Iron, zinc and vitamin B_{12} deficiency can impair growth, cognitive development and school performance with life-long implications for health and socio-economic success (UNSCN, 2004). The best dietary sources of these nutrients are animal source foods (meat) and leafy green vegetables and legumes for iron.

Even though the nature of the evidence is still circumstantial, many authors argue that there is a reasonable and compelling case for increased agricultural and forest biological diversity leading to a more varied diet, which in turn improves specific health outcomes (Johns and Sthapit, 2004; Johns and Eyzaguirre, 2006; Toledo and Burlingame, 2006; Bélanger and Johns, 2008; Lutaladio, 2010). Forest ecosystems seem to provide more diversified wild foods compared to other land uses within the same region, especially if animal sources are accounted for. Powell *et al*. (2011), in a study of 270 households across six villages in the East Usambara Mountains (Tanzania), showed that individuals consuming forest foods had significantly more diverse and nutrient dense diets, and consumed a larger number of animal source food items. Those who consumed forest foods also had greater tree cover in close proximity to the house (Figure 2).

Using Demographic Health Survey data for children between the ages of 12 and 59 months from 21 African countries, Ickowitz *et al*. (2013) found an inverted-U-shaped relationship between tree cover and dietary diversity, which peaked at 61 percent tree cover. The authors found a similar relationship between forest cover and consumption of fruits and vegetables, which reached a maximum at 48 percent forest cover.

Figure 2. Total number of wild species from the forest and other land-use types consumed by 270 surveyed households, grouped by different food types (East Usambara Mountains, Tanzania)



Source: Powell et al. (2011).

"Bushmeat" or wild meat constitutes the main source of animal protein in many tropical forested landscapes, especially in the Congo and Amazon basins (Arnold *et al*., 2011). Bushmeat also supplies many important micronutrients in much higher amounts or with higher bioavailability than plant source foods. Although still a concern, protein deficiency is not considered a widespread problem, while micronutrient deficiencies are common (UNSCN, 2004) and can be addressed by improving the consumption of animal source foods. A recent study from Madagascar estimated that the loss of bushmeat from the diet of children, without substitution by other sources, would result in a 29 percent increase in children suffering from iron deficiency anaemia (Golden *et al*., 2011).

However, over-exploitation of certain wild animal populations is leading to the extinction of species with levels of vulnerability to hunting, depending on habitat, species and hunting methods (Nasi *et al*., 2011). The resulting bushmeat crisis, documented by Nasi *et al*. (2008), is threatening the food security and livelihoods of some forest communities (Heywood, 2013), especially where home consumption is more common than bushmeat trading.

Fruit consumption in sub-Saharan Africa (SSA) has been estimated to fall considerably short of the recommended daily amount, and between 48 and 68 percent of the population, mostly women and children, suffer from some form of under nutrition (HarvestPlus, 2013). Iron and vitamin A deficiency are among the most common forms of under nutrition in SSA. Kehlenbeck *et al*. (2013) show that a number of indigenous fruit trees have a high vitamin and mineral content and the potential to contribute to the micronutrient supply of local communities (Table 2). For example, consuming 40–100 g of berries from *Grewia tenax* (Forrsk.) Fiori[5] could supply almost 100 percent of a child's (under 8 years of age) daily iron

[5] *Grewia tenax* is a fruit-producing deciduous shrub or small tree of widespread occurrence in semi-arid and sub-humid tropical climates, growing wild at low elevations throughout the Sahelian zone, northern and southern Africa, in the Arabian Peninsula, and from Iran to India.

requirement. In addition to micronutrients, the high sugar content of fruits such as tamarind (*Tamarindus indica L.*) and baobab (*Adansonia digitata L.*) make them important sources of energy (Table 2). The fruits of *Dacryodes edulis* (G.Don) H.J.Lam, and the seeds of *Irvingia gabonensis* (Aubrey-Lecomte ex O'Rorke) Baill., *Sclerocarya caffra* Sond. and *Ricinodendron rautanenii* Schinz have a higher fat content than peanuts (Barany *et al*., 2004).

Colfer *et al*. (2006) point out that data on the nutrient content of many indigenous fruits are either unavailable or unreliable. In addition, the bioavailability of nutrients varies and also depends on what other foods are being eaten. To fully understand the contribution of a single food to nutrition, an understanding of the nutrient composition, bioavailability and the steps used to process, conserve, prepare and consume the food is required.

A recent review by Stadlmayr *et al*. (submitted) on the nutrient composition of selected indigenous fruits from sub-Saharan Africa notes the very high variability in nutrient contents naturally occurring among different populations of the same species, when undomesticated. This has also been documented in vegetables (Msuya *et al*., 2008) and cereals (Barikmo *et al*., 2007).

Table 2. Nutrient contents of some African indigenous and exotic fruits per 100 g edible portion (high values are highlighted in bold)

Species	Energy (Kcal)	Protein (g)	Vit C (mg)	Vit A (RE) (µg)	Iron (mg)	Calcium (mg)
Indigenous fruits						
Adansonia digitata L.	340	3.1	150-**500**	0.03-0.06	1.7	360
Grewia tenax (Forrsk.) Fiori	N.A.	3.6	N.A.	N.A.	**7.4-20.8**	**610**
Sclerocarya birrea Hochst.	225	0.5	68-**200**	**0.035**	0.1	6
Tamarindus indica L.	270	**4.8**	3-9	0.01-0.06	0.7	260
Ziziphus mauritiana Lam.	21	1.2	70-165	0.07	1.0	40
Exotic fruits						
Guava (*Psidium guajava* L.)	68	2.6	**228.3**	0.031	0.3	18
Mango (*Mangifera indica* L.)	65	0.5	27.7	0.038	0.1	10
Orange (*Citrus sinensis* (L.) Osbeck)	47	0.9	53.0	0.008	0.1	40
Pawpaw (*Carica papaya* L.)	39	0.6	62.0	**0.135**	0.1	24

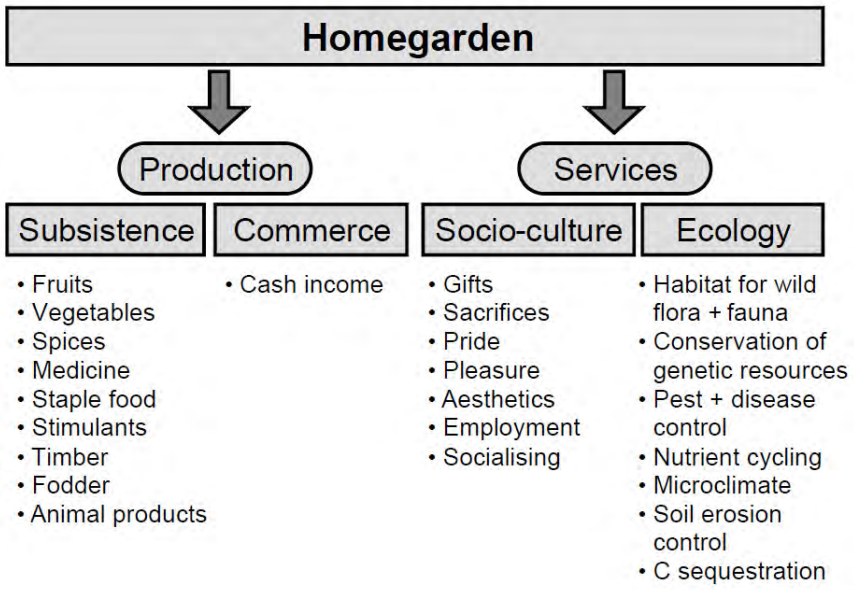
Note: RE is retinol equivalents.
Source: Kehlenbeck et al., 2013, compiled from different sources.

Until a decade ago, there was little available research on the range and origin of intraspecific genetic variation behind variable nutritive values and other properties of edible products from key tree species. Domestication programmes are now being developed to bring many wild tree species into cultivation and integrate them into agroforestry systems (see "Agroforestry, food and nutritional properties").

The role of home gardens has been investigated in relation to nutritional outcomes. Home gardens are highly diverse and provide many ecosystem goods and services (Figure 3). These systems are common in

most parts of the world, especially in tropical and subtropical regions, and it has been estimated that around 1 billion people in the tropics obtain produce from home gardens supported by semi-subsistence agriculture (Heywood, 2013). Some studies have found that the presence of a home garden is associated with children's nutritional status and that diversity, rather than size of the garden, is the important factor (Jones *et al*. 2005). Home garden interventions can be highly effective for improving micronutrient intake (Tontisirin *et al*., 2002; Berti *et al*., 2004).

Figure 3. Main functions of homegardens and selected products/service outputs



Source: Kehlenbeck et al., 2007.

Many factors beyond agricultural produce influence nutritional status, such as the circumstances under which people participate in these interventions, their health and sanitation environment, cultural practices, and so on (Masset *et al.*, 2012). These factors affect project implementation and confound outcomes of programmes aimed at promoting agrobiodiversity for better nutrition and health. This further reinforces past studies that argue for a combined livelihoods, agriculture, health, and education approach to improving nutritional status, and emphasizes the need for more carefully designed evaluations of the impacts of home gardens on overall nutrition.

Cultural importance of forest foods

In most societies that traditionally inhabit areas with significant forest cover, forest foods have been used for generations and many have social and cultural importance. Wild edible plants are part of the intangible cultural heritage of local populations (UNESCO, 2003; Pieroni, 2008) and are even related to cultural identity (Ndam *et al*., 2001; Pieroni *et al*., 2005; Macía, 2004; Dansi *et al*., 2008; Maxia *et al*., 2008).

Knowledge about the identification, preparation and sustainable management of forest and wild foods is part of indigenous knowledge systems and practices that have been developed over many generations. These play an important part in decision-making in local food production, human and animal health, and

management of natural resources (Slikkerveer, 1994). In South Africa, most forest foods traded in local markets maintain a key position in local culture; in several cases commercial substitutes of forest foods do not exist, and wild resources are generally preferred even when alternative products can be found (Shackleton *et al*., 2008). A recent extensive review of indigenous food systems, including a range of NFTPs, highlights both their nutritional and cultural importance (Kuhnlein *et al*., 2009).

Indirect contribution of NTFPs to improved livelihoods allowing access to other food sources

NTFPs can contribute indirectly to food security and nutritional outcomes through the income generated by their sale. In some cases, the need to generate income from forest foods may take precedence over direct consumption. A study in Viet Nam revealed that forest vegetables, bamboo shoots and mushrooms collected were eaten in wealthier households, but in poorer ones had to be sold in order to buy rice (Nguyen Thi Yen *et al*., 1994). Similar results were obtained from a study on fruits in the Amazon basin (Melnyk, 1993) and bushmeat in parts of West Africa (Brown and Williams, 2003). Selling off collected foods can have both positive and negative nutritional impacts (the income generated may be used to purchase other types of food); therefore generalizations are not appropriate.

A growing literature suggests that forest foods contribute to income and poverty reduction, and that wild harvested plants and animals are of particular importance to the economy of the world's rural poor, particularly for forest communities (Nepstad and Schwartzman, 1992; Colfer, 1997; Pimentel *et al*., 1997; Shanley *et al*., 2002; Belcher and Schreckenberg, 2007; Paumgarten and Shackleton, 2009). Locally important forest products contribute significantly to livelihoods, not only for rural people, but also in urban and peri-urban environments where intermediaries and traders of NTFPs often come from poorer and more marginalized sectors of society (Kaimowitz, 2003; Stoian, 2005; Termote, 2012b). However, a thorough examination of all local supply chains of NTFPs and their stakeholders, as well as rural-urban linkages, is needed to arrive at a correct valuation of forests and forest products, and to assess the role and potential of NTFPs at local, regional and national levels (Hegde *et al*., 1996; Sundriyal and Sundriyal, 2004; Stoian, 2005; Jensen, 2009).

Efforts to understand the role of NTFPs have moved away increasingly from isolated case studies to global analyses based on uniform criteria, so as to draw lessons at a broader scale (Belcher *et al*., 2005; Angelsen *et al*., 2011) across regions (Ruiz-Perez *et al*., 2004) or different products (Marshall *et al*., 2006). Results indicate that, as a general pattern, the relative contribution of forest products to total household income is higher for poorer and more marginalized people (see the preliminary results from the Poverty Environment Network: www.cifor.org/pen).

Environmental aspects of forest foods systems

Forest food systems are low input systems not reliant on costly external inputs, which can be polluting and damaging to the environment. While a large part of global agricultural production takes place at the expense of biodiversity and the wider environment (McMichael, 2005), forest food systems have a smaller ecological footprint: forests and trees are carbon sequestering (Montagnini and Nair, 2004), use fewer (or no) chemical inputs, and rely on natural precipitation instead of groundwater. The value of forest foods and other forest products is often not sufficiently taken into account when decisions are taken about land-use planning.

Challenges and opportunities to strengthen the role of forest foods in sustainable diets

The concept of sustainale diets presented here is recent and its translation into an operational framework has not yet been implemented. Taking into consideration the following series of factors can help to strengthen the potential contribution of forest foods to sustainable diets.

Cultural challenges

One of the most widely reported factors likely to determine differences in the use and value of food tree products is ethnicity (Chadare *et al*., 2008; De Caluwe *et al*., 2009; Fandohan *et al*., 2010; Assogbadjo *et al*., 2011; Termote *et al*., 2011). Traditional knowledge should therefore be taken into consideration when promoting nutritious forest foods as part of a diet, and in the selection of priority species for marketing and domestication.

Many indigenous people, including those living in forested environments, also often face issues arising from poverty, prejudice, discrimination and marginalization, which can affect access to traditional resources and collecting grounds, with potentially severe negative impacts on nutrition and health (Kuhnlein and Receveur, 1996). Indigenous foods valued in the past may become perceived as old-fashioned or inferior. Other reasons responsible for declining use, depending on the context, may include: physical shortage of the product as a consequence of resource depletion, reduced time to gather wild foods as a result of changes in the availability or allocation of a household's supply of labour, increasing pressure on women's time, loss of knowledge about use of forest foods (Falconer, 1990), and limited opportunities to commercialize production (Kuhnlein *et al*., 2009; Bharucha and Pretty, 2010).

Changes in forest use often result in dietary change with both positive and negative repercussions. Changes in livelihood strategies and the process of urbanization, coupled with the commercialization of food and changes in diets (high salt and energy density, but lower nutrition) have resulted in considerable modification in consumption and natural resource-use patterns (Pingali, 2007). An extreme example of maladaptation to "modern" conditions is the process of sedentarization of former hunter-gatherers groups, such as the Baka and Kola Pygmies of Cameroon and the Tubu Punan of Borneo, resulting in negative nutritional and epidemiological consequences (Dounias *et al*., 2007; Dounias and Froment, 2011). The abandonment of forest-based livelihoods and traditional food regimes in these groups has been associated with diets lower in protein and fibre and higher in salt, milk and sugar – a shift often referred to as the nutrition transition (Popkin, 2004).

Sustainability of use of NTFPs and threats to the resource base

Several threats to forests and other tree-based systems could curtail their capacity to provide food and nutrients. Unsustainable harvesting of wild resources has been documented in different contexts. A review of important fruit species for the local economy and diet, regularly consumed in the region surrounding Iquitos, Peru (Vasquez and Gentry, 1989), revealed that out of 193 fruit species used, 120 were exclusively wild-harvested and 19 additional species originated from both wild and cultivated sources. However, the availability of several of the most popular fruit species had decreased markedly and destructive harvesting techniques and increasing market pressures were rapidly depleting wild populations (Sundriyal and Sundriyal, 2004; Delvaux *et al*., 2010). This highlights the need to take measures to manage the threat of

overexploitation in any attempt to extract forest food products. Sustainability of NTFP use, including forest foods, depends greatly on level of use and the population dynamics of the species (Ticktin, 2004; Belcher *et al*., 2005).

Conflict between different uses of trees for timber and NTFP can pose additional threats. In the Congo Basin, timber exploitation is placing growing pressure on local biodiversity, with potential negative repercussions on food security and livelihoods (Rist *et al*., 2012). NTFPs used locally as sources of food and medicine are being depleted in areas where people depend on them most. Some species have edible fruits and oil extracted from seeds; others host caterpillars that make up 75 percent of the protein eaten by Baka pygmies during the period when caterpillars are available (Ndoye and Tieguhong, 2004). Examples of conflicts between multiple uses are also documented in Asia (Limberg, 2007) and South America (Guariguata *et al*., 2010).

In West Africa, when woodland is cleared for traditional agriculture, some selected multipurpose trees supplying food, wood and medicinal functions are maintained (Faye *et al*, 2010b); however useful trees and shrubs are progressively disappearing due to shortening fallow periods, tenure issues, drier climate, browsing by livestock and the absence of conservation practices to protect regeneration (Gijsbers *et al*., 1994; Nikiema, 2005; Maranz, 2009).

For most wild-collected animal and plant species there is minimal available knowledge regarding the effect that collection has on the genetic diversity and long-term survival of species' populations (see the case of *Gnetum* spp. in Sunderland *et al*., 2002; Ndoye and Awono, 2010; Ingram *et al*., 2012). Detailed inventories of these wild species exist for only few countries and the literature is scattered (Scoones *et al*., 1992; FAO, 1995, Townson, 1995; Colfer *et al*., 2006; Vinceti, 2008; Special issue of International Forestry Review edited by Sunderland and Pottinger, 2011; Heywood, 2013).

Increased reliance on food-based approaches

The role of micronutrients in health and well-being and the synergies with the physiological functions of nutrients are increasingly recognized (Frison *et al*., 2006; Remans *et al*., 2011). Nutrition interventions should thus focus on improving overall diet quality. This calls for promoting dietary diversification and food-based nutritional interventions (Frison *et al*., 2006; Torheim *et al*., 2010), taking into account the role of forest foods. The increasing focus on dietary diversity, defined as the number of unique food categories consumed over a given period of time, as an indicator of food security (Hoddinott and Yohannes, 2004) and a proxy for diet quality (Arimond *et al*., 2010; Kennedy *et al*., 2011; Ruel, 2003a), allows to better capture the whole-diet approach in a quick and low cost manner. Translating this approach into programmes is challenging, however, and researchers are investigating the best tools for evaluating diversity in diets, nutritional outcomes and assessment (Ruel, 2003b; Torheim *et al*., 2004; Savy *et al*., 2005; Frison *et al*., 2006; Savy *et al*., 2007; Kennedy *et al*., 2010).

Furthermore, there is growing interest in using micronutrient-rich foods, including food from indigenous or traditional trees and plants, to meet the high nutrient needs of infants and children, whose diets are founded predominantly on cereals and legumes (Kuyper *et al*., 2013). Based on local availability and ease of access, underused complementary foods may be affordable and potentially more acceptable than other options. An example is the fermented condiment obtained from the seeds of *Parkia biglobosa* (Jacq.) R.Br.

ex G.Don, in West Africa, called "soumbala". A rich source of iron (16.9 mg/100 kcal) (Ouedraogo *et al*., 2010) it is often used as a low-cost meat substitute by families (Savadogo *et al*., 2011).

Increasing knowledge

There is room to increase the use and consumption of diverse foods including traditional forest foods by enhancing the knowledge of policy-makers, healthcare workers and extension agents through the provision of information (Bisseleua and Niang, 2013; Smith, 2013). Nutritional education activities to promote forest food consumption should be based on sound scientific knowledge of their nutritional values, and should be able to stimulate local positive attitudes towards wild edible plants (Kuhnlein, 2009). Promoting the necessary behaviour change to use and consume what are often considered inferior foods remains one of the biggest challenges due to the growing aversion to consuming certain traditional complementary foods (e.g. insects; see DeFoliart, 1999). Another aspect to be carefully taken into account is palatability, as it may be difficult for infants to consume large amounts of certain underused micronutrient-rich foods.

Food composition tables should be expanded based on local biodiversity, and some actions have already been taken in this respect (Burlingame *et al*., 2009; Nesbitt *et al*., 2010). Generation and use of better composition data for forest foods can be combined with research on ecology, management and (participatory) domestication so that appropriate nutritionally rich species can be integrated into fields and home gardens (Pudasaini *et al*., 2013; see "Agroforestry, food and nutritional security"). Examples of increased consumption of micronutrient-rich foods as a result of information dissemination and promotion are available (e.g. Low *et al*., 2007) and such an approach should be adopted for forest foods. Nevertheless, nutrition interventions remain complicated by measurement issues and limited understanding of the actual requirements of many micronutrients.

Adapting management of forests and trees to account for forest foods

Many traditional communities actively manage the wild resources they use, and in many cases, customary methods of resource management may be fundamental to the sustainable conservation of habitats and species (Schroeder, 1993; Greenberg, 2003; Anderson, 2006; Castle, 2006; Moller *et al*., 2009).

In cases of conflict over the use of multipurpose species that supply both timber and food products, forest management plans should be negotiated with timber concessions and adapted to consider the interests of both local communities and timber companies (Ndoye and Tieguhong, 2004). Such an approach should be based on a sound cost-benefit analysis that takes into account livelihoods and the food and nutritional benefits of forest foods in the diets of the most vulnerable: women and children.

Women have a central role in ensuring food security and adequate nutrition (de Schutter, 2011). The food security literature indicates that interventions directed towards women are likely to have a particularly beneficial impact (Hoddinot, 1999). Supporting the role of women as producers and consumers would help to remove barriers to improved nutrition, including higher consumption of forest foods (see the background paper on "Gender aspects"). Maintaining forest cover around villages and homes may be necessary if forest foods are to remain in the diet, with important implications for village and household-level land management.

Furthermore, nutritionally important indigenous trees can be introduced into farming systems to produce traditional forest foods through processes of domestication to improve quality and yield (see "Agroforestry, food and nutritional security").

Access rights to forest foods

A lack of secure access rights and land tenure discourage many poor or marginalized communities from investing in more productive land management, and from protecting and planting key species, which could play a key role in terms of food security and nutrition – as in the case of parklands in West Africa (Teklehaimanot, 2004; Ræbild *et al*., 2011). Weak and ineffective political and institutional arrangements in support of local control and management of forests still widely constrain access by the poor to resources that can yield forest foods and income. Policies and programmes that actually enable local people to have a genuine role in decision-making are rare (Larson and Ribot, 2007).

Community biodiversity management is an approach to natural resource management that contributes to the empowerment of agricultural and forest communities to better manage their biological resources, and to make informed decisions on the conservation and use of biodiversity including forest and tree resources (de Boef, 2013). Steps involved in community biodiversity management include: the introduction and domestication of wild species in home gardens; the creation of networks of extension agents and community members; social institutional empowerment (land tenure rights); generation of livelihood benefits and income through consumption and sale of tree products.

Integrating forest biodiversity into complex landscapes managed for multiple benefits

The diversity of foods that can be derived from different land uses, such as forest, fallow and agricultural margins, could help to provide the range of micronutrients needed for a sustainable human diet (High and Shackleton, 2000; Padoch and Pinedo-Vasquez, 2010). Forest fallows can be equally productive of forest foods as pristine forests (Davies and Richards, 1991). In many contexts, fallow land and farm bush areas are actively managed to protect and regenerate species of value to local communities. Examples include the babaçu palm (*Attalea speciosa* Mart. ex Spreng.) in northeast Brazil, which is integrated into local farmers' shifting cultivation systems (Mayso *et al*., 1985), and fruit trees planted at an early stage in agricultural settlements (Arnold and Dewees, 1997). Research and development practitioners must start thinking about ways to develop innovative new roles for agro-ecosystems and heterogeneous landscapes, so as to ensure that food production systems and value chains are more nutrition sensitive, while minimizing their ecological footprint (Hunter and Fanzo, 2013).

General recommendations

1. Prioritize research and development into nutritious forest foods including analysis and documentation of their nutritional composition, digestibility and bioavailability, the effect of storage and processing on the nutritional value of specific forest foods, and the potential for domestication and integration of important species into value chains.

2. Encourage research that examines the relative contribution of forest foods to local diets and nutrition. Describe and measure the sustainability of diets reliant on forest foods in relation to indigenous peoples' food systems, and compare these systems in terms of resilience, health, cost-effectiveness and sustainability with other diets and food systems across countries and regions.

3. Support research on governance and access issues and on the development of nutrition-sensitive value chains involving forest foods, with a particular focus on improving understanding of the risks associated with potential overharvesting and changes to access, as targeted NTFPs become more valuable.

4. Ensure extension services, NGOs, schools, hospitals and health centres are aware of the benefits and promote the consumption of nutritious forest foods within their programmes and interventions, including efforts to counter negative perceptions and attitudes to local, traditional foods.

5. Promote the better integration of information and knowledge on nutritious forest foods and their conservation into national nutrition strategies and programmes by establishing cross-sectoral policy platforms that bring together environment, health, development, agriculture and other sectors to better mainstream the use of tree biodiversity with high nutritional value in strategies addressing food security, nutrition, conservation, and land-use planning and policy.

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