DISCUSSION PAPER

Food security and nutrition

The role of forests

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Cover photo by Terry Sunderland
Transporting bush mango seeds (*Irvingia gabonensis*), Ekuri, Cross River State, Nigeria

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Executive Summary

With a growing global population, much of the current discourse on food security is focussed on increasing and expanding agricultural production. Much of this expansion is speculated to be at the expense of natural systems. However, some suggest that we already grow enough food and food scarcity is primarily caused by inadequate distribution, a lack of purchasing power and other non-productive causes. Thus the emphasis on production alone is not sufficient to guarantee future food security.

Forests and tree-based agricultural systems contribute directly and indirectly to the livelihoods of an estimated one billion people globally. Wild foods are important for food security and nutrition while trees and forests are vital for their role in the provision of ecosystem services to agriculture. The alarming expansion of large-scale industrial production systems in tropical regions threaten the contributions of forests and tree-based agriculture systems to food security, diets and nutrition in the tropical regions of the world in particular may threaten the potential contributions of forests to the food security, diets and nutrition of a growing world population. Despite this, the role of forests in supporting human food security and nutrition remain largely under-researched and understood. With food security and nutrition high on the agenda in many political and scientific spheres, it is crucial to understand the contribution of forests and trees to a food secure and nutrition-sensitive future. This improved understanding will be essential for building on synergies and minimizing trade-offs between biodiversity conservation and sustainable agriculture in order to feed an estimated global population of nine billion people by 2050.

Although existing evidence is limited, a considerable body of work suggests that forests support both food security and contribute to improved nutrition across the globe. Wild fruits and vegetables are a crucial source of micronutrients in many rural and smallholder communities, and often provide a major contribution to cash income at the household level. Bushmeat and fuelwood for subsistence and income generation contribute both directly and indirectly to food security and nutrition in sub-Saharan Africa, South-East Asia and Latin America. There is now an urgent need for research that can provide broader perspectives and allow of cross-site comparisons of the contributions of forests and tree-based agricultural systems to food security, livelihoods, healthy diets and nutrition.

In addition, evidence is required on the contribution of forests based ecosystems service in order to ensure forests and biodiversity conservation remains on the agenda of policy makers and practitioners in conservation, agriculture and nutrition. The dearth of empirical descriptions and quantification of ecosystems services to agriculture limits the inclusion on initiatives related to the sustainable intensification of agriculture for example and in depth studies could contribute to a better understanding on the trade-offs between land sharing and land sparing as strategies for future food production.

We believe that forests, biodiversity conservation and agro-ecology should feature prominently in political and scientific discourse on agricultural production and the concomitant challenge of sustainable forest management. Greater attention to the direct and indirect benefits of forest in food security, livelihoods and nutrition should enhance local and global efforts to end hunger and improve the nutrition of communities living in forested areas as well as those living in areas removed from forests.

1. Background

Current estimates suggest a 100% increase in food production that will result in the conversion of roughly 1 billion ha of land by 2050 (Tilman *et al.* 2011). Much of this agricultural expansion is speculated to come at the expense of natural systems, including forests and other tree-based systems, despite the current pervasive paradigm of intensification to "spare" land from conversion (Phelps *et al.* 2013). Although other studies assert that agricultural production is already sufficient to achieve global food security and we grow enough food to provide for current and future populations at estimated human growth rates, thus there is little need to convert forests and other land for agriculture (Stringer 2000), the view that increased food production should be pursued at all costs including at the expense of nature as the only means of achieving global food security seems to be the currently accepted wisdom (Pinstrup-Andersen 2013).

However, forests and tree-based agricultural systems make essential contributions to human livelihoods and well-being through both the provision of direct and indirect ecosystem services (Arnold *et al.* 2011; Hoskins 1990). Forested landscapes and other areas with tree cover provide many wilds foods which, although making a limited contribution to overall energy, or calorie, intake, contribute to overall food security by ensuring dietary diversity and micronutrient intake. The essential ecosystem goods and services provided by forests and trees needed for productive and sustainable food and agricultural systems are also often overlooked in agricultural research, policy and practice. It is estimated that forests and trees contribute in some way to the basic livelihoods of up to one billion people (Agrawal *et al.* 2013). A recent global comparative study of rural incomes implemented by CIFOR and its partners demonstrated that forests and the wider natural environment provide up to one fifth of incomes to households in their vicinity[1].

With food and nutrition security currently prominent in terms of global development priorities, it is therefore important to fully comprehend the role of forests and trees in food and nutrition security. Often, however, food security is measured solely in terms of food energy, or calorie, production, losing sight of the fact that, by definition, food security includes secure access to the foods needed for a nutritionally balanced diet2. Thus the contribution of forests and tree based ecosystem services to food security is often overlooked when food security is operationalized as access to calories alone. As such, the focus on energy production has contributed to a dichotomization in which food production and forest management and conservation are portrayed as mutually exclusive. It has been argued that the clear disaggregation of biodiversity conservation and agricultural production has been an impediment in achieving optimised outcomes for either (Sunderland 2011).

1.1 Direct Provisioning for Food and Nutrition Security among the Rural Poor

Earlier work on direct benefits of forests to food security were coined in physical and economic terms (Hoskins 1990). Physical benefits were focussed on the provision of fruits, vegetables, and bushmeat whereas economic benefits included fuelwood. Obviously the boundaries of these categorisations continue to be debated (de Merode *et al.* 2004). The direct contribution of forests to diets is considerable and often crucial, if often overlooked. For instance, data show that approximately 4.5 million tons of bush meat is extracted annually from the Congo Basin forests alone (Nasi *et al.* 2011). The use of wild fruit and vegetables is also widespread around the world, particularly in complex landscape mosaics that include significant forest cover (Jamnadass *et al.* 2011).

Micronutrient Intake and Dietary Diversity

Micronutrient deficiency is often referred to as the *hidden hunger* because it can, and often does, occur even when the diet contains an adequate amount of energy (FAO 2012). While it is currently estimated that 868 million people do not have access to sufficient calories, estimates for the number of people who are micronutrient deficient are more than twice that, at over 2 billion people (FAO 2012). Iron, vitamin A, iodine and zinc are the micronutrients most commonly deficient in diets around the world.

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1 http://www.cifor.org/pen/

2 The internationally accepted definition of food security adopted at the World Food Summit in 1996: "*Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life*" Pinstrup-Andersen, P. 2009. Food security: definition and measurement. *Food Security* 1:5-7.

There are 2 billion anaemic people in the world (<30% of the global population), largely due to deficient iron intake (WHO 2012). Even mild iron deficiency can impair growth and cognitive development, school performance, work productivity and increase maternal mortality (UN-SCN 2004). The best dietary sources of iron include: animal source foods (meats), legumes, leafy greens, fish, and fortified cereals.

Vitamin A is the next most common micronutrient deficiency worldwide. Over 250 million preschool aged children are estimated to have vitamin A deficiency (WHO 2012) which causes up to 500,000 children to go blind each year. Because vitamin A plays an essential role in the human body's immune response, of the children who go blind, half of them die within the next 12 months. Even mild vitamin A deficiency is associated with significantly reduced immunity and higher rates of infection (diarrhea, measles, respiratory tract infections, etc.) (UN-SCN 2004; Underwood 2004). Good dietary sources of vitamin A (and vitamin A precursors such as beta carotene) include: leafy greens, orange vegetables (carrots, sweet potato, pumpkin), orange fruit, and dairy products (including human milk).

Much less is known about global rates of other micronutrients such as zinc, which is also linked to immune function and children's growth (Hotz and Brown 2004). This lack of knowledge, combined with the fact that multiple micronutrient deficiencies often occur simultaneously has led to increasing interest in dietary diversity as a measure of diet quality and proxy for overall micronutrient intake (Arimond and Ruel 2004; FAO 2012; Kennedy *et al.* 2011; Ruel 2003). Individuals scoring poorly on dietary diversity scores have often not consumed sufficient animal source foods, fruits, vegetables and legumes (Daniels *et al.* 2007; Moursi *et al.* 2008; Powell 2012). The importance of these types of food for micronutrient intake helps to explain why dietary diversity scores are usually associated with better nutritional status (Kennedy *et al.* 2011).

Wild foods obtained from forested landscape mosaics are most often vegetables, fruit and animal source foods (Powell *et al.* in press; Vinceti *et al.* 2008). Because these types of foods are often good sources of micronutrients, demanding few resources in terms of time and cash, with the highest nutrient density, it is not surprising that a number of studies have funds that wild foods make important contributions to the intake of many micronutrients. In a case study from Tanzania, wild foods obtained from a forest-farm landscape mosaic contributed 31% vitamin A, 26% iron and 23% calcium (Powell *et al.* in press). The same study found that wild food contributed 15% of the diversity in the diet and that tree cover was positively correlated with dietary diversity (Powell *et al.* 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 into adolescence. In DRC, those individuals who had consumed wild plant foods had traces of more vitamin A and more calcium than those who had not (Termote *et al.* 2012). Ickowitz *et al.* (2013) have found that across Africa, children's dietary diversity increases with tree cover for the majority of the population.

Fruits and Vegetables

Fruit and vegetable availability and intake are well below WHO recommendations in most countries (WHO and FAO 2004). Globally, insufficient intake of fruit and vegetables has been linked to 2.7 million deaths per year (WHO 2003), due to associations between fruit and vegetable intake and: micronutrient intake, risks of ischaemic heart disease and stroke as well as risk of type 2 diabetes mellitus (WHO and FAO 2004). Fruits and vegetables are important sources of vitamin A, vitamin C, folate, and phytochemicals. Although minerals are less bioavailable in plant foods, vegetables provide a large proportion of minerals such as iron and calcium consumed in rural populations in developing countries. In the Mekong Delta of Vietnam wild vegetables contributed 38% of vitamin A, 35% of vitamin C, 30% of calcium and 17% of iron consumed by women (Ogle *et al.* 2001a). In the same populations, all vegetable accounted for up to 33% of folate consumed (Ogle *et al.* 2001b). In the East Usambara Mountains (Tanzania), vegetables contributed 35% of vitamin A, 26% of iron, 23% of calcium, 22% of vitamin C and 13% of folate consumed by children aged 2 to 5 years and their mothers during the wet season, a period of food insecurity. The amount of vegetables consumed was found to be the best predictor of over-all nutrient adequacy across multiple nutrients (Powell *et al.* 2012).

There is emerging evidence of a link between tree cover and fruit and vegetable consumption. Initial evidence suggests that forests and areas with tree cover may play an important role in enhanced vegetable access and production among small-holder farmers, at least in Africa. Research undertaken by

CIFOR found that across 21 African countries, there is a statistically significant and non-linear relationship between tree cover and fruit and vegetable consumption which peaks at around 53% tree cover (Ickowitz *et al.* 2013). In the East Usambara Mountains, Tanzania, in the dry season, having tree cover within 2km from the home was associated with enhanced vegetable consumption (Powell *et al.* 2012). Forests and areas with tree cover may enhance vegetable intake by providing vegetables in the form of leaves and fruit from trees, but possibly also through the ecosystem services provided by trees and forests within agricultural systems likely support availability of wild and cultivated vegetables by providing the microclimates needed for vegetables to grow and other ecosystem services (WHO and FAO 2004).

Bushmeat

Data show that approximately 4.5 million tons of bush meat is extracted annually from the Congo Basin forests alone. Fallow forests play critical function in the food and dietary security of millions of rural families in Amazonia (Börner *et al.* 2007). Because animal source foods are good sources of highly bio-available micronutrients the nutritional importance of game species is widely acknowledged (Murphy and Allen 2003); in many rural settings bushmeat provides much of the animal source foods consumed (Fa *et al.* 2003; Nasi *et al.* 2008). This is particularly true in areas where livestock production is limited due to tsetse fly and other environmental constraints. Data from Madagascar have shown that the loss of access to wild bushmeat would result in a 29% increase in the number of children with anaemia (Golden *et al.* 2011).

While the process of defaunation is leading to a decline in the population of large game species, small game species are increasingly managed by Amazonian farmers in fallows and forests. Currently, small-game species, primarily managed by women and children, constitute the main source of protein for rural families and the relatively small amount of bushmeat from large game species are hunted by men and are sold in the market. Similarly bushmeat hunted from agricultural lands was found to an important source of food and nutrients for rural households in western Panama (Smith (2005). Each different land use makes a unique contribution to the access to different species of bushmeat: highlighting the importance of integrated landscape management and approach.

Mitigating a Nutrition Transition and Double Burden of Nutrition

There are now over 1.4 billion over-weight or obese people in the world (FAO 2012). Being overweight and obese are no longer ailments of the rich; in many developed countries they are increasingly associated with lower socio-economic status. Likewise in many developing countries, the same populations that have not yet overcome under-nutrition are now faced with increasing rates of obesity. In many settings, the lowest socio-economic groups now have the highest rates of obesity. There are increasing numbers of households with both: overweight or obese mothers, and stunted (with growth failure), micronutrient deficient children. This has been termed the *double burden of nutrition* (Doak *et al.* 2004). Bizarrely, this double burden can even be experienced within the same individual; in the United States overweight and obese children and adolescents are more likely to be anaemic than those that are of normal weight (Nead *et al.* 2004; Pinhas-Hamiel *et al.* 2003). This double burden of nutrition results from a *nutrition transition;* a shift away from traditional diets towards diets high in time-saving processed foods and diets higher in energy, fats and refined sugar (Popkin *et al.* 2001), as well as changes in physical activity levels. Nutrition transitions are inevitably associated with epidemiological transitions. For example, increasing obesity rates lead to increases in rates of type II diabetes mellitus, cardiovascular disease and other chronic diseases. There are now over 146 million people in developing countries alone who have diabetes (Yach *et al.* 2006).

The solution lies in food systems that make healthy nutrient dense[3] foods readily available and that minimize incentives to consume foods high in calories, fat, refined sugar (Drewnowski 2010). To mitigate nutrition transitions, populations will need to maintain their consumption of fruits and vegetables, many of which are traditional foods, without increasing their consumption of processed foods, fats and refined sugars (WHO and FAO 2004). Because of the essential contribution forests make in ensuring access to these traditional foods, they could play an important role in mitigating nutrition transitions and the resulting double burden of nutrition in developing countries. Avoiding the nutrition transition is yet another reason it is imperative to move away from agricultural policy that is too heavily focused on yield of staple crops.

3 More micronutrients per calorie of energy.

Fuelwood

Fuelwood is an essential, but often overlooked component of local food systems (Kuhnlein 2009). Deforestation combined with continued high demands for fuelwood in developing countries have resulted in a looming fuelwood shortage crisis in many areas (Arnold and Persson 2003; Knight and Rosa 2012). The Millennium Ecosystem Assessment estimated that more than half of the world's population relied on solid fuels for cooking and heating (MillenniumEcosystemAssessment 2005).

Fuelwood access contributes to food and nutrition security in a number of ways. Firstly, the collection of fuelwood can be very time-demanding. Time spent collecting fuelwood is time not spent engaging in agriculture or other income generating activities, not spent cooking and caring for children and not spent achieving full educational potential (education is strongly linked to household wellbeing, nutrition and food security). Even in areas with moderate fuelwood scarcity, women have been reported to travel over 10km to collect wood (Wan *et al.* 2011).

Secondly, the collection of fuel and water are energy demanding activities, possibly more so than most agricultural activities. In some areas with fuelwood scarcity, women have been reported to carry up to 70kg of wood (Wan *et al.* 2011). Rough energy expenditure estimates would suggest that an average fuelwood collection trip (a 55kg woman carrying 25kg of wood 4 km) requires over 1000 kcal, increasing a woman's daily food and energy requirements by 50% (e.g. (Panter-Brick 1993). Conversely, moderate physical activity associated with fuel, fodder and water collection can be part of a healthy and active lifestyle needed to prevent obesity and associated chronic diseases that rural women increasingly suffer from.

Thirdly, changes in access to cooking fuel is associated with changing cooking practices (Wan *et al.* 2011). Fuelwood scarcity can affect cooking practices and dietary choices including: skipping meals and avoidance of foods that are particularly fuel demanding (Brouwer *et al.* 1996; Brouwer *et al.* 1997; Wan *et al.* 2011).

1.2 Broader Ecosystem Services for Productive and Sustainable Agricultural Systems

More robust evidence is also needed for the contribution of forests to agricultural productivity and sustainability in general. We are only starting to understand the important roles of forests and trees for ecosystem services necessary to maintain agricultural productivity over the long-term and in the face of environmental and climatic shocks. Relatively little is understood about the impacts of agriculture on forests and other biodiversity systems and there is urgent need to identify landscapes and land use systems that deliver biodiversity, ecosystem services and productivity functions at the same time.

Ecosystem Services for Productive and Sustainable Agricultural Systems

Forests form a dwindling part of a finite land area where conversion to agricultural fields poses a major threat. If the result of the conversion is large-scale, intensive monocropping, this change presents significant challenges to biodiversity, including agrobiodiversity, conservation, to the continued supply of ecosystem goods and services, and thus to the long-term food security of rural and urban people alike. While cultivated cropland may retain trees or accommodate natural tree regeneration, these are generally insufficient to alone provide the environmental goods and services garnered from formerly intact or largely natural forests. And while conversion of forest to agriculture can in some cases improve rural incomes, all too often deforestation leads to impoverishment of both ecosystems and livelihoods in the long term. The loss of these environmental goods and services has implications for the food security of millions across the tropics (Arnold *et al.* 2011).

Some of the better understood ecosystem services essential to agricultural productivity and sustainability which are dependent, to a greater or lesser degree, on forests and biodiversity include: ecological processes such as the maintenance of watershed services, soil fertility, pollination, seed dispersal, nutrient cycling, and natural pest and disease control (Hajjar *et al.* 2008; MillenniumEcosystemAssessment 2005; Sunderland 2011). Wild relatives of today's crops, grow in forested or uncultivated areas within an agricultural landscape mosaic, and provide valuable genetic material essential for future crop breeding and innovation (Frison *et al.* 2011; Hajjar *et al.* 2008; Toledo and Burlingame 2006). The majority of today's modern crop and livestock varieties are derived from their wild relatives and it is estimated that products derived from genetic resources (including agriculture, pharmaceuticals etc.) are worth estimated $500 billion/annum (ten Kate and Laird 1999). Pollination is perhaps one of the best measured ecosystem services from forests and biodiversity (Garibaldi *et al.* 2011; Kevan and Phillips 2001). Gallai *et al.* (2009) report that vegetables and fruits are the leading crop categories in value provided by insect pollination services, which may help to explain emerging relationships between tree cover and consumption of fruits and vegetables; the majority of the global vitamin C, vitamin A (RAEs), calcium and much of the folic acid are supplied by animal (and insect) pollination dependent crops (Eilers *et al.* 2011).

Any reduction in forest quality or quantity can result in a loss or diminished supply of key agricultural inputs, meaning they have to be replaced or purchased elsewhere, which ultimately undermines net benefits to farming households. The maintenance of a certain proportion of forested lands is therefore good, even essential, for both smallholder agriculture as well as large-scale industrial production. Agricultural systems with a diversity of cropping and land-use types are also more resilient to extreme weather events caused by climate change (Brookfield *et al.* 2002). More robust evidence is also needed of the role of forests and their contribution to agricultural productivity, the impacts of agriculture on forests and other biodiversity systems and the identification of agricultural systems that deliver biodiversity, ecosystem services and productivity functions at the same time.

The importance of Landscape Level Approaches for recognizing the role of Forests in Food and Agricultural Systems

Zimmerer (2010) notes that several scales of analysis are needed to describe the ways biodiversity contributes to food security, and provides examples of the role of seed exchange across communities in supporting crop genetic diversity. Because food security is dependent on complex and intertwined issues of sustainability, availability, access, utilisation and diet quality, and not calorie intake alone, it is evident that new approaches are needed to feed the world's population both efficiently and equitably (Vinceti *et al.* 2012). Increases in food production over the past fifty years have been made largely at the cost of forest biodiversity and ecosystem service provision (Foley *et al.* 2005), yet there is considerable evidence that diverse agro-ecological tree-based systems can be equally, if not more productive in terms of actual yield (Rosegrant and Cline 2003; UNITED NATIONS 2011), notwithstanding the biodiversity benefits of such approaches (Brussaard *et al.* 2010). In order for this to happen, knowledge from forest/ecological science and agricultural research and development fields need to be systematically integrated. This provides a unique opportunity for forestry, agroforestry and agricultural research to coordinate efforts at the conceptual and implementation levels to achieve more sustainable, and integrated, agricultural systems.

1.3 Adaptation Food and Agricultural Systems to Climate and other Rapid Change

The safety-net function of biodiversity and wild foods is widely acknowledged, particularly during times of low agricultural production(Angelson and Wunder 2003; Karjalainen *et al.* 2010) during seasonal or cyclical food gaps (Arnold 2008; Vinceti *et al.* 2008) or during periods of climate induced vulnerability (Cotter and Tirado 2008). In Niger, 83% of informants reported increased reliance on wild foods during drought (Humphry *et al.* 1993). In Tanzania, wild foods made up a significantly larger percentage of the food items consumed during periods of food insecurity (Powell *et al.* in press). However the role of forests and trees in local people's ability to maintain an adequate diet and good nutrition in general and especially in the face of social, economic, environmental or climate change, remains poorly delineated.

Beyond the Safety–Net Function

Most estimates suggest that populations in areas which will face the most severe effect of climate change are also those who are least equipped to cope (Parry *et al.* 2005; Patz *et al.* 2005). Moreover, a larger proportion of these people live in under-developed tropical areas. The ecosystem services provided by forests and trees also act to protect households against climate change by reducing exposure and sensitivity to climatic variability (MillenniumEcosystemAssessment 2005). As populations around the world increasingly experience the impacts of climate change, we will need to employ all the strategies available to enhance their ability to adapt. It is thus essential that we collect a diverse set of case studies documenting how local communities draw on forest resources and ecosystem services during specific episodes of climate variability (early cropping floods, late cropping floods, landslides, hail, drought) in order to maintain their food and nutrition security. The ability to employ forest goods and services to support climate change adaptation would also be enhanced though long-term modeling of climate change scenario projections for net primary productivity (NPP), and specific crop suitability, and assessment of how present trends in government policies for land use change are likely to result in improved or reduced regional/national food self-sufficiency (Peng *et al.* 2007).

The contributions forests and trees make to income and livelihood diversity is potentially even more important during shocks. Typically, rural households employ diverse livelihood strategies, and so the maintenance of a variety of forest functions is very often an economic priority. Many case studies (Cotter and Tirado 2008; Herndon and Butler 2010; Rosegrant and Cline 2003; Walker and Salt 2006) have noted that rural communities turn to forest activities when other sources of income are restricted or curtailed or during the need for cash at the household level, e.g. medical or educational needs. Research on livelihood resilience and local people's coping strategies during times of economic or climatic shocks suggests that households use their assets to mitigate the impact of a shock on their food and nutrition security (Arnold *et al.* 2011). In rural communities, many such assets are derived from forests. In many parts of the world, livestock represent one of the most common and most valuable (and transferable) assets. In areas with forest cover, the maintenance of livestock is directly dependent on access to forest resources, either through grazing on communally or state owned forested land or though fodder collected from uncultivated areas.

Considerably more research is needed to understand the contribution of forests to livelihood diversity and how livelihood diversity influences other coping strategies such as migration. Migration is one of the most common, and oldest, coping strategies during periods of stress, such as food insecurity: a strategy with significant implications for future land use and biodiversity conservation. Recent work from Mexico suggests that out migration may have negative impacts on biodiversity conservation because rural depopulation could lead to the disintegration of community based forest management institutions and loss of traditional agricultural practices that maintain a diverse landscape mosaic (Robson and Berkes 2011a; Robson and Berkes 2011b).

1.4 Forest Governance, Forest Policy and Food and Nutrition Security as a Cross-Cutting issue in Capacity-building

Forest governance can have a major impact on local people's livelihoods and food security. The impact of factors such as unclear land tenure or insecure access rights to resources, poorly regulated extraction, trade and investment regimes, nonexistent or inchoate land use planning, a growing trend toward land grabbing, the progressive depletion of tree genetic resources and biodiversity, and the unequal distribution of economic and social benefits from forests, trees and agroforestry systems, on food security and nutrition need to be better understood. Conversely, discourse and rhetoric from food security and food sovereignty are increasingly used and manipulated to gain power and control over land use and land use policy, both by indigenous groups and by agri-business.

Forest and Land use Policy

In theory, the intensification of farming could spare land for biodiversity (Phalan *et al.* 2011). As crop productivity per unit of land is increased, less land will be required to supply a given level of harvest. This idea is supported by the observation that global agricultural output has increased by 140% since the 1960s for only an 11% increase in cropland area. In addition, countries with higher agricultural yields have lower deforestation rates. Some studies show reduced expansion of agricultural areas as crop yield increases. But, simply increasing yield has been shown to not necessarily reduce deforestation, particularly if farmers are responding to market opportunities. Local deforestation rates have been shown to increase in line with increases in commodity prices. In Africa, Asia and Latin America, forest loss increased between 2000-2005, while both the urban population and exports of agricultural products have grown (FAO 2011). The value of adopting land-sparing approaches will need to be assessed on a case-by-case basis. Alternative land-sharing schemes that incorporate forests, and agroforestry and that harbour significant biodiversity and offer substantial ecosystem services may offer more acceptable, sustainable, and equitable solutions in many areas.

Biofuel production is an important example of a recent shift in land use policy. Although primarily associated largely with tropical forests (e.g. the planting of oil palm in Indonesia), more resilient biofuels such as *Jatropha* have also resulted in large tracts of drylands that have been declared degraded and unfit for food production being set aside and converted for biofuel production (Wani *et al.* 2009). This has a direct impact on rural livelihood and food security of some of the dry tropics' most vulnerable populations, since land previously suited for food production is being converted for energy production. Changes in land use may result in changes in access and tenure with important implications for food security. For example qualitative work from Mali and Gambia (Schroeder 1993; Wooten 2003), report that transitions to commercially oriented vegetable horticulture, particularly of imported fruits and vegetables, led to a loss of land tenure by the women over of semi-wild communal land along streams where women traditionally collected and managed wild traditional vegetables. Although access rights may not lead to improved income, it could be an important prerequisite for food security and food sovereignty.

As discussed earlier, the value of ecosystem services to agriculture has largely been overlooked by policy-makers and the private sector. However, payments for ecosystem services (PES) such as carbon, water and some agro-environmental benefits are becoming more common, particularly in developed countries. Another example is China's 'Grain for Green' programme that aims to take steep slopes out of cultivation for reforestation (Peng *et al.* 2007; Xu *et al.* 2007). Agro-environmental schemes and PES could be further developed as a tool to contribute to both rural development and conservation of ecosystem services (Daily and Matson 2008; Pagiola *et al.* 2005). There is urgent need to better understand how the changing role of forests in livelihoods will affect local people's diets, food security and nutrition.

While REDD+ and other payment for environmental services policies will most likely lead to greater cash income for participating communities, it cannot be assumed that economic growth will always translate into better food security and nutrition[4]. Attention to food security and nutrition in REDD+ design and implementation is needed, as are case studies which look at the impact of existing PES on local diets and food security. One such case study from Mexico portrays a cautionary tale (Ibarra *et al.* 2011). If we are to stimulate policies that recognize the value of the services that forests provide to agriculture, we will need stronger documentation and new models of agriculture, agroforestry, and forest management. To fully value biodiversity and ecosystem services, we will also need ways of measuring and apportioning the costs and benefits of maintaining ecosystem services.

1.5 In summary

Although food security is dependent on issues of sustainability, availability, access and utilisation, and not production alone, it is evident that a "new agriculture" (Steiner 2011) needs to be found to feed the world's population both efficiently and equitably. Increases in food production over the past fifty years have been at the cost of biodiversity and ecosystem service provision, yet there is considerable evidence that diverse agro-ecological systems can be equally productive, if not more so in terms of actual yield outputs, notwithstanding the biodiversity benefits of such approaches. As such, the United Nations (2011) vision of an "agro-ecological" approach that combines biodiversity concerns along with food production and provides a more compelling vision of future food production. The integration of biodiversity conservation and agricultural production goals must be a first step, whether through land sharing or land sparing. However, conservation and restoration in human dominated ecosystems must strengthen connections between agriculture and biodiversity (Novacek and Cleland 2001). Managing landscapes on a multi-functional basis that combines food production, biodiversity conservation and the maintenance of ecosystem services should be at the forefront at efforts to achieve food security.

In order for this to happen, knowledge from biodiversity science and agricultural research and development need to be integrated through a systems approach. This provides a unique opportunity for forestry and agricultural research organisations to coordinate efforts at the conceptual and implementation levels to achieve more sustainable agricultural systems.

A clear programme of work on managing forest landscapes directly for food, but also indirectly for the biodiversity and ecosystem services that underpin sustainable food production, should be increasingly placed at the center of future development initiatives.

4 As noted in the 2012 FAO State of World Food Insecurity report titled: "Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition": http://www.fao.org/publications/sofi/en/

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