The role of forests, trees and wild biodiversity for nutrition-sensitive food systems and landscapes

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Abstract

Many contend that in order to overcome the world's nutrition problems, nutrition must become a cross-cutting issue, with concrete commitment and attention from a wide range of disciplines. From this assertion has grown the promotion of nutrition-sensitive approaches to economic growth, development, agriculture and food systems (nutrition-specific interventions target malnutrition directly, whereas nutrition-sensitive interventions target the causes of malnutrition by integrating nutrition into policies and programs in diverse sectors). There have been repeated calls for the international community to prioritize identification ways to leverage agriculture (and agricultural landscapes) to enhance nutrition (and health). Land use change is an often overlooked driver of change in diets, nutrition and food security, especially for rural communities. The synergies between food systems approaches to food security and nutrition and landscape approaches to integrated biodiversity and forest conservation should be explored and built on.

Forests and trees support food security and nutrition in a number of ways. Forests and wild biodiversity provide nutritionally important foods (including fruits, vegetables, bush meat, fish and insects), that contribute to the diversity and nutritional quality of diets of people living in heterogeneous landscapes. Forests and trees provide fuelwood, an essential and often overlooked component of the food systems in rural areas across the globe. Forests and tree products make invaluable contributions to the income of people living in and around them, often providing the only means of accessing the cash economy, thus enabling access to nutritious foods through purchasing. Forests also sustain resilience: forest products are often consumed more frequently in times of food scarcity and can provide livelihood safety nets. When they reach markets, forest and tree products can contribute to the nutrition-sensitivity of global food systems (approximately 53% of the fruit available for consumption globally is produced by trees), especially when market chains are supported and developed in a nutrition-sensitive manner. Biodiversity, forests and trees outside forests also provide an array of ecosystem services essential for the sustainability and nutriton-senstivity of agricultural systems (e.g. pollination, water provisioning, genetic resources). A better understanding of the importance of these relationships, and the spatial scales at which they function, is needed to ensure they are not overlooked in policy and practice.

The importance of forests and trees in agricultural systems and the nutritional importance of forest and tree foods highlight their role in both the sustainability and nutrition-sensitivity of food systems. To achieve goals for reductions in global malnutrition it will be essential to ensure that nutrition becomes a cross-cutting issue: a priority not only in the field of health, development, education and agriculture, but for those also working in forestry and conservation.

Key Words: Agricultural systems, landscapes, dietary diversity, nutrient-dense, ecosystem services, fruits and vegetables, animal source foods, fuelwood, traditional food systems

1. Introduction

1.1 Breaking down silos to improve nutrition: A place at the table for forestry and conservation

Experts contend that in order to overcome the world's nutrition problems, nutrition must become a cross-cutting issue (Pinstrup-Andersen 2009; Swaminathan 2012). Nutrition-specific interventions, that target malnutrition directly, will not be sufficient alone to achieve sustainable improvements: the causes of malnutrition must also be targeted. Concrete commitment and actions to address the drivers of nutrition are needed across disciplines and sectors (agriculture, nutrition, health, education, etc.). Nutrition-sensitive approaches, policies and interventions are now promoted in economic growth, development, agriculture and food systems (Pinstrup-Andersen 2013; Thompson and Amoroso 2013). The FAO defines *nutrition-sensitive agriculture* as "Agriculture that effectively and explicitly incorporates nutrition objectives, concerns, and considerations to achieve food and nutrition security (FAO/AGN)" (Thompson and Amoroso 2013). Pinstrup-Andersen (2013) gives the Green Revolution as an example of an agriculture policy and intervention that was not nutrition-sensitive. He notes that the Green Revolution failed to reduce rates of micronutrient deficiency and that the decreased price of wheat and rice relative to prices for other foods such as fruits and vegetables that resulted may have contributed to the global dietary and nutrition transition.

Because successful sustainable improvements in nutrition require complex, system wide changes in food production, consumption, and related health (Allen and Gillespie 2001; Berti, Krasevec and Fitzgerald 2004; Herforth 2010b; Tontisirin, Nantel and Bhattacharjee 2002; Underwood and Smitasiri 1999), overcoming malnutrition will require conscious and sustained efforts from the health and agricultural sectors, as well as those in diverse fields including forestry, conservation, economics, development and education (Herforth 2010a; Herforth 2010b; Powell 2012). Calls to break down disciplinary silos in order to overcome global malnutrition are increasing, including in the popular press[1]. However, in order to achieve positive change we must ensure that nutrition is a cross-cutting issue: a priority not only in the field of health, development, education and agriculture, but for those working in forestry and conservation as well. The debate around nutrition-sensitive food systems has to date, not identified forestry and conservation as a sector where nutrition-integration and nutrition-sensitive approaches need to be a priority (so far sectors identified as needing nutrition-sensitive approaches included: agriculture, education, health, livestock, fisheries, development, social welfare, water and hygiene) (UN-SCN 2013).

[1] e.g. Klaus Kraemer, director of Sight and Life, piece "We can't address food security without addressing nutrition security." The Economics Group, December 13th 2012, Accessed Jan 4th, 2012 - http://www.management-thinking.org) and Lawrence Haddad's "Let's make malnutrition visible", BBC News Magazine, 29 November 2012 (Accessed Jan 7th, 213: http://www.bbc.co.uk)

It is widely acknowledged, forests, trees on farms and biodiversity are essential for the sustainability of food and agricultural systems; even large-scale monoculture agricultural systems in developed countries are dependent on distant forests and biodiversity for ecosystem services such as water regulation, and genetic material for future breeding and innovation (Millennium Ecosystem Assessment 2005). For rural people in many developing countries, biodiverse agriculture ecosystems are simultaneously necessary for sustainably achieving improved nutrition, and play an essential role in biodiversity conservation, as has been highlighted within the global policy priorities such as the Convention on Biological Diversity, COP 8 decision viii/23: "Agricultural biodiversity, cross-cutting initiative on biodiversity for food and nutrition" (CBD 2006). Diverse systems are also more resilient to economic shocks and less vulnerable to extreme climatic events. However, despite the increasing emphasis of the importance of resilience and sustainability in agricultural and food systems, and the integral role of biodiversity, there remains little coverage of forests and conservation in food security and nutrition discourse (Vinceti et al. 2013) – despite the fact that conservation goals and priorities have historically had significant influence over land use planning and policy. Likewise, although those working in forestry and conservation have long sought win-win options for forest conservation and local people's livelihoods, there has historically been little attention to the impact of forests and forest policy on food security and nutrition. However there is growing enthusiasm for the enhanced integration of conservation, agriculture and development efforts, sought though integrated landscape approaches, providing a paradigm into which nutrition and food security goals can be incorporated (Arnold et al. 2011; Chazdon et al. 2009; Cunningham, Scherr and McNeely 2002; Sayer 2009; Sayer et al. 2013). Landscapes must be managed not only to balance productivity and biodiversity conservation, but to enhance nutrition-sensitivity. Significant progress cannot be expected until nutrition is a collective responsibility – including for those involved in large-scale land use planning and conservation (Powell 2012; Sayer et al. 2013).

1.2 The Landscape Approach: Making room for Nutrition in Forest and Biodiversity Conservation

Some health experts have long noted that it is not practical nor efficient to address human health and ecosystem health in isolation: co-management of systems and landscapes that simultaneously influence human health and the environment is essential (Lebel 2003). Around 30% of the earth's surface is covered by forests (FAO 2011); forests thus have a profound role in the broader landscapes in which many agricultural systems exist. International meetings in 2012 (the Convention on Biological Diversity COP 11 in Hyderabad, the Climate Change COP 18 in Doha) saw increased attention to landscape approaches to conservation and land use management policy - an approach which has long been promoted by those seeking to account for the needs of forest peoples in forest conservation research and policy (Arnold et al. 2011; Chazdon et al. 2009; Cunningham, Scherr and McNeely 2002; Sayer 2009; Sayer et al. 2007; Sayer et al. 2013). The landscape approach seeks a more holistic approach to landscape management and has the potential to allow for the incorporation of evolving knowledge on how to make agricultural landscapes and food systems more nutrition-sensitive and nutritionally resilient.

In this paper we examine the contribution of forests and trees to the nutrition-sensitivity of food and agricultural systems. Although the widely accepted definition of forests: "Forests are lands of more than 0.5 hectares, with a tree canopy cover of more than 10 percent, which are not primarily under agricultural or urban land use" (FAO 1998, FRA 2000), specifies areas of at least 0.5 ha, this paper examines the contributions of large areas of unbroken forests, to small patches of forest remnants on farms, fallow areas with trees, to agroforestry systems and the nutrition-sensitivity of food and agricultural systems.

1.2 Overview: Forests, Trees and Wild Biodiversity and their Contribution to Nutrition

As a central part of the wider landscape in which many communities secure their livelihoods, forests and trees contribute food systems and nutrition of local people in many important ways:

- Wild foods from forests and agricultural land with tree cover can make important contributions to dietary diversity, often increase the nutrient density of local diets and are of central social and cultural importance in many traditional / indigenous food systems.
- Although they may be less central to the production of energy rich staple foods, forests and tree-based agricultural systems contribute to the provisioning of under-consumed food groups essential for a nutritionally balanced diet (such as nutrient-dense fruits and vegetables and nuts).
- Agricultural systems that include significant forest or fallow within the landscape can provide sustainable sources of meat, in the form of bush-meat: the main supply of animal source food for many people in developing countries (especially in the Congo and Amazon basins).
- Traditional foods both wild and cultivated, obtained from forested landscapes and traditional agricultural systems that include significant tree cover are often lower in energy (calories), fat and refined sugar and higher in fibre and micronutrients, compared to imported and modern food items which tend to be more processed and higher in energy (calories), fat and sugar. Because of this, the maintenance of traditional foods in food systems may help to mitigate a transition to diets high in processed and important foods
- Forests and trees also provide fuelwood and other forms of energy (e.g. charcoal). Wood is remains an essential component of many local food systems: cooking is needed to make many foods palatable and safe. Fuelwood is rarely considered adequately in agricultural and food security policy, planning and programming.
- Economic growth is recognized as an essential factor contributing to the reduce global malnutrition. Forests and trees provide income for local people and in some cases can provide for the only cash income of households. Adequate income make possible the purchase of diverse and nutritious and foods.
- Forests and trees products provide safety nets in times of crisis: when crops fail, food prices fluctuate, or livelihood strategies are challenged by political, economic and environmental shocks, local people often turn to forest resources to supplement both diet and income

Forests and trees also contribute to food security and nutrition of people living in areas that are distant from forests:

- Forests provide the Ecosystem Services essential for the sustainability of global agriculture; their role is often tacitly acknowledged, but rarely incorporated into agriculture and food security policy
- The loss of ecosystem services can have both short and long term impacts on nutrition:
    - The loss of pollination services could have immediate negative implications, with potentially greater impact on the most nutritionally important foods (e.g. fruits and vegetables)
    - The loss of genetic resources maintained in local varieties of different agricultural systems and crop-wild-relatives in wild and less managed parts of the landscape has significant repercussions for the success of bio-fortification, now widely promoted for the reduction of micronutrient deficiencies
    - Soil fertility can be enhanced through integrated systems that include planted trees. Fodder trees for livestock keeping can simultaneously enhance soil fertility and increase the availability of diary and meat for local consumption
    - Water provisioning services provided by trees and forests are essential for agricultural production and food security in general. Moreover, clean drinking water contributes to reduced malnutrition through the inter-relationships between nutrition and infection
- As forests and agroforests are important for the production of under-consumed and nutritionally important food groups such as fruits and vegetables, the maintenance of these forms of agriculture within the landscape will be essential to ensure a sustainable, nutritionally balanced global food system. Nutrition-sensitive food systems need to ensure availability, accessibility and use of nutrient-dense foods and dietary diversity. It will also be essential to ensure that the market chains for nutritionally important tree and forest products are developed so that such products can reach distant consumers while remaining affordable for everyone (including improving methods of storage, preservation and transportation, market chain development).

2. Forests for Wild Food, Diet and Nutrition of Local People

Forest peoples are herein defined as any people living in or near a landscape with tree cover or forest (with a focus on developing countries). Using this definition, most forest people in the world today are small-scale farmers; practicing swidden agriculture, agroforestry or more intensive and more permanent forms of small-scale agriculture. Although some forest peoples may have been traditionally hunter-gatherers it is unlikely that any group remains wholly dependent on forest resources today – all engage in some form of agriculture or trade (Bailey et al. 1989; Colfer 2008; Mercader 2002).

2.1 Biodiversity, Wild foods and Tree cover for Dietary Diversity

Dietary diversity has been linked to nutrient intake, adequacy and status, and has been suggested to be an important pathway through which biodiversity contributes to human nutrition (Johns and Sthapit 2004; Powell 2012). The importance of crop and agricultural diversity for dietary diversity, micronutrient intake, and food system sustainability is increasingly recognized (Ekesa, Walingo and Abukutsa-Onyango 2008; Frison, Cherfas and Hodgkin 2011; Herforth 2010b; Johns and Sthapit 2004; Torheim et al. 2004); however, the contributions of forests, trees and uncultivated biodiversity that exist within and adjacent to agricultural systems have often been overlooked.

Recent work from the East Usambara Mountains, Tanzania showed a positive association between dietary diversity and tree cover within a landscape mosaic of farms and forests (Powell 2012). A forthcoming paper by Ickowitz et al. (under review, 2013) finds that, after controlling for confounders (such as distance to market, road density, etc) children's dietary diversity increases with tree cover for the majority of the population across 21 African countries.

2.2 Wild and Forest Foods for more Nutrient Dense Local Diets

Malnutrition and hunger are not simply a result of inadequate quantities of food, the type of foods that the diet is composed of is equally, if not greater importance (Swaminathan 2012). Micronutrient deficiencies are often called "hidden hunger" and can result in sever and lifelong health issues, increased mortality rates and physical and cognitive impairment. Under many traditional food subsistence strategies, agricultural activities focus on the production of staple crops (high in energy, i.e. calories, but not necessarily nutrient-dense), with less effort spent on the cultivation of side dish and other foods such as vegetables, fish, and meat, as well as fruit. These nutrient-dense non-staple food are often harvested from wild, managed natural regeneration or semi-domesticated sources. Reviews highlight that wild foods are ubiquitously and habitually used by rural populations around the world, in both hunter-gather and agricultural communities (Bharucha and Pretty 2010; Penafiel et al. 2011; Scoones and Bishop 1994). Further work from anthropology (on the Optimal Foraging Theory) has also highlighted the dual importance of cultivated staples and non-cultivated complementary foods in the diets of many traditional societies (Johnson and Behrens 1982; Rappaport 1968; Smith 1979).

The potential contributions of wild plant foods to nutrition and nutrient intake have been highlighted (Bharucha and Pretty 2010; Fleuret 1979; Grivetti and Ogle 2000; Scoones and Bishop 1994). Fruits, vegetables and animal source foods are the types of foods that most often come from wild, uncultivated or semi-domesticated sources; these types of foods almost always have high nutrient density (Powell et al. in press; Vinceti, Eyzaguirre and Johns 2008). Recent work from the East Usambara Mountains (Tanzania) showed that wild foods were used by virtually all informants but contributed only 2% of total energy in the diet; however, they contributed 31% of vitamin A (RAE), 20% of vitamin C and almost 20% of iron consumed (Powell et al. in press). In the same study sample, the use of wild food from the forest (used less frequently than wild foods from across the diverse landscape) was positively associated with better dietary quality for children (Powell, Hall and Johns 2011). In Gabon, Blaney et al. (2009) found

that use of natural resource (i.e. wild plant and animal foods), was associated with dietary nutrient adequacy in children (over 2 years of age) and adolescence. In DRC, those individuals who had consumed wild plant foods had consumed more fruits, fibre, vitamin A and calcium than those who had not (Termote et al. 2012).

2.3 Forests and Tree Cover for Fruit and Vegetable Consumption

Vegetables and fruit are particularly important components of food systems: ensuring nutrient-dense diets and therefore increasing the likelihood of adequate micronutrient intake without contributing the increased risk of obesity. Fruits and vegetables intake is associated with wide range of health benefits (Slavin and Lloyd 2012; WHO and FAO 2004) and widely under-consumed (Ruel, Minot and Smith 2005). For example, in Sub Saharan Africa consumption of fruits and vegetables extremely low: with an average daily intake of 36g in East Africa, 70g in Sothern Africa, 90g in West and Central Africa (Ruel, Minot and Smith 2005).

In the East Usambara Mountains, the quantity of vegetable consumed by children was positively correlated with nutrient intake, adequacy and density of their diets. The study identified 38 species of traditional vegetables, of which 63.2% of which were wild species. Traditional vegetables contributed 35% of vitamin A (RAEs), 26% of iron, 23% of calcium and 20% of vitamin C consumed (Powell et al. 2012); similar contributions of wild vegetables to micronutrient intake have been reported in Vietnam (Ogle, Hung and Tuyet 2001). The data from this Tanzanian case study also showed that in the dry season (when vegetable consumption was lowest) the amount of tree cover within 1.5 and 2km radii from the home was associated with enhanced vegetable consumption (Powell et al. 2012). A forthcoming paper finds that children's fruit and vegetable use increases with tree cover for the majority of the population (Ickowitz, Powell and Sunderland 2013). In the few contexts where wild vegetables are less prominent in rural people's diets such as the Amazon (daSilva and Begossi 2009; Katz et al. 2012), wild fruit and animal source foods are of even greater importance for micronutrient intake.

Admittedly, the consumption of fruits and vegetables in many contexts (especially developed countries) is largely bound by consumer choice and behavior, with complex social, cultural and psychological drivers. However, recently the environmental and structural determinants of healthy choices have been increasingly emphasized (it is no longer acceptable to foist full responsibility for health choices on vulnerable populations who have limited control over their food environments - the impact of tobacco control policies, targeting structural change, on smoking rates has shown that it is not all just a matter of consumer choice). A recent paper in *Science*, suggests that rather than fighting to change conscious behavior, interventions targeting more automatic process may be more effective (Marteau, Hollands and Fletcher 2012), for example making healthier diet choices more accessible than less health ones. Forests and trees within the landscape may be essential for the maintenance of easy access to fruit and vegetables for local people. Tree diversity is particularly important for year-round access to fruits which are highly seasonal (Vinceti et al. 2013). If combined with appropriate, locally adapted and culturally-

sensitive public health messages[2] that highlighting the importance of fruit and vegetable consumption, maintenance of forests and trees within agricultural systems could be a powerful means for ensuring healthy dietary choices in rural farming communities.

2.4 Bushmeat and Animal Source Foods

The nutritional importance of animal source foods (ASF) is widely acknowledged. ASFs are especially important for micronutrient deficient young children, whose growth and cognitive development, and thus life-long potential, can be improved though sufficient ASF consumption (Murphy and Allen 2003). In many rural settings, especially in areas with significant forest cover, bush meat provides much of the ASF consumed (Fa, Currie and Meeuwig 2003; Nasi et al. 2008). "In rural areas of the Congo Basin, five to six million tonnes of bush meat are harvested each year and account for up to 80 percent of the fats and proteins consumed by local communities" (Nasi, Taber and Vliet 2011). Data from Madagascar have shown that the loss of access to wild bush-meat would result in a 29% increase in the number of children with anemia (Golden et al. 2011).

In western Panama, agricultural areas within a forested landscapes, were found to be an equally important source of bush meat as natural forests (Smith 2005). The study described how each different land use (fallows, fields, shifting cultivation, and forests) make a unique contribution to the access to different species of bushmeat: highlighting the importance of integrated landscape approaches for both research and conservation. In many contexts hunting is pursued both as a source of meat and to reduce pest damage to agricultural crops (Powell et al. 2010) and thus has a dynamic role in local food and agricultural systems. Sustainability is an important aspect of the role of wild ASF in nutrition and nutrition-sensitive food systems, especially in the face of population growth (at least for mammal and bird species) (Nasi et al. 2008; Powell, Hall and Johns 2011). While the populations of many species plummet under even moderate hunting pressure, some smaller species have been found to be more resilient, although in high human population-density contexts all hunting may be unsustainable (Arnold 2008; Nasi et al. 2008; Nielsen 2006; van Vliet et al. 2010).

In rice-based aquatic agricultural systems, wild biodiversity is an important source of wild foods such as fish, crustaceans and insects which can improve the nutritional content of the food system (Halwart 2006). The role of fish in nutrition and micronutrient supply is well established (Kawarazuka and Béné 2011). In areas where fish are an important source of ASFs, forests—especially mangroves—support the healthy aquatic ecosystems necessary to maintain fish stocks. In many topical forests, fish (most often procured from local rivers) represent the main ASF in the diet (in the Amazon (daSilva and Begossi 2009), in Laos (Powell et al. 2010)). In Rio Negro (the Brazilian Amazon) da Silva and Begossi (2009) found that fish (caught in flooded forests and forest rivers) accounted for 70% of the animal protein in

[2] Social marketing has seen success when applied to other health messages (seatbelt wearing, condom use, iron supplementation and has significant potential of the promotion of traditional fruits and vegetables given their inherent cultural value.

the diet, not including other aquatic species such as turtles which were also important in certain seasons.

The nutritional importance of forest insects has also recently (re)gained attention, highlighted in work by the FAO (FAO 2013). Many forests are managed by local people to enhance the supply of edible insects (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). Although based on limited nutrient composition analyses, the potential nutritional quality of insects is promising (Schabel 2010). Caterpillars are reported to be rich in vitamin B6 and avian brood rich in vitamin D (Schabel 2010), understudied nutrients that could otherwise be deficient in diets lacking other ASFs.

2.5 Social and Cultural importance of Traditional Foods and Local Food Systems

Local, or what are sometimes called "traditional", food systems include culturally important and locally available foods, the technologies needed to obtain, process and prepare those foods, and the associated social and cultural characteristics, beliefs and practices, including traditional knowledge (Kuhnlein and Receveur 1996). Traditional food systems are defined by both the natural and social, economic and cultural contexts in which they occur (Kuhnlein 2009); in forest areas, forests are a central aspect of traditional food systems. Food is a central part of individual, social and cultural identity: "Food makes the eater: it is therefore natural that the eater should try to make himself by eating", or in anthropologist Levi-Strauss's words "A society's cookery is the language into which it translates its structure" (Fischler 1988: 282). These social and cultural characteristics of food traditional food systems, contribute to the social, cultural, emotional, mental and spiritual aspects of well-being (Kuhnlein 2009; Kuhnlein and Receveur 1996).

Although income has been linked to improved food security and higher micronutrient intake at multiple scales (FAO 2012), the process of transitioning from traditional diets to diets with more purchased foods has been found to have quite negative impacts on the nutritional quality of diets and indigenous people's health (Dounias and Froment 2006; Dounias et al. 2007; Kuhnlein 2009; Kuhnlein and Receveur 1996). Dietary transitions away from local, unprocessed foods towards more processed foods, higher in refined sugar, salt and fat and lifestyle transitions associated with urbanization and decreasing physical activity are linked to a nutrition transition and increasing rates of obesity, and associated epidemiological transition and climbing rates of chronic nutrition-related diseases such as diabetes mellitus type II (Popkin 2001; Popkin 2004). In many contexts, obesity rates are climbing while micronutrient deficiency rates remain unimproved leading to a double burden of nutrition (Doak et al. 2005). The maintained use of healthy traditional food from forests and traditional agricultural systems may help to mitigate these transitions.

3. Fuelwood: an Essential Component of most Rural Food Systems

Over two billion people depend on fuelwood for their energy needs, particularly those in developing countries. In Africa fuelwood is often the only available and affordable source of energy and accounts for almost 90 percent of primary energy consumption (FAO 2010). Fuelwood is needed to cook foods that, in some cases, would otherwise be inedible or unpalatable. Fuelwood scarcity can affect cooking practices and dietary choices; it can result in skipping meals; and avoidance of foods which are particularly fuel demanding (Brouwer et al. 1996; Brouwer, Hoorweg and Van Liere 1997; Wan, Colfer and Powell 2011). Issues of fuelwood access and use, must be included in agricultural systems and planning – poor access to cooking fuel can mean that household resources, in terms of either time or money, are spent to procure fuel rather than healthy and nutritious food. Fuelwood scarcity can exacerbate gendered imbalances in workloads, leaving women with less time for child care, less time to engage in productive and income generating activities and exposing them to health risks (Wan, Colfer and Powell 2011). Careful attention to the species of fuelwood available (from farms, agroforests and forests) will help ensure access to those that are more efficient, produce less smoke, produce less toxic smoke thereby not only reducing the amount of work needed to collect fuelwood but decreasing the risk respiratory tract infection for those involved in cooking (Wan, Colfer and Powell 2011).

4. Forests and Trees for Income Generation

There is strong evidence that as national incomes increase, rates of undernutrition fall. Income is clearly an important factor contributing to falling global rates of undernutrition (FAO 2012). Increases in income has the potential to enhance access, through purchase, to a wide range of health foods. However, economic growth has been called a “double-edged sword”, because while undernutrition rates decline, overnutrition and obesity rates almost always increase (Ruel and Alderman 2013). Economic growth needs to be guided towards investment in policies that work: it needs to be nutrition-sensitive (Ruel and Alderman 2013; Thompson and Amoroso 2013). Forest income contributes about 1/5th of the income of rural households in developing countries (data from a sample of about 8000 households from 24 developing countries across Asia, Africa, and Latin America) (Angelsen et al. forthcoming). Forest incomes can be diverse, including: the sale of firewood, charcoal, timber, crafts and tree products such as fruits, oils, nuts, medicines, vegetables, employment in forest related industry such as timber, and the sale of agricultural produce produced under agroforestry systems (coffee, cacao, rubber, etc). Agroforestry have been shown to make important contributions to farmer’s income and well-being across a diverse range of settings (Garrity 2006; Thorlakson and Neufeldt 2012; Verchot et al. 2007). Jamnadass and colleagues (2011) note that in Africa, domestic markets for fruit are predicted to grow rapidly in the next two decades with increasing urbanization and as economies grow and provide local consumers more income to spend on fruit. The potential incomes for African farmers provided through supply for domestic markets for fruit is in the order of hundreds of millions of US Dollars annually. They also note that in order for local farmers to benefit from these expanding markets, many bottle-necks

need to be addressed, including improving market value chains to bring greater benefits to producers is needed.

Not enough is understood about how income from forests is used, including if it can translate into improved food and nutrition. In some indigenous and remote populations, increases in income has been associated with dietary and nutrition transitions associated in increased rates of obesity (Ibarra et al. 2011). Health and nutrition policy and other structural and environmental determinates may be stronger determinates of health and nutrition outcomes than income (Black and Macinko 2008; Glanz et al. 2005; Ickowitz 2011). Whether forest income is associated with increased expenditure on nutritious foods, may be linked to gender equality in access to and benefit from forest income (Holding 2013). Research has shown that women spend money under their control differently than do men: with women tending to spend more on food and health (Blumberg 1988; Hoddinott and Haddad 1991; Kabeer 2003; Katz 1994). In Guatemala, increases in women's income from the introduction of non-traditional export crops, such as broccoli and snow peas, had twice the impact on food expenditure than increases in men's income (Katz 1994). In addition, children from homes where women earned a larger percentage of the family income had better nutritional status (Engle 1993). The importance of ensuring that forest and tree related economic development translate into improved nutrition is especially pertinent in the current context of increasing commoditization of forest through payment for environmental services (PES) schemes such as REDD+. It is essential that we ensure that forest related economic development is nutrition-sensitive.

5. Forests, trees and biodiversity for nutritional resilience

Biodiversity from across the agricultural system landscape (including forests) is important for the nutritional resilience of local people in the face of social, economic and environmental change. Forests and trees on farms may be particularly important to poor people in developing countries for coping with *cyclical* and *transitory* shortages (seasonal variation, drought, illness and other external shocks) (Arnold 2008). Indigenous tree species are particularly adapted to local climates and often more resilient in the face to local climatic extremes.

5.1 Wild foods in times of crisis: "famine foods"

The 'safety-net' function of wild food has been noted previously (Colfer 2008; Humphry et al. 1993). In Niger, 83% of informants reported increased reliance on wild foods during drought (Humphry et al. 1993). In the East Usambara Mountains (Tanzania), wild foods were consumed more frequently in the wet (food insecure season) than the dry (Powell et al. in press). Moreno-Black and Somnasang (2000) reported higher wild food usage in Thailand in the dry season (when wild foods were less available) but food insecurity is highest. All these findings suggest that wild and forest foods are important as a source of resilience in the food system.

5.2 Agroforests and Agrobiodiversity for Nutritional Resilience

Agroforestry, the integration of trees with annual crop cultivation, livestock production and /or other farm activities, is a series of land management approaches practiced by more than 1.2 billion people worldwide (Garrity 2004). Agroforestry systems may range from open parkland type assemblages to dense tropical-rainforests-like tree gardens, with different levels of human management of the various components. Based on a geospatial analysis of remote sensing derived global datasets, Zomer *et al*. (2009) estimated that 560 million people, including many small-scale farmers in the tropics, live in farm landscapes that have more than 10% tree cover. The cultivation and management of trees by smallholders in agroforestry systems can provide a variety of products, some of which enter local, national and international markets, while others meet subsistence needs. Challenges that agroforestry can help address include: the limited agricultural productivity of staple crops due to soil fertility depletion; the loss of biodiversity through forest cutting and degradation; anthropogenic climate change resulting in global warming and increasingly variable weather conditions and extreme weather events; restricted fuel availability meaning poor communities do not have access to their energy needs for proper development; and the poor dietary intake in poor communities (Snelder and Lasco 2008).

The diversity and ubiquity of products and services provided from agroforests, and the diverse pathways by which they impact on peoples' lives, provides substantial resilience for local farmers (e.g. (Shackleton et al. 2007; Shackleton, Delang and Angelsen 2011)). For example**,** In Indonesia diverse rubber agroforests, though less profitable than mono-specific plantations under normal circumstances, provided livelihood security when the prices of rubber decreased in the international market in late 2008 by offering an alternative source of income from secondary products (e.g. fruit) (Feintrenie, Chong and Levang 2010; Feintrenie and Levang 2009). Exotic and indigenous fruits can provide an emergency food during the hunger periods in the agricultural cycle. A study in Malawi, Mozambique and Zambia revealed that 26-50% of rural households relied on indigenous fruits as a coping strategy during critical seasonal hunger period which usually lasts for three to four months per year (Akinnifesi et al. 2004). Studies in Zimbabwe revealed that improvements in tree yield and earlier fruiting of certain fruits created incentives for farmers to cultivate indigenous fruits on their farms (Mithöfer and Waibel 2003). The same authors reported that the household's vulnerability to hunger and poverty can be reduced by 33% during the critical period that occurs between August through March. The studies revealed further that households used indigenous fruits to diversify their diets and income, particularly in the critical time when income is generally low, and when agricultural labour demands are high (Mithofer 2005). Diverse 'Fruit tree portfolios', combinations of species that fruit in different months, provide important nutrients throughout the year, including at times when micronutrient intake are lowest (Akinnifesi, Leakey and Ajayi 2008; Fukushima et al. 2010; Vinceti et al. 2013).

Homegardens are a common agroforestry system that include tall trees intercropped with shrubs and annual crops in close proximity to homesteads. Because of the high diversity of plant species that exist in many homegardens they can provide many products and services, often with relatively low labour, cash or other external inputs (Kehlenbeck, Arifin and Maass 2007). Food products from homegardens often compliment staple crops from fields and, due to the close proximity to the home, provide easy

access to nutritionally important foods. Both the presences of a homegarden, and the diversity of homegardens, have been linked to improved nutrition and nutrient intake (Eyzaguirre and Linares 2010; Jones et al. 2005; Tontisirin, Nantel and Bhattacharjee 2002). Homegardens fulfill not only important nutritional and ecological, but also many social and cultural functions as well.

6. Forests and Trees for Ecosystem Services

The Millennium Ecosystem Assessment (MEA) (2005) laid out a diverse set of Ecosystem Services provided by biodiversity (such as soil, nutrient, water regulation, pollination, genetic resources, etc.). With tropical forests being the home to much of the world's biodiversity, they are important providers of these services on a global scale. While all of the ecosystem services listed in the MEA have important repercussions for human health, the loss of some would have significant impacts on the ability of agricultural systems to provide nutritious diets at both local and global scales.

Gallai et al. (2009) report that vegetables and fruits are the leading crop categories dependant on insect pollination services. The majority to the global supply of vitamin C, vitamin A (RAEs), calcium and much of the folic acid comes from animal / insect pollinated crops (Eilers et al. 2011). Findings by Ickowitz et al. (2013) and Powell (2012) linking tree cover to greater fruit and vegetable consumption may be due to the fact that local people are consuming fruits and vegetables from trees, but could also be due to the ecosystem services that trees and forests within agricultural systems provide. Areas with greater tree cover could also be providing microclimates that support the growth of both wild and cultivated vegetables, thus supporting greater availability of vegetables, with a particular seasonal effect.

Local varieties of crops and crop-wild-relatives maintained in biodiverse agricultural systems and forests represent significant store of genetic resources. The manipulation of tree and other species through selective management by humans over several millennia has likely enhanced many desirable genetic traits found in useful tree species around the world. The impact of the loss of these resources may not be immediate but could be potentially severe; reducing the global capacity for bio-fortification to contribute to reductions in micronutrient malnutrition around the world, as well as the potential for plant breeding to produce new crop varieties needed for agricultural systems to adapt to global climate change. Biodiversity holds the genetic material needed for future innovation and adaptation (Frison, Cherfas and Hodgkin 2011; Hajjar, Jarvis and Gemmill-Herren 2008; Toledo and Burlingame 2006).

Trees in forested and farm landscapes can also play an important part in maintenance of soil fertility. Without major efforts to reverse current unfavourable trends in agricultural productivity, the prospects for meeting staple crop demand in many parts of the tropics are bleak due to a rapid decline in soil fertility. Planted trees also reduce erosion and soil runoff. Integrated soil fertility practices using agroforestry have been shown to increase crop yields substantially. One of the most common practices is using fodder trees to support animals needed for the production of manure (often through zero-grazing techniques). Livestock keeping simultaneously provides manure needed to enhance soil fertility and milk and meat for human consumption and therefore the nutrition-sensitivity of the food system.

The repercussions of the loss of water services are less specific to nutrient-dense foods, but can have significant implications for agricultural productivity in general and therefore staple food availability and income (Hajjar, Jarvis and Gemmill-Herren 2008; Jackson, Pascual and Hodgkin 2007). However the importance of water provisioning services from forests for nutrition become apparent in the context of the well-established links between nutrition and infection (Semba and Bloem 2008). For example there are important links between vitamin A and infection (including diarrhoea, and intestinal parasites), iron and infection (particularly malaria), zinc and immunity and the impact of intestinal parasites and schistosomiasis on the status of multiple micronutrients (Semba and Bloem 2008). Because of this, children's growth (stunting – a measure of growth failure that compares a child's height and age against standard WHO growth curves) is more strongly associated with infection rates than dietary intake in some contexts (Allen 1994; Dewey and Mayers 2011). Easy and reliable access to clean drinking water is another aspect of nutrition-sensitive food systems to which forests and trees make an important contribution.

7. Forest, Agroforests and Tree Products in the Global Food System

BOX 1: The Importance of Trees in Global Fruit Supply

53% of the edible portion (in weight) of fruits produced globally comes from trees

To support our arguments in this paper, we used FAOSTAT data for global production of crops (in tonnes, for 2010) and the USDA's percent refuse information for fruits to calculate the edible portion produced globally for each of the 30 most important (in terms of value) fruits listed in the FAOSTAT data set and calculate the percent of the global fruit supply produced by trees. We acknowledge that this is a very rough estimate, most lemons and cranberries produced globally are used for juice and classification of tree and non-tree depends on the variety for fruits (e.g. many commercial quince, apple and peach varieties are very short). We assumed that proportion of the edible portion of fruit produced that is actually consumed is not different for tree vs. non-tree fruits.

The top 30 fruits included 20 tree species [Apples, Apricots, Avocados, Cashewapple, Cherries, Dates, Figs, Grapefruit (inc. pomelos), Kiwi fruit, Lemons and limes, Mangoes (and mangosteens and guavas), Oranges, Peaches and nectarines, Pears, Persimmons, Plums and sloes, Quinces, Sour cherries, Tangerines (incl. mandarins, clem.)] and 10 non-tree species [Bananas, Papayas, Blueberries, Cranberries, Currants, Grapes, Other melons (inc.cantaloupes), Pineapples, Raspberries, Strawberries, Watermelons]. The data indicate that trees produce more than the 50% of the fruit consumed globally. Because of the nutritional importance of fruits, tree-based cropping systems need to be given greater attention to ensure the nutrition sensitivity of the global food system.

The importance of fruits and vegetables for nutrition and other health outcomes is increasingly recognized (Ruel, Minot and Smith 2005; WHO and FAO 2004). As forests and agroforests are essential for the production of these under-consumed and nutritionally-important foods, the maintenance of

forms of agriculture that include trees within large agricultural systems will be essential to ensure a nutritionally sound and nutritionally balanced global food system (see Box 1). It will also be essential to develop nutrient- sensitive value chains for important tree and forest products to ensure that they reach distant consumers while remaining affordable for everyone and retain their nutritional value throughout post-harvest handling and value addition (storage, preservation, processing and transportation).

8. Conclusions

Food and agricultural systems are defined not only by their environmental context but by social, cultural and economic contexts (Kuhnlein 2009; Kuhnlein and Receveur 1996). Diverse aspects of the food system interact in complex ways to mediate individual nutrient intake including: income and market integration, education and local knowledge systems, social and cultural beliefs and practices, biodiversity and environment. Recent years have seen increasing commitment to reducing malnutrition around the world (for example from the World Health Assembly's target for reducing the number of stunted children), however, to meet these targets "the world's leaders will need to prioritize an innovative science-based marriage of nutrition and agriculture" (Swaminathan 2012). The increasing acceptance for an integrated landscape level approach to conservation, signals the readiness of conservation researchers and practitioners to engage with efforts to improve food security and nutrition globally – to seek innovative ways to enhance the nutrition-sensitivity of landscapes that include both forests and farms. Given the importance of nutrition for the achievement of other health and development outcomes (UN-SCN 2004), it will be essential that landscape management and land use planning seek to optimize nutrition, not just staple crop production and biodiversity conservation.

Fuelwood access must also be included in agricultural system and landscape planning – poor access to cooking fuel can mean that household resources (either time or money) are spent to procure fuel rather than healthy and nutritious food.

Maintenance of biodiversity, forests and forest patches, tree cover and agroforests within agricultural systems are essential and often overlooked aspects of the sustainability of all agricultural and food systems. The role of wild biodiversity and forests in maintaining sustainability, resilience and dietary diversity in nutrition-sensitive agricultural systems must not be overlooked. Johns et al. (forthcoming, 2013) note: "Making food systems simultaneously productive, nutrition-sensitive and sustainable within integrated global, national and local responses poses a major challenge in policy and practice." Although trees and forests may have a limited role in enhancing agricultural productivity, their role in sustainability is well established, and emerging evidence indicates they also make important contributions to the nutrition-sensitivity of both local and global food systems and merits further attention.

9. Recommendations

- Make landscapes and food systems more nutrition-sensitive and enhance the nutritional resilience of local communities and the growing global population

- Ensure nutrition and food security become a greater priority for those working in forestry and conservation (Promote research into the relationships between forests, trees, food security and nutrition. Ensure that those working on forest governance and land use policy examine their work though a nutrition-sensitive lens)
- Forestry and conservation practitioners have an important role in the health and food security of rural communities: they often work with remote areas, with communities who may not have access to other sources of information on health, nutrition and food security. (Develop curricula on food security and nutrition for forestry and conservation students)
- Enhance the understanding of the importance of forests, trees and biodiversity for ecosystem services and sustainability of food and agricultural systems. Disseminate this knowledge widely so that agricultural programmes and policy are broadened from the traditional focus on yield to include greater attention to sustainability. Also, the proximity requirements to maximize the contributions of forests to agricultural production and sustainability are not well understood and deserve further research
- Because of the nutritional importance of fruit and the fact that more than 50% of the fruit in the world come from trees, tree-based cropping systems need to be given greater attention to ensure the nutrition-sensitivity of the global food system. Post-harvesting processing and market chains for nutritionally important food such as vegetables, fruits and other tree products need to be given equal or more attention as less nutrient-dense crops such as grains. We need to seek ways to reduce the cost of fruits and vegetables relative to other foods to provide better purchasing incentives
- Dietary choices, especially fruit and vegetable consumption are in determined in part by structural and environmental factors. In rural areas of developing countries, proximity to tree-based agricultural systems (including home gardens) and forests has been linked to increased consumption of fruits and vegetables and nutritious foods. The impact of land use, conservation and agriculture and food security planning and policy on the structural / environmental constriants on dietary choices and the food environment must be considered. Reduced access to forest and tree foods may alter dietary decision making in unexpected ways, even if equivalent food items are available, accessible and affordable in local markets
- Seek a better understanding f how income from forest resources and activities is spent so as to inform policies and interventions to help ensure that increases in income contribute to improved nutrition
- Fuelwood access must be included in agricultural systems and planning – poor access to cooking fuel can mean that household resources (either time or money) are spent to procure fuel rather than healthy and nutritious food
- Promote integrated landscape level approaches to better achieve conservation, livelihoods, food security and nutrition goals across the landscape, build on synergies between goals and incorporated nutrition into land use policy and decision making

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