Contents

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Cover photo: Boys selling pods of *Parkia biglobosa* by the roadside on the Labe to Conakry road, Guinea (T.C.H. Sunderland)

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Mutually beneficial company-community partnership in ensuring its long-term viability: emerging lessons from Indonesia

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  Paper or chapter in proceedings
  SMITH, W.J. 2001. Selection of tree species for arid environments. In: BLACKBURN, J.W. (ed.) *Multipurpose trees and shrubs for fuelwood and agroforestry*. CNRD Monograph No4. 366 pp.

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Contents

EDITORIAL: Forests, biodiversity and food security

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Forests are a considerable source of biodiversity and, as such, are inextricably linked to people's food security, nutrition and health in a number of fundamental ways. While previous work has examined the links between forests and human health, much of the focus has been on the contributions of forest biodiversity to plant based pharmacopoeias, the correlations between forests and disease and more recently between forests and physiological well-being (Anyonge *et al.* 2006, Colfer 2008, Colfer *et al.* 2006, Karjalainen *et al.* 2010, Nilson *et al*. 2011, Olson *et al.* 2010, Wilcox and Ellis 2006). Building on existing work examining the relationships between forest, food security and human nutrition (Pimentel *et al*. 1997, Falconer 1990, Hoskins 1990, Johns and Maundu 2006, Vinceti *et al.* 2008) this special issue contains a set of papers that explore these linkages and their implications. The contributions range in perspective from global overviews of the role of forest biodiversity in agriculture and food security, the health impacts of forest use on women, to regional comparisons analyzing bush meat consumption and trade in Amazonia and the Congo, and the effects of sedentarisation on nomadic tribes in Borneo and West Africa. Two case studies offer detailed examination of the causes and consequences of changing patterns of forest use within Tanzania and Cameroon. Furthermore, payment for environmental services (PES) is examined as one potential tool to promote conservation while improving livelihoods in Chinantla, Mexico.

Forests in the broader food security framework

The most widely used definition of food security states that: "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals as the focus of concern" (FAO 2003).

Broader than other definitions, which often place heavy emphasis on calories with little attention to other components of food essential to health, this definition emphasises that access to food is as important as food availability. Food security is therefore often linked to the ability to purchase as well as produce food, and to avoid or offset both chronic (long term and persistent), cyclical and transitory food insecurity (where a particular shock leads to food shortage or sudden rise in prices) (see Sunderland this issue). Food-insecure households may live where there is enough food, but they lack income or 'entitlements' (production, trade, labour or transfer-based) to get it. Food-insecure people may live in food-secure households, due to household preferences or gender or age discrimination (Pinstrup-Andersen 2009). The FAO definition also emphasises that food security includes nutrition security; access to food which ensures adequate macro- and micronutrient intake without excessive intake of calories, fats or refined sugars.

Forests contribute to food security in many diverse ways including through its protective environmental role and provision of ecosystem services (Ferraro and Hanauer 2011). This stresses the importance of forest cover in: maintaining the soil and water base that underpins sustainable agriculture; providing habitats conducive to the biological interactions that maintain crops and livestock; and in mitigating impacts of climate change and extreme weather events at the landscape scale (Seymour 2011, Sunderland this issue). The Millennium Ecosystem Assessment also highlights the contributions of these ecosystem services to human health and well-being (http://www.millenniumassessment.org/en/Synthesis.aspx).

Forests, food and health

Probably the majority of rural households in developing countries, and a large proportion of urban households, rely on forest products to meet some part of their food, nutritional, health and livelihood needs.

Although forest foods seldom provide staple items of diets, and rarely make up the majority of items in the diet (by number or volume), for many rural people they supplement what is available from agriculture and other resources, in three main ways:

- Forests provide a diversity of healthy foods, high in micronutrients and fibre and low in sodium, refined sugar and fat;
- Products from forests are often culturally valued, integral to local food systems and food sovereignty, and;
- They help households fill seasonal and other cyclical food gaps and act as a 'safety net' or 'buffer' in times of shortages due to drought, crop failure, illness or other kinds of emergency or external shock.

Forests are crucial in maintaining the biodiversity that underpins crop and livestock agriculture and are an undervalued repository of food and other resources that play a major role in food security and human health (Sunderland, this issue).

The sale of fuelwood or charcoal from clearance of forest or bush fallow, in order to create new land for crop agriculture, has been shown to be a well established practice whereby young and migrant farmers assemble capital to create new farms in the forest zone across West Africa. Low barriers to entry, and the fact that many of these production, processing and trading activities are open to participation by women as well as men, can make these trades widely accessible.

Fuel wood, essential for cooking in many rural food systems, must not be over looked in a discussion of food security. Many rural and forest communities in developing countries rely exclusively on fuel wood, having no alternative cooking fuel readily available. Improperly cooked food can be unsafe and lead to illness which can worsen nutritional status. Limited fuel wood access causes many families to alter what they eat, often leading to decreased legume / bean consumption, and associated protein and micronutrients. Shrinking access to firewood near the home often means women have less time for other activities that ensure the food security and health of their families (Wan *et al*. this issue). In addition to the well established links between firewood use and respiratory disease, Wan *et al*. (this issue) note a number of other, often overlooked issues. These include the high risks to pregnant women from the arduous work of carrying heavy fuelwood loads which can contribute to reproductive-related illnesses and still births. Cultural restrictions regarding women's intake of certain foods can also erode their nutritional status, leading to a greater susceptibility to life threatening diseases such as malaria. Finally, lack of control over their reproductive health contributes to increased population pressure on forests, thus undermining other conservation efforts.

Many forest-based income generating activities are seasonal, either because certain crops can only be gathered at certain times of year, or because of seasonal fluctuations in availability of labour. Many activities therefore decline in agricultural and planting seasons, or are phased to take advantage of slack periods in the agricultural calendar. Others are governed by seasonally induced cash needs, such as school fees, chronic or unexpected illness, the need for income to buy food during the 'hungry period' between harvests, to purchase seed stock or other inputs needed for the next cropping season, or to generate the working capital that women traders need for business activities (Arnold 2008).

There is increasing evidence from numerous regions that many forests products are particularly important to more vulnerable members of a community. Vinceti and colleagues (2008) reported that "people at risk of food insecurity, or hunger or malnutrition, generally have the highest degree of reliance on forest products for income and food". Wan *et al*. (this issue) highlight the fact that due to gendered division of labour women are more dependent on many forest products, especially firewood and wild food plants than men. Women may also be more vulnerable when changes in forest management or deforestation alter their access to forest products. Forest foods have also been suggested to provide a "safety net" in times of food scarcity and uncertainty (Colfer *et al.* 2006, McSweeney, 2004, Powell *et al.* 2010, Vinceti *et al.* 2008, Sunderland, this issue).

The shift from hunting to agriculture and resultant dietary changes

The shift from hunting to farming and the correlated sedentary lifestyle accompanying agriculture is considered one of the major epidemiological transitions in the history of mankind (Dounias and Froment, this issue, Popkin 2001). According to Dounias and Froment, the abundance of meat is a sign of health and well being; shortage is associated with "meat hunger" a condition which saps strength and vitality not only of the hunter but of the whole community. Cultures reliant on hunting often use associated collectivist social regulations for sharing food and mutual aid that generally disintegrate in sedentary communities which become increasingly individualistic and opportunistic.

In the shift to sedentarisation, diets in many rural areas of developing countries have become heavily based on starchy staples such as maize or cassava, with low intake of animal sources foods (meat, eggs, milk, etc.) (Stephenson *et al.* 2010). Low intake of such foods can result in inadequate intake of protein and inadequate intake and low bioavailability of many micronutrients as well (Murphy and Allen 2003).

The hunting, consumption and trading of bushmeat in West Africa and Latin America that is examined in the paper by Nasi *et al*. (this issue) illustrate several features of changing dietary patterns. Bushmeat remains the principal source of animal protein in many tropical forested landscapes, and especially in the Congo and Amazon basins with vulnerability to hunting depending upon habitat and species With low barriers to entry, and requiring labour inputs that can be easily reconciled with the agricultural cycle, trading bushmeat is easily incorporated into livelihoods that are more secure if based on a range of activities (Brown and Williams 2003, Nasi *et al*. this issue). In the Congo and Amazon basins as well as Chinantla, Mexico, many of the frequently hunted species are secondary forest species or agricultural pest species with high reproductive capacity (Ibarra *et al*. and Nasi *et al.* this issue). While bushmeat is an important commodity in West Africa, it is far less commonly sold in Amazonian markets, due in large part to the widespread prevalence of cattle ranches and consequent availability of beef for a broad swath of society (Nasi *et al.* this issue). In the East Usambara Mountains of Tanzania, Powell *et al*. (this issue) found that households who lived in close proximity to the forest were more likely to use foods from the forest, and those who did consumed more animal source foods. While hunting is dominated by men, the processing and trading is predominantly carried out by women. Though bushmeat forms an important part of their diets, recent studies in West Africa have found that income from bushmeat sales was particularly important for the poorest households, and was often given higher priority by them than their own consumption (De Merode *et al*. 2003).

Changing dynamics of forests, food and human health

The papers included in this special issue, and indeed the broader forest and conservation literature in general, highlight that relationships between forests and people's food security

and health are far from static. A few of the important drivers for change include: forest cover loss and environmental change from agricultural expansion (Nasi *et al*. this issue, Powell *et al*. this issue, Sunderland, this issue); socio-cultural changes (Dounias and Froment this issue, Laird *et al*. this issue); and changes in income, market access and market integration (Ibarra *et al*. this issue, Jamnadass *et al*. this issue).

Forest cover and environmental change:

In many regions worldwide, diminished access to wild foods occurs as deforestation increases and forest cover becomes more distant from settlements. In some regions, natural forest cover is being replaced with plantations, tree crops or farm trees, which provide less diverse dietary inputs than foods sourced from forests. With 30–40% of available global land converted to agriculture, and human population expected to reach nine billion by 2050, expansion of industrial agriculture could lead to irreversible loss of plants and animal life and associated ecosystem services fundamental to human survival.

Drawing upon this scenario, Sunderland (this issue) distinguishes between intensive, industrial agriculture which has resulted in a drastic loss of wildlands and ecosystem services, and traditional farming systems which often enhance biodiversity and food security through multi-functional landscapes. Synthesizing a wealth of environmental, agricultural and socio-political literature, this paper argues that protected areas have led to limited outcomes for either food security or biodiversity conservation, and that more integrated approaches need to be vigorously pursued. An argument is made not only from a conservation perspective, but from a human health angle; in developing countries up to 80% of populations rely on biodiversity for primary health care and wild-harvested meat provides 30–80% of protein intake for many rural communities (Nasi *et al*. this issue). In addition, deforestation disrupts protective functions of biodiversity, altering the subtle balance among vectors and parasites in humans and animals and dramatically increasing the burden of transmissible diseases (Dounias and Froment, this issue).

Depletion of forest resources may also be a consequence of sustained heavy local use of forest foods, or forest products harvested to generate household income. Populations of some animals hunted for bushmeat can plummet with heavy hunting, though other smaller bushmeat species can prove resilient and even increase. Moreover, some may also become more abundant as the forest cover is opened up and altered from forest to fallow and farm bush (Nasi *et al*. this issue). Roadways, while opening up avenues for people to sell forest goods, can lead to rising rates of deforestation, unsustainable off-take of high value forest goods and decreased reliance on forest goods by locals.

Powell *et al*. (this issue) examine the relationship between people's dietary diversity and forest cover and use in a mountain area in Tanzania. Although most of the wild foods in the diet were collected on farm land, villagers consuming wild foods from forest areas were found to have better diets. The amount of forest cover within a 0.5–2 km radius of the house was strongly associated with the likelihood of forest food use, suggesting that use seemed to be conditioned by both availability and access to (in terms of time and user rights) forest areas.

Social and cultural change

Several of the papers in this issue explore social and cultural aspects of changing relationships between forests and human health. The subsistence and life-way transitions associated with sedentarisation described by Dounias and Froment (this issue) provide an example of major rearrangements in social and cultural structures, which are permanently altering peoples relationships with forests. Examples from West Africa and Borneo chronicle the impact which drastic alterations of forest ecosystems have had on forest-reliant hunter gatherers. The authors describe the "mis-adaptation" which indigenous groups suffer including nutritional disorders, phycho-cultural ill-being, discrimination, erosion of collectivity and mutual aid and mental diseases. They note, "declining diets and increasing illnesses are symptomatic warnings of these ecological and socio-cultural mis-adaptations that former hunter-gatherers currently pay to achieve their share of modernity"

Laird *et al*. compare and contrast established practices of resource management and use by indigenous and other long established populations with those practiced by migrant newcomers, in a well endowed area in the Mount Cameroon region in West Africa. Their findings show that indigenous livelihoods draw upon management of a broader range of habitats and species than migrants, and have a much greater use of forest products in the subsistence component of their livelihoods, due to their superior knowledge of the resource.

Decline in use of forest food can also occur due to decline in knowledge about its use. As children spend more time in school, rather than in the fields and the bush, opportunities to learn about wild foods are reduced. A move to a more settled lifestyle is a widespread change that can separate people from knowledge about the food sources they used to be familiar with. Poorer knowledge about which plants can be consumed, and which cannot, constrains people's use of these foods even when the latter are still available and important for dietary balance. Vinceti *et al*. (2008) report that "the erosion of traditional knowledge about forest biodiversity has been observed to affect food choices considerably and to lead to dietary simplification and negative repercussions on human health".

Income, market access and market integration:

Forest products also widely form a major source of income for rural households with which to purchase foods or the inputs they need for agricultural production. In many situations use of forest foods and income is changing, often significantly. Reduction or changes in the role that forest food plays in household nutrition may be due to penetration of rural markets by other food products, changing tastes or cultural attitudes, or decreased availability. The latter may reflect physical shortage of the product as the resource becomes depleted, or changes in

the availability or allocation of a household's supply of labour so that its members have less time to gather wild foods and fuelwood. Increasing pressure on women's time is a frequently cited factor in this respect (e.g. Wan *et al*. in this issue), as is the major impact that HIV/AIDS has had on labour availability in households, in particular in Africa. Both Wan et al. and Sunderland's review of the literature indicate that increased equity for rural women can lead to improved livelihood outcomes as women are responsible for over 50% of the food grown worldwide and serve as repositories of knowledge regarding nutrition and general health.

Jamandass *et al*. (this issue) advocate strongly for the need for small-scale African farmers to have better access and integration in local, national and international market systems. The authors suggest that the enhanced income from market integration and the sale of fruits and other tree crops could make important contributions to food security and health in Africa and other developing countries. However, market integration has not always been found to improve food security and nutrition (Belcher *et al.* 2005, Dewey 1989, Kennedy 1989, Kuhnlein and Receveur 1996). Ibarra *et al*. (this issue) describe changes in the local Chinantla food system that occurred after the initiation of Payment for Environmental Services (PES) program. They report that since the initiation of the hunting ban, local people have replaced wild animal source foods with purchased animal source foods. Their economic valuation suggests that the cost of purchased meat is in fact greater than the payment received though PES. Moreover, cessation of hunting has lead to increased pest damage to agricultural crops. The authors suggest various pathways though which involvement on the PES program is leading to the disintegration of the traditional agricultural and food systems.

Consequences of changing dynamics

Although changes to the dynamic relationships among forests, biodiversity, food security and human health are as complex and varied as the forests and cultures of the globe, the papers presented herein suggest that many current changes are placing the food security and health of forest people in jeopardy. An emerging theme is that changes in forest use often lead to a transition in local people's diets; away from traditional and unprocessed foods high in fibre and micronutrients towards a diet with more processed foods, high in salt, refined sugar, simple carbohydrates and fat. Such nutrition transitions lead to increasing rates of obesity and chronic, nutrition-related diseases including cardiovascular disease and type II diabetes mellitus (often further burdening populations still suffering from micronutrient malnutrition and high rates of infectious diseases) (Kuhnlein and Receveur 1996, Popkin 2001, Popkin and Gordon-Larsen 2004). Evidence of the complexity and severity of nutrition transitions is seen in the fact that all over world one finds households with both overweight individuals and undernourished individuals (in some contexts, overweight individuals are more likely to be micronutrient deficient for some micronutrients) (Doak *et al.* 2004, Doak *et al.* 2000, Garrett and Ruel 2005). As Sunderland (this issue) notes "wheat, rice and maize alone account for more than 50% of the global energy intake". Food security is often a result of unequal distribution of food, resulting in as many overweight individuals globally as are malnourished: "Such inefficiencies are particularly problematic as much of this agricultural production is at the expense of biodiversity and the wider environment" (Sunderland this issue).

Ibarra and colleagues (this issue) note that the potential negative health outcomes of changing forest use in the Chinantla are associated with increased reliance on outside food sources, increased consumption of processed foods and the loss of the health benefits of traditional and culturally important forest and wild foods. Powell and colleagues (this issue) suggest possible explanations for the limited use of forest foods and substantial reliance on purchased foods (even in a very rural forested landscape in one of the poorest countries in Africa). They note that, given the nutrient profile of many forest foods (especially fruit, mushrooms and vegetables), high in phytochemicals, micronutrients and fibre, low in salt, fat and simple sugars – the maintained use of these foods could help to mitigate the progression and consequences of the nutrition transition. The trade-offs between faunal conservation, bush meat consumption and sale, and food security and nutrition are further complicated in the context of the nutrition transition.

Managing forests for food

Within the broad framework of approaches proposed by FAO and IFPRI in order to address food security issues (Løvendal and Knowles 2005, Hoddinot 1999) there are two main areas where initiatives specifically directed at the ways in which forests relate to food security have been concentrated. One is that of strengthening local access to and control over forest resources which the poor draw upon for food and other inputs. The other focuses on increasing the nutrition and health related content and impact of forest and tree resources accessible to the needy.

A large literature attests to the problems that have attended many initiatives to give poor users *effective* control over use of forest resources on which they depend. In addition to the well known problems arising from different interests among richer and poorer users, there can also be increasing conflict between user and conservation priorities. Ibarra *et al*. (this issue) examine the consequences of a programme of community conservation and payments for environmental services (PES), in an area in Mexico. This study argues that the resulting changes in traditional resource management have had negative impacts on crop yields, fallow cycles, and meat consumption – with adverse consequences for people's dietary diversity and local environmental knowledge and skills.

Jamnadass *et al*. (this issue) address aspects of another central approach to better managing the resource, that of assisting users to improve tree stocks that they grow at the farm and community level. The paper, which is based on the experience of the World Agroforestry Centre (ICRAF), reviews key interventions that have been developed to enable improvement of yield, quality and delivery in farmer domestication of indigenous fruit trees. Other work in this area

underlines the need to also focus on how well the qualities of particular fruit species match actual nutritional needs in the areas where the trees are to be grown (Frankenberger *et al*. 2005).

CONCLUSIONS

As the papers in this special issue show, forests are a major repository of food and other resources that play a crucial role in food security. In addition, maintaining diversity in agricultural production systems leads to increased resilience to shocks particularly in the context of a changing climate. Traditional knowledge held by traditional farmers is a valuable source of practices and techniques which have produced centuries-old resilient and diverse production systems

Forest foods are particularly important in coping with cyclical (seasonal) shortages, and transitory shortages due to drought, illness or other external shocks, and are less likely to provide solutions to chronic long term food shortages. As such, forest foods and income are widely important in helping the poor cope with poverty (poverty alleviation), but are less likely to provide them with a pathway out of poverty (poverty reduction).

Improved tenure and access rights to forest resources, particularly for women, could support more sustainable resource management for food security. In addition, women's rights to reproductive health care and education can ease population pressures on forests thereby supporting broader conservation efforts.

Exchange between agricultural and forestry governmental agencies and educational institutions can help to promote improved and holistic efforts toward conservation to continue to bridge the current yawning gap between agriculture and biodiversity in forested landscapes. This needs to be based on the premise of a broad holistic definition of food security such that researchers and practitioners in forestry and conservation can find more common ground with those working in more traditional agricultural fields to combine efforts and work together towards achieving biodiversity conservation, sustainable food production and human health.

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REFERENCES

ANYONGE, C.H., RUGALEMA, G., KAYAMBAZINTHU, D., SITOE, A. and BARANY, M. 2006. Fuelwood, food and medicine: the role of forests in the response to HIV and AIDS in rural areas of southern Africa. *Unasylva* **224**.

ARNOLD J. E. M. 2008. *Managing Ecosystems to Enhance the Food Security of the Rural Poor: A Situation Analysis prepared for IUCN*. http://intranet.iucn.org.

BELCHER, B., RUIZ-PEREZ, M. and ACHDIAWAN, R. 2005. Global Patterns and Trends in the Use and Management of Commercial NTFPs: Implications for Livelihoods and Conservation. *World Development* **33**: 1435–1452.

BROWN, D. and WILLIAMS, A. 2003. The case for bushmeat as a component of development policy: issues and challenges. *International Forestry Review* **5**(2): 148–155.

COLFER, C.J.P, SHEIL, D. and KISHI, M. 2006. *Forests and Human Health: Assessing the Evidence*. Occasional Paper No. 45, CIFOR.

COLFER, C.J.P. 2008. *Human Health and Forests: Global Overview of Issues, Practice and Policy.* London, UK: Earthscan.

COLFER, C.J.P., SHEIL, D., KAIMOWITZ, D. and KISHI, M. 2006. Forests and human health in the tropics: some important connections. *Unasylva* **224**.

DE MERODE, E., HOMEWOOD, K. and G. COWLISHAW. 2003. *Wild resources and livelihoods in Democratic Republic of Congo*. ODI Wildlife Policy Briefing, No. 1, Overseas Development Institute.

DEWEY, K.G. 1989. Nutrition and the commoditation of food systems in Latin America and the Caribbean. *Social Science & Medicine* **28**: 415–424.

DOAK, C.M., ADAIR, L.S., BENTLEY, M., MONTEIRO, C. and POPKIN, B.M. 2004. The dual burden household and the nutrition transition paradox. *Int J Obes Relat Metab Disord* **29**: 129–136.

DOAK, C.M., ADAIR, L.S., MONTEIRO, C. and POPKIN, B.M. 2000. Overweight and Underweight Coexist within Households in Brazil, China and Russia. *The Journal of Nutrition* **130**: 2965–2971.

FALCONER, J. 1990. "Hungry season" food from the forest. *Unasylva* **160**.

FERRARRO, P.J. and HANAUER, M.M. 2011. Protecting ecosystems and alleviating poverty with parks and reserves: "win-win" or tradeoffs? *Environmental Resource Economics* **48**: 269–286.

FRANKENBERGER, T., ANTONSSON-OGLE, B. and RUKUNGA, G. 2005. *Agroforestry, Health and Nutrition – ICRAF's Niches and Priorities: A Centre Commissioned External Review*. World Agroforestry Centre, Nairobi.

GARRETT, J.L. and RUEL, M.T. 2005. *Stunted Child-Overweight mother Pairs: An Emerging Policy Concern?* In: FCND Discussion Paper. IFPRI, Washington, D.C.

HODDINOT, J. 1999. *Operationalizing Household Food Security in Development Projects: An Introduction*. IFPRI.

HOSKINS, M. 1990. The contribution of forestry to food security. *Unasylva* **160**.

JOHNS, T. and MAUNDU, P. 2006. Forest biodiversity, nutrition and population health in market-oriented food systems. *Unasylva* **224**.

KARJALAINEN, E., SARJALA, T. and RAITIO, H. 2010. Promoting human health through forests: overview and major challenges. *Environmental Health and Preventive Medicine* **15**: 1–8.

KENNEDY, E. 1989. *The effects of sugarcane production on food security, health and nutrition on Kenya: a longitudinal analysis.* In: Research report. Washington, DC.: International Food Policy Research Institute.

KUHNLEIN, H.V. and RECEVEUR, O. 1996. Dietary change and traditional food systems of indigenous peoples. *Annual Review of Nutrition* **16**: 417–442.

LØVENDAL, R.L. and KNOWLES, M. 2005. *Tomorrow's Hunger: A Framework for Analysing Vulnerability to Food Insecurity*. ESA Working Paper No. 05–07, Agricultural and Development Economics Division, FAO.

MCSWEENEY, K. 2004. Forest product sale as natural insurance: the effects of household characteristics and the nature of shock in eastern Honduras. *Society and Natural Resources* **17**(1): 39–56.

MURPHY, S.P. and ALLEN, L.A. 2003. Nutritional Importance of Animal Source Foods. *Journal of Nutrition* **133**: 3932S–3935S.

NILSSON, K., SANGSTER, M., GALLIS, C. HARTIG, T. DE VREIS, S., SEELAND, K. AND J. SCHPPERIJN (eds) 2011. *Forests Trees and Human Health*. Springer 427 p.

OLSON, S.H., GANGNON, R., SILVEIRA, G.A. and PATZ, J.A. 2010. Deforestation and malaria in Mâncio Lima County, Brazil. *Emerg Infect Dis.* **16**: 1108–1115.

PIMENTEL, D., MCNAIR, M., BUCK, L., PIMENTEL, M. and KAMIL, J. 1997. The Value of Forests to World Food Security. *Human Ecology* **25**: 91–120.

PINSTRUP-ANDERSEN, P. 2009. Food security: definition and measurement. *Food Security* **1**: 5–7.

POPKIN, B.M. 2001. Nutrition in transition: the changing global nutrition challenge. *Asia Pac J Clin Nutr* 10 Suppl: S13–18.

POPKIN, B.M. and GORDON-LARSEN, P. 2004. The nutrition transition: worldwide obesity dynamics and their determinants. *Int J Obes Relat Metab Disord* **28** Suppl 3: S2–9.

POWELL, B., MAUNDU, P., KUHNLEIN, H.V. and JOHNS, T. forthcoming. Wild and Forest Foods in the Local Food System of Tanzania's East Usambara Mountains. *(to Economic Botany)*.

POWELL, B., WATTS, J., BOUCARD, A., URECH, Z., FEINTRENIE, L., LYIMO, E., ASAHA, S. and SUNDERLAND-GROVES, J. 2010. *The Role of Wild Species in the Governance of Tropical Forested Landscapes, Chapter 7*. In: COLFER C.J.P. and PFUND J-L., (eds.) *Collaborative Governance of Tropical Landscapes*. London: Earthscan.

SEYMOUR, F. 2011. Forests and food security: What we know and need to know. Director General's Blog, CIFOR http://blog.cifor.org/2011/04/20.

STEPHENSON, K., AMTHOR, R., MALLOWA, S., NUNGO, R., MAZIYA-DIXON, B., GICHUKI, S., MBANASO, A. and MANARY, M. 2010. Consuming cassava as a staple food places children 2–5 years old at risk for inadequate protein intake, an observational study in Kenya and Nigeria. *Nutrition Journal* **9**: 9.

VINCETI, B., EYZAGUIRRE, P. and JOHNS, T. 2008. *The nutritional role of forest plant foods for rural communities (Chapter 4)*. In: COLFER C.J.P. (ed.) *Human health and forests: a global overview of issues, practice and policy*. London, UK.: Earthscan.

WILCOX, B.A. and ELLIS, B. 2006. Forests and emerging infectious diseases of humans. *Unasylva* **224**.

Food security: why is biodiversity important?

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SUMMARY

Agriculture and biodiversity have often been regarded as separate concerns. Although biodiversity underpins much of modern agriculture, the development of contemporary production systems has resulted in extensive land conversion and concomitant biodiversity loss. In order to feed an ever growing population, innovative and acceptable ways of integrating biodiversity conservation and food production need to be identified. Maintaining diversity within agricultural systems is not a novel approach but one practiced by many smallholder farmers globally, in many different ways. The nutritional and livelihood benefits of diverse production systems are one way of achieving food security. Such systems are also more resilient to climate induced events or other shocks. Forests represent an important repository of food and other resources that can play a key role in contributing towards food security, especially if integrated into complex systems that are managed for multiple benefits.

Keywords: Food security, forests, biodiversity, agriculture, ecosystem services

Sécurité des aliments: pourquoi la biodiverstiré est-elle importante?

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L'agriculture et la biodiversité ont souvent été considérées comme des questions différentes. Bien que la biodiverstité soutienne une grande partie de l'agriculture moderne, le développement des systèmes de production contemporains a résulté en une conversion poussée de la terre, et en une perte de la biodivesrité s'y attachant. Pour nourrir une population en croissance permanente, il est nécessaire d'identifier des manières innovatives et acceptables d'intégrer la conservation de la biodiversité à la production alimentaire. Le maintien de la diverstiré au sein des systèmes d'agriculture n'est pas une nouvelle approche, étant déjà pratiquée par par nombre de petits fermiers globalement, de toutes sortes de façons. Les bénéfices nutritionnels et pour les revenus de divers systèmes de production ne sont qu'une manière de parvenir à la sécurité alimentaire. De tels systèmes sont également plus résistants aux évènements résultant du climat et à d'autres chocs. Les forêts représentent un dépôt important de nourriture et d'autres ressources pouvant jouer un rôle clé dans la contribution à la sécurité alimentaire, et ce, particulièrement s' il est intégré dans des systèmes complexes gérés en vue de bénéfices multiples.

Seguridad alimentaria: ¿por qué es importante la biodiversidad?

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A menudo las preocupaciones por los temas de agricultura y biodiversidad han seguido caminos separados. Aunque la biodiversidad es en gran medida una de las bases de la agricultura moderna, el desarrollo de los sistemas de producción actuales ha resultado en una considerable conversión del suelo y una pérdida de biodiversidad concomitante. Para poder alimentar a una población cada vez mayor, es necesario identificar maneras innovadoras y aceptables de integrar la conservación de la biodiversidad con la producción de alimentos. El mantenimiento de la diversidad dentro de los sistemas agrícolas no es una idea novedosa, pero es algo que practican de diferentes maneras un gran número de pequeños productores en todo el mundo. Los beneficios de los sistemas de producción diversos en cuanto a nutrición y a los medios de subsistencia son una manera de alcanzar la seguridad alimentaria. Dichos sistemas son al mismo tiempo más resistentes y adaptables a eventos climáticos u otros impactos. Los bosques representan un almacén importante de alimentos y otros recursos que pueden tener un papel clave a la hora de contribuir a la seguridad alimentaria, especialmente cuando están integrados en sistemas complejos gestionados con vistas a obtener múltiples beneficios.

INTRODUCTION

Although long considered mutually exclusive (Tscharntke *et al*. 2005, Brussard *et al*. 2010), biodiversity conservation and food security are two sides of the same coin. Although ecologists and conservation biologists focus primarily on biodiversity conservation in non-agricultural lands it has been recognized that a strictly conservation focus is limited in scope, particularly in terms of fulfilling production requirements (Schroth *et al*. 2004, Chappell and LaValle 2011, Godfray *et al*. 2010). This is pertinent given that the majority of the world's biodiversity remains outside of protected areas, often in complex, multi-functional landscapes occupied by people and their associated farming systems, particularly in the tropics (Alcorn 1993, Putz *et al*. 2001, Sayer and Maginnis 2005, Padoch and Pinedo-Vasquez 2010).

The conventional model to achieve food security has been to convert wild lands to intensive commercial agricultural use (Goklany 1998, Thrupp 2000, Green *et al*. 2005) leading to the increased homogenisation of natural landscapes (Heitala-Koivu *et al*. 2004). An immediate result of this model of land use has been a drastic loss of wildlands, the biodiversity they contain and the ecosystem services they provide (Tscharntke *et al*. 2005; Lamarque *et al*. 2011). Perrings *et al*. (2010: 263) suggest that society has "traded off biodiversity" to achieve food security. Approximately 30–40% of the earth's surface is now under some sort of agricultural system (Scherr and McNeeley 2005, Chappell and LaValle 2011). Although the Green Revolution was intended to intensify production in existing agricultural lands, it is estimated that 20% of the yield increases resulted in direct land conversion (Evenson and Gollin 2003). In addition, these increases in production have been achieved through industrial agriculture that is heavily dependent on fossil fuels and agro-chemicals further indirectly affecting biodiversity and a wide range of ecosystem services, arguably contributing to climate change processes (Perrings *et al*. 2010). With the human population estimated to grow to nine billion by the year 2050 (Godfray *et al*. 2010), it is suggested that there is a concomitant need to increase agricultural production two- to three-fold (Green *et al*. 2005) and that any marked increase in production will undoubtedly be at the expense of currently unproductive lands (Kaimowitz and Angelsen 1998, Tscharntke *et al*. 2005, Ewers *et al*. 2009,). However, further expansion of industrial agriculture through land conversion could have a continuing devastating effect of the world's remaining biodiversity (Lambin and Meyfroidt 2011).

In response to the conversion-driven biodiversity crisis, there has been an exponential increase in the number of protected areas in recent years (Chape *et al*. 2005). The global network of protected areas now covers 11.5% of the worlds' surface area with the majority of these falling within categories I-IV of the IUCN's classification, (Rodrigues *et al*. 2004, Schmitt *et al*. 2009); the highest levels of protection, effectively annexing large areas of land from human use and productivity (Ferraro and Hanauer 2011), although the reality is that many of these protected areas are in fact encroached upon for agricultural production (Scherr and McNeely 2005). Hence, no matter how expansive, this protective area network has fundamentally failed to halt biodiversity loss (Coad *et al*. 2009, Mace *et al*. 2010). It might be argued that the clear disaggregation of conservation goals with those of agricultural production (Perrings *et al*. 2010, Brussard *et al*. 2010) have led to limited outcomes for either food security or biodiversity (Steiner 2011). In order to achieve biodiversity conservation and food security goals, more integrated and inclusive approaches need to be more actively pursued (Scherr and McNeely 2005, Pretty 2008, Brussard *et al*. 2010, Chappell and LaValle, 2011, Lambin and Meyfroidt 2011).

Biodiversity: a fundamental feature of agricultural systems and human well-being

Biodiversity at three levels, ecosystems, the species they contain and the genetic diversity within species, underpins much of modern agriculture as well as the livelihoods of many millions of people. 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.) is worth estimated $500 billion/annum (ten Kate and Laird 1999). Biodiversity provides an important safety-net during times of food insecurity, particularly during times of low agricultural production (Anglesen and Wunder 2003, Karjalainen *et al*. 2010) during other seasonal or cyclical food gaps (Arnold 2008, Vinceti *et al*. 2008) or during periods of climate-induced vulnerability (Cotter and Tirado 2008). Wild harvested meat provides 30–80% of protein intake for many rural communities (Pimentel *et al*. 1997, Fa *et al*. 2003, Nasi *et al*. this issue), particularly in the absence of domesticated alternative sources of protein. The World Health Organisation estimates that in many developing countries up to 80% of the population relies on biodiversity for primary health care (Herndon and Butler 2010) and the loss of biodiversity has been linked to the increased emergence and transmission of infectious diseases with deleterious impacts on human health (Keesing *et al*. 2010).

Around one billion people rely on wild harvested products for nutrition and income and the "invisible" trade in wild resources is estimated to generate $90 billion/annum (Pimentel *et al*. 1997). In India alone the livelihoods of around 6 million people are maintained by the harvest of forest products (Tuxill 1999) and many studies highlight just how important wild harvested plants and animals are to the economy of the world's rural poor, particularly from forests (de Beer and McDermott 1989, Nepstad and Schwartzman 1992, Prance 1992, Colfer 1997, Pimentel *et al*. 1997, Shanley *et al*. 2002, Scherr and McNeely 2005, Belcher and Schreckenberg 2007, Paumgarten and Shackleton 2009). In many rural locations, particularly areas that lack basic infrastructure and market access, the collection of wild resources provides considerable subsistence support to local livelihoods (Delang 2006). In addition, the harvest and sale of wild products often provides one of the only means of access to the cash economy (Ros-Tonen and Wiersum 2005). Access to markets is particularly important for food security: it is not

enough to be able to collect or grow food, but the ability to purchase food is also a major factor in ensuring food security, hence the more vulnerable and poorest members of society are particularly at risk from lack of access to food (Arnold 2008). Highly urbanised societies such as Hong Kong and Singapore that have no agricultural base are food secure because of their considerable purchasing power, while India, although self-sufficient in agriculture, has much of its population that is food insecure primarily due to social inequity and poverty (Schmidhuber and Tubiello 2007).

Although more needs to be understood regarding biodiversity providing the "natural capital" (Jackson *et al*, 2007: 197) for ecosystem services, ecological processes such as the maintenance of watershed services, soil fertility, pollination, seed dispersal, nutrient cycling, natural pest and disease control etc. all rely to a greater or lesser extent on biodiversity, or components of it; processes that are critical to the maintenance of agricultural systems (Thrupp 2000, Benton 2007). Most high-intensity agricultural systems seek to remove wild species in the hope that potential weeds, predators and other pests are not compromising production (Scherr and McNeely 2005). The immediate effects of intensification or expansion of agriculture leads to a considerable decline in avian diversity and numbers, often to local extinction for habitat specialists (Green *et al*. 2005, Benton 2007) and pollinator diversity is reduced (Steffan-Dewenter *et al*. 2005) primarily due to the homogenization of insect populations (Ekroos *et al*, 2010). Commercial agriculture often favours synanthropic species (those that are adapted to live in anthropogenic landscapes), often causing a reduction in both species diversity and ecosystem function.

Despite the value of ecosystem goods and services to production systems (Rahel et al 2009), there are clear trade-offs between the economic value of agricultural conversion compared to the ecosystem services provided by a diversified environment (Perrings *et al*. 2010, Brussard *et al*. 2010). These trade-offs are only recently being recognised, stimulated in part by the increasingly adverse effects of climate change and the recognition of the need for greater resilience of productive ecosystems (Scherr and McNeely 2005, Brussard *et al*. 2010). Reward schemes that focus on the maintenance of biodiversity in agricultural landscapes and the associated provision of ecosystem services have gained considerable attention in recent years (Pascual and Perrings, 2007). However, such financial incentives will not only have to be sufficient to out-compete other source of incomes, but will need to ensure the right people are actually rewarded (Campbell 2009).

What is food security?

Most definitions related to food security refer to the availability of food and one's access to it. For example, the World Bank defines food security as "*access by all people at all times to sufficient food for an active, healthy life*" (Maxwell and Wiebe 1999: 828). The most commonly accepted and used definition for food security, agreed upon at the World Food Summit is as follows: "*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 2009: 5).

However, these definitions infer that access to *enough* food is an adequate criterion to achieve food security at the household, national or global scales (Pinstrup-Anderen 2009) yet access to food must be sustainable in the long term. A household cannot be considered food secure if it has current access to sufficient food to meet immediate nutritional requirements while depleting the natural capital that would have provided future resources (Maxwell and Wiebe 1999, Perrings *et al*. 2010). In addition, some commentators point out that even if food availability is satisfactory, the attainment of human well-being is closely related to access to wider environmental health such as access to clean water, sanitation and diverse productive ecosystems, therefore food security does not always equate to *nutritional* security (Swaminathan 2001, Schmidhuber and Tubiello 2007, Pinstrup-Andersen 2009). Indeed, any rural societies share this more holistic approach, with little distinction being made between food security, general health and the environment (Karjalainen *et al*. 2010). Due to the strong cyclical links between nutrition and infection, nutritional security is also dependant on the diverse ecosystem services biodiversity and forests provide that serve to limit infection and disease transmission (Semba and Bloem 2001).

Global trends in agriculture and impact on biodiversity

Agriculture began around 12,000 years ago and approximately 7,000 plant species and several thousand animal species have been used historically for human nutrition and health requirements (Ehrlich and Wilson 1991, Tuxill 1999, Toledo and Burlingame 2006). Since 1900, there has been a significant global trend towards diet simplification (Frison *et al*. 2006, Johns 2006). Today, 12 plant crops and 14 animal species today provide 98% of world's food needs with wheat, rice and maize alone account for more than 50% of the global energy intake (Ehrlich and Wilson 1991, Thrupp 2000).

Uniformity of production and wider biodiversity destruction has led to the loss of many wild relatives of crop plants (Tuxill 1999) and livestock (Pilling 2010). The FAO suggests that three-quarters of the varietal genetic diversity of agricultural crops has been lost in the past 100 years (FAO 2008). Since the 1960's it is estimated that China and India have lost thousands of landraces of rice and Mexico more than 80% of its maize diversity (Tuxill 1999). Diverse and genetically unique livestock species, those that are probably more resilient to emerging diseases, are also being lost at an alarming rate (Pilling 2010). This biological loss has been exacerbated by concomitant cultural loss as society becomes increasingly globalised (Pretty *et al*. 2008).

The genetic erosion of our nutritional base has considerable implications for food security, nutrition and health (Vinceti *et al*. 2008). Relying on a narrow genetic base for nutrition makes society considerably vulnerable to risk and there are many examples of the dangers of monoculture

BOX 1 Selected policy and legislative frameworks related to biodiversity and food security:

Universal Declaration on Human Rights Article 25: "*Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food*". http://www.un.org/en/documents/udhr/index.shtml

Efforts to link biodiversity, food and nutrition issues are expected to contribute to achieving the **Millennium Development Goals**, in particular number 1C: which aims to "*reduce by half, by 2015, the proportion of people who suffer from hunger*". Also linked to Goal 7A: "*Integrate the principles of sustainable development and reverse the loss of environmental resources*". http://www.un.org/millenniumgoals/

Convention of Biological Diversity: Main conclusions on the CBD cross-cutting initiative on biodiversity for food and nutrition: "*Biodiversity is essential for food security and nutrition and offers key options for sustainable livelihoods. Existing knowledge warrants the sustainable use of biodiversity in food security and nutrition programmes as a contribution to the achievement of the Millennium Development Goals*". http://www.cbd.int/agro/food-nutrition/

International Covenant on Economic Cultural and Social Rights (Article 11): *the right to adequate food from productive land or other natural resources*. (Article 12): *the right to the highest attainable standard of health. Conditions to achieve this include access to adequate food and nutrition*. http://www2.ohchr.org/english/law/cescr.htm

FAO's Strategic Framework 2000–2015 stipulates that the Organization is expected to take fully into account "*progress made in further developing a rights-based approach to food security*" in carrying out its mission "*helping to build a food-secure world for present and future generations*." http://www.fao.org/righttofood/

Chennai Declaration: "*Biodiversity is the raw material for food and health security, as well as for the biotechnology industry, and it must be conserved to ensure that it can continue in this function so that farming systems become climate resilient*". http://www.fao.org/nr/giahs/giahs-home/chennai-declaration/en/

Rome Declaration on World Food Security: "*Agricultural production increases need to be achieved while ensuring both productive capacity, sustainable management of natural resources and protection of the environment*" http://www.fao.org/docrep/003/w3613e/w3613e00.HTM

IFPRI 2020 Vision: "*is a world where every person has access to sufficient food to sustain a healthy and productive life, where malnutrition is absent and where food originates from effective, efficient and low-cost food systems that are compatible with the sustainable use of natural resources*". http://www.ifpri.org/book-753/ourwork/program/2020-vision-food-agriculture-and-environment

agriculture leading to past recorded crop failures and ultimately, famine, due to genetic uniformity (Thrupp 2000). Despite considerable advances in agriculture in terms of quantity (Pretty 2008), a reduction in crop diversity has reduced diet quality and there are considerable nutritional effects resulting from diet simplification. Thus an issue of concern is not *how much* food is required to achieve food security but *what kind* of food; thus food composition is as important as food access and availability (Goklany 1998, Frison *et al*. 2006). Increased availability and consumption of cereals, particularly in developing countries have led to increased micronutrient deficiencies (Frison *et al*. 2006). An estimated one billion people suffer from deficiencies in micro-nutrients such as vitamin A, iron, and zinc (Goklany 1998, Dangour and Uauy 2006, Vinceti *et al*. 2008). The diversity of forest, fallow and agricultural margin foods can often help provide the range of micronutrients needed for the human diet (High and Shackleton 2000, Padoch and Pinedo-Vasquez 2010).

In many instances, the underlying causes of food insecurity are not due to limits of agricultural production but are rooted in political, social and economic influences (Pinstrup-Andersen and Pandya-Lorch 1998). For example, although in much of the world, catastrophic famine has been eliminated, the three major famines that have recently occurred in sub-Saharan Africa were largely preventable (Devereaux 2009). Food inequity is also a major global problem. Although more than 800 million people are classified as under-nourished (Toledo and Burlingame 2006, Pinstrup-Andersen 2009) and in 2009, one billion people were classified as "hungry", the highest number in human history (FAO 2009) there is an equal number of people who are overweight or obese (Dangour and Uauy 2006, Pinstrup-Andersen 2006). Fuelled by urbanisation and increasingly sedentary lifestyles, the health impacts over food over-consumption are also a major cost to society with greater incidences of cardio-vascular disease and adult-onset diabetes in particular, notably in developing or transitional economies (Dangour and Uauy 2006, Raymond *et al*. 2006, Mitra *et al*. 2009, Dixon 2009). Ultimately, an unlimited increased calorie intake does not result in better human health. Clearly there is something awry with our means of agricultural production if poor nutrition and over-consumption co-occur, accompanied by negative human health implications at both ends of the food security spectrum (Dixon 2009). Such inefficiencies are particularly problematic as much of this agricultural production is at the expense of biodiversity and the wider environment (McMichael 2005, Pretty 2009).

Challenges to biodiversity-friendly agriculture

Population growth

The world's population is expected to grow to nine billion by the year 2050 (Perrings *et al*. 2006). If the current model of commercialised monoculture is to be followed, feeding the global population is stated to require the conversion of yet more wild lands, at the expense of biodiversity and ecosystem service provision (Kaimowitz and Angelsen 1998, Green *et al*. 2005, Lambin and Meyfroidt 2011). Scherr and McNeely (2005) estimate that a billion hectares of natural habitat will need to be converted to agricultural production, especially once the effects of climate change on crop yields are taken into account. However, Molden (2007) and Pretty (2008) argue that while current levels of food production are indeed adequate to feed the growing population, the diversion of food crops for non-nutritional uses and changing diets from grains to meat, compounded by with increased economic wealth and trends towards urbanisation will result in a concomitant need to increase agricultural production and associated biodiversity loss.

Demand for meat is increasing globally, particularly from the burgeoning urban populations of India and China, and as the world becomes increasing prosperous. Meat production is a notoriously inefficient use of resources and the implications of this are that a greater proportion of grains and oilseeds are being used to feed livestock and poultry, rather than people (Scherr and McNeely 2005, United Nations 2011). A significant rise in greenhouse gas emissions is also a major side effect of the increased production in meat and dairy products (Dixon 2009). The diversion of foodstuffs to biofuel production also has an impact on food security. For example, nearly a third of all corn produced in the United States is now used for fuel and in 2010 this diverted more than 100 million tonnes of corn to ethanol production (Dapice 2011). Fuelled by considerable subsidies, ethanol production also contributes to price rises in grain and meat. Overall, it is argued, biofuel production does not improve energy security, increases environmental degradation, raises basic food prices and thus threatens food security (Pimentel 2003, 2011). Finally, a considerable proportion of food is simply wasted in both developing and developed countries, but for different reasons. Loss of food in developing countries is often the result of pre- and immediate post-harvest losses due to pests and disease and poor market access, while waste in developed countries is primarily due to the availability of large quantities of relatively cheap food, which is simply uneaten and discarded once it has reached the table, be it within the household or the commercial kitchen. Reappraising the non-consumptive uses of agricultural produce and mitigating food waste could result in an equivalent rise in agricultural output, lessening the need for further land conversion and further biodiversity loss (Scherr and McNeely 2005).

Climate change

Climate change and its potential impacts represent one of the greatest contemporary threats to food security (Bohle *et al*. 1994, Sanchez 2000, Schmidhuber and Tubiello 2007, Gregory *et al*. 2010). Extreme and unpredictable weather will affect crop yields and it is estimated that agricultural yields in Africa alone could decline by more than 30 percent by 2050 (Juma 2010). Such yield decline will primarily affect the world's poor, who will not only lose direct access to food but are less capable of absorbing the global commodity price changes that characterise a reduction in supply (Sanchez 2000, Cotter and Tirado 2008). Three of the most recent famines in sub-Saharan Africa, although primarily precipitated by non-production or supply issues, were exacerbated by unexpected weather patterns that pushed already vulnerable livelihoods into major food insecurity and, ultimately, famine (Devereaux 2009).

Climate-related events are being blamed for the recent spike in the price of staple foods (Dapice 2011), which are now at an all-time high (FAO 2011a). Extreme weather can have a devastating effect on crops as the recent droughts in Russia and China, and floods in Australia, India, Pakistan and Europe indicate. The impacts of rising temperatures and more-extreme weather events will likely hurt the poor, especially rural farmers (Schmidhuber and Tubiello 2007, Juma 2010) and the World Bank (2011) estimates that 44 million more people have slipped back into poverty since June 2010. Urban populations who are more vulnerable to reductions in purchasing power are particularly vulnerable to increases in basic food prices. Food riots in Cameroon and Haiti in 2008 and the recent regime changes in Tunisia and Egypt have been directly linked to increased prices of basic foodstuffs (FAO 2011b).

Biodiverse multi-functional landscapes are more resilient to extreme weather effects and can provide a "*natural insurance policy against climate change*" (Cotter and Tirado 2008: 3). Greater crop diversification by integrating a diversity of crops and varieties into small-holder systems in particular will increase resilience to severe changes in weather patterns leading to calls for "sustainable agriculture" (Pretty 2008), "conservation agriculture" (Hobbs *et al*. 2008: 543), "agro-ecological" (United Nations 2011) and "eco-agriculture" (Scherr and McNeely 2005) approaches. Such approaches rely on a broader agricultural base integrated with diverse ecosystems and are thus more analogous to "natural" ecological processes. More diverse agricultural systems not only increase resilience against extreme climate-related events but can also increase yields. But recognition of this is not new. Small scale shifting cultivators have been practicing biodiversity friendly for generations (Padoch and Pinedo-Vasquez 2010) and farmers around the world clearly understand and use agrobiodiversity to mitigate against environmental and climatic uncertainty (Powell *et al*. this issue). In a survey of eco-farming projects in 57 different countries, the integration of natural pest control and improving soil fertility resulted in yield increases of up to 80% (United Nations 2011). And in Africa, a review of "agro-ecological" approaches showed that cereal yields improved by 50–100% when more integrated methods of production were promoted (Rosengrant and Cline 2003).

Gender inequity

Women are pivotal to ensuring food security (United Nations 2011). It is estimated that women produce more than 50% of the food grown worldwide, primarily in small-scale farming systems (Maxwell and Wiebe 1999). Indeed women tend to grow a greater diversity of products, experiment more with folk varieties and landraces and are often reliant on biodiversity for the family herbal (Agarwal 1992, Dhali 2008). Although women comprise up to 80% of farmers in sub-Saharan Africa and 60% in Asia, ratios that are increasing due to male out-migration and moves towards off-farm sources of income, their access and control over land and resources is generally inferior to that of men in the same household or community (Mathur 2011). Where women do have access to land, they will generally use it for food production and income generated from such land is more likely to be utilised for the well-being of the household, whether for nutritional, health or other benefits. Women are also primarily responsible for food preparation and allocation and, as such, are usually the "*guardians of household food security*" (Maxwell and Wiebe 1999: 836). In times of food insecurity, maternal food deprivation can impact the long-term productivity of the wider community through childhood malnutrition and ill-health, effects that can linger long into adulthood, ultimately affecting their productivity and ability to feed themselves (Osmani and Sen 2003).

However, many female farmers lack access to credit, extension services despite evidence suggesting that investment aimed at women leads to the increase of both farm and non-farm incomes at the household level (Godfray *et al*. 2010). Although development policy makers and agencies increasingly recognize the crucial contributions of women farmers to food security, contemporary agricultural policies and research do not often directly address the needs of women farmers, focusing more on traditionally male dominated cropping practices. Such "gender blindness" in the context of agricultural development is a major risk to future food security (Mathur 2011, United Nations 2011).

Tenure

Although it is argued that tenure rights in agricultural landscapes are less ambiguous for forested regions (Campbell 2009), greater clarity of tenure is needed across the entire biodiversity-agriculture nexus (Maxwell and Wiebe 1999). Tenure rights have figured prominently in debates surrounding conservation (Campese *et al*. 2009), land tenure and food security have both, separately, been the subject of extensive research yet critical links between the two remain somewhat unexplored (Maxwell and Wiebe 1999). Secure tenure is critical for food security in a number of ways. The lack of secure access rights and land tenure may be a disincentive for many poor or marginalised communities to invest in managing land more productively, investing in required inputs and making the raising of capital that much more difficult (Godfray *et al*. 2010). Inadequate or unclear tenure regimes also limit the efficient delivery of payments for environmental services and other reward mechanisms. Such incentive schemes will undoubtedly favour landowners with secure tenure, including the state and the private sector, with smallholder farmers marginalised (Campbell 2009).

Agricultural investment

International funding for agricultural development has dropped significantly over the last decade and is now at an historic low, representing around 3% of total overseas aid (Pinstrup-Andersen and Pandya-Lorch 1998). Crop yields have fallen in many regions primarily due to declining investments in agricultural research, irrigation and infrastructure (Rosegrant and Cline 2003) and Juma (2010) estimates that the lack of agricultural development investment has led to yield declines in Africa of ca.10% since 1960. National investment in agricultural development also remains very low, often representing less than 0.5% of agricultural GDP, despite the significant contribution of farming to most developing countries' economies ((Pinstrup-Andersen and Pandya-Lorch 1998). This is primarily due to the gradual withdrawal of state support to agriculture under structural adjustment conditionalities (Devereaux 2009). Structural adjustment programmes also disaggregated agriculture from wider natural resource management (NRM) initiatives. Thus NRM and agriculture have been artificially divided. Unfortunately for the millions of small-holder farmers who are responsible for the vast majority of food production, bio-cultural diversity and agricultural production these lines are considerably less well-defined.

CONCLUSION

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. 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 landscapes and ecosystems for biodiversity conservation and food security should be central to development aid.

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REFERENCES

AGARWAL, B. 1992. The gender and environment debate: lessons from India. Feminist Studies **18**(1): 119–158.

ALCORN, J. 1993. Indigenous peoples and conservation. *Conservation Biology* **7**: 424–426.

ANGELSON, A. and WUNDER, S. 2003. *Exploring the forest-poverty link: key concepts, issues and research implications*. CIFOR Occasional Paper No. 40, Centre for International Forestry Research, Bogor

ARNOLD, J.E.M. 2008. *Managing ecosystems to enhance the food security of the rural poor*. A situation analysis prepared for IUCN, Gland. 33 p.

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

BENTON, T.G. 2007. Managing farming's footprint on biodiversity. *Science* **315**: 341–342.

BOHLE, H.G., DOWNING, T.E. and WATTS, M.J. 1994. Climate change and social vulnerability: towards a sociology and geography of food insecurity. *Global Environmental Change* **4**: 37–48.

BRUSSARD, L., CARON, P., CAMPBELL, B., LIPPER, L., MAINKA, S., RABBINGE, R., BABIN, D. and PULLEMAN, M. 2010. Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. *Current Opinion in Environmental Sustainability* **2**: 34–42.

CAMPBELL, B.M. 2009. Beyond Copenhagen: REDD+, agriculture, adaptation strategies and poverty. *Global Environmental Change* **19**: 397–399.

CAMPESE, J., SUNDERLAND, T., GREIBER, T. and OVIEDO, G. (eds.) 2009. *Rights Based Approaches: Exploring Issues and Opportunities for Conservation*. Center for International Forestry Research, Bogor. 305 p.

CHAPE, S., HARRISON, J., SPALDING, M. and LYSENKO, I. 2005. Measuring the extent and effectiveness of protected areas as an indicator of meeting global biodiversity targets. *Phil Trans R Soc (B)* **360**: 443–455.

CHAPPELL, M.J. and LAVALLE, L. 2011. Food security and biodiversity: Can we have both? An agroecological analysis. Agriculture and Human Values **28**(1): 3–26.

COAD, L., BURGESS, N., FISH, L., RAVILLIOUS, C., CORRIGAN, C., PAVESE, H., GRANZIERA, A. and BESANÇON, C. 2009. Progress towards the Convention of Biological Diversity terrestrial 2010 and marine 2012 targets for protected area coverage. *Parks* **17**: 35–42.

COLFER, C. 1997. *Beyond slash and burn: building on indigenous management of Borneo's tropical rain forests*. Advances in Economic Botany. Vol. II, New York. 183 p.

COTTER, J. and TIRADO, R. 2008. *Food security and climate change: the answer is biodiversity*. Greenpeace Research Laboratories Report, June.

DANGOUR, A.D. and UAUY, R. 2006. Nutrition challenges for the twenty-first century. *British Journal of Nutrition* **96** Suppl. 1 S2–S7.

DAPICE, D. 2011. As food prices cause pain, nations need to bring crisis-solving policies to the table. *Jakarta Globe*, February 21st. http://www.thejakartaglobe.com/commentary/extreme-food-prices-require-crisis-solving-menu/423778.

DE BEER, J. and MCDERMOTT, M. 1989. The economic value of non-timber forest products in Southeast Asia. Netherlands Committee for IUCN, Amsterdam. 197 p.

DELANG, C.O. 2006. The role of wild plants in poverty alleviation and biodiversity conservation in tropical countries. *Progress in Development Studies* **4**: 275–286.

DEVEREAUX, S. 2009. Why does famine persist in Africa? *Food Security* **1**: 25–35.

DHALI, H.H. 2008. Deforestation and its impacts on indigenous women: a case from the Chittagong Hill Tracts in Bangladesh. *Gender, Technology and Development* **12**: 229–246.

DIXON, J. 2009. From the imperial to the empty calorie: how nutrition relations underpin food regime transitions. *Agriculture and Human Values* **26**: 321–333.

ECONOMIST. 2011. The future of food: crisis prevention. *The Economist Magazine*. http://www.economist.com/node/18229412?story_id=18229412.

EHRLICH, P.R and WILSON, E.O. 1991. Biodiversity studies: science and policy. *Science* **253**: 758–762.

EKROOS, J., HELIÖLÄ, J. and KUUSSAARI, M. 2010. Homogenisation of Lepidopteran communities in intensively managed agricultural landscapes. *Journal of Applied Ecology* **47**: 459–467.

EVENSON, R.E. and GOLLIN, D. 2003. Assessing the impact of the Green Revolution, 1960 to 2000. *Science* **300**: 758–762.

EWERS, R.M., SCHARLEMANN, J., BALMFORD, A. and GREEN, R. 2009. Do increases in agricultural yield spare land for nature? *Global Change Biology* **15**: 1716–1726.

FA, J.E., CURRIE, D. and MEEUWIG, J. 2003. Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. *Environmental Conservation* **30**: 71–78.

FAO. 2008. *Biodiversity to curb world's food insecurity*. Food and Agriculture Organisation, Rome. http://www.fao.org/newsroom/en/news/2008/1000841/index.html.

FAO. 2009. *1.02 million hungry: one sixth of humanity undernourished – more than ever before*.
Food and Agriculture Organisation, Rome. http://www.fao.org/news/story/0/item/20568/icode/en/.
FAO. 2011a. *Tight cereal markets as food prices increase again***.** Food and Agriculture.
Organisation, Rome. http://www.fao.org/news/story/en/item/51913/icode/.
FAO. 2011b. *Forests for improved nutrition and food security*. Food and Agriculture Organisation, Rome. http://www.fao.org/docrep/014/i2011e/i2011e00.pdf.
FERRARRO, P.J. and HANAUER, M.M. 2011. Protecting ecosystems and alleviating poverty with parks and reserves: "win-win" or tradeoffs? *Environmental Resource Economics* **48**: 269–286.
FRISON, E.A., SMITH, I.F., JOHNS, T., CHERFAS, J., and EYZAGUIRRE, P. 2006. Agricultural biodiversity, nutrition and health: making a difference to hunger and nutrition in the developing world. *Food and Nutrition Bulletin* **27**(2): 167–179.
GODFRAY, C.H., BEDDINGTON, J., CRUTE, I., HADDAD, L., LAWRENCE, D., MIUR, J., PRETTY, J., ROBINSON, S., THOMAS, S. and TOULMIN, C. 2010. Food security: the challenge of feeding 9 billion people. *Science* **327**: 812–818.
GOKLANY, I.M. 1998. Saving habitat and conserving biodiversity on a crowded planet. *BioScience* **48**: 941–953.
GREEN, R., CORNELL, S., SCHARLEMANN, J. and BALMFORD, A. 2005. Farming and the fate of wild nature. *Science* **307**: 550–555.
GREGORY, P.J., INGRAM, J.S.I. and BRKLACICH, M. 2010. Climate change and food security. *Phil. Trans. R. Soc. B.* **360**: 2139–2148.
HEITALA-KOIVU, R., LANKOSKI, J. and TARMI, S. 2004. Loss of biodiversity and its social cost in an agricultural landscape. *Agriculture, Ecosystems and Environment* **103**: 75–83.
HERNDON, C.N. and BUTLER, R.A. 2010. Significance of biodiversity to human health. *Biotropica* **42**: 558–560.
HIGH, C. and SHACKLETON, C.M. 2000. The comparative value of wild and domestic plants in home gardens of a South African rural village. *Agroforestry Systems* **48**: 141–56.
HOBBS, P.R., SAYRE, K. and GUPTA, R. 2008. The role of conservation agriculture in sustainable agriculture. *Proc. Trans. Roy. Soc. B.* **363**: 543–555.
JACKSON, L.E., PASCUAL, U. and HODGKIN, T. 2007. Utilising and conserving agrobiodiversity in agricultural landscapes. *Agriculture, Ecosystems and Environment* **121**: 196–210.
JOHNS, T. 2006. Linking biodiversity, diet and health in policy and practice. *Proceedings of the Nutrition Society* **65**: 182–189.
JUMA, C. 2010. *The new harvest: agricultural innovation in Africa*. Oxford University Press. 296 p.
KAIMOWITZ, D. and ANGELSEN, A. 1998. *Economic models of tropical deforestation: a review*. Center for International Forestry Research, Bogor. 137 p.
KARJALAINEN, E., SARJALA, T. and RAITO, H. 2010. Promoting human health through forests: overview and major challenges. *Environmental Health and Preventive Medicine* **15**: 1–8.
KEESING, F., BELDEN, L.K., DASZAK, P., DOBSON, A., HARVELL, C.D., HOLT, R.D., HUDSON, P., JOLLES, A., JONES, K.E., MITCHELL, C.E., MYERS, S.S., BOGICH, T. and OSTFELD, R.S. 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature* **468**: 647–652.
LAMARQUE, P., QUÉTIER, F. and LAVOREL, S. 2011. The diversity of the ecosystem services concept and its implications for their assessment and management. *Comptes Rendus Biologies* doi:10.1016/j.crvi.2010.11.007.
LAMBIN, E.F. and MEYFROIDT, P. 2011. Global land use change, economic globalisation and the looming land scarcity. *Proceedings of the National Academy of Sciences* **108**: 3465–3472.
MACE, G.M., CRAMER, W., DIAZ, S., FAITH, D.P., LERIGAUDERIE, A., LE PRESTRE, P., PALMER, M., PERRINGS, C., SCHOLES, R., WALPOLE, M., WALTHER, B., WATSON, J. and MOONEY, H.A. 2010. Biodiversity targets after 2010. *Current Opinion in Environmental Sustainability* **2**: 1–6.
MATHUR, A. 2011. *Women and food security: a comparison of South Asia and Southeast Asia*. Asia Security Initiative Policy series, Working Paper No. 12.
MAXWELL, D. and WIEBE, K. 1999. Land tenure and food security: exploring dynamic linkages. *Development and Change* **30**: 825–849.
MCMICHAEL, A.J. 2005. Integrating nutrition with ecology: balancing the health of humans and biosphere. *Public Health Nutrition* **8**: 706–715.
MITRA, A., BASU, B. and MUKHERJEE, S. 2009. Significance of different dietary habits in sections of Indian diabetics. *Journal of Human Ecology* **26**: 89–98.
MOLDEN, D. (ed.) 2007. *Water for food, water for life*. Earthscan, London. 275 p.
NEPSTAD, D.C. and SCHWARTZMAN, S., (eds.) 1992. Non-timber products from tropical forests: evaluation of a conservation and development strategy. *Advances in Economic Botany* **9**. 164 p.
NOVACEK, M.J. and CLELAND, E.E. 2001. The current biodiversity extinction event; scenarios for mitigation and recovery. *Proceedings of the National Academy of Science* **98**: 5466–5470.
OSMANI, S. and SEN, A. 2003. The hidden penalties of gender inequality: fetal origins of ill-health. *Economics and Human Biology* **1**: 105–121.
PADOCH, C. and PINEDO-VASQUEZ, M. 2010. Saving slash and burn to save biodiversity. *Biotropica* **42**: 550–552.
PARDEY, P.G., ALSTON, J.M., CHRISTIAN, J.E. and FAN, S. 1996. *Hidden harvest: US benefits from international research aid*. Food Policy Report: The International Food Policy Research Institute (IFPRI), Washington DC. 17 p.

PASCUAL, U. and PERRINGS, C. 2007. Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes. *Agriculture, Ecosystems and Environment* **121**: 256–268.

PAUMGARTEN, F. and SHACKLETON, C. 2009. Wealth differentiation in household use and trade in non-timber forest products in South Africa. *Ecological Economics* **68**: 2950–2959.

PERRINGS, C., JACKSON, L., BAWA, K., BRUSSARD, L., BRUSH, S., GAVIN, T., PAPA, R., PASCUAL, U. and DE RUITER, P. 2010. Biodiversity in agricultural landscapes: saving natural capital without losing interest. *Conservation Biology* **20**: 263–264.

PILLING, D. 2010. Threats to animal genetic resources for food and agriculture – approaches to recording, description, classification and analysis. *Animal Genetic Resources* **47**: 11–22.

PIMENTEL, D., MCNAIR, M., BUCK, L., PIMENTEL, M. and KAMIL, J. 1997. The value of forests to world food security. *Human Ecology* **25**: 91–120.

PIMENTEL, D. 2003. Ethanol fuels, energy balance, economics and environmental impacts are negative. *Natural Resources Research* **12**: 127–134.

PIMENTEL, D. 2011. Ethanol fuels; energy security, economics and the environment. *Journal of Agricultural and Environmental Ethics* DOI: 10.1007/BF02229143.

PINSTRUP-ANDERSEN, P. 2006. Agricultural research and policy to achieve nutrition goals. *Poverty, Inequality and Development* **1**: 353–370.

PINSTRUP-ANDERSEN, P. 2009. Food security: definition and measurement. *Food Security* **1**: 5–7.

PINSTRUP-ANDERSEN, P. and PANDYA-LORCH, R. 1998. Food security and sustainable use of natural resources: a 2020 vision. *Ecological Economics* **26**: 1–10.

PRANCE, G.T. 1992. Rainforest harvest: an overview. In: Counsell, S. and Rice, T. (eds). *The rainforest harvest: sustainable strategies for saving the tropical forests*. Friends of the Earth Trust, London, pp 21–25.

PRETTY, J. 1998. Agricultural sustainability: concepts, principles and evidence. *Phil. Trans. Roy. Soc. B*. **363**: 447–465.

PRETTY, J. 2009. Can ecological agriculture feed nine billion people? *Monthly Review*, November.

PRETTY, J., ADAMS, B., BERKES, F., DUDLEY, N., DE ATHAYDE, S., HUNN, E., MAFFI, L., MILTON, K., RAPPORT, D., ROBBINS, P., SAMSON, C., STERLING, E., STOLTON, S., TAKEUCHI, K., TSING, A., VENTINNER, E. and PILGRIM, S. 2008. How do biodiversity and culture intersect? Plenary paper for Conference "*Sustaining cultural and biological diversity in a rapidly changing world; lessons for global policy*" 5–8 April. AMNH, IUCN and Terralingua.

PUTZ, F.E., BLATE, G.M., REDFORD, K.H., FIMBEL, R. and ROBINSON, J. 2001. Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology* **15**(1): 7–20.

RAHEL, S., VARGHESE, A., BRADBEAR, N., DAVIDAR, P., ROBERTS, S., ROY, P and POTTS, S. 2009. Benefits of biotic pollination for non-timber forest products and cultivated plants. *Conservation and Society* **7**: 213–219.

RAYMOND, S.U., LEEDER, S. and GREENBERG, H.M. 2006. Obesity and cardio-vascular disease in developing countries: a growing problem and an economic threat. *Current Opinion in Clinical Nutrition and Metabolic Care* **9**: 111–116.

RODRIGUES, A.S.L., ANDELMAN, S.J., BAKARR, M.I., BOITANI, L., BROOKS, T.M., COWLING, R.M., FISHPOOL, L.D.C., DA FONSECA, G.A.B., GASTON, K.J., HOFFMANN, M., LONG, J.S., MARQUET, P.A., PILGRIM, J.D., PRESSEY, R.L., SCHIPPER, J., SECHREST, W., STUART, S., UNDERHILL, L.G., WALLER, R.W., WATTS, M.E.J. and YAN, X. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature* **428**: 640–643.

ROS-TONEN, M.A.F. and WIERSUM, K.F. 2005. The scope for improving rural livelihoods though non-timber forest products: an evolving research agenda. *Forests, Trees and Livelihoods* **15**: 129–148.

ROSEGRANT, M.W. and CLINE, S.A. 2003. Global food security; challenges and policies. *Science* **302**: 1917–1919.

SANCHEZ, P.A. 2000. Linking climate change research and food security and poverty reduction in the tropics. *Agriculture Ecosystems and Environment* **82**: 371–383.

SAYER, J.A. and MAGINNIS, S. (eds.) 2005. *Forests in landscapes: ecosystem approaches to sustainability*. Earthscan, London. 257 p.

SCHERR, S.J. and MCNEELY, J.A. 2005. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. *Phil. Trans. R. Soc. B* **363**: 477–494.

SCHMIDHUBER, J. and TUBIELLO, F.N. 2007. Global food security under climate change. *PNAS* **104**: 19703–19708.

SCHMIDT, C.B., BURGESS, N.D., COAD, L., BELOKUROV, A., BESANÇON, C., BOISROBERT, L., CAMPBELL, A., FISH, L., GLIDDON, D., HUMPHRIES, K., KAPOS, V., LOUCKS, C., LYSENKO, I., MILES, L., MILLS, C,. MINNEMEYER, S., PISTORIUS, T., RAVILIOUS, C., STEININGER, M. and WINKEL, G. 2009. Global analysis of the protection status of the world's forests. *Biological Conservation* **142**: 2122–2130.

SCHROTH, G., DA FONSECA, A.B., HARVEY, C.A., GASCON, C., VASCONCELOS, H.L. and IZAC, A-M. (eds.) 2004. *Agroforestry and biodiversity conservation in tropical landscapes*. Island Press, Washington. 523 p.

SEMBA, R.D. and M.W. BLOEM. 2001. *Nutrition and Health in Developing Countries*. Humana Press. New York. 591 p.

SHANLEY, P., LUZ, L. and SWINGLAND, I.R. 2002. The promise of a distant market: a survey of Belém's trade in non timber forest products. *Biodiversity and Conservation* **11**: 615–636.

STEFFAN-DEWENTER, I., POTTS, S.G. and PACKER. L. 2005. Pollinator diversity and crop pollination services are at risk. *Trends in Ecology and Evolution* **20**: 651–652.

STEINER, A. 2011. Conservation and farming must learn to live together. *New Scientist*. http://newscientist.com/article/mg21028085.100-conservation-and-farming-must-learn-to-live-together.

SWAMINATHAN, M.S. 2001. Food security and sustainable development. *Current Science* **81**: 948–954.

TEN KATE, K. and LAIRD, S.A. 1999. *The commercial use of biodiversity*. Earthscan, London. 398 p.

THRUPP, L.A. 2000. Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture. *International Affairs* **76**: 265–281.

TOLEDO, A. and BURLINGAME, B. 2006. Biodiversity and nutrition; a common path toward global food security and sustainable development. *Journal of Food Composition and Analysis* **19**: 477–483.

TSCHARNTKE, T., KLEIN, A., KRUESS, A., STEFFAN-DEWENTER, I. and THIES, C. 2005. Landscape perspectives on agricultural intensification and biodiversity: ecosystem service management. *Ecology Letters* **8**: 857–874.

TUXILL, J. 1999. Appreciating the Benefits of Plant Biodiversity. In: BROWN, L.R., FLAVIN, C., FRENCH, H. and STARKE, L., *State of the World 1999: a Worldwatch Institute Report on Progress Toward a Sustainable Society*, W.W. Norton, New York. 96–114.

UNITED NATIONS. 2011. *Report submitted by Special Rapporteur on the right to food: Olivier de Schutter.* UN General Assembly Human Rights Council. http://www.srfood.org/index.php/en/component/content/article/1-latest-news/1174-report-agroecology-and-the-right-to-food.

VINCENTI, B., EYZAGUIRRE, P. and JOHNS, T. 2008. The nutritional role of forest plant foods for rural communities. In: COLFER, C.J.P. (ed.) *Human health and forests: a global overview of issues, practice and policy*. Earthscan, London. pp 63–93.

WORLD BANK. 2011. Food price hike drives 44 million people into poverty. Press Release No:2011/333/PREM http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22833439~pagePK:64257043~piPK:437376~theSitePK:4607,00.html.

The interweave of people and place: biocultural diversity in migrant and indigenous livelihoods around Mount Cameroon

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SUMMARY

In order to further understanding of the links between biological and cultural diversity, this study examined the role of forest species and biodiversity in the livelihoods of indigenous Bakweri villagers and migrants to the Mount Cameroon region. Surveys of resources consumed and sold by 118 households were undertaken in five villages over the course of one year. The contributions of different habitats and management systems (compounds, farms, fallow, forest) and species (native and introduced; cultivated and wild-harvested) to local livelihoods were evaluated. The study showed that indigenous households depend to a much greater extent upon a range of habitats and species than migrant households, particularly for subsistence. Indigenous resource management systems grow from historical relationships between people and place, and promote resilience, well-being and adaptation in an area long characterized by environmental, social, political, and economic uncertainty. The managed landscapes of indigenous villages can contribute to broader conservation efforts in the region, including those associated with the newly established Mount Cameroon National Park.

Keywords: biocultural diversity, traditional forest management, Mount Cameroon, Bakweri, non-timber forest products

Entremêlement humanité/location: diversités culturelles et biologiques dans les vies des indigènes Bakweri et des immigrants dans la région de Mount Cameroon , au Cameroun

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Afin de comprendre plus profondément les liens réunissant les diversités culturelles et biologiques, cette étude a examiné le rôle des espèces forestières et de la biodiversité sur les moyens d'existence des villageois indigènes Bakweri et des immigrants dans la région de Mount Cameroon. Une examination des ressources consommées et vendues par 118 foyers s'effectua dans cinq villages sur une durée d'une année. Les contributions des différents habitats et des systèmes de gestion (enceintes, fermes, jachères, forêts) des espèces (originaires de la région et introduites, cultivées et récoltées au naturel) jusqu'aux moyens d'existence locaux furent évalués. Cette étude montrait que les foyers indigènes dépendent beaucoup plus d'un assortiment d'habitats et d' espèces que les foyers d'immigrants, pour leur subsistence en particulier. Les systèmes de gestion indigène des ressources croissent à partir des relations historiques entre les peuplades et le site, et encouragent la persévérance, le bien-être et l'adaptation dans une zone depuis longtemps caractérisée par des fragilités environnementales, sociales, politiques et économiques. Les paysages gérés des villages indigènes peuvent contribuer aux efforts plus larges de conservation dans la région, ainsi qu'à ceux associés avec le Parc National de Mount Cameroon, récemment établi.

Un entramado de personas y lugares: diversidad biológica y cultural en la vida de la población indígena Bakweri y la de inmigrantes en la región del Monte Camerún

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Para poder entender más profundamente los vínculos entre la diversidad biológica y la cultural, este estudio examinó el papel de las especies forestales y la biodiversidad en los medios de subsistencia de los habitantes de las comunidades Bakweri y de los inmigrantes en la región del Monte Camerún. Durante un periodo de un año se realizaron encuestas en cinco localidades a fin de contabilizar los recursos consumidos y vendidos por 118 hogares. Se evaluó la contribución individual de los diferentes hábitats y sistemas de uso del suelo (mixtos, agrícolas y ganaderos, barbechos, bosques) y especies (nativas e introducidas; cultivadas o silvestres) a los medios de subsistencia locales. El estudio mostró que los hogares indígenas dependen en mucha mayor medida de una variedad de hábitats y especies que los hogares de los inmigrantes,

especialmente en cuanto a su subsistencia. Los sistemas indígenas de gestión de recursos provienen de las relaciones históricas entre las personas y el lugar, y fomentan la resiliencia, el bienestar y la adaptación a una región que se ha caracterizado desde hace mucho por la incertidumbre medioambiental, social, política y económica. Los paisajes bajo el uso de las localidades indígenas pueden contribuir a los esfuerzos de conservación del resto de la región, como los relacionados con el recientemente establecido Parque Nacional del Monte Camerún.

INTRODUCTION

Forests and biodiversity are central to indigenous livelihoods, health and well-being around Mount Cameroon. They are an integral part of complex and dynamic cultural systems that have adapted to enormous change over hundreds of years, including the forced removal of indigenous villages onto marginal lands to make room for German colonial plantations in the late 19th century (Ardener 1996, Kofele-Kale 2010). Despite this, more recent pressures on land and resources, and the forces of globalization, indigenous groups have nonetheless maintained sophisticated, multi-dimensional management and livelihood systems (Laird in press).

These systems integrate a range of habitats, species, and practices, accommodate and capitalize on seasonal change, and grow from local ecological processes. Similar management systems have been shown to retain significant forest cover and biological diversity, and replicate structural and functional elements of the forest (e.g. Alcorn 1989, Alexiades and Shanley 2005, Gomez-Pompa 1990, Redford and Padoch 1992, Peters 2000, Posey and Balee 1989, Posey 1999). They also conserve soil, regulate temperature, and resist pests and diseases better than more intensive agricultural systems, while contributing to genetic and species conservation, carbon sequestration, watershed protection, and wildlife habitat (Eyzaguirre and Linares 2004, Leakey and Tchoundjeu 2001, Sonwa *et al.* 2001, Zapfack *et al.* 2002).

Indigenous management systems around Mt. Cameroon do not primarily maximize the cash income possible from a given area, and instead aim to manage and maximize diversity as a way of reducing risk and maintaining a range of livelihood strategies in keeping with tradition, taste and personal preference. In this way, these systems provide a 'safety net' or 'natural insurance' during seasonal and cyclical food gaps, and during difficult years (Arnold and Ruiz-Perez 2001, Neumann and Hirsch 2000, Shackleton *et al*. 2011a), while also promoting resilience in an area long characterized by environmental, economic, political, social, and more recently accelerated climate, change. Migrant livelihood strategies vary depending upon how long families have lived in the area, where they came from, the extent of contact with forests, and other factors. On the whole, however, migrant households maximize gain to a greater extent, and use a far less diverse range of species and habitats, than indigenous households (Laird *et al.* 2007).

Indigenous people around Mount Cameroon are not 'noble' conservationists, nor are they a homogenous "community", however (Sharpe 1998, Burnham 2000). There is a great deal of variation in livelihood strategies and relationships to the forest within and between villages in the area. Many individuals will mine species when commercial opportunity presents itself, as in the case of bushmeat, timber or the medicinal bark of *Prunus africana* (Cunningham and Mbenkum 1993, Ingram 2008). Others will rent or sell land to migrants for farms although this is socially frowned upon, and some local elites clear forests for plantations. Despite this, being a "son of the soil" or indigenous to the area has been used in recent decades by some to further political or economic ends in ways that alienate and disempower migrants, many of whom have resided in the area for generations and have developed their own close relationships with the local environment (Geschiere 2009, Konings and Nyamnjoh 2003, Jua 2001, Sharpe 1998).

As a whole, however, and within the context of a region undergoing dramatic and persistent change, indigenous knowledge and practices reflect uniquely deep historical and cultural connections to particular places and species. This paper examines these connections, and what is increasingly termed "biocultural diversity". "Biodiversity" is the variability among living organisms from all sources, including diversity within species, between species and of ecosystems (Convention on Biological Diversity 1992). "Culture" refers to the shared, learned and symbolically expressed aspects of human experience and society. Cultural relationships with forests include traditional ecological knowledge on flora and fauna, edible versus inedible foods, plant medicines, and forest management systems, as well as shared notions of kinship, marriage, prohibitions, cosmology and ritual (Balee 1994), and 'cultural diversity' describes variability in these relationships. "Biocultural diversity" is the interweave of biological and cultural diversity, people and place, and the continuing adaptation and co-evolution between natural landscapes and ways of life (Cocks 2006b, Maffi 2005, Maffi and Woodley 2010, Wilson 2008). It is not a concept reserved for indigenous peoples, and describes a range of relationships between local people and biologically diverse environments (Cocks 2006a and 2006b).

Cultural diversity and biological diversity have long been the subjects of distinct areas of study, with the exception of multi-disciplinary – and so often marginalized – fields like ethnobiology (eg Alexiades 1996, Alexiades 1999, Alcorn 1989, Balee 1994, Gadgil 1993, Gomez-Pompa 1990, Martin 1995, Posey 1999). It is increasingly more widely accepted, however, that the richness and diversity of indigenous livelihood systems and peoples' relationships with nature cannot be understood or productively examined as independent domains (Pretty *et al*. 2009). Conservation, livelihoods, health and well-being are linked and interdependent parts of a whole (Colfer 2008, Cunningham *et al.* 2008, Dounias and Colfer 2008, Hladik *et al*. 1990, Hladik *et al*. 1993, Karjalainen *et al*. 2010, Posey 1999).

This paper reports on an ethnobiological study that integrated different approaches and disciplines in order to

examine the role of species from different habitats and management systems in the livelihoods of indigenous villagers and migrants to the Mt Cameroon region. The objective was to better understand the interweave of biological and cultural diversity, but the limits of any one study or approach in addressing such a complex and wide-ranging topic are acknowledged. Specifically, the study sought to answer the following questions: To what extent are indigenous livelihoods dependent upon a range of species and habitats (and so biodiversity)? How do indigenous livelihood systems compare to those of people new to the area without traditional and historical ties to the forest, species, and landscapes in which they live? Are there important relationships between cultural and biological diversity around Mt Cameroon that can inform and contribute to plans for a new national park and conservation goals in the region?

THE MOUNT CAMEROON REGION

The Mt Cameroon region is characterized by environmental, social and political change, and the lives of indigenous groups by adaptation and resilience. The largest mountain in West Africa, Mt Cameroon rises 4095 m from the Atlantic Ocean's Gulf of Guinea, on the southwest coast of Cameroon, to the summit 20 km inland. At 9.1 degrees east and 4.5 degrees north, it is the last active member of a range of volcanoes that extend from the island of Principe, around 100 km to the southwest, through Fernando Po of Equatorial Guinea (2850 m) to the highlands of Adamoua in Cameroon and Obudu in Nigeria. The Mt Cameroon region consists of two distinct peaks, Mt Cameroon (locally known as Fako) to the north-east, and the older Mt Etinde (1715 m) to the south-west (Letouzey 1968, Fraser *et al.* 1998).

Mt Cameroon comprises lowland and lower montane rainforest, upper montane and sub-alpine rainforest, and montane and sub-alpine grasslands (Ndam 1998; Cable and Cheek 1998). It is one of the most biologically diverse sites in Africa, with great altitudinal range, varied aspect and climate, and regular volcanic eruptions (including most recently in 1982, 1999 and 2000), producing a diversity of vegetation types and unusual levels of species endemism and richness (WWF 2001). This includes roughly 2500 indigenous and naturalized plant species (Cable and Cheek 1998), a recorded 370 species of birds including numerous endemics (Fotso *et al*, 2007), and important populations of large mammals, including forest elephants and chimpanzees, drills and other primates (Forboseh *et al.* 2007, Gadsby and Jenkins 1992). Mt Cameroon is part of what is known within the conservation community as the 'Guinean Forests of West Africa Biodiversity Hotspot'[1] (Conservation International 2011) and is an 'Important Bird Area' for Africa (Birdlife International 2011). Due to its extremely high species diversity and levels of endemism, and threats to its forests and biodiversity, Mt Cameroon is considered a global and national priority area for conservation (Birdlife International 2011, Conservation International 2011, Myers *et al.* 2000, Oates *et al*. 2004, WWF 2001).

The indigenous groups living around Mount Cameroon include the Bakweri, Bomboko, Bakolle, Balong, Isubu, and Wovea. All have a long history of interaction with external groups. For hundreds of years, African and European traders, explorers, scientists, missionaries, German and British colonial administrations, and others have been drawn to the dramatic landscape, fertile soils, and natural wealth of the region. Portuguese traders first arrived in 1472, and gave the country its name, and in 1884 the Germans established a colony in Cameroon (Ardener 2002, LeVine 1971). Following a series of battles, in 1901 the Germans established their headquarters in Buea, at the heart of Bakweri territory. Bakweri villages were forcibly relocated, usually up the slopes of the mountain, and their lands taken in order to establish the tea, rubber, oil palm, banana and other plantations that remain to this day, managed in recent decades by the Cameroon Development Corporation (CDC) (Kofele-Kale 1981, Ardener 1996). Boundaries between villages and plantations continue to be negotiated as part of what is called the "Bakweri land question", and in the last decade some villages have re-acquired marginal lands taken from them more than 100 years ago. Privatization of the parastatal CDC brought the Bakweri land problem to the forefront, and in 2002 the Bakweri Land Claims Committee (BLCC) brought their case to the African Human Rights Commission (Kofele-Kale 2010, BLCC 2011). The case was returned to Cameroon in order to exhaust domestic remedies, but the government has yet to enter into negotiations with the Bakweri (Kofele-Kale pers. comm. 2011).

Workers on the plantations have long been drawn from other parts of Cameroon, including francophone Cameroon, Nigeria, the Bamenda highlands and other parts of Southwest Province (Ardener *et al.* 1960, Ardener 1996, Konings and Nyamnjoh 2003). Many migrants have resided in the area for generations, and others continue to settle in local towns and to farm. Regardless of one's personal or family history, however, all non-indigenes are known as "strangers", or "came-no-goes" in pidjin English, by indigenous groups that have resented the influx of migrants since the 1920s (Geschiere 2009). This in-migration meant that by 1960 indigenous groups made up only 30% of the population of what was then known as Victoria Division, on the southern slopes of Mount Cameroon (Ardener 1996). A more recent study estimated that the indigenous population now makes up less than a quarter of the roughly 250,000 people in the Mount Cameroon region (Schmidt-Soltau 2003), and that percentage is falling as the population increases. In more remote and

[1] The Guinean Forests hotspot includes an estimated 9,000 vascular plant species, about 20% of which are thought to be endemic; 785 bird species of which 75 species and 7 genera are thought to be endemic; and 320 species of mammals, representing a quarter of the roughly 1100 mammal species found on the entire continent of Africa, with 60 of these endemic to the region, including 18 species of primates (Conservation International 2011).

rural areas, however, and with the exception of the cocoa-growing frontier around the Bomboko Forest Reserve, many villages remain entirely indigenous.

In December 2009, the Cameroon government established a national park on Mt Cameroon covering 58,178 hectares. The objectives of the park include protection of biodiversity, wildlife and 'non-consumptive' natural resources, as well as 'reducing pressure on the use of natural resources by introducing and promoting alternative sources of income to the local population' (WWF 2010). This is a complex region, with a highly dynamic and diverse population, environment, politics and economy. Conservation programs will be most effective when they grow from significant understanding of this complexity and the natural resource management strategies that have grown up in its midst over hundreds of years. This paper is an effort to shed light on one part of the interface between culture and nature – the dependence of indigenous and migrant households on forests and biodiversity for food, medicine, construction and other needs.

The study villages

The study was undertaken in five villages around Mount Cameroon – Ekonjo, Etome, Likombe, Upper Buando and Bova Bomboko (Figure 1). The first four villages are entirely indigenous Bakweri villages found on the southern slopes of Mount Cameroon. The study also included migrant farmers from other parts of Cameroon and Nigeria that rent or buy farm land in the vicinity of these villages but live elsewhere, including Cameroon Development Corporation plantation camps (Saxenhof Tea Estate camp) and in mixed indigenous and migrant villages closer to towns (Batoke and Wututu). By incorporating migrants farming on village lands, we could study differences in resource use and management in the same environments.

The fifth village, Bova Bomboko, is located at the north-eastern foot of Mount Cameroon. Originally an indigenous Bomboko village, it is now populated primarily by cocoa farmers from other regions of Cameroon (primarily North-west, Southwest, West and Centre Provinces) and Nigeria. Bomboko make up less than 10% of the village population (Table 1). Bova Bomboko abuts the roughly 26,667 ha Bomboko Forest Reserve created in 1939 as the Bomboko Native Authority Forest Reserve, and now absorbed into the new Mount Cameroon National Park. The potential to farm cocoa, including in the Reserve, has attracted individuals from other regions of Cameroon and Nigeria with scarce land and greater poverty. It is unclear whether significant in-migration

FIGURE 1 *Study area*

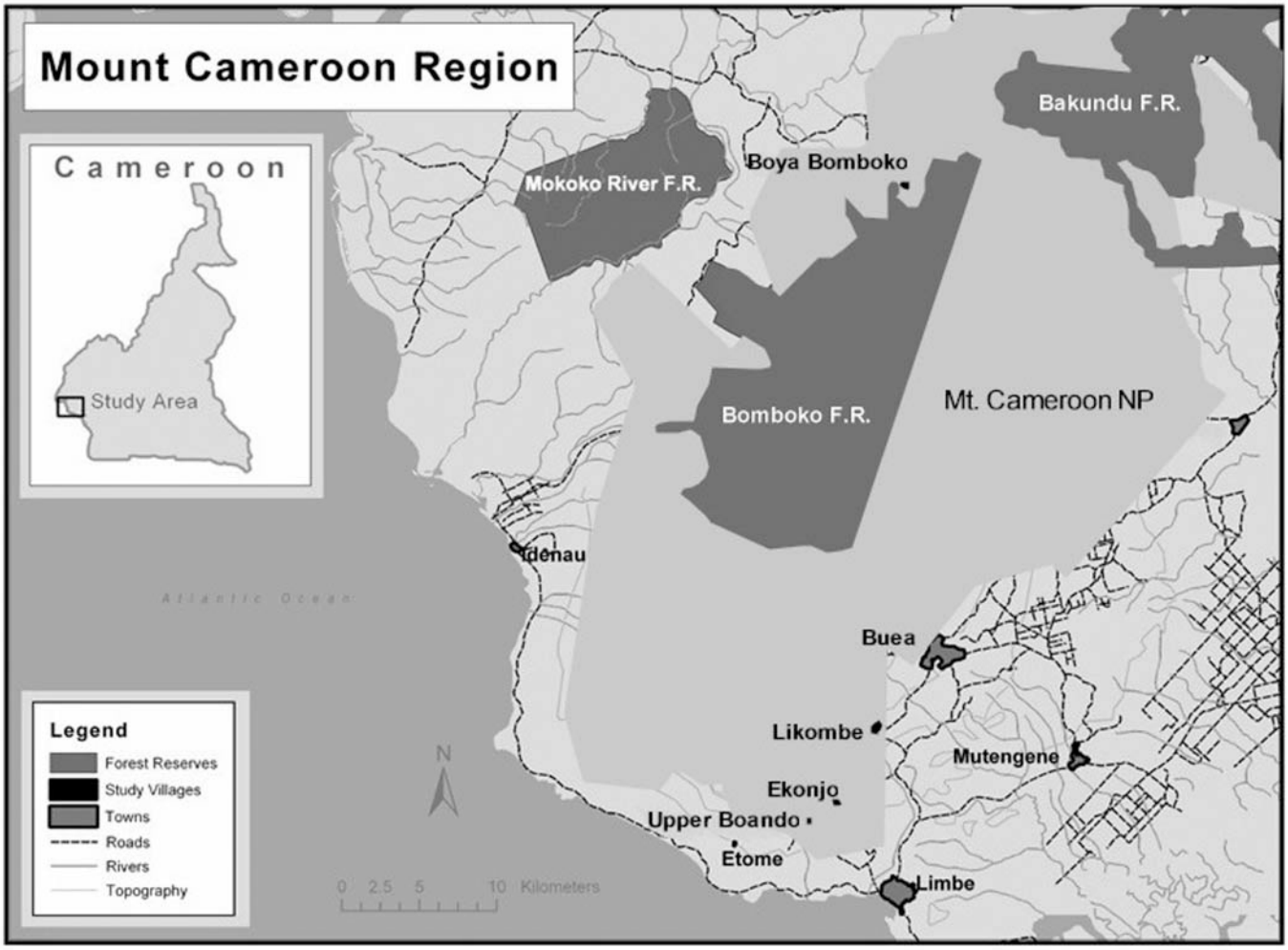

TABLE 1 *Population, structures and households in five study villages in the Mount Cameroon region in 2000*

Villages	Community type	Number of permanent residents	Number of separate structures or houses	Number of households living in village	Number of households in the household survey (# of individuals in these households)
Bova Bomboko	< 10% indigenous; remaining migrant	1151	129	212	48 (268)
Etome	Indigenous	67	18	10	10 (67)
Ekonjo	Indigenous	61	25	19	19 (61)
Likombe	Indigenous	265	79	61	23 (119)
Upper Buando	Indigenous	66	25	15	15 (66)

Source: village census

will continue if the new national park boundaries are more aggressively patrolled than were those of the Reserve.

Populations of the four indigenous Bakweri villages range in size from 61 to 265, with the mixed ethnicity Bova Bomboko being much larger at 1151 (Table 1). Bova Bomboko also has the youngest population of any village studied, with 89% of individuals under age 40 and 30% under the age of 10. Only 11% of the population is over the age of 40 (2% over the age of 60), compared with more than 30% of residents in Bakweri villages over the age of 40, and 11% over the age of 60. Some Bakweri villages have high proportions of older people, and smaller household sizes, and younger members of the community move in and out of the village, using it as a base of last resort when jobs fall through in local towns. Other villages with a more even spread of ages have more opportunities to earn a living while based in the village, and on average are more affluent.

METHODS

The project employed a wide range of qualitative and quantitative ethnobiological methods including a village census, daily household surveys, market surveys, and a range of resource use and management studies.

Village census

The initial phase of research included a village census, village mapping and household surveys of resource use. The census was undertaken in 2000 in the five study villages – Likombe, Etome, Ekonjo, Upper Buando, and Bova Bomboko – in a total of 317 households. Every household in each village was visited, and information collected on all members of the household and family, including: gender, age, ethnic group, relationship to household head, education level, residency (permanent, temporary, outside village), occupations, and relatives in village. For each household, sources of income were initially evaluated using pie charts (and at times stones, seeds, or other representations). Free-listing of species most widely used, valued, and most significant for household income, were undertaken. The total number of buildings in each village, as well as the total number of active households, was recorded (Table 1). In addition, demographic surveys were undertaken of migrant farmer households farming lands rented by and in proximity to the four Bakweri villages, but living outside in Batoke and Wututu villages, and Saxenhof Tea Estate camp.

Daily household surveys

Following the village census, intensive daily household surveys were undertaken to document resources gathered from farm, compound, fallow and forest for subsistence use and sale, as well as purchased items. The household survey allowed comparison of differences in resource use between ethnic and age groups, individuals with different occupations, and study villages of different size, geography, and proximity to forest, markets and urban centers. The daily household survey recorded all things collected and consumed, or sold, by households, and allowed us to move beyond identifying and listing what is generally reported as 'useful', to quantifying the nature of use. The products recorded include agricultural crops, wild foods (fruits, greens, mushrooms, spices, etc.), construction materials, fuelwood, medicines, protection and cultural species, and others.

In the larger villages, a sample of households was selected, stratified according to gender of household head, age of head, relative wealth, kinship, education level, source of income, and extent of reliance on forest (hunters, herbalists, weavers, and NTFP collectors, for example, depend more on the forest than those that primarily farm). In Likombe, 23 households were included in the household survey (29%), and in Bova Bomboko, 48 households (37%). In Etome, Ekonjo, and Upper Buando, household numbers are small enough that all households were included in the daily surveys. In each village, households were interviewed for five consecutive days, every other month, over the course of a year. With a total of 118 households included in the study, multiplied by 30 days across the year, a total of 3540 day surveys were administered. A total of 8779 entries for products (species) harvested and bought in local markets were recorded for all villages combined across the year (Table 2).

TABLE 2 *Number of plant products harvested from compounds (home gardens), farms, fallow and forest and bought by households in each study village in the Mount Cameroon region over the course of one year*[a]

Village	Products harvested	Products bought	Household type
Bova Bomboko	1226	944	<10% indigenous Bomboko; remaining migrant
Etome	519	232	indigenous
Ekonjo	690	455	indigenous
Likombe	1473	835	indigenous
Upper Buando	903	368	indigenous
Batoke	143	302	only migrant households surveyed
Saxenhof	225	197	only migrant households surveyed
Wututu	127	140	only migrant households surveyed

[a]Plant uses include food, medicine, spice, construction, fuelwood, symbolic or protective, and other uses.
Source: daily household survey

Market surveys and valuing products

In order to calculate a monetary value for products harvested for subsistence, market surveys were undertaken. For each village, a study in the main local market was undertaken to account for variations in prices between markets. Markets vary enormously in size and specialization, from under fifty sellers to more than one thousand (e.g. Limbe)[2].

Market surveys recording prices for products in both the rainy and dry seasons were undertaken because there can be significant seasonal variations in price. Fuelwood is not widely traded, but prices in local markets were obtained, and individuals in villages were asked how much they would be willing to pay for fuelwood. For plant medicines, wild greens and fruits, forest ropes, and other products that are not commonly sold, we selected a low figure (e.g. 100 CFA per bundle for medicines), or used a substitute product value. This approach undoubtedly undervalued these resources, but nonetheless allowed for their incorporation in the analysis (Campbell and Luckert 2002).

Broader resource use and management studies

This paper reports on the results of household and farm surveys, but the discussion is informed by a larger qualitative and quantitative research project undertaken over a period of eight years with a primary emphasis on indigenous biocultural diversity and relationships to the environment. Additional research with indigenous villages included a range of free-listing exercises; resource-specific surveys and field collections (wrapper leaves, forest ropes, fish, greens/vegetables, yams, mushrooms, medicinal plants); village income, artifact (household products, musical instruments, game pieces), and resource rights surveys; and dozens of 'walks in the woods', or interviews, with healers, basket-makers, hunters, NTFP gatherers, and others. Additional studies undertaken with both indigenous and migrant households include surveys and mapping of useful species found in compounds (home gardens) and cocoa and other farms, which provided finer detail on species use and management practices, and a "tree trail" exercise that helped to identify differences in plant knowledge across age, gender, occupation, ethnic group, and village.

RESULTS AND DISCUSSION

Brief overview of resource use and management systems

Drawing upon the larger study mentioned above, below we briefly review primarily Bakweri, and to a lesser extent Bomboko and migrant, resource use and management systems in order to provide a context for the quantitative data presented in subsequent sections.

Farm management and establishment

Bakweri management systems integrate a range of habitats, species and practices that vary by season. Households have on average between 3–4 farms, often in different locations around the village, in different stages of succession and management, and with varying crops depending upon soil fertility, altitude, and other factors. Individual farms tend to be 0.5–1 hectare in size, with the total area farmed by a single family usually between 2–5 hectares, although there is considerable variation. Most farms are cleared from fallow of around 6 years (fewer years than previously), and are farmed for roughly 5 years, depending upon the crop, before reverting to fallow

[2] Ekonjo sells and buys products mainly in Bonjongo and Limbe; Etome mainly in Batoke followed by Limbe; Likombe in Bokwango, Buea, Mile 4, and Wututu markets (and in the village to buyers coming from Douala to purchase wholesale bitterleaf and pepper, plantain and banana); Upper Buando residents sell and buy products in Limbe and Bobende; and Bova Bomboko is oriented towards Muyenge market.

again. Clearing farms from fallow takes place in the dry season, usually between December – March.

The vast majority of farms are inherited from parents or grandparents, with only a small number cleared from village land in the "black bush" (late secondary or mature forest). A few young men still clear new farms from black bush, since it allows them to claim land and the soil is fertile, but this practice remains an exception. Older individuals no longer have the strength to clear black bush, and others report a lack of time and the associated hardships: trees are large, black bush is often far from the village and uphill, and so transporting crops back is difficult, farms are exposed to animal predation, and tuber crops – central to Bakweri farming – do not do well in the first year due to tree roots in the soil.

Pressure on forest habitats for an expansion of "slash and burn" agriculture by Bakweri villagers is limited. Most households support their members with existing farms and fallow, and land held by the family. However, sale of land to migrant farmers living elsewhere or to local elites for plantations appears to be on the rise, and these result in both increased and often permanent forest clearance, and can involve the use of chemical inputs that reduce species diversity on farms. In the village of Bova Bomboko, the benefits for young migrants of clearing black bush for cocoa farms and to claim land far outweigh the costs. The result is farming systems that place significant pressure on the forest (Laird *et al*. 2007).

Farm and compound products

Cocoyam (*Colocasia esculenta*) and plantains (*Musa paradisiaca* varieties) are the main crops produced in all villages, complemented by dozens of others, most introduced to the region like banana (*Musa sapientum* varieties), cassava (*Manihot exculenta*), maize (*Zea mays*), and pepper (*Capsicum annuum*). In many Bakweri and Bomboko households indigenous crops like yams[3] and a wide range of cultivated and semi-domesticated native greens[4] are still important for both subsistence and to some extent sale (eg bitterleaf and sweet bitterleaf), but the bulk of agricultural crops farmed for subsistence and sale today – by both Bakweri and migrant households – are introduced to the region (Laird *et al*. in press).

As we discuss below, farms produce the vast majority of food for all villages and all ethnic groups, but indigenous households also rely extensively on species harvested from compounds (home gardens), fallow and forest. Compounds incorporate medicinal and food species collected from the forest, fallow and farm, given by friends or neighbors, and planted at home for easy access, including during the extreme rainy season when moving beyond one's compound can be difficult. They also include species intended to protect the home and its inhabitants.[5] Indigenous compounds symbolically may contain dozens of species collected from a range of sources over time, with healers' compounds proving the most diverse. Migrants' compounds tend to be extremely simple with one or two popular medicinal species, and perhaps a few crops (Laird *et al.* in press).

Fallow and forest products

Products harvested from fallows vary depending upon fallow age but include domesticated and semi-domesticated food, fruit, spice, fuelwood, medicinal, 'protection', and construction species like banana, plantain, pear (*Persea americana*), orange and lime (*Citrus* spp.), oil palm (*Elaeis guineensis*), raphia (*Raphia hookeri* – for 'mbanja' rope, thatches, palm wine), 'plum' (*Dacryodes edulis*) and other tree crops. Fallows are also home to a range of useful forest species that are not usually planted but might be nonetheless managed (e.g. retained, protected, and weeded). These include the spice and medicinal climber bush pepper, 'veove' (*Piper guineense*), and the spice trees 'njangsang' (*Ricinodendron heudelotii*) and bush mango, 'maiva' (*Irvingia gabonensis*). Some tree species planted or retained on farms generations ago are still found in fallows, which can reflect layers of use and management across generations.[6] As we will discuss below, fallow is not extensively used by migrants, however the more widely-known and used species found in indigenous fallows are often planted or retained on migrants' cocoa farms around Bova Bomboko (Laird *et al*., 2007).

Other useful products found in fallow and forest, and harvested primarily by indigenous households, include mushrooms (e.g. *Pleurotus* spp*., Polyporous* sp*., Marasmius* spp.; and *Letinus* sp.); wild greens like 'eru' for sale, and more commonly those consumed for subsistence (e.g. 'ngole', 'kalavanje', and 'wosango', *Solanum nigrum*); and 'wrapper leaves' from the Marantaceae family used to wrap food.[7] Some species collected from forest or very old fallow are widely known and used, including wrapper leaves; wild fruits like 'bwembi' and 'kaso' (*Tetracarpidium conophorum*);

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[3] Cultivated and wild-harvested yams include 'yono', *Dioscorea rotundata*; 'evie', *D. alata*; 'lisua', *D. dometurum*; 'liwoko', *D. bulbifera*; 'kumbu', *D. mummularia* (Laird in press). See the discussion in Dounias 1993 of Baka 'paracultivation' of yams in southern Cameroon, taking place at the interface of the domesticated and the wild.

[4] Cultivated native greens include bitterleaf, *Vernonia amygdalina*, sweet bitterleaf, *V. hymenolepsis*, and fluted pumpkin or 'mojojo', *Telfaria occidentalis,* and wild and semi-domesticated native greens include 'eru' *Gnetum africanum,* 'kalavanje' *Solanecio biafrae,* and 'ngole' *Celosia pseudovirgata* (Laird in press).

[5] Dounias 2010 describes the important role of homegardens in the "symbolic control of supernatural forces" in the lives of five ethnic groups in southern Cameroon; homegardens contribute in complex, multi-dimensional ways – ecological, spatial, social, historical, linguistic and symbolic – to household health and well-being.

[6] Examples include very old individuals of 'wulule' (*Kigelia africana*) on a cocoa farm in Bova Bomboko, and bush pineapple, 'wokeku', (*Myrianthus arboreus*), monkey cola, 'mombwesi' (*Cola argentea*) and 'bwembi' (*Treculia africana*) in Likombe fallow and farm margins.

[7] The main wrapper leaf species used in this region are 'vendomba', *Marantochloa ramosissima*, 'esongo', *Hypselodelphys scandens*, 'eteve', *Thaumatococcus danielii*,and 'ngongo', *Megaphrynium macrostachyum* (Laird in press).

spices like bush mango, 'njangsang', and bush onion (*Afrostyrax kamerunensis* and *A. lepidophyllus*); forest ropes like 'meveve' (*Cercestis mirabilis*); and timber species like iroko, 'momangi' (*Milicia excelsa*), camwood, 'ibwua' (*Pterocarpus soyauxii*) and mahogany, 'bou' (*Entandophragma cylindricum* and *E. angolense*). Other forest species are known and harvested primarily by individuals who spend a lot of time in the forest like operators and hunters (e.g. the subsistence foods monkey cola, 'mombwesi' *Cola* spp., and bush carrot, 'wonjonji' *Lavigeria macrocarpa*), or specialists like basket-makers and healers.[8]

This discussion is intended to broadly illustrate the range of species found in the four categories of 'habitat' used in the household survey and presented in the quantitative results below – compounds, farms, fallow, and forest. These distinctions are drawn sharply to identify and analyze broad patterns of habitat use, but are necessarily simplified and species are found and harvested from different sources – they are not only 'compound', 'farm', 'fallow', or 'forest' species[9]. Likewise, many species are not only 'wild' or "cultivated", and management often takes many intermediate forms. As found in similar studies around the world, habitats and management practices exist along a continuum rather than as distinct categories, and there is much nuance it was not possible to incorporate in the quantitative survey (e.g. fallow and forest of varying ages, different types and locations of farms, species that are not planted, but are retained and weeded on farms).

Activities that generate cash income

Subsistence farming and wild-harvesting dominate indigenous livelihoods. However, households also need cash to pay school fees, buy medicines, construction materials, kerosene, and various foodstuffs. In order to generate cash, most households grow and sell crops[10], and many harvest forest products, hunt, or work as laborers outside the village. Others work as petty traders or in various trades (carpentry, plumbing, basket-making, healing), or undertake small-scale logging.

Forest (and fallow) product collection for sale in markets, primarily by women, also brings in cash income, and varies by village depending upon species availability, proximity to forest and markets, and tradition. The main species collected for sale include 'mbanja' (*Raphia hookeri*) rope used to tie food, eru (*Gnetum africanum*) and wrapper leaves. 'Mbanja' ropes can be cleaned, coiled, and bagged, and wrapper leaves heated, stacked and packed during the evenings at home by women, with the children often helping. 'Mbanja' is produced by most households in Etome, and roughly a quarter of households elsewhere, and is collected mainly from fallow and farms, with 97% of collections sold and 3% for household use.[11] In Ekonjo and Upper Buando eru (*Gnetum africanum*) is more common in the forest than in other villages, and is more widely harvested and sold. Other NTFPs sold from these villages include 'bush pepper' (*Piper guineense*), 'kucha' (*Momordica cabraei*), and 'wrapper leaves'. In all villages, women also harvest and sell leaves from plantain and banana.

Basket-makers, mat-makers, hunters and healers also earn cash from their work, which is highly dependent upon a diversity of habitats and on biodiversity. For example, six men in Likombe village are healers of various kinds, with three earning a substantial part of their income this way (women also use medicinal plants and heal, but primarily for their families). Two older women are basket makers, and four men are active hunters, with three earning a significant income from hunting. One hunter is also a healer and an operator, as well as a farmer (typically, a range of activities contribute to household income, with some – like this household – more dependent upon biodiversity than others). In addition to generating cash, hunting contributes food for subsistence, with more than half of all bushmeat consumed in villages.[12]

In Bova Bomboko, livelihoods are oriented more towards generating cash income than to subsistence. The vast majority of individuals are primarily cocoa and food crop farmers, with more than 50% of all income coming from cocoa sales, and 40% from crops like cocoyams, plantains, and cassava. Ten percent of households are also petty traders or have jobs or a trade (eg electricians, plumbers, or carpenters). A small percentage (around 15%) of households harvest non-timber forest products (NTFPs) and earn roughly 5% of their income from about a half dozen NTFPs.[13] Subsistence use of NTFPs by migrants in Bova Bomboko is significantly less than

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[8] Scores of medicinal species – for example 'kwave' (*Strychnos* sp.), 'liembemba (*Palisota hirsute*), and 'mosongosongo' (*Clerodendron* spp.) – are collected almost exclusively by highly specialized healers.

[9] Household surveys documented the location of a product's harvest on a given day, and this might vary over time. In one day a household could also harvest the same product from two sources – e.g. plantains from the farm and compound – and the amounts harvested would be recorded separately under each habitat category.

[10] The main food crops grown for sale in all villages include plantain (*Musa paradisiaca* varieties) and banana (*Musa sapientum* varieties), cassava (*Manihot esculenta*), bitterleaf (*Vernonia amygdalina*), sweet bitterleaf (*Vernonia hymenolepsis*), pepper (*Capsicum annuum*), maize (*Zea mays*), palm nuts (*Eleais guineensis*), plum (*Dacryodes edulis*), mango (*Mangifera indica*), *Citrus* spp. and other fruits. Species produced vary by village, and depend upon altitude, climate and markets.

[11] In Etome, 'vendomba' *(Marantochloa ramosissima*), and to a much smaller extent 'esongo' (*Hypselodelphys scandens*) are the main wrapper leaves harvested, with more than 90% collected for sale.

[12] Bushmeat species reported most regularly in household surveys include flotambo, monkey, deer, rat mole, porcupine, bushcat and, on two occasions, chimpanzee.

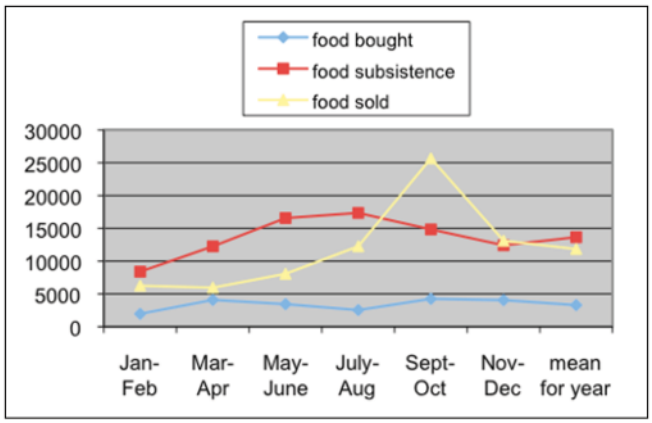
[13] The main NTFPs harvested in Bova Bomboko for sale in local markets include *Ricinodendron heudelotti* (njangsang), *Irvingia gabonensis* (bush mango), *Gnetum africanum* (eru), *Piper guineense* (bush pepper), *Cola lepidota* (monkey cola), *Garcinia kola* (bitter cola), and bushmeat.

TABLE 3 *Variation by Seasons: The Average Value (CFA) per Household of Food Bought, Consumed for Subsistence, or Sold in the Villages of Etome, Ekonjo, Likombe, Upper Buando*

	Food bought (CFA)	Food consumed for subsistence (CFA)	Food sold in local markets (CFA)
January – February	1,743	8,975	4,767
March – April	2,795	13,315	5,934
May – June	2,071	16,882	6,937
July – August	888	18,674	9,304
September – October	2,844	16,438	6,575
November – December	3,370	12,460	7,069
Mean for year	2,285	14,449	6,773

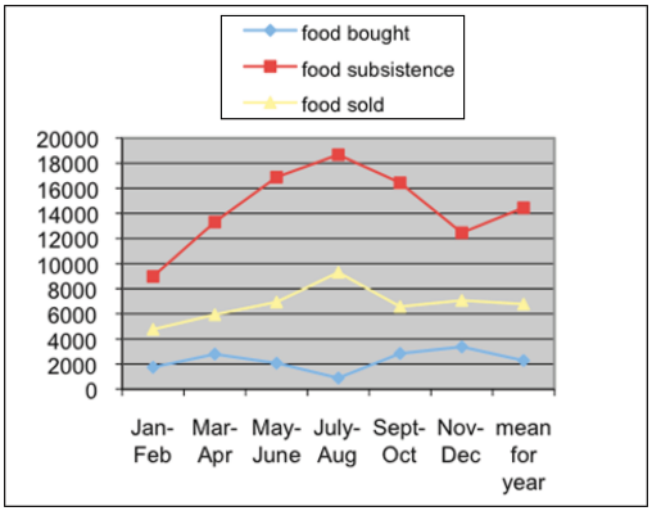
Source: household surveys

FIGURE 2 *Seasonal Average Value (CFA) per Household of Food Sold, Bought, for Subsistence (Bova Bomboko, Etome, Ekonjo, Likombe, Upper Buando, and Migrant Farmers)*



* The peak in food harvested for sale in September–October reflects the sale of cocoa in Bova Bomboko.
** 500 CFA = approximately $1

FIGURE 3 *Seasonal Average Value (CFA) per Household of Food Sold, Bought, for Subsistence (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*



500 CFA = $1

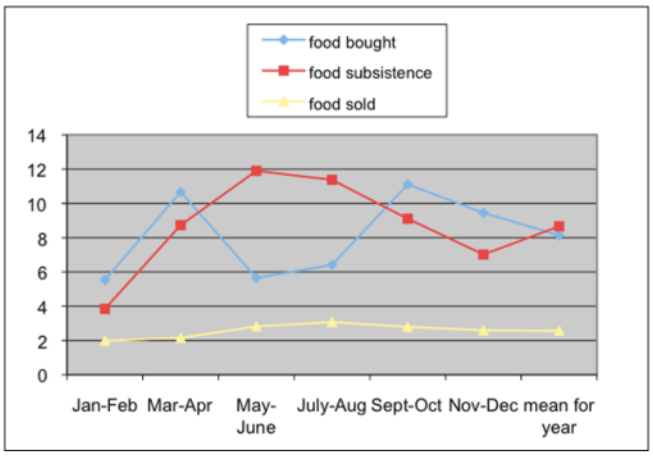
for Bomboko or Bakweri households, and species harvested for both subsistence and sale are those widely known and consumed throughout the forest zone of Cameroon (Laird *et al*. 2007).

Food harvested for subsistence, sale, and bought for household consumption

All villages included in this study produce more food for subsistence than they do for sale, or than they buy in local markets. The exception to this is Bova Bomboko in September-October, during the cocoa harvests (Figure 2). During this time, sale of cocoa surpasses the harvest of all other products combined in that village. In all villages, wild, semi-domesticated and cultivated food production peaks with the rainy season, between May and October. In the Bakweri villages of Etome, Ekonjo, Likombe and Upper Buando, the relationship between the harvest of food for subsistence and sale is more or less constant, with more than twice as much harvested for subsistence than for sale year round (Figure 3; Table 3). Food bought by households is consistently and significantly lower in value and number of items purchased than that harvested for sale or subsistence. Items bought by households drop significantly at the same time production from farms, and wild harvests from all habitats, increases, and so the need to buy food decreases[14]. (Table 3).

[14] The relationships between increased food harvested for subsistence and sale, and decreased purchase of food are significant. The quadratic component for 6 villages, value of products harvested (CFA): F (1) = 10.882, p = .003. The quadratic component for 6 villages, number of different products harvested: F(1) = 28.476, p = .000.

FIGURE 4 *Average Number of Food Items Sold, Bought, Consumed for Subsistence by Households (Bova Bomboko, Etome, Ekonjo, Likombe, Upper Buando, and Migrant Farmers)*



A much larger number (meaning diversity) of products are harvested for subsistence than for sale throughout the year. A core group of products like plantain and banana are sold consistently, but this group is far less diverse than those consumed for subsistence. The diversity of products harvested for subsistence is most apparent during the rainier half of the year, when wild fruits, greens, mushrooms, spices and other products become available (Figure 4).

Because many of these products are not sold in markets, and do not have high CFA values, numbers of items brought into households each day were compared, along with the value of those items. If a household sells 5,000 CFA of plantains, and consumes approximately a 100 CFA bundle of wild greens, and a 100 CFA handful of mushrooms, the importance of the latter two would be lost if only the CFA value were measured. Measuring the number of items brought into a household captures – albeit crudely – some of the biological diversity integral to peoples' lives, and the importance of cultural as well as economic values that drive many seasonal subsistence practices, including taste, nutrition, tradition, health and well-being.

The role of different habitats in livelihoods

Villages around Mt Cameroon depend upon a range of different habitats and species. Farms dominate the livelihoods of both indigenous and migrant households, but natural forest, fallow and compounds also contribute significantly to subsistence and the generation of cash income, particularly for indigenous households (Table 4). The vast majority of all species harvested from compounds, fallow, and forest are consumed for subsistence; from all four sources more than three times as much of all food, medicine, construction, and fuelwood is harvested for subsistence than for sale.

As Table 4 demonstrates, combined indigenous household income (subsistence and products sold) from compounds,

TABLE 4 *Annual mean CFA[1] contribution and number of items harvested per household from compound, farm, fallow and forest by indigenous and migrant farmer households in five villages in the Mount Cameroon region*

	Number of households in survey	Compound (CFA)	Farm (CFA)	Fallow (CFA)	Forest (CFA)	TOTAL (CFA)	Compound (No.)	Farm (No.)	Fallow (No.)	Forest (No.)	TOTAL (No.)
Bakweri/Bomboko – indigenous households	72	104,016 a	799,491	89,924 a	313,832	1,307,263	123 a	354	116 a	56 a	649
Migrants – SouthWest[2]	11	19,179 b	1,730,565	63,487 a	115,030	1,901,261	45 b	380	22 b	24 b	471
Migrants – NorthWest (30), other parts of Cameroon (2), Nigeria (3)	35	16,564 b	1,225,237	27,078 b	72,548	1,341,427	36 b	325	26 b	29 b	416
All households surveyed	118	70,169	1,012,567	67,162	223,733	1,516,650	90	348	80	45	563
Significance (*P*)		<0.001	0.093	<0.001	0.463		<0.001	0.647	<0.001	0.029	

Source: household survey, in 5 study villages; Laird *et al*, 2007.
Means in the same column that do not share a superscript are significantly different from each other by Tukey hsd.
[1]500 CFA = approximately $1US
[2]Farmers from the South West Province share many species and traditions with indigenous households around Mount Cameroon and have greater knowledge of species names and uses than other migrants.

TABLE 5 *Seasonal Average Household Food Harvested (CFA) from Compound, Farm, Fallow, and Forest (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*

	Compound	Farm	Fallow	Forest
January – February	910	12,109	507	216
March – April	2,435	15,623	738	456
May – June	3,313	18,333	491	1,676
July – August	3,694	21,477	313	2,500
September – October	2,749	17,644	1,200	1,362
November – December	1,269	16,343	297	1,627
mean for year	2,395	16,921	591	1,306

Source: household surveys in 5 study villages

FIGURE 5 *Seasonal Average Value (CFA) per Household of Food Harvested from Compound, Fallow, Forest (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*

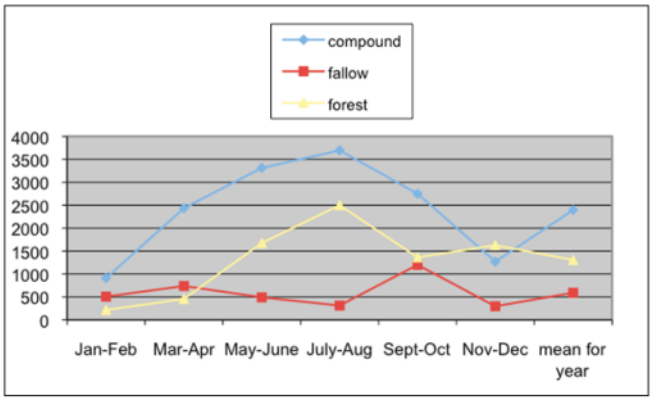
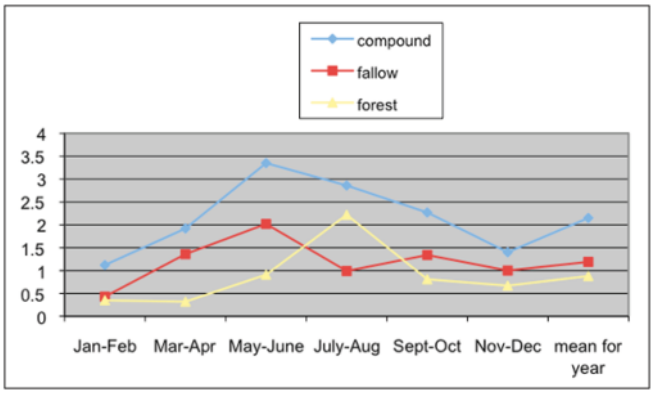


FIGURE 6 *Seasonal Average Number of Items per Household of Food Harvested from Compound, Fallow, Forest (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*



fallow, and forest makes up almost 40% of the value of products harvested from all sources, compared with roughly 10% for migrant households. Indigenous households also collect at least twice as many items in a year from the forest and five times as many from fallow than migrants to the region, with the exception of migrants who have come from neighboring areas in South West Province. These groups integrate more diversity into their livelihood strategies than other migrants, although still less than indigenous groups.

There are seasonal variations in the role different habitats play in local livelihoods. Farms provide the vast majority of food in all villages, across all seasons, and there is a very significant difference between the amounts of food produced from farms compared with other habitats.[15] For indigenous Bakweri villages, compounds follow farms in importance as a food source, then forest and fallow (Table 5). As noted above, compounds are an important source of food during the heavy rains in July and August, but all sources of food peak during the rainy months of May–October, and forests become an important wild food source (Figures 5 and 6). As the rains begin in May and June, fallow also shows an increase in numbers of items harvested, likely due to wild green (vegetable) and mushroom harvesting, and spice and fruit trees, which account for a large number of collections in Bakweri villages, but are of relatively small cash value.

Actual values for species harvested by Bakweri households from forest and fallow are likely higher than those reported in our study. This is because high-value products like timber and bushmeat are often illegally harvested, and thus generally under-reported, and hundreds of species are difficult to adequately capture and value properly in household surveys because they are consumed inconsistently, seasonally, or for subsistence as medicine, spice, wild foods, and other purposes. Even given this likely under-valuing of these species, it is clear from both the value and number (diversity) of products harvested from different sources that indigenous livelihoods depend upon the active use and management of a broader range of habitats than do those of migrants to the region.

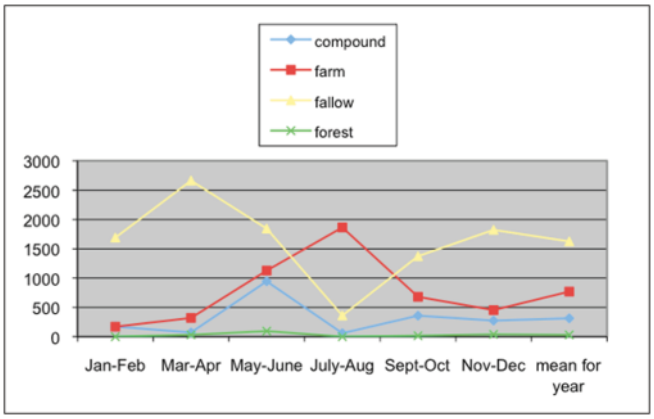
[15] The linear and quadratic components were both significant, suggesting real differences between farms and other sources of products: F (1) = 30.10, p = .000.

TABLE 6 *Seasonal Average Value (CFA) of Fuelwood Harvested from Compound, Farm, Fallow, and Forest (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*

	Compound	Farm	Fallow	Forest
January – February	172	170	1691	0
March – April	71	320	2664	32
May – June	945	1129	1845	95
July – Aug	59	1865	361	0
Sept-Oct	359	681	1374	16
Nov-Dec	275	454	1824	39
mean for year	314	770	1626	30

Source: household surveys in 5 study villages

FIGURE 7 *Seasonal Average Value (CFA) per Household of Fuelwood Harvested from Compound, Farm, Fallow, and Forest (Bakweri Villages – Etome, Ekonjo, Likombe, Upper Buando)*



Fuelwood and the role of different habitats

Fuelwood has been identified as a cause of forest degradation in the area by some conservation agencies, but in the Bakweri study villages the harvest of fuelwood for subsistence use in cooking is largely from fallows, followed by farms. Commercial fuelwood harvests (eg for the tea estate's driers) would appear to put pressure on forests (although this was not studied as part of this research), but subsistence fuelwood consumption in Bakweri villages does not depend upon the forest (Table 6, Figure 7)[16]. Fuelwood harvests in Bova Bomboko, on the other hand, are part of a land clearance and farming system that does cause forest loss and degradation. In this area, forest is available in what was the Bomboko Forest Reserve, forest abuts many cocoa farms and so is accessible to farmers as a source of fuelwood, and farms continue to be cleared from forest (Laird *et al.* 2007).

Total fuelwood harvesting in all villages remains fairly consistent throughout the year with a peak between March–June, and some variation in sources depending upon the season (Table 6). In December and January, fallow is cleared and fuelwood collected as part of clearing. In addition, large trees are burned at this time, and by April –May they are ready for felling and fuelwood is stockpiled for the rainy season, accounting for the peak in fuelwood harvests. In the rainy season fuelwood collection from fallow declines due to difficulties collecting and carrying fuelwood in rainy conditions, and fuelwood is harvested, if still needed, alongside crops from farms. Analysis of variance between sources of fuelwood indicated that differences between them are significant[17].

The use of native and wild species

Indigenous households use a significantly larger number of species, for a wider range of purposes, than migrants to the region. Bakweri villages use hundreds of species (more than 400 plant species are included in the checklist from this study alone), in order to meet almost every imaginable need, and these are sourced from a wide range of habitats and subject to varying degrees of management. In contrast, most migrant households in this study make regular use of only about 30 species. Migrants will harvest high-value non-timber forest products (NTFPs) like 'eru' (*Gnetum africanum*), 'bush mango' (*Irvingia gabonensis*), 'njangsang' (*Ricinodendron heudelotii*), 'bush pepper' (*Piper guineense*) and other species, as noted above, that are widely traded and consumed throughout the region, and those that are best studied to date (e.g. Awono *et al.* 2002, Awono *et al.* 2009, Ewane *et al.* 2009, Fuashi *et al.* 2010, Ndoye *et al.* 1997, Ndumbe 2010, Sunderland and Ndoye 2004, Sunderland *et al.* 1999,). Migrants are, however, unfamiliar with the full range and diversity of useful species in their adopted home. This is not surprising given that many grew up in extremely different environments (e.g. grasslands of the North West Province), lack historical and cultural ties to species and the landscapes in which they farm, may not have access to many resources, and usually direct their livelihood strategies to maximize cash income, which supports large families and is returned in part to home villages.

Close to 100 of the more than 400 species used by indigenous households were introduced to the region, and agriculture is dominated by introduced species. However, the contribution of native species (cultivated, semi-domesticated, and wild-harvested) to indigenous household income is not far behind that of introduced species (Table 7), which is striking given the dominance of farm income, and the difficulties

[16] Preferred fuelwood species vary by village, but some of the most commonly collected from farm and fallow include 'bwangu' (*Bridelia micrantha*), 'yumbaenge' (*Allophyllus africanus*), 'mbava' (*Anthonotha fragrans*), 'ebwebwe' (*Neoboutonia mannii*), 'ewowo' (*Macaranga occidentalis*), and 'mosenge' (*Macaranga monandra*).

[17] The quadratic component was significant, indicating significant differences between compound, farm, fallow and forest as sources of fuelwood: F (1) = 33.92, p = .000.

TABLE 7 *Annual mean income in CFA[1] and annual mean number of items collected by indigenous and migrant households that were: 1. cultivated or wild, and 2. native or introduced species, in five villages in the Mount Cameroon region*

Household type	Number of households in survey	Income from cultivated species (CFA)	Income from wild species (CFA)	Income from native species (CFA)	Income from introduced species (CFA)	Number of collections of cultivated species	Number of collections of wild species	Number of collections of native species	Number of collections of introduced species
Bakweri/Bomboko (indigenous households)	72	820,231 a	563,141	637,659	775,657 a	178	157 a	195 a	138
Migrants – SouthWest[2]	11	1,817,832 b	156,585	194,323	1,779,762 b	184	46 b	85 b	144
Migrants – NorthWest (30), other parts of Cameroon (2), Nigeria (3)	35	1,195,490 ab	127,993	145,115	1,176,682 ab	184	51 b	81 b	154
All households combined	118	1,024,533	399,580	450,237	988,208	180	115	151	143
Significance (*P*)		0.020	0.780	0.705	0.018	0.213	<0.001	<0.001	0.28

Source: household survey, in 5 study villages; Laird *et al*, 2007.

Means within the same column that do not share a superscript are significantly different from each other by Tukey hsd.

[1]500 CFA = approximately $1US

[2]Farmers from the South West Province share many species and traditions with indigenous households around Mount Cameroon and have greater knowledge of species names and uses than other migrants.

associated with adequately valuing native and wild harvested species in this study. Indigenous households also collect larger numbers of native and wild species over the course of a year than cultivated and introduced species, further illustrating the role of biological diversity in their livelihoods. When compared with migrant households, Bakweri households derive roughly 4 times the annual income from native and wild species, and bring 2–3 times as many wild and native items into the home (Table 7).

Bakweri households vary in their practices, with some making greater use of a mix of habitats, and native and wild species, than others. In some cases this can be explained by occupation (eg hunters and healers use a wider range of species and habitats), age (older individuals tend to know about and use more species, although they have a harder time accessing them), and other factors. But in many cases heavy reliance on biodiversity does not follow from community-wide trends as much as the internal workings of households, including personal taste and interests, and family tradition.

Biocultural diversity and conservation around Mt Cameroon

The cosmopolitanism of indigenous groups around Mt Cameroon – their incorporation of introduced weeds and crops, plastics and zinc, their clothes, proximity to towns, their long contact and engagement with outsiders, and the participation by some in selling land and resource 'mining' to serve urban and overseas markets – is sometimes viewed as evidence of a lack of real connection with land, species, and place. After a brief spell during which the Germans saw the Bakweri as fierce warriors, colonial regimes viewed the Bakweri (now removed from their lands) as 'indolent" or apathetic and in decline (Geschiere 2009). The biological diversity of Mt Cameroon is widely remarked upon, but the cultural diversity and traditional practices interwoven with biological diversity remain poorly understood. Indigenous resource management is often assumed to negatively impact forests, albeit in vague and unquantified ways, and to be at the same time somehow inefficient and under-developed. As elsewhere in Africa (eg Fairhead and Leach 1996, Homewood 2004, Igoe and Brockington 2007, Sullivan 2002), some conservation programs in recent decades have sought to promote natural resource-based "alternatives" that increase income from the forest and "improve" forest management, while overlooking sophisticated traditional practices that instead minimize risk and enhance resilience and quality of life in an area characterized by uncertainty and change.

At the same time, traditional knowledge with deep roots in the local environment, including that associated with wild foods, medicinal plants, games, dance, musical instruments, secret societies, and weaving, is under pressure alongside biodiversity, and as a result of many similar causes. Growing local towns and increasing access to global media through cell phones and the internet make villages a last resort for young people. The blight of HIV and other health problems weakens indigenous societies and requires the purchase of expensive medicines. Extreme social and economic inequity resulting from a broken and predatory government, liberalization of markets and the attendant uncertainties for commodity producers, and a breakdown of civil society mean that many local people struggle to make ends meet. Whether to pay school fees, buy food and medicine, purchase kerosene, cement, zinc or cooking pots, the pressure to generate cash is enormous.

Spikes in demand for forest products driven by urban and overseas markets combine with the need for cash and advances in technology and transportation to accelerate the depletion of bushmeat, medicinal plants, timber, and other forest resources. Migrants from poorer regions come to the Mt Cameroon area because it is relatively better off and has fertile soils, further taxing the forest. And centuries old demand from overseas for the natural resources of the area continues with a new suite of actors eyeing the fertile agricultural soils, timber and recently oil of the region. At the same time, traditional institutional structures and norms that control short-term exploitation at the expense of long-term health have weakened. Traditional knowledge and practices have adapted and accommodated external claims on forests, land and resources for hundreds of years, but the intensity of cultural and social change has perhaps never been greater.

Distinct from these pressures and the changes they have wrought in indigenous lives are elements of resource management systems and relationships to place that have adapted and evolved, but were handed down to current generations from parents and grandparents. Rather than directed towards quick gains, these systems place a premium on endurance, resilience and well-being over time. This is consistent with reports from tropical forest ecosystems from around the world. In environments so inherently complex and uncertain, traditional forest management commonly relies on strategies that minimize risk by incorporating diversity, accommodate uncertainty, and make use of mosaics of vegetation in different stages of succession to produce a range of products and services across seasons and years (e.g. Alcorn 1989, Balee 1994, Dove 1993, Falconer 1992, Parajuli 1999, Posey 1999, Redford and Padoch 1992, Richards 1999). In many areas, these systems have been shown to actually enhance rather than reduce biological diversity, and although it was not the subject of this study, seasonal and highly varied diets and traditional medicinal plant use would also appear to support local health and nutrition (Cunningham *et al.* 2008, Dounias *et al*. 2007, Shanley and Luz 2003, Sills *et al*. 2011, McGarry and Shackleton 2009).

There is a danger in extolling the virtues of indigenous resource management systems in an area with a long and recently highly active politics of identity that excludes migrants – many having lived in the region for generations – from access to economic and political resources based on criteria for belonging (Gerchiere 2009, Konings and Nyanmjoh 2003, Sharpe 1998). As Geschiere (2009) argues, despite its apparent naturalness and self-evidence, the concept of autochthony, and having "come first", is uncertain and pliable and has been used in Cameroon to not only marginalize migrants but also divide the opposition and bolster a corrupt regime. Around the world, the valorization of some forest

actors has served to undermine the legitimacy of others. In Brazil, for example, international and national conservation agencies have come to support indigenous peoples' and rubber tappers' claims to forest but remain cool on migrants and peasants (Campos 2006, Campos and Nepstad 2006). In South Africa, non-traditional groups living in peri-urban or urban environments consume wild resources but are often not considered part of the biocultural diversity of that country (Cocks 2006a). The point of this paper is not to contribute to a divisive dialogue but to instead build understanding of the biocultural diversity of Mt. Cameroon, which has been poorly studied to date. Even modified, and diminished in many households in recent decades, traditional resource management continues to form the backbone of rural indigenous livelihoods around Mt. Cameroon, and these practices and knowledge are tightly woven into the local landscape and its biological diversity.

Whatever its strengths, traditional knowledge and practices cannot address the primary causes of deforestation and biodiversity loss – poverty, political, economic and social inequity, and natural resource 'mining' – and local communities can do little to reverse the deterioration in government institutions over the last few decades, and the rise of corruption that contributes to forest and biodiversity loss (Assembe 2009, Burnham and Sharpe 1997, Egbe 2001, Laird *et al*. 2010, Pye-Smith 2010, Cerutti and Lescuyer 2011, Ndoye and Awono 2010, Transparency International 2010). In fact, indigenous resource management accounts for only a small part of the total Mt Cameroon area today. But traditional knowledge and practices can complement western scientific studies of species and ecosystems, and reveal and support approaches to conservation that embrace uncertainty, complexity, and change (eg Dove 1993, Fairhead and Leach 1996, Igoe and Brockington 2007, Parajuli 1999, Richards 1999). In a region as densely populated as Mt Cameroon, with enormous pressure on remaining forests, managed landscapes – including those of indigenous communities – will be integral to broader conservation efforts around the Mt Cameroon National Park.

CONCLUSION

At first glance, the livelihood systems of indigenous and migrant households seem alike. With variations in emphasis, they rely on a similar suite of crops for cash income and subsistence, and collect similar high-value forest products known throughout the region. Upon closer inspection, however, it becomes apparent that Bakweri households use a much larger number and variety of species – native and introduced, wild and cultivated – and actively manage and use a range of habitats. The diversity inherent in these systems is greatest, but most invisible to the outside eye, as manifested in subsistence use. Products sold in markets for cash – whether crops or forest products – are drawn from a pool of resources that is small compared with those used for subsistence, and their harvest responds to external demand. Subsistence, on the other hand, reflects long cultural ties to place, to the landscape, species, seasons, and history.

The arrival of mushrooms and wild greens at the start of the rains, visiting a favourite fruit tree planted by a relative when it bears briefly, or a healer's mixture of dozens of medicinal species, many collected from very particular locations at particular times – all speak to a system that not only generates cash, but also accommodates many other social needs, material as well as symbolic. For conservation to succeed in a region so densely populated, with fertile soil and rich in natural resources that bring outside groups, large and small, to the area, managed landscapes must be part of conservation planning. The managed landscapes of indigenous groups around Mt Cameroon cover only a small portion of the area today, but are expressions of long-standing, diverse and dynamic relationships between people and place, culture and nature and, rather than threats, can significantly contribute to biodiversity and forest conservation in the region.

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REFERENCES

ALCORN, J. 1989. Process as resource: the traditional agricultural ideology of Bora and Huastec resource management and its implications for research. In: POSEY, D.A. and BALEE, W. (eds). *Resource management in Amazonia: Indigenous and folk strategies*. Advances in Economic Botany, the New York Botanical Garden, **7**(1): 2163–77.

ALEXIADES, M.N. and SHANLEY, P. 2005. *Forest products, livelihoods and conservation: Case studies of non-timber forest product systems*. Volume 3 – Latin America, CIFOR, Bogor, Indonesia.

ALEXIADES, M. 1996. *Selected guidelines for ethnobotanical research: a field manual.* Advances in Economic Botany, the New York Botanical Garden, Bronx, NY.

ALEXIADES, M.N. 1999. *Ethnobotany of the Ese Eja: Plants, Health and Change in an Amazonian Society*. Ph.D. Dissertation. City University of New York. Ann Arbor, Michigan, UMI Microform.

ARDENER, S. (ed.). 2002. *Swedish ventures in Cameroon 1883–1923: Trade and travel, people and politics: The memoir of Knut Knutson.* Berghahn Books, Oxford. 288 p.

ARDENER, E. 1996. *Kingdom on Mount Cameroon: Studies in the History of the Cameroon Coast*, 1500–1970. Berghahn Books, Oxford.

ARDENER, E., ARDENER, S., and WARMINGTON, W.A. 1960. *Plantation and village in the Cameroons*. Oxford University Press, London.

ARNOLD, J.E.M. and RUIZ- PEREZ, M. 2001. Can non-timber forest products match tropical forest conservation and development objectives? *Ecological Economics* **39**(3): 437–447.

ASSEMBE, S.M. 2009. State failure and governance in vulnerable states: An assessment of forest law compliance and enforcement in Cameroon. *Africa Today* **55**(3): 85–102.

AWONO, A., NDOYE, O., SCHRECKENBERG, K., TABUNA, H., TEMPLE, L. 2002. Production and marketing of safou (*Dacryodes edulis*) in Cameroon and internationally. *Forests, Trees and Livelihoods* **12**(1): 125–147.

AWONO, A., DJONGNEP, A., ZAPFACK, L., NDOYE, O. 2009. The potential of *Irvingia gabonensis*: Can it contribute to the improvement of the livelihoods of producers in Southern Cameroon? *International Journal of Social Forestry* **2**(1): 67–85.

BAKWERI LAND CLAIMS COMMITTEE (BLCC). 2011. http://www.blccarchives.org.

BALEE, W. 1994. *Footprints of the forest: Ka'apor ethnobotany – The historical ecology of plant utilization by an Amazonian People.* Columbia University Press, New York.

BIRDLIFE INTERNATIONAL. 2011. *Important bird areas factsheet: Mount Cameroon and Mokoko-Onge*. http://www.birdlife.org.

BURNHAM, P. 2000. Whose forest? Whose myth? Conceptualisations in community forests in Cameroon, pp 31–58. In: ABRAMSON, A. and THEODOSSOPOULIS, D. (eds). *Land, Law and Environment: Mythical Land, Legal Boundaries*. Pluto Press, London, 232 p.

BURNHAM, P. and SHARPE, B. 1997. *Political, institutional, social and economic dimensions of Cameroon's forestry and conservation sectors*. University College, London.

CABLE, S. and CHEEK, M. 1998. *The plants of Mt Cameroon: A conservation checklist*. Royal Botanic Gardens, Kew, London.

CAMPBELL, B.M. and LUCKERT, M.K. 2002. *Uncovering the hidden harvest: Valuation methods for woodland and Forest resources*. Earthscan, London.

CAMPOS, M.T. and NEPSTAD, D.C. 2006. Smallholders, the Amazon's new conservationists. *Conservation Biology* **20**(5): 1553–1556.

CAMPOS, M.T. 2006. *New Footprints in the Forest: Environmental Knowledge, Management practices, and Social Mobilization among 'Colonos' from the Transamazon Region*. Doctoral Dissertation, Yale University.

CERUTTI, P. and LESCUYER, G. 2011. *Le marche domestique du sciage artisanal au Cameroun: état des lieux, opportunités et défis*. Occasional paper 59. Center for International Forestry, Bogor, Indonesia.

COCKS, M. 2006a. *Wild plant resources and cultural practices in rural and urban households in South Africa: Implications for bio-cultural diversity conservation*. PhD thesis Wageningen Universitty, Wageningen, The Netherlands

COCKS, M. 2006b. Biocultural diversity: Moving beyond the realm of 'indigenous' and 'local' people. *Human Ecology* **34**(2): 185–200.

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

CONSERVATION INTERNATIONAL. 2011. *Biodiversity hotspots: Guinean forests of West Africa*. www.biodiversityhotspots.org.

CONVENTION ON BIOLOGICAL DIVERSITY. 1992. www.biodiv.org.

CUNNINGHAM, A.B. and MBENKUM, F.T. 1993. *Sustainability of harvesting Prunus Africana bark in Cameroon: a medicinal plant in international trade*. WWF/UNESCO/ Kew People and Plants Working Paper No. 2.

CUNNINGHAM, A.B., SHANLEY, P. and LAIRD, S.A. 2008. Health, habitats and medicinal plants use, pp 35–62. In: COLFER, C.J.P. 2008. *Human health and forests: A global overview of issues, practice and policy*. Earthscan, London.

DOUNIAS, E. 2010. "An ounce of prevention is worth a pound of cure"; Fang homegarden organization as a means to prevent health risks. *The Open Complementary Medicine Journal* 2010 (2), pp. 31–41.

DOUNIAS, E. and COLFER, C.J.P. 2008. Socio-cultural dimensions of diet and health in forest dweller's systems. In: COLFER C.J.P. (ed.) *Human health and forests. A global overview of issues, practice and policy*. Earthscan, London, pp. 279–296.

DOUNIAS, E., SELZNER, A., KOIZUMI, M., and LEVANG, P. 2007. From sago to rice, from forest to town: The consequences of sedentarization for the nutritional ecology of Punan former hunter-gatherers of Borneo. *Food and Nutrition Bulletin* 28 (2), United Nations University, pp. 294–302.

DOUNIAS, E. 1993. The perception and use of wild yams by the Baka hunter-gatherers in south Cameroon rainforest. In HLADIK, C.M., PAGEZY H., LINARES, O.F., HLADIK, A., SEMPLE, A., HADLEY M. (eds.) *Tropical Forests, People and Food: Biocultural interactions and applications to development*. UNESCO-Parthenon, Man and Biosphere Series, Paris, pp. 621–632.

DOVE, M.R. 1993. Uncertainty, humility and adaptation to the tropical forest: the agricultural augury of the Kantu. *Ethnology* **40**(2): 145–167.

EGBE, E.S. 2001. The concept of community forestry under Cameroonian law. *Journal of African Law* **45**(1): 25–50.

EWANE, M., V. INGRAM and A. AWONO. 2009. *Market chain baseline for bush mango (Irvingia* spp.*) in the South*

West and Eastern Regions of Cameroon. GCP/RAF/408/EC. CIFOR and the European Commission, Yaounde, Cameroon.

EYZAGUIRRE, P.B. AND LINARES, O.F. 2004. *Home Gardens and Agrobiodiversity*. Smithsonian Books, Washington DC. 296 p.

FALCONER, J. 1992. A study of non-timber forest products in Ghana's forest zone. In: *The rainforest harvest: Sustainable strategies for saving the tropical forests?* Friends of the Earth, London.

FAIRHEAD, J. and LEACH, M. 1996. *Misreading the African Landscape: society and ecology in a forest-savanna mosaic*. Cambridge University Press, Cambridge UK.

FORBOSEH, P.F., ENO-NKU, M. and SUNDERLAND, T. C.H. 2007. Priority setting for conservation in south-west Cameroon based on large mammal surveys. *Oryx* **41**(2): 1–8.

FOTSO, R., DOWSETT-LEMAIRE, F., DOWSETT, R.J., CAMEROON ORNITHOLOGICAL CLUB, SCHOLTE, P., LANGUY, M. and BOWDEN, C. 2007. *Important bird areas in Africa and associated island – Cameroon*. Birdlife International.

FRASER, P.J., HALL, J.B, and HEALEY, J.R. 1998. *Climate of the Mount Cameroon Region: Long and medium term rainfall, temperature and sunshine data*. University of Wales, Bangor; Mount Cameroon Project and Cameroon Development Corporation. School of Agricultural and Forest Sciences Publication Number 16.

GADGIL, M. 1993. Indigenous knowledge for biodiversity conservation. *Ambio* **22**: 151–156.

GADSBY, E.L. and JENKINS, P.D. 1992. *Report on wildlife and hunting in the proposed etinde forest reserve*. Unpublished report, Limbe Botanic Garden and Rainforest Genetic Conservation project, Limbe, Cameroon.

GESCHIERE, P. 2009. *The perils of belonging: Authochtony, citizenship, and exclusion in Africa and Europe*. The University of Chicago Press, Chicago and London. 283 p.

GOMEZ-POMPA, A. 1990. Traditional management of tropical forests in Mexico. In: ANDERSON, A. (ed.) *Alternatives to deforestation: Steps towards sustainable use of the Amazon Rainforest*. Columbia University Press, New York.

HLADIK, C.M., PAGEZY H., LINARES, O.F., HLADIK, A., SEMPLE, A., HADLEY M. (eds.). 1993. *Tropical Forests, People and Food: Biocultural interactions and applications to development*. UNESCO-Parthenon, Man and Biosphere Series, Paris.

HLADIK, C.M., BAHUCHET, S. and GARINE, I. DE (eds). 1990. *Food and Nutrition in the African Rain Forest.* UNESCO-Parthenon, Man and Biosphere Series, Paris.

HOMEWOOD, K.M. 2004. Policy, environment, and development in African rangelands. *Environment, Science and Policy* **7**(3): 125–143.

IGOE, J. and BROCKINGTON, D. 2007. Neoliberal conservation: A brief introduction. *Conservation and Society* **5**(4): 432–449.

Ingram, V. 2008. *Lobby for sustainable harvesting of Prunus in Cameroon.* Working Paper, The Netherlands Development Organization (SNV), Bamenda, Cameroon.

JUA, N. 2001. Democracy and the construction of allogeny/authochthony in postcolonial Cameroon. *African Issues Ethnicity and Recent Democratic Experiments in Africa* **29**(1/2): 37–42.

KARJALAINEN, E., SARJALA, T. and RAITO, H. 2010. Promoting human health through forests: overview and major challenges. *Environmental Health and Preventive Medicine* **15**: 1–8.

KOFELE-KALE, N. 2010. Asserting permanent sovereignty over ancestral lands: the Bakweri land litigation against Cameroon. *Annual Survey of International and Comparative Law* **13**(1/6): 103–156.

KOFELE-KALE, N. 1981. *Tribesmen and patriots: political culture in a poly-ethnic African state*. University Press of America, Washington DC.

KONINGS, P. and NYAMNJOH, F.B. 2003. *Negotiating an Anglophone identity: A study of the politics of recognition and representation in Cameroon*. Leiden and Boston: Brill, Afrika-Studiecentrum Series No 1. 230 p.

LAIRD, S.A., INGRAM, V., AWONO, A., NDOYE, O., SUNDERLAND, T., LISINGE FOTABONG, E., NKUINKEU, R. 2010. Integrating customary and statutory systems: the struggle to develop a legal and policy framework for NTFPs in Cameroon. In: LAIRD, S.A., MCLAIN, R. and WYNBERG, R.P. (eds) *Wild product governance: Finding policies that work for non-timber forest products*. Earthscan, London.

LAIRD, S.A., MCLAIN, R. and WYNBERG, R.P. 2010. *Wild product governance: Finding policies that work for non-timber forest products*. Earthscan, London, 393 p.

LAIRD, S.A., LEKE, G.A. and LYSINGE, R.J. 2007. Cocoa farms in the Mount Cameroon region: biological and cultural diversity in local livelihoods. *Biodiversity and Conservation, Special Issue: Biodiversity Conservation in Cocoa Production Landscapes* **16**(8): 2401–2427.

LAIRD, S.A. (in press) An ethnoecology of Mt Cameroon: diversity and resilience in peoples' relationship to place.

LAIRD, S.A., LEKE, G.A. and E.L. NDIVE (in press). *A snapshot of biocultural diversity: home gardens around Mt Cameroon*.

LEAKEY, R.R.B. and TCHOUNDJEU, Z. 2001. Diversification of tree crops: domestication of companion crops for poverty reduction and environmental services. *Exp. Agric.* **37**: 279–296.

LETOUZEY, R. 1968. Note phytogéographique du Cameroun. Encyclopedie Biologique, 49, 508.

LE VINE, V.T. 1971. *The Cameroon Federal Republic*. Cornell University Press, Ithaca, NY.

MAFFI, L. 2005. Linguistic, cultural, and biological diversity. *Annual Review of Anthropology* **34**: 599–617.

MAFFI, L. and WOODLEY, E. 2010. *Biocultural diversity conservation: A global sourcebook.* Earthscan, London.

MARTIN, G. 1995. *Ethnobotany: A methods manual*. Chapman and Hall, London.

MCGARRY, D.K. and SHACKLETON, C.M., 2009. Children navigating rural poverty: rural children's use of wild resources to counteract food insecurity in the Eastern Cape province, South Africa. *J. Child Povert.* **15**: 19–37.

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., DA FONSECA, G.A.B. and KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.

NDAM, N. 1998. *Tree Regeneration, vegetation dynamics and the maintenance of biodiversity on Mount Cameroon: the relative impact of natural and human disturbance.* Dissertation, University of Wales, Bangor.

NDOYE, O., RUIZ-PEREZ, M. and EYEBE, A. 1997. *The markets of non-timber forest products in the Humid Forest Zone of Cameroon*. Rural Development Forestry Network, Network Paper 22c, ODI, London.

NDOYE, O. and AWONO, A. 2010. Policies for *Gnetum spp*. trade in Cameroon: overcoming constraints that reduce benefits and discourage sustainability. In: LAIRD, S.A., MCLAIN, R. and WYNBERG, R.P. *Wild product governance: Finding policies that work for non-timber forest products*. Earthscan, London. pp 71–76.

NDUMBE, N.L. 2010. *Markets and market chain analysis for Gnetum spp. in South West and Littoral regions of Cameroon*. Unpublished MSc thesis, University of Buea, Cameroon.

NEUMANN, R.P. and HIRSCH, E. 2000. *Commercialisation of non-timber forest products: review and analysis of research.* Center for International Forestry Research/FAO, Bogor, Indonesia.

OATES, J.F., BERGL, R.A. and LINDER, J.M. 2004. *Africa's gulf of Guinea forests: Biodiversity patterns and conservation priorities*. Advances in Applied Biodiversity Science No 6, Centre for Applied Biodiversity Science, Washington DC.

PARAJULI, P. 1999. Peasant cosmovisions and biodiversity: some reflections from South Asia. In: POSEY, D.A. 1999. *Cultural and spiritual values of biodiversity.* United Nations Environment Programme, Nairobi, Kenya.

PETERS, C.M. 2000. Precolumbian silviculture and indigenous management of neotropical forests. In: LENTZ, D.L. (ed.) *Imperfect balance: Landscape transformations in the Precolumbian Americas.* Columbia University Press, New York.

POSEY, D.A. 1999. *Cultural and spiritual values of biodiversity*. United Nations Environment Programme, Nairobi, Kenya.

POSEY, D.A. and BALEE, W. 1989. Resource management in Amazonia: Indigenous and folk strategies. *Advances in Economic Botany*, the New York Botanical Garden **7**(1): 2163–77.

PRETTY, J., ADAMS, B., BERKES, F., FERREIRA de ATHAYDE, S., DUDLEY, N., HUNN, E., MAFFI, L. MILTON, K., RAPPORT, D., ROBBINS, P., STERLING, E., STOLTON, S., TSING, A., VINTINNERK, E. and PILGRIM, S. 2009. The intersection of biological diversity and cultural diversity: towards integration. *Conservation and Society, 100–112*. www.conservationandsociety.org.

PYE-SMITH, C. 2010. *Cameroon's hidden harvest*. Center for International Forestry Research, Bogor, Indonesia.

REDFORD, K. and PADOCH, C. (eds). 1992. *Conservation of Neotropical Forests: Working from traditional resource use.* Columbia University Press, New York.

RICHARDS, P. 1999. *Musanga cecropioides:* biodynamic knowledge encoded in mythic knowledge. In: POSEY, D. A. *Cultural and Spiritual Values of Biodiversity*. United Nations Environment Programme, Nairobi, Kenya.

SCHMIDT-SOLTAU, K. 2003. *Rural livelihoods and social infrastructure around Mt Cameroon: Background information for the Mount Cameroon socio-economic geographical information system* (MC-SE-GIS). Im Auftrag der Deutschen Gesellschaft fur Technische Zusammenarbeit (GmbH).

SHACKLETON, S., DELANG, C.O. and ANGELSEN, A. 2011a. From subsistence to safety nets and cash income: exploring the diverse values of non-timber forest products for livelihoods and poverty alleviation. In: SHACKLETON, S., SHACKLETON, C. and SHANLEY, P. (eds). *Non-Timber Forest Products in the Global Context*. Springer Verlag, Berlin.

SHACKLETON, S., SHACKLETON, C. and SHANLEY, P. 2011b. *Non-timber forest products in the global context*. Springer Verlag, Berlin.

SHANLEY, P. and LUZ, L. 2003. The impact of forest degradation on medicinal plant use and implications of health care in Eastern Amazonia. *Bioscience* **53**: 573–84.

SHARPE, B. 1998. First the forest: conservation, "community" and "participation" in south west Cameroon. *Africa* 68(1).

SILLS, E., SHANLEY, P., PAUMGARTEN, F., DE BEER, J. and PIERCE, A. 2011. Evolving perspectives on non-timber forest products. In: SHACKLETON , S., SHACKLETON, C. and SHANLEY, P. *(eds). Non-Timber Forest Products in the Global Context*. Springer Verlag, Berlin.

SONWA, D., WEISE, S.F., TCHATAT, M., NKONGMENECK, B., ADESINA, A.A., NDOYE, O. and GOCKOWSKI, J. 2001. The role of cocoa agroforests in community and farm forestry in Southern Cameroon. Rural Development Forestry Network Paper, 25 p., London.

SULLIVAN, S. 2002. How sustainable is the communalising discourse of 'new' conservation? The masking of difference, inequality and aspiration in the fledgling 'conservancies' of Namibia, pp. 158–187 *In* Chatty, D. and Colchester, M. (eds.) 2002 *Conservation and Mobile Indigenous people: Displacement, Forced Settlement and Sustainable Development*, Berghahn Press, Oxford.

SUNDERLAND, T.C.H. and NDOYE, O. 2004. Forest products, livelihoods and conservation: case studies of non-timber forest product systems. Volume 2 – Africa. CIFOR, Bogor, Indonesia.

SUNDERLAND, T.C.H., CLARK, L.W. and VANTOMME, P. 1999. Non-wood forest products of Central Africa: Current research issues and prospects for conservation and development. FAO, Rome.

TRANSPARENCY INTERNATIONAL. 2010. Corruption perceptions index 2010. www. transparency.org.

WILSON, K. 2008. Guides and gatherers. *Resurgence*. Issue 250, September/October 2008.

WORLD WILDLIFE FUND. 2001. *Mt Cameroon and Bioko Montane Forests.* Wild World Report, www.worldwildlife.org.

WORLD WILDLIFE FUND, Central Africa Program. 2010. Fact sheet, Mount Cameroon National Park. Panda.org.

ZAPFACK, L., ENGWALD, S., SONKE, B., ACHOUNDONG, G. and MADONG, B.A. 2002. The impact of land use conversion on plant biodiversity in the forest zone of Cameroon. *Biodiversity and Conservation* **11**: 2047–2061.

From foraging to farming among present-day forest hunter-gatherers: consequences on diet and health

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SUMMARY

Throughout history, forests dwellers have adapted to permanent changes of forest ecosystems that, in essence, are dynamic. Accordingly, they have long served as models of how humans lived when their lifestyles and genetic endowment were complementary. What is now commonly described as the "paleodiet" tends to be put forward as a benchmark for present-day efforts to promote health and prevent nutritional diseases, even in industrialized countries. Although forest ecosystems provide food and medicines to forest dwellers, over the last half-century these ecosystems have undergone unprecedented pressure to make way for economic growth and industrialization, often at the cost of ecological functions that may affect human health, both in short term (i.e. increase in infectious diseases) and long term (incidence of global change). As radical alterations occur such as deforestation, modification of resource availability, and the penetration of cash economies, forest dwellers encounter increasing difficulties in accommodating their socioeconomic, cultural, and political systems, thus impeding their ecological success. Diets and diseases are sensitive indicators of the ecological and cultural costs that former hunter-gatherers currently pay to achieve their share of modernity. This paper exposes the nutritional and epidemiological consequences of the maladaptation of former hunter-gatherers in relation to their recent sedentarization. It is primarily based on case studies carried out among the Baka and Kola Pygmies of Cameroon, and the Tubu Punan of Borneo.

Keywords: forest hunter-gatherers, mobility, sedentarization, epidemiological transition, nutritional transition

De la collecte à l'agriculture chez les chasseurs-cueilleurs forestiers actuels: conséquences sur leur alimentation et leur santé

E. DOUNIAS et A. FROMENT

À travers leur histoire, les peuples forestiers ont toujours su s'adapter aux changements permanents des écosystèmes forestiers qui, par essence, sont dynamiques. C'est la raison pour laquelle ils ont longtemps servi de modèle pour analyser la vie des humains lorsque leur mode de subsistance et leur profil génétique étaient intimement liés. Ce que l'on qualifie communément de «paléorégime» tend à constituer l'argument clé des discours en vogue jusque dans nos sociétés industrialisées, qui veulent promouvoir une vie saine et exempte des troubles nutritionnels. Depuis un demi siècle, les écosystèmes forestiers qui fournissent incontestablement toutes sortes de nourritures et de médicaments aux peuples forestiers, sont l'objet de pressions sans précédent ; elles visent certes à favoriser le développement économique et l'industrialisation, mais se font au détriment des fonctions écologiques. La dégradation de ces fonctions affecte la santé humaine, tant à court terme (p. ex. accroissement des maladies infectieuses) qu'à long terme (p. ex. incidence du changement global). Face à ces altérations radicales — déforestation, modification de la disponibilité des ressources, pénétration de l'économie de marché — les peuples forestiers peinent à ajuster leurs systèmes socio-économique, culturel et politique, compromettant alors leur succès écologique. Le régime alimentaire et la santé sont des indicateurs sensibles du prix écologique et culturel que les derniers chasseurs-cueilleurs doivent aujourd'hui payer pour avoir accès à la modernité. Cet article expose les conséquences nutritionnelles et épidémiologiques de la maladaptation de ces chasseurs-cueilleurs consécutive à leur sédentarisation récente. Il repose principalement sur des études de cas réalisées chez les Pygmées Baka et Kola du Cameroun, et chez les Punan Tubu de Bornéo.

De la búsqueda de alimento a la agricultura entre los cazadores-recolectores de hoy: consecuencias para la dieta y la salud

E. DOUNIAS y A. FROMENT

A través de la historia, los pobladores del bosque se han adaptado a los cambios permanentes de unos ecosistemas forestales que, en esencia, son dinámicos. De acuerdo con ello, y durante mucho tiempo, han servido de modelos de como vivía el ser humano cuando sus estilos de vida y las facultades genéticas que poseía eran complementarios. Lo que ahora se describe comúnmente como «paleodieta» tiende a ser propuesta como una cota de referencia en los esfuerzos actuales por fomentar la salud y prevenir las enfermedades nutricionales, incluso en países

industrializados. Aunque los ecosistemas forestales proporcionan alimento y medicinas a los pobladores del bosque, estos ecosistemas han experimentado una presión sin precedentes durante el último medio siglo en pro del crecimiento económico y la industrialización, a menudo a expensas de aquellas funciones ecológicas que podrían afectar a la salud humana, tanto a corto (es decir, aumento de las enfermedades infecciosas) como a largo plazo (efecto del cambio global). A medida que suceden cambios radicales como la deforestación, diferencias en la disponibilidad de recursos, y la penetración de economías monetarias, los pobladores del bosque encuentran cada vez más dificultades para adaptar sus sistemas socioeconómicos, culturales y políticos, viendo entorpecida por ello su prosperidad ecológica. La dieta y las enfermedades son indicadores sensibles de los costos ecológicos y culturales que tienen que pagar en la actualidad los cazadores-recolectores de antaño para poder encontrar su espacio en la vida moderna. Este artículo presenta las consecuencias nutricionales y epidemiológicas de la maladaptación de quienes fueron cazadores-recolectores en relación a su sedentarización reciente. Está basado principalmente en estudios de caso realizados entre los pigmeos Baka y Kola de Camerún y los Tubu Punan de Borneo.

INTRODUCTION

In late spring 2008, an unnamed community of Amerindians living in a remote area of Acre Province in the Brazilian forest was widely talked about in the media, with massive support of anachronistic images showing frightened archers shooting their arrows towards the airplane that was flying over their settlement (http://www.uncontactedtribes.org). According to Survival International, more than one hundred communities scattered around the world still refuse contact of any sort with outsiders. This refusal makes them today much more vulnerable than other forest dwellers who gradually increased their relations with the rest of the world — some foraging societies like the Kubu of Sumatra and a few Punan groups of Borneo are even described as "professional hunter-gatherers" who have been involved in commercial trades of non-timber forest products for several centuries (Fox 1969, Hoffman 1984, Persoon 1989) — since the drastic change affecting the last remains of natural forests appears inevitable. With regard to globalization and to its many induced environmental transformations, there is no longer a way out for these unwavering societies — generally confined in protected areas — to avoid the opening up of their territories and their exposure to invasive migrants in search of land and better life conditions, to the extension of ranching, to the overwhelming expansion of logging and mining industries, to the conversion of forests into monocropping landscapes by agro-industrial plantations (Scott 2009). As radical alterations occur, forest foragers encounter increasing difficulties in accommodating their socioeconomic, cultural, and political systems, thus impeding their ecological success. When they are not victims of violence exerted by outsiders, they are dramatically devastated by nutritional disorders and epidemics (Napolinato 2007, Napolinato and Ryan 2007).

The health problems that affect today the last nomadic hunter-gatherer societies are dramatically emblematic of the interconnections between the ecology of health and conservation of biodiversity. While trying to adapt to the consequences of their renunciation of their original lifestyle, which is seriously affected and modified by various forms of environmental change, these societies are forced in just a few decades to make an adaptation whose achievement took several centuries for our western societies.

Diets and diseases are sensitive warnings of the ecological and cultural costs that former hunter-gatherers currently pay to achieve their share of modernity. By focusing on nutrition and epidemiology, the goal of this paper is to demonstrate the maladaptation of former nomadic hunter-gatherers that is a direct consequence of their recent and brutal sedentarization — generally hastened by external drivers (Dounias *et al.* 2007). Arguments are primarily based on first-hand case studies carried out among various groups of Pygmies (Baka, Kola) in Cameroon, as well as among a group of Punan living in the Tubu watershed in Eastern Borneo.

CHANGE AND INDUCED TRANSITIONS THROUGH HUMANKIND'S HISTORY

Change among human societies induces a continuous emergence of infectious diseases (Cohen 2000, Wilson *et al*. 1994). During their lifetime, humans are constantly exposed to countless endemic and epidemic infectious diseases, and their history is marked by a succession of new emerging diseases (Diamond 1997, May *et al.* 2001, McNeil 1976). Infectious diseases exert a selective pressure on human evolution and are widely admitted to be a driving force of natural selection that have shaped the evolution of the human genome and oriented the differentiation of human populations that we observe today (Barreiro *et al.* 2008, Williams and Nesse 1996).

In fact, when considering the difference in life expectancy between existing human societies, the significant gap that separates poor and developed countries occurred only after the industrial revolution and is more a consequence of the booming progress among the latter countries in controlling infectious diseases than an impaired immunodeficiency among individuals (Casanova and Abel 2005): the comparison of mortality curves from Palaeolithic period to modern times (WHO website) shows that the increase in life expectancy occurring in the 20th century is not correlated to an increased immunity to infectious agents. The persistent lack of immunity to infection has in fact been overshadowed by medical progress (Kwiatkowski 2000).

Hominid history has been marked by a succession of major physiological, demographic, cultural and dietary transitions — from quadrupedalism to bipedalism; from scavenging to hunting; from hunting and gathering to farming and herding; from rural to urban. . . — which have been accompanied by epidemiological shifts. As stressed by Froment (2010), the epidemiology of hominization could be summarized as a continuous process of autodomestication.

Epidemiological transitions were globally marked by a succession of pathocenoses revealing a long progression of humankind from a high prevalence of infectious diseases to the current predominance of chronic diseases (Grmek 1969, Olshansky and Ault 1986). These changes in disease were accompanied by a demographic transition, which enabled humankind to shift from a regime of high fecundity counterbalancing high mortality, to a regime of low mortality inducing a fall in fecundity (Barrett *et al.* 1998). They should as well be interpreted in close interaction with an overall nutritional transition that evolved from a "paleodiet" lately praised by nutritionists as a model of well balanced food consumption (Eaton and Eaton 2000), to the current western diet that is heavily rich in saturated fat, salt and sugar but dramatically poor in fibres (Popkin 2002). There is no longer need to demonstrate the strong link between the modern food regime and the expansion of chronic and degenerative diseases in industrialized countries (Daily and Ehrlich 1996, Meslé and Vallin 2000).

Among these various transitions, the shift from hunting to farming and the correlated shift from a nomadic to a sedentarized lifestyle are unanimously considered as the major epidemiological transition in the history of humankind (Barrett *et al.* 1998, Larsen 1995, Omran 1971, Popkin 2002, Swedlund and Armelagos 1990, Wirsing 1985).

This sedentarism transition occurred during the Neolithic age and massively increased the development of commensal mammals (mainly rodents) that are major vectors of plague and hemorrhagic fevers (Wolfe *et al.* 2005). Furthermore, sedentarization induced significant social modifications that were indirect causes of new health disorders — work overload, territorial conflicts, advent of political hierarchy and its related inequities in resource access and redistribution, etc. These changes favoured the spread of infectious diseases that were until then quiescent. The Neolithic age was also marked by the domestication of mammals (Clutton-Brock 1987): diphtheria, syphilis, influenza, salmonella, plague, tuberculosis, leprosy and many other diseases that first hit humankind in these ancient times, have their microbial equivalent among animals. Brucellosis and anthrax became common diseases among cattle herders. Malaria exploded with the advent of the very first farming clearings, and irrigated rice-growing sizeably increased human contact with microbes (cholera, anterovirus) and parasites (bilharzia, distomiasis) (Gualdé 2006, Guégan and Choisy 2008, Susanne *et al.* 2003).

Recalling what happened during the Neolithic age is important since the related epidemiological transition that took place throughout the several thousand years of this historical period is taking place within just a few decades for the last present-day nomadic hunter-gatherers.

EPIDEMIOLOGICAL ADVANTAGES OF A NOMADIC LIFESTYLE IN TROPICAL FORESTS

The widely admitted pattern that diversity of plant and animal species declines along with distance from the equator (Chown and Gaston 2000) also supports the distribution of parasitic and infectious species around the world. Guernier *et al.* (2004) have demonstrated the fundamental role of climatic factors and established the link between latitude and richness of human pathogens. The high correlation between the diversity of parasitic and infectious diseases and the distribution of tropical humid forests has nourished the persistent belief that forests are inhospitable environments for humans.

Besides the fact that forests — be they natural or anthropogenic — directly provide plenty of food, medicines, raw materials, clean water and other resources to forest dwellers, the many, though indirect, ecosystemic services obtained from the high biodiversity that is hosted in forests have for long been underestimated (Millenium Ecosystem Assessment 2005). One of the key services consists of controlling the emergence and spread of infectious diseases by maintaining a subtle balance among predators and prey, and among vectors and parasites in plants, animals, and humans (Chivian and Bernstein 2008). However consideration of such indirect protective functions of biodiversity is fairly recent and still requires further research.

Over the last few decades, humid tropical forests have undergone unprecedented pressure to make way for economic growth and industrialization of the developing countries in which these forests are located. Food insecurity is generally put forward as the main threatening pressure on health. However, deforestation and the related loss of ecosystemic services exert much more pressure as they dramatically increase the burden of transmissible diseases (Patz *et al.* 2000). But more indirect consequences also contribute to global change and over a longer term, with damaging effects on human health worldwide.

Mobility was an excellent adaptive response of hunter-gatherers to the risk to contract a parasitic or infectious disease. Living in ephemeral and temporary camps considerably reduced exposure to transmissible diseases, airborne and food-borne diseases, and faecal pollution. More than the scarcity of food, excessive parasites (fleas, lice and ticks) in the camp provided a strong motivation to move to another place. A fundamental principle of this mobility lies in the necessity to live and move in small communities that are scattered in vast territories (human density below one inhabitant/square km (Dunn 1977)). Small, dispersed human communities are less visible to vectors and are comparatively unattractive hosts to pathogens. Nomadic Punan and Pygmies were free of malaria since they constantly moved outside the flight range of anopheles before the malaria-causing parasites (*Plasmodium* spp.) were able to reproduce (a part of the reproduction cycle occurs in the mosquito, the other part intervenes in the blood of the host bitten by the mosquitoes).

In many foraging societies, a death within the community pushed the survivors to abandon camp, split and shift to new settlements. This cultural practice aimed to protect the living relatives from the wandering and harassing spirit of the dead, and reduced at the same time the risk of any lethal factor contaminating other members of the group.

The absence of food storage among forest foraging peoples reduced the likelihood of proliferation of potential vectors of rodent-borne diseases. For the same purpose, most

of the rainforest shifting cultivators cultivated crops that were propagated clonally and thus naturally stored in the field, not in the home.

The nomadic Punan had little trouble with smallpox that was, in contrast, a serious problem for nearby Kenyah farmers, because the Punan practised silent barter, which served as a social fence protecting them from the epidemics that plagued their sedentary Kenyah neighbours. To avoid direct physical contact during epidemics, the Punan and the traders convened on marked sites where the hunter-gatherers could deposit their non-timber forest products in exchange of the goods left in the same place by the traders (Knapen 1998).

In conditions of low pollution and high recycling by aquatic fauna, the Punan who use the river for sanitary purposes are less exposed to faecal pollution than some other forest-dwellers who are not accustomed to defecate into flowing water. Favouring healthy rivers in which to collect clean water for domestic purposes is still a decisive argument advanced by the Tubu Punan to refuse to resettle downstream and closer to town (Levang *et al*. 2006).

High mobility was significantly made easier by i) light burdens and limited material goods; ii) the art of producing ephemeral everyday tools and instruments which were abandoned after use and renewed according to needs (Dounias 2001); iii) a limited number of dependents (infants, young children and elders). Groups migrated following extended and linear territorial trails. A simple clearing of the undergrowth to establish a temporary camp along these trails provided favourable light conditions to the regeneration of most frequently used food resources. The seeds of eaten plants that were left near huts could take advantage of the surrounding organic remains (detritus, faeces, food leftovers, ashes accumulated around the fireplaces) to germinate in optimal conditions (Ichikawa 1999).

Exogamic matrimonial alliances opened extensive though codified access to the territories owned by the allied families, thus extending the spectrum of potentially accessible resources.

The stereotype of the noble savage in perpetual quest for food is definitely outmoded. Historical ecology has now validated the fact that nomadic hunter-gatherers perfectly managed the spatial and temporal availability of their key food resources. Their daily search for food was definitely not a random and uncertain activity (Laden 1992).

Lastly, nomadic lifestyle favoured a good physical fitness and high muscular activity. This was confirmed by lower rates of body fat compared to that of farming neighbours (Dounias *et al.* 2007) and the absence of risk for arterial hypertension, high rates of cholesterol, cancer or cardiovascular accidents (Eaton and Eaton 1999). Since the forerunner works by Sahlins (1972), the advantages of a nomadic lifestyle have been largely backed up by the paleodiet hypothesis (PaleoDiet.com 1997). Supported by the most recent archaeological evidence, this hypothesis argues that nomadic hunter-gatherers were rarely subjects to famine and enjoyed a sane food regime that was rich in protein and fibres, and poor in salt, milk, and sugar.

However, these undisputable advantages of a nomadic lifestyle should not give way to excessive romanticism regarding their life conditions and epidemiological situation (Edgerton 1972). The relatively good physical condition of forest foragers was partially jeopardized by various causes of brutal death: accidental trauma (injury during hunting expeditions, falling trees), predation (by large carnivores), poisoning (accidental consumption of toxic food, venomous biting) and various forms of "social" regulation (warfare, cannibalism, infanticide, geronticide, witchcraft, sacrifice, etc). Hunter-gatherers were not spared autochthonous diseases (Wirsing 1985). If their nomadic lifestyle in small communities prevented them from fast-spreading diseases, it was helpless against slowly evolving diseases. But the diseases that caused the massive extinction of Amerindian hunter-gatherers were those that were introduced by outsiders (TABLE 1): smallpox, yellow fever, typhoid fever, malaria, measles, whooping cough, and poliomyelitis (Neel 1977, Newman 1976). Mobility provided a fairly good ecological equilibrium

TABLE 1 *Differential febrile reactivity to measles vaccination between Amerindians and cosmopolitans (adapted from Black 1990). Several mutually non-exclusive hypotheses — weakness of immune system, social disorders, inbreeding depression (the breeding of related individuals resulting from isolation is a well known cause of fitness degradation) (Black 1975, Cook 1998) — are advanced to explain this significantly higher reactivity by Amerindians, which is illustrative of the massive extinction of native Amazonians after their first contact with Westerners. An absence of heterosis enhances their sensitivity to exotic viruses. The isolation of hunter-gatherer groups that is commonly reported throughout the Neotropics is an exception among forest foragers in the Old World, who have for long been involved in economic exchange and matrimonial alliances with their farming neighbours. The crossing of gene pools and induced hybrid vigour ensure a more efficient resistance to exotic pathogens.*
NB: for equivalent febrile status, rectal measurements of temperature always provide significantly higher values than axillary measurements.

Group	%>39°C	%>40°C	Average elevation T° (°C)
Amerindian children (n = 150)[a]	25.3	3.3	1.0
Caboclo children (n = 142)[a]	7.7	2.8	0.6
Amerindian adults (n = 238)[a]	13.0	2.9	0.9
Icelandic adults (n = 148)[b]	7.4	1.4	0.6

[a] axillary T°; [b] rectal T°

and a relative tolerance to familiar diseases. They managed to put up with them through cultural ripostes like pharmacopeia and traditional healing (Telban 1988). For instance, hunter-gatherers living in the Neotropics were constantly exposed to treponematosis, amoebic and bacillary dysenteries, pneumopathies of viral origin, salmonella, streptococcal arthritis, ascariasis, bartonella, leishmania, and American trypanosomiasis.

The child mortality registered nowadays among former hunter-gatherers is not so different from what was reported for Europe a few centuries ago. Low life expectancy and high child and infant mortality among contemporary foragers (Figure 1) are clear reminiscent evidence of the Darwinian selection that have ensured their demographic stability and the sustainability of their lifestyle, which depends on the extensive availability of forests resource in space (territory) and time (seasonal fluctuation) (Froment 2001).

SEDENTARIZATION AND ITS TRAIL OF NEW DISEASES

Renunciation of a nomadic lifestyle and shift to permanent settlement are necessarily accompanied by a reassembling of the family unit. The increasing density in the human habitat inexorably alters the surrounding landscape and eventually exerts hunting and gathering pressure on proximate forest resources. The rapid decline of nearest resources has to be compensated by seasonal migrations or more distant hunting and gathering expeditions. These migrations and expeditions become increasingly problematic to organize because of the loosening of access rights on previous territories and drastic modification of gender division of labour within the communities — women are increasingly involved in agricultural activities and less participate to hunting, fishing and collecting of forest products — that generally compromises family mobility — seasonal expeditions in the forest are now most exclusively composed of male participants (Dounias and Leclerc 2006). Adoption of agriculture is often the only and inexorable alternative that efficiently compensates for the decline in forest resources near villages. But it is also a turning point since it marks, more than sedentarization, a definitive renunciation of the former nomadic lifestyle.

Forest lands that are cleared for installation of new permanent settlements are exposed to more pronounced ranges of temperature and atmospheric humidity between night and day. Rudimentary housing and absence of warm clothes and blankets favours acute pulmonary infection, which dramatically increases child morbidity (Figure 2).

Parasitic load, a consequence of faecal pollution, goes along with sedentarization and induced promiscuity. High rates of intestinal worms are a direct consequence of increased contact with all sorts of human and animal detritus, combined with an absence of sanitation. Such contacts cause intestinal infections of bacterial and viral origins and are the principal cause of malnutrition, infectious diarrhoea, anaemia and possibly delayed growth among children, with potentially dramatic consequences for their psychic development.

Through the history of humankind, new zoonotic diseases have constantly emerged from wildlife; their expansion is hardly limited to sedentary lifestyle. 58% of species that are pathogenic to humans have a zoonotic origin (Woolhouse and Gowtage-Sequeria 2005). The risk of contracting a zoonotic disease is increased by the proliferation of rodents that are attracted by domestic remains and food storage in permanent villages. Permanent settlements also facilitate contact with a broader range of domesticated animals, thus increasing the interspecific transfer of pathogens. Enhanced human density in permanent villages and accelerated communication between settlements (roads, modern navigation equipment) have been facilitating factors of zoonose proliferation since the infected victims now come into contact with larger human population. Today, as the volume and speed of trade and travel are constantly rising, the epidemiology of emerging infectious diseases has acquired a worldwide scale. The former nomadic hunter-gatherers who are now confined in

FIGURE 1 *Age pyramids of Pygmy and Punan hunter-gatherers (adapted from Dounias and Froment 2006). The large bases of the two charts on the left reveal a high birth rate that counterbalances the high child mortality. By contrast, the tighter base of the age pyramid for periurban Tubu Punan expresses a lower birth rate subsequent to decreasing child mortality owing to facilitated access to medical care. Current life span remains low: among Kola Pygmies as well as among remote Tubu Punan, elders aged above 65 years old represent less than 2% of total population, versus more than 17% on average in industrialized countries*

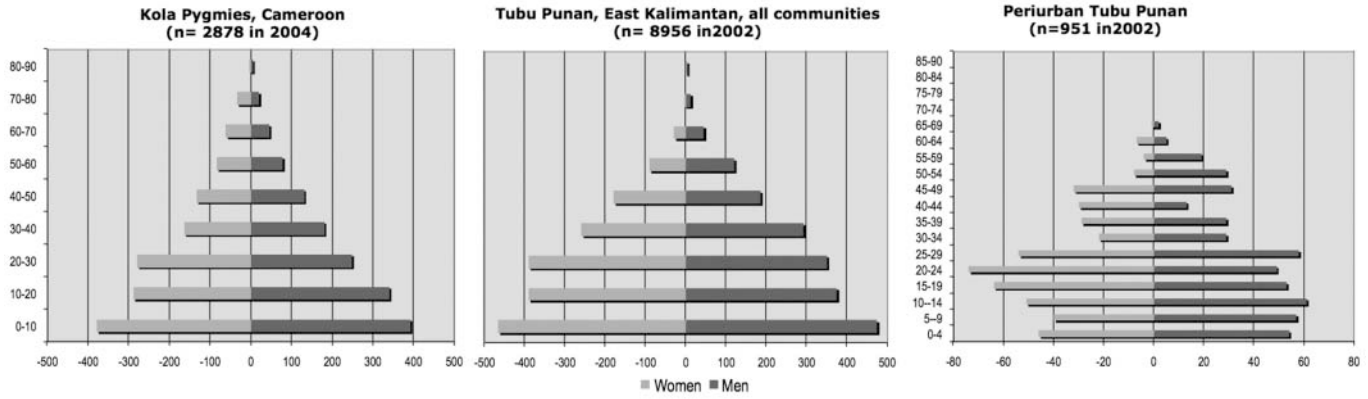
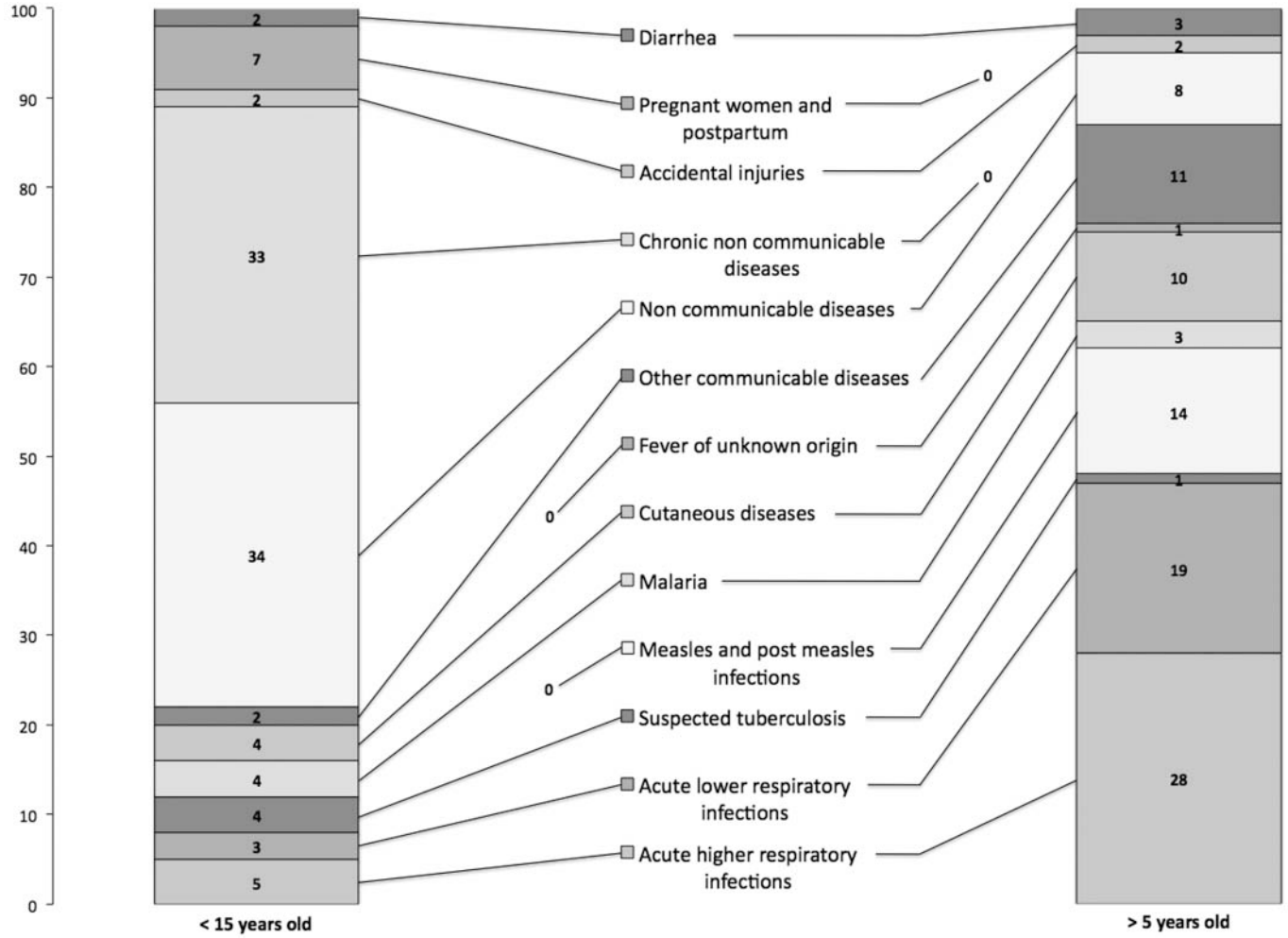


FIGURE 2 *From July 2005 to March 2008, eight successive campaigns of clinical examination and medical care were carried out in collaboration with the French humanitarian NGO* Médecins du Monde *among the most remote settlements of Tubu Punan in Eastern Kalimantan. 2,639 consultations were given, representing an average of 333 patients per campaign (at least 45% of the total population benefited from these campaigns). Children less than 5 years old, young people aged between 5 and 15 years old, and adults aged above 15 years old represented 27%, 21% and 52% of the patients, respectively.*
The two graphs comparing the major causes of ailments between children and adults reveal striking differences. While morbidity among children is highly dominated by acute transmissible diseases (respiratory infections, measles and post-measles infections, coetaneous diseases), non-communicable diseases predominate among adults who mainly suffer from headaches, vertigo, dental problems, arthritis and muscular pains. Children pay the highest cost of the emergence of infectious diseases.
As stated by WHO (1998) among the 140,000 people who die daily in the world, 30,000 are children and infants less than 5 years old, who die from diarrhoea and dehydratation, measles and acute respiratory infections; 50,0000 die from infection (5,000 from HIV AIDS, 3,000 from malaria); 40,000 from cardio-vascular diseases; 15,000 from cancer; and 10,000 from brutal death



permanent and more crowded settlements undergo unprecedented exposure to zoonotic diseases and unconsciously contribute to their spreading (Wolfe *et al.* 2005). Blood analyses reveal higher levels of immunoglobulins — an indicator of propensity for infection (Froment 2001) — among these tribes than among their neighbouring agriculturalists. Sedentary hunter-gatherers are trapped in a vicious circle since infection often leads to malnutrition, which affects bodily resistance, thus preparing a propitious field for the advent of new infection. . .

The native garb of most forest foragers was minimal when they were still nomadic. Today most of them wear European clothes, urged on them by missionaries and local authorities, even though such clothes are not well suited for use in the forest. In the absence of soap, the same clothes are worn dirty until they wear out, creating a hospitable ground for infectious skin diseases.

A LEGITIMATE THOUGH DELETEROUS ACCESS TO MODERNITY

Modern forms of exploitation of forest resources by outsiders bring in opportunities to formerly nomadic forest dwellers to

experience the "charms" of industrialization and urbanization as well as their dramatic consequences on diet and nutritional status, especially for children. Modernization not only brings new food, but also alters the availability of local resources and the social modalities of their distribution within communities. Sedentarised periurban Punan as well as Kola and Baka Pygmies in Cameroon tend to eat foods that are richer in fat and free sugar — fast absorbed sugar that is not naturally contained in food but is rather artificially added — but that are poor in slow burning glucides. The links between such a diet and the emergence of chronic degenerative diseases — cardiovascular disorders, cancer — especially during adulthood, are now well established. New nutritional troubles like anaemia, obesity, hypertension, high rates of cholesterol and diabetes, are commonly reported among recently sedentarized hunter-gatherers. Globally, the legendary good physical condition of hunter-gatherers is seriously compromised by sedentarization and appears to be less enviable than that of their farming neighbours.

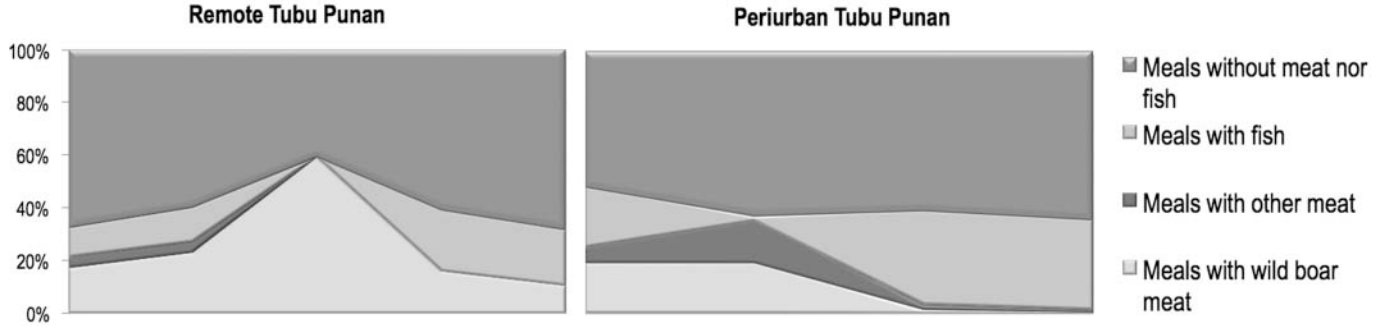
Accordingly, yaws affects the sedentarised Baka Pygmies in eastern Cameroon much more frequently than their Bantu neighbours (80% versus 37% respectively) because these two communities have unequal access to dispensaries that are located along roads or in proximity to cities (Froment 2004).

In their large majority, civil servants have a scornful perception of hunter-gatherer lifestyle and refuse to be outposted in a remote settlement. The very few who have no choice but to accept these posts (young and recent holders of their diploma) generally disappear after a few months of purgatory. For the hunter-gatherers, the fleeting illusion of development is rapidly replaced by frustration and a sad feeling that they have been left behind. Concomitantly, the collectivist social regulations (mutual aid, food sharing) that sealed these communities when they were still nomadic, fade and make way to more opportunistic and individualistic attitudes (Kaskija 2007, Levang *et al.* 2004). Among the Punan (Dounias *et al.* 2007) but also among the Orang Asli (Colin *et al.* 2003, Endicott and Dentan 2004, Lin 2008), the increasingly individualistic behaviour jeopardizes high-risk persons like elderly widows who depend on the generosity of other members of the community for nutrition and health.

Even in the absence of measured dietary deficiencies, forest dwellers all complain about lean periods in food supply, which are characterized by a decline in availability of culturally valued food. Such temporary shortage may provoke severe psychological unrest (Harrison 1982), which has a cultural component exhibiting tangible effects and possibly negative health consequences. In case of occasional lack of meat, nomadic hunter-gatherers like African Pygmies and Punan express a "meat hunger" and complain of tiredness, loss of vital strength and illness (Thomas 1987). Meat is perceived as essential for health not only because it is a vital source of nutrients: hunting indeed requires all one's mental and physical abilities and abundance of meat is accordingly perceived as a sign of the hunter's good condition. In contrast, a meat shortage is unconsciously and symbolically associated with an unhealthy hunter who affects, through him, the vitality of the whole community (Motte-Florac *et al.* 1993). Hunting is certainly the productive activity which is the most impacted by sedentarization (Figure 3).

Mental diseases like stress and depression are increasingly observed among former forest foragers. They are premises to other disorders including marital violence as well as substance abuse. These addictions are not only the causes of direct intoxication; they also precede other exploding pathologies such as tuberculosis. Former nomadic hunter-gatherers are easy prey for proselytism. Religious dogmatism may sometimes mitigate some addictions: Christian religion has certainly reduced the consumption of alcohol among the Punan of Borneo, but increasing reported cases of emphysema and cancer among these forest peoples are certainly the consequence of heavy cigarette smoking (Strickland and Duffield

FIGURE 3 *Comparison of diet between remote Punan and periurban Punan of Eastern Kalimantan (Borneo) (in cumulative percentage over 12 months of quantification). The frequency of vegetarian meals is the same for both groups and barely varies through the year. Meals based on meat or fish more discriminate the two groups. Remote Punan consume fish only in case of bushmeat scarcity, whereas periurban Punan who have lesser access to bushmeat have adopted fish as their main source of animal protein. Wild boar, which is the favourite source of meat for these hunter-gatherers, ensures 97% of the biomass of meat consumed by the remote Punan. This meat is banned from town where the majority of civil servants are muslims not native to Borneo. Furthermore, wild boar is rare in the deforested lands surrounding the cities and periurban Punan have to make do with the other game they can catch only occasionally. Meat hunger and related mental disorders are common among periurban Punan (adapted from Dounias* et al. *2007)*



1998). The prevalence of sexually transmissible diseases, especially HIV-AIDS, is dramatically rising and is another sad proof of the "fatal attraction of development" (Froment 2004, Hamill and Dickey 2005).

The new generation of Punan who have grown up near the city are accustomed to live with electricity and television. Nevertheless, they are persistently harassed by a discrimination that compromises their access to job opportunities. Nutritional disorders and mental diseases are undisputable signs of their fast-rising psycho-cultural ill-being. A dramatic illustration of such ill-being is given by suicide rates among younger Amerindian (especially the Guarani of Brazil) and Aborigine communities, which are among the highest in the world. (Coloma *et al.* 2006, Woodman and Grigs 2007).

CONCLUSION

The purpose of evoking the Neolitic age transition as an introduction is not to extrapolate the past into modern times. It aims to emphasize on the evolutionary dimension of the interactions of humankind and the surrounding pathogens. The sudden shift of contemporary forest hunter-gatherers from nomadic to sedentary lifestyle has nothing in common with the slow evolutionary process that occurred ages ago. The slow evolutionary transition that happened during the Neolithic age (but which can be considered as brutal when compared to the time length of human presence on earth) and that was a crucial stage of humankind adaptation to a new pathogenic environment does not undergo for modern times hunter-gatherers. Processes and pathogens remain the same, but time scale of encounter, thus propensity to adapt is tremendously impaired. Human adaptation to the epidemiological transition engendered a great diversity of situations and cultural strategies along a wide spectrum ranging from the persistence of a nomadic and hunter-gatherer lifestyle to a very speculative form of monocropping agriculture, encouraging all kinds of intercultural interactions.

The forest dwellers on the Neotropics illustrate this diversity of trajectories of transition to agriculture. Agriculture has for long been a determining part of the economy of Amazonian forest dwellers because this region is the centre of domestication of many staple crops (cassava, arrow root, sweet potato) and fruit trees (cocoa, cashew nut, avocado, coursop, guayava, papaya), that are commonly cultivated today throughout the tropics. Semi-nomadism (seasonal mobility from a permanent settlement) would best characterize the lifestyle of forest Amerindians who settled down in small, and most frequently, isolated communities. The current explosion of epidemiologic problems in the last uncontacted tribes of Amazonia is definitely not imputable to the renunciation of nomadic lifestyle, but rather to the loss of isolation.

With regard to their extremely high ecosystem diversity, the mosaics of tropical forests are dynamic in essence. So are the various human societies whose livelihoods depend on forest resources. Accordingly, and contrary to the preconceived idea that these societies have for long been stuck in an immutable way of life, adaptation is consubstantial of the history of forest dwellers who have always had to adapt to the continuous changes in forest ecosystems.

Nevertheless these indigenous peoples are confronted today with unprecedented changes in their environment. These recent drastic alterations of forest ecosystems are no longer of natural origin but are direct consequences of human activities that are generally carried out by protagonists of industrialized countries. For instance, there is some sad irony to point out that those who are going to suffer most from the effects of climate change are those who are the least responsible for the worldwide accumulation of greenhouse gases (Dounias 2009).

Rapid land use conversion of the forests and induced reductions of resource availability irremediably modify the social, cultural, economic and political systems of forest foragers. The solutions that these people are forced to implement in a rush in response to such changes are no longer tested empirically and their long-term societal and ecological consequences are too complex to anticipate. For present-day hunter-gatherers, possible adaptation strategies are twice compromised by the brutality of change and by the imposition of the way to take to abandon a nomadic lifestyle.

The last hunter-gatherer societies are paying heavily for their legitimate aspiration to be beneficiaries of ongoing globalization. The ecological and cultural consequences of this aspiration are clearly revealed by the changes in their diets and continuous exposure to emerging diseases, which are explicit indicators of their growing maladaptation to their changing forest environments. However, declining diets and increasing illnesses are only symptomatic warnings of these ecological and sociocultural maladaptations, and the great majority of actors who are committed to assisting these people content themselves with treating these "symptoms". Interventions by outsiders eventually nourish a Daedalus syndrome: they pretend to bring solutions which in fact raise more complex problems which in turn require more complex solutions, guiding the people that they pretend to help to unavoidable collapse.

Providing medical assistance to cope with the malnutrition and diseases of these people would only provide short-term respite from the superficial symptoms. However, this should not overlook other more helpful long-term interventions that should consider the ecological, social, political and economic drivers of change that indirectly affect the health of forest foragers: more acute than malnutrition and diseases are the insecurity and discrimination caused by social prejudice. As stressed by Colfer (2005) and Colfer *et al.* (2006), the healthy future of these groups depends on socioeconomic and socio-political factors such as access to education, acknowledgement of traditional rights, protection against outsiders, equity of chance on job opportunities. Déjà vu!

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REFERENCES

BARREIRO, L.B., LAVAL, G., QUACH, H., PATIN, E. and QUINTANA-MURCI, L. 2008. Natural selection has driven population differentiation in modern humans. *Nature Genetics* **40**(4): 340–345.

BARRETT, R., KUZAWA, C.W., MCDADE, T. and ARMELAGOS, G.J. 1998. Emerging and re-emerging infectious diseases: the third epidemiologic transition. *Annual Review of Anthropology* **27**: 247–271.

BLACK, F.L. 1975. Infectious diseases in primitive societies. *Science* **187**: 515–518.

BLACK, F.L. 1990. Infectious disease and the evolution of human populations: the examples of South American forest tribes. In: SWEDLUND, A.C. and ARMELAGOS, G.J. (eds.) *Disease in Populations in Transition: Anthropological and Epidemiological Perspectives*. Bergin & Garvey, South Hadley, pp. 55–74.

CASANOVA, J.L. and ABEL, L. 2005. Inborn errors of immunity to infection: the rule rather than the exception. *JEM* **202**(2): 197–201.

CHIVIAN, E. and BERNSTEIN, A. ed. (2008). *Sustaining life. How human health depends on biodiversity.* Center for Health and the Global Environment, Boston, 541 p.

CHOWN, S.L. and GASTON, K.J. 2000. Areas, cradles and museums: The latitudinal gradient in species richness. *Trends Ecol Evol* **15**: 311–315.

CLUTTON-BROCK, J. 1999. *A natural history of domesticated mammals*. Cambridge, Cambridge University Press, 238 p.

COHEN, M.L. 2000. Changing patterns of infectious disease. *Nature* **406**: 762–767.

COLFER, C.J.P., SHEIL, D. and KISHI, M. 2006. Forests and human health: assessing the evidence. Cifor, Bogor, 111 p.

COLOMA, C., HOFFMAN, J.S. and CROSBY, A. 2006. Suicide Among Guaraní Kaiowá and Nandeva Youth in Mato Grosso do Sul, Brazil. *Archives of Suicide Research* **10**(2): 191–207.

COOK, D.N. 1998. *Born to die: disease and New World conquest, 1492–1650*. Cambridge University Press, Cambridge, 268 p.

DAILY, G.C. and EHRLICH, P.R. 1996. Global change and human susceptibility to disease. *Annual Review of Energy and the Environment* **21**: 125–144.

DIAMOND, J. 1997. *Guns, Germs, and Steel: The Fates of Human Societies*. W.W. Norton & Company, New York, 496 p.

DIAMOND, J. 2002 Evolution, consequences and future of plant and animal domestication, *Nature* **418**: 700–707.

DOUNIAS, E. 2001. The management of wild yam tubers by the Baka Pygmies in Southern Cameroon. *African Study Monographs* **26**: 135–156.

DOUNIAS, E. 2009. The sentinel key role of indigenous peoples in the assessment of climate change effects on tropical forests. *IOP Conf. Series: Earth and Environmental Science* **6**(2009): 572008.

DOUNIAS, E. and COLFER, C.J.P. 2008. Socio-cultural dimensions of diet and health in forest dweller's systems. In COLFER, C.J.P. (ed.) *Human health and forests. A global overview of issues, practice and policy*. Earthscan Books, London, pp. 279–296.

DOUNIAS, E. and FROMENT, A. 2006. When forest-based hunter-gatherers become sedentary: consequences for diet and health. *Unasylva* **57**(2): 26–33.

DOUNIAS, E. and LECLERC, C. 2006. Spatial shifts and migration time scales among the Baka Pygmies of Cameroon and the Punan of Borneo. In: DE JONG, W., TUCK-PO, L. and KEN-ICHI, A. (eds.) *The social ecology of tropical forest: Migration, populations and frontiers*. Kyoto University Press and Trans Pacific Press, Kyoto, pp. 147–173.

DOUNIAS, E., KISHI, M., SELZNER, A., KURNIAWAN, I. and LEVANG, P. 2004. No longer nomadic. Changing Punan Tubu lifestyle requires new health strategies. *Cultural Survival Quarterly* **28**(2): 15–20.

DOUNIAS, E., SELZNER, A., KISHI, M., KURNIAWAN, I. and SIREGAR, R. 2007. Back to the trees? Diet and health as indicators of adaptive responses to environmental change. The case of the Punan Tubu in the Malinau Research Forest. In: GUNARSO, P., SETYAWATI, T., SUNDERLAND, T. and SHACKLETON, C *Managing forest resources in a decentralized environment: Lessons learnt from the Malinau Research Forest, East Kalimantan Indonesia*. CIFOR, Bogor, pp. 157–180.

DOUNIAS, E., SELZNER, A., KOIZUMI, M., LEVANG, P. 2007. From sago to rice, from forest to town. The consequences of sedentarization on the nutritional ecology of Punan former hunter-gatherers of Borneo. *Food and Nutrition Bulletin* **28**(2): S294-S302.

DUNN, F.L. 1977. Health and disease in hunter-gatherers: Epidemiological factors. In: LANDY, D. (ed.) *Culture, Disease, and Healing.* Macmillan, New York, pp. 99–113.

EATON, S.B. and EATON, S.B. III 2000. Paleolithic vs modern diets. Selected pathophysiological implications. *European Journal of Nutrition* **39**: 67–70.

EATON, S.B. and EATON, S.B. III. 1999. Hunter-gatherers and human health. In: LEE, R.B. and DALY, R. eds. *The Cambridge Encyclopedia of Hunters and Gatherers.* Cambridge, Cambridge University Press, pp. 449–455.

EDGERTON, R.B. 1972. *Sick societies: Challenging the myth of primitive harmony.* The Free Press, New York, 288 p.

ENDICOTT, K., and DENTAN, R.K. 2004. Into the Mainstream or Into the Backwater? Malaysian Assimilation of Orang Asli. In DUNCAN, C.R. (ed) *Civilizing the Margins: Southeast Asian Government Policies for the Development of Minorities*. Cornell University Press, Ithaca, NY, pp. 24–55.

FOX, R. 1969. Professional primitives. *Man in India* **49**: 139–160.

FROMENT, A. 1997. Une approche écoanthropologique de la santé publique. *Natures, Sciences, Sociétés* **5**(4): 5–11.

FROMENT, A. 2001. *Evolutionary biology and health of hunter-gatherer populations*. In: PANTER-BRICK, C., LAYTON, R.H. and ROWLEY-CONWY, P. (eds.)

Hunter-gatherers: an interdisciplinary perspective. Cambridge University Press, Cambridge, pp. 239–266.

FROMENT, A. 2004. Do people belong in the forest? *Cultural Survival Quarterly*, **28**(2): 36–40.

FROMENT, A. 2008. Biodiversity, environment and health among rainforest-dwellers: An evolutionary perspective. In: COLFER, C.J.P. (ed.) *Human health and forests. A global overview of issues, practice and policy*. Earthscan Books, London, pp. 259–273.

FROMENT, A. 2010. Eléments d'épidémiologie bioanthropologique. In: CHAPUIS-LUCCIANI, N., GUIHARD-COSTA, A.M. and BOËTSCH G. (eds.) *L'anthropologie du vivant: objets et méthodes*. CNRS, Paris, pp. 29–31.

GRMEK, M. 1969. Préliminaires d'une étude historique des maladies. *Annales ESC* **24**: 1437–1483.

GUALDÉ, R. 2006. *Comprendre les épidémies. La coévolution des microbes et des hommes.* Le Seuil, Paris, 403 p.

GUÉGAN, J.F. and CHOISY, M. (eds.) 2008. *Introduction à l'Épidémiologie Intégrative des maladies infectieuses et parasitaires.* De Boeck, Bruxelles, 552 p.

GUERNIER, V., HOCHBERG, M.E. and GUÉGAN, J.F. 2004. Ecology drives the worldwide distribution of human diseases. *PLoS Biology*, **2**(6): 740–746.

HAMILL, S. and DICKEY, M. 2005. Cultural competence: What is needed in working with native Americans with HIV/AIDS? *Journal of the Association of Nurses in AIDS Care* **16**(4): 64–69.

HARRISON, G.A. 1982. Life style, well-being and stress. *Human Biology* **54**(2): 139–202.

HOFFMAN, C.L., 1984. Punan foragers in the trading networks of Southeast Asia. In SCHRIRE, C. (ed) *Past and present in hunter-gatherers studies*. Academic Press, Orlando, pp. 123–149.

ICHIKAWA, M. 1999. Interactive process of man and nature in the Ituri Forest of the Democratic Republic of Congo (Zaire). An Approach from Historical Ecology. In: ELDERS, S., BIESBROUCK, K. and ROESSEL, G. (eds) *Hunters and Gatherers in Equatorial Africa: Challenging Elusiveness*. CNWS Publications, Leiden, pp. 141–152.

KASKIJA, L. 2007. 'Stuck at the Bottom': Opportunity Structures and Punan Malinau Identity. In SERCOMBE, P. AND SELLATO, B. (eds) *Beyond the Green Myth: Borneo's Hunter-Gatherers in the 21st Century*. Nordic Institute of Asian Studies, Copenhagen, pp. 135–159.

KNAPEN, H. 1998. Lethal diseases in the history of Borneo. Mortality and the interplay between disease environment and human geography. In: KING V.T. (ed.) *Environmental challenges in South-East Asia*. Curzon Press, Richmond, Surrey, pp. 69–94.

KWIATKOWSKI, D. 2000. Science, medicine, and the future: susceptibility to infection. *British Medical Journal* **321**: 1061–1065.

LADEN, G.T. 1992. *Ethnoarchaeology and land use ecology of the Efe (Pygmies) of the Ituri rain forest, Zaire: A behavioral ecological study of land use patterns and foraging behavior.* Ph. Dissertation, Harvard University, Cambridge.

LARSEN, C.S. 1995. Biological changes in human populations with agriculture. *Annual Review of Anthropology* **24**: 185–213.

LEAMAN, D.J., ARNASON, J.T., YUSUF, R., SANGAT-ROEMANTYO, H., SOEDJITO, H., ANGERHOFER, C.K. and PEZZUTO, J.M. 1995. Malaria remedies of the Kenyah of the Apo Kayan, East Kalimantan, Indonesian Borneo: a quantitative assessment of local consensus as an indicator of biological efficacy. *Journal of Ethnopharmacology*, **49**(1): 1–16.

LEVANG, P., DOUNIAS, E. and SITORUS, S. 2004. Out of forest, out of poverty? *Forests, Trees, and Livelihoods* **15**(2): 211–235.

LEVANG, P., SITORUS, S. and DOUNIAS, E. 2007. City life in the middle of the forest: A Punan hunter-gatherer's vision of conservation and development. *Ecology and Society* **12**(1): 18.

LIN, C.Y.O. 2008. Autonomy Reconstituted: Social and Gendered Implications of Resettlement on the Orang Asli of Peninsular Malaysia. In RESURRECCION, B.P. and ELMHIRST, R. (eds) *Gender and Natural Resource Management: Livelihoods, Mobility and Interventions*,. Earthscan, London, pp. 109–126.

MAY, R.M., GUPTA, S. and MCLEAN, A.R. 2001. Infectious disease dynamics: what characterizes a successful invader? *Phil Trans R Lond* **B356**: 901–910.

MCNEILL, W.H. 1976. *Plagues and Peoples*. Anchor Books, New York, 368 p.

MESLÉ, F. and VALLIN, J. 2000. Transition sanitaire: tendances et perspectives. *Médecine/Science* 2000 **16**(11): 1161–1171.

MILLENIUM ECOSYSTEM ASSESSMENT 2005. http://www.maweb.org.

MOTTE-FLORAC, E., BAHUCHET, S. and THOMAS, J. M.C. 1993. The role of food in the therapeutics of the Aka Pygmies of the Central African Republic. In: HLADIK, C.M., PAGEZY, H., LINARES, O.F., HLADIK, A. SEMPLE, A. and HADLEY, M. (eds.) *Tropical Forests, People and Food: Biocultural Interactions and Applications to Development.* Man and Biosphere Series, Unesco-Parthenon, Paris, pp. 549–560.

NAPOLITANO, D.A. 2007. Towards understanding the health vulnerability of indigenous peoples living in voluntary isolation in the Amazon Rainforest: Experiences from the Kugapakori Nahua Reserve, Peru. *EcoHealth* **4**: 515–531.

NAPOLITANO, D.A. and RYAN, A.S.S. 2007. The dilemma of contact: voluntary isolation and the impacts of gas exploitation on health and rights in the Kugapakori Nahua Reserve, Peruvian Amazon. *Environmental Research Letters*: 045005.

NEEL, J.V. 1977. Health and disease in unacculturated Ameridian populations. In: CIBA FOUNDATION SYMPOSIUM (ed.) *Health and disease in tribal societies*. Elsevier, Amsterdam, Oxford, New York, pp. 155–177.

NEWMAN, M.T. 1976. Aboriginal New World epidemiology and medical care, and the impact of Old World disease

imports. *American Journal of Physical Anthropology* **45**: 667–672.

NICHOLAS, C., TIJAH YOK, C., and TIAH, S. 2003. *Orang Asli Women and the Forest: The Impact of Resource Depletion on Gender Relations Among the Semai*. Subang Jaya, Malaysia: Center for Orang Asli Concerns.

OLSHANSKY, S.J. and AULT, A.B. 1986. The fourth stage of the epidemiologic transition: the age of delayed degenerative diseases. *Milb Quart* **64**(3): 355–391.

OMRAN, A.R. 1971. *The Epidemiologic Transition: A Theory of the Epidemiology* of Population Change Milbank Memorial Fund Quarterly **49**(4): 509–538.

PALEODIET.COM. 1997. http://paleodiet.com

PATZ, J.A., GRACZYK, T.K., GELLER, N. and VITTOR, A.Y. 2000. Effects of environmental change on emerging parasitic diseases. *International Journal of Parasitology* **30**: 1395–1405.

PERSOON, G. 1989. The Kubu and the outside world (South Sumatra, Indonesia): The modification of hunting and gathering. *Anthropos* **84**: 507–519.

POPKIN, B.M. 2002. An overview on the nutrition transition and its health implications the Bellagio meeting. *Public Health Nutrition* **5**(1a): 93–103.

ROTH, E.A. 1985. A note on the demographic concomitants of sedentism. *American Anthropologist* **87**: 380–382.

SAHLINS, M. 1972. Stone age economics. Aldine-Atherton, Chicago.

SCOTT, J.C. 2009. *The Art of Not Being Governed: An Anarchist History of Upland Southeast Asia*. Yale University Press, New Haven, CT.

STRICKLAND, S.S. and DUFFIELD, A.E. 1998. Nutrition and ecosystems in Sarawak: The role of the areca nut. *Asia Pacific Journal of Clinical Nutrition* **7**(3–4): 300–306.

SURVIVAL INTERNATIONAL 1969. http://www.survivalinternational.org.

SUSANNE, C., REABATO, E. and CHIARELLI, B. (eds.) 2003. *Anthropologie biologique: Evolution et biologie humaine.* De Boeck Université 768 p.

SWEDLUND, A.C. and ARMELAGOS, G.J. (eds.) 1990. *Disease in Populations in Transition: Anthropological and Epidemiological Perspectives*. Bergin & Garvey, South Hadley, 400 p.

TELBAN, B. (1988). *People, illness and plants: Ethnomedicine in the highlands fringe of New Guinea.* Master's thesis, University of Zagreb, Yougoslavia.

THOMAS, J.M.C. 1987. Des goûts et des dégoûts chez les Aka, Ngbaka et autres (Centrafrique). In: KOECHLIN, B., SIGAUT, F., THOMAS, J.M.C. and TOFFIN, G. (eds.) *De la voûte céleste au terroir, du jardin au foyer.* EHESS, Paris, pp. 489–504.

TRUSWELL, A.S. 1977. Diet and nutrition of hunter-gatherers. In: CIBA FOUNDATION SYMPOSIUM (ed.) *Health and disease in tribal societies*. Elsevier, Amsterdam, Oxford, New York, pp. 213–226.

UNCONTACTED TRIBES 2011. http://www.uncontacted-tribes.org.

VOEKS, R.A. and SERCOMBE, P. 2000. The scope of hunter-gatherer ethnomedecine. *Social Science & Medicine* **51**: 679–690.

WHO website 2011. Global burden of disease: http://www.who.int/topics/global_burden_of_disease/en/.

WHO 1998. *The world health report 1998. Life in the 21st century: A vision for all.* WHO, Geneva, 232 p.

WILLIAMS, G. and NESSE R.M. 1996. *Why we get sick: the new science of Darwinian medicine*. Vintage Books, New York, 304 p.

WILSON, M.E., LEVINS, R. and SPIELMAN, A. 1994. Disease in evolution: global changes and emergence of infectious diseases. *Ann. NY Acad. Sci.*, **740**: 1–503.

WIRSING, R.L. 1985. The health of traditional societies and the effects of acculturation. *Current Anthropology* **26**: 303–323.

WOLFE, N.D., DASZAK, P., MARM KILPATRICK, A. and BURKE, D.S. 2005. Bushmeat hunting, deforestation, and prediction of zoonoses emergence. *Emerging Infectious Diseases* **11**(12): 1822–1827.

WOODMAN, J. and GRIG, S. (eds.) 2007. *Progress can kill. How improved development destroys the health of tribal peoples.* Survival International, London, 58 p.

WOOLHOUSE, M.E.J. and GOWTAGE-SEQUERIA, S. 2005. Host range and emerging and reemerging pathogens. *Emerging Infectious Diseases* **11**(12): 1842–1847.

YAMAUCHI, T., SATO H. and KAWAMURA, K. 2000. Nutritional status, activity pattern and dietary intake among the Baka hunter-gatherers in the village camps in Cameroon. *African Study Monographs* **21**(2): 67–82.

Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania

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SUMMARY

Food insecurity and malnutrition in local populations both result from and drive deforestation. This paper examines the relationships between diet of local people and measures of forest cover and use in the East Usambara Mountains, Tanzania. Data on dietary diversity and intake were collected for 270 children and their mothers. Area of tree cover within the vicinity of each household was examined in relation to forest use and diet. Individuals using foods from forest and other non-farm land had higher dietary diversity, consumed more animal source foods and had more nutrient dense diets. They also had more tree cover in a close proximity to the home, suggesting a relationship between tree cover and forest food use. Households reporting trips to the forest had lower area of tree cover within close proximity, suggesting that land close to the home with tree cover such as agroforest and fallow is important for obtaining subsistence products. Although historically there has been little motivation for local people to participate in forest conservation in the East Usambaras, the maintenance of tree cover in the landscape around the home, especially on agricultural and village land, may be important in ensuring continued access to the health benefits potentially available in wild and forest foods.

Keywords: East Usambara Mountains, forest cover, wild food, dietary diversity, nutrition

Couvert forestier, utilisation et alimentation dans les montagnes Usambara de l'Est en Tanzanie

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La nourriture non assurée et la malnutrition chez les populations locales résultent toutes deux de la déforestation, tout en la faisant empirer. Cet article examine les relations entre la nutrition des populations locales et la proportion de couvert forestier et son utilisation dans les montagnes Usambara de l'Est en Tanzanie. Des données sur la diverstité nutritionnelle et la consommation ont été recueillies auprès de 270 enfants et de leurs mères. La zone de couvert forestier autour de chaque foyer a été examinée du point de vue de l'utilisation de la forêt et de la nutrition. Les personnes consommant de la nourriture en provenance de la forêt et d'autres terres non-cultivées connaissaient une diversité nutritionnelle plus importante, mangeaient davantage de nourriture de source animale, et leur régime était plus concentré en substances nutritives. Il existait également une plus grande zone de couvert forestier à close proximité de leur foyer, suggérant une relation entre le couvert forestier et l'utilisation de la nourriture forestière. Les foyers effectuant des déplacements vers la forêt avaient une moindre zone de couvert forestier à proximité, suggérant qu'un terre couverte d'arbres proche du foyer, telle que l'agroforêt et la forêt inexploitée est importante pour l'obtention des produits de subsistance. Bien que les populations locales aient une motivation très limitée, historiquement, pour participer à la conservation forestière dans les Usambaras de l'Est, la gestion du couvert forestier dans le paysage encadrant les foyers, particulièrement sur la terre cultivée et celle des villages, pourrait bien être importante pour assurer un accès non interrompu aux bénéfices sanitaires potentiellement obtenus dans les aliments sauvages et forestiers.

Cubierta forestal, usos, y consumo en la dieta en las Montañas Usambara del Este, Tanzania

B. POWELL, J. HALL y T. JOHNS

La inseguridad alimenticia y la malnutrición en las comunidades locales son a la vez causa y resultado de la deforestación. Este artículo examina las relaciones existentes entre la dieta de las comunidades locales y la cantidad de cubierta forestal y su uso en las Montañas Usambara del Este, en Tanzania. Se recolectaron datos sobre la diversidad y el consumo en la dieta de 270 niños y sus madres. Se estudió el área de cubierta forestal en los alrededores de cada vivienda en relación con el uso del bosque y la dieta. Los individuos que hicieron uso de alimentos procedentes del bosque, y otras áreas no cultivadas, mostraron dietas más diversas, consumieron más alimentos de origen animal, y sus dietas contuvieron una densidad de nutrientes más alta. También disponían de una mayor cubierta forestal próxima a su hogares, lo cual sugiere que la cubierta forestal y el uso de alimentos del bosque están relacionados. Los hogares que mencionaron caminatas para llegar al bosque disponían de una menor cubierta forestal en las proximidades, sugiriendo que para la obtención de productos de subsistencia es importante la existencia de áreas cercanas al hogar con cubierta forestal, p. ej. agroforestales o en barbecho. Aunque históricamente las comunidades locales apenas han tenido motivación para participar en la conservación del bosque en las Usambara del Este, el mantenimiento de una cubierta forestal en el paisaje alrededor del hogar,especialmente en terrenos agrícolas y comunales, podría ser importante para asegurar el acceso ininterrumpido a los posibles beneficios que los alimentos silvestres y del bosque ofrecen para la salud.

INTRODUCTION

Human and ecosystem health are integrally linked, in part through the contributions both wild (non-domesticated) and cultivated (domesticated species and crop varieties) biodiversity make to human health by improving food security and nutrition. The role of agricultural biodiversity in improved dietary diversity and human nutrition is increasingly well established (CBD 2006, Johns and Sthapit 2004). Many authors assert the importance of forests and the biodiversity they provide for food security and nutrition (Colfer *et al.* 2006, Johns and Maundu 2006, Vinceti *et al.* 2008), however empirical documentation of these relationships remains scarce. Tree products from forests and agroforests have been suggested to be important in times of food insecurity (Falconer 1990). While the consumption of bush meat is often in conflict with conservation objectives, it is an important part of many local diets (Fa *et al.* 2003, Nasi *et al.* 2008, van Vliet and Nasi 2008). Colfer and colleagues (2006) note that there are likely no contemporary communities in the world which wholly depend on wild gathered food, but that for most communities living in or near forests, these foods make important contributions by supplying micronutrients (e.g. vitamins A or iron) often deficient in food from agricultural and purchased sources, and by providing a safety-net in times of food insecurity. In many settings, the poorest members of the community are also the most dependant on forest resources (Colfer *et al.* 2006, Harris and Mohammed 2003).

Global malnutrition is increasingly attributable to insufficient micronutrients (vitamins and minerals), as opposed to lack of protein and energy. Micronutrient deficiency is associated with growth failure, impaired cognitive development and physical fitness, decreased ability to work, weakened immunity and increased risk of chronic disease (UN-SCN 2004).

Concerns about sustainability of harvesting, even for plant-based forest resources, have in the past often meant that conservation priorities override the importance of forest ecosystems for local nutrition. Over the past two decades, the development of the field of landscape ecology has led the global conservation community to recognize the need to understand the role of humans in landscape level processes, and to approach trade-offs between human and ecosystem health in a more holistic manner (Wiens 2009). Understanding the importance of foods from different land use types (forest, fallow, farm) to the diets of local populations sheds light on the drivers of human actions across landscapes and highlights links between forest conservation, well-being and livelihoods (e.g. Chomitz 2007). Using a landscape ecology approach, incorporating humans as part of the ecosystem (Pfund 2010, Sayer *et al.* 2007), this study seeks to understand the synergies and trade-offs between livelihoods and forests in the East Usambaras by addressing the following three questions: What is the contribution of wild food species (both plant and animal) to the local diet? What is the importance of different land use types in the diets of local people? How does forest use and tree cover in the landscape specifically relate to the local diet and consumption of wild foods?

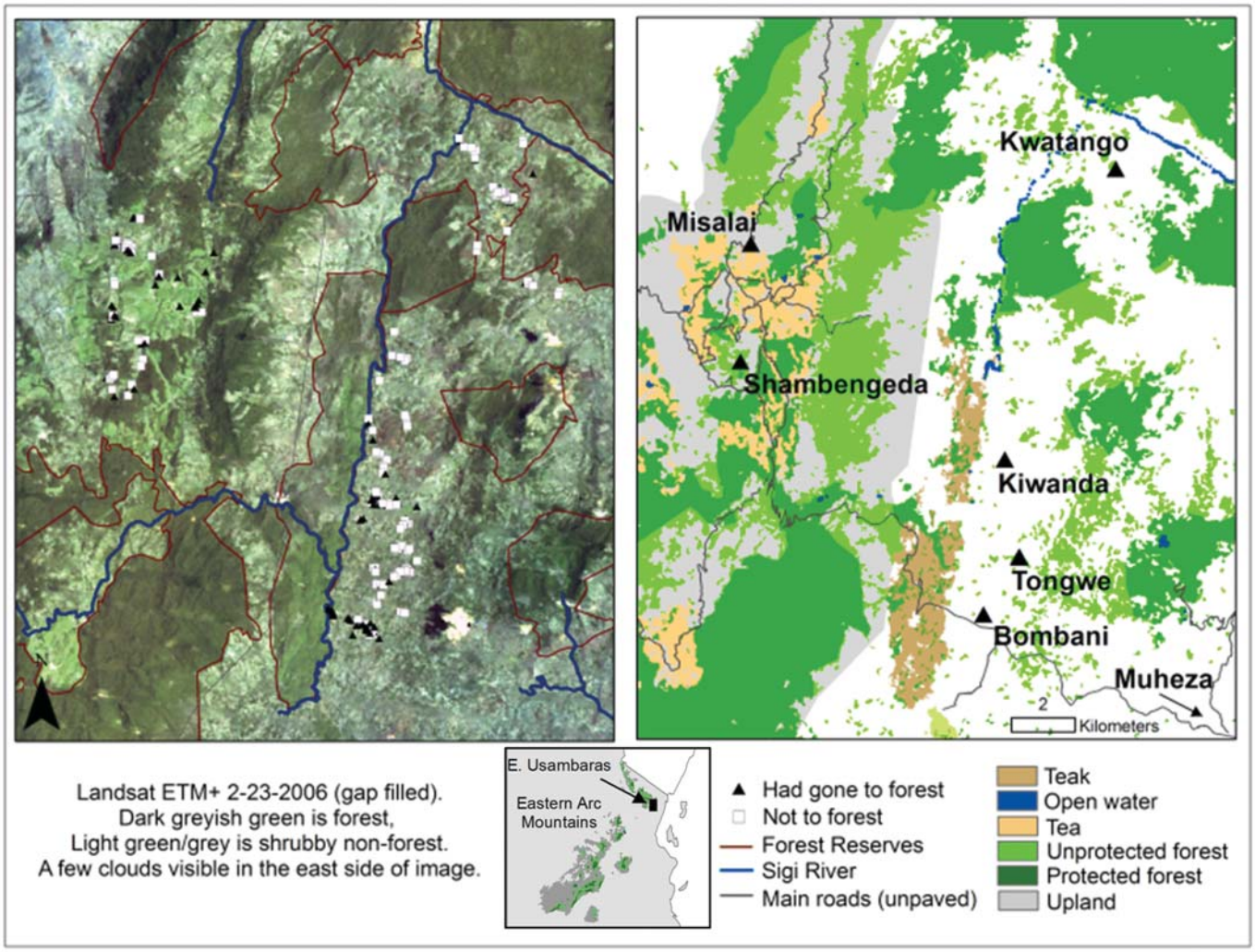
METHODOLOGY

Study site – East Usambara Mountains, Tanzania

In north-eastern Tanzania, the East Usambara Mountains rise from 200m to over 1200m and receive an average of 1500mm of rain annually (data from 2007–2009). Part of the Eastern Arc Mountains, the East Usambaras are renowned for a high concentration of endemic species (Burgess *et al.* 2007), and have been identified as one of the world's most threatened forest ecosystems (Myers *et al.* 2000), with deforestation prevalent throughout the area's unprotected forests (Dewi and Ekadinata 2010, Hall *et al.* 2009). The area contains moist tropical montane forest above ~600m and some of the last remaining but ecologically important lowland montane forest in East Africa (Brooks *et al.* 2002). Forest in the East Usambaras exists under varying degrees of protection, although most lies within government reserves. The East Usambaras encompass some of the oldest protected areas in East Africa; these have historically excluded local people from management and decision making and placed major restrictions on use by local people. Recently there have been significant efforts to decentralize forest management in Tanzania, including in the East Usambaras, where both joint forest management and community-based forest management have been initiated (Rantala 2010, Vihemäki 2005). Despite these efforts aimed "to promote and facilitate active participation of people in sustainable planning, management, use and conservation of forests" (Vihemäki 2005) access to forests under various types of protection for food (and other resources) remains limited (some deadwood collection has long been allowed in even the most highly protected areas) (Rantala 2010).

Although the Usambara Mountains derive their name from the Wasambaa (Shambaa) people who make them their home, the East Usambaras have always been culturally diverse; home to the Zigua, Bondei, and Digo ethnic groups as well (Willis 1992). The ethnic groups of the area have historically inter-married, a tradition which continued as the area experienced significant in-migration of people looking for employment in the tea and timber industries. Ethnic intermixing in the area was further enhanced by nationalistic (and anti-tribal) values promoted by the Tanzanian government under Nyerere (1964–1985) (Yeager 1989). With a population density of 61 people per square kilometre in the East Usambaras, both population density and population growth are higher than most other biodiversity hotspots and the global average (Cincotta *et al.* 2000, Tanzania 2002). Local livelihoods are based primarily on subsistence agriculture, supplemented with cash crops and wage labour (Kessy 1998). Wild or uncultivated foods have long been important in the diets of the Wasambaa (Feierman 1974, Fleuret 1979). People in the area use a high diversity of traditional vegetables and a higher ratio of wild to cultivated vegetables compared to other parts of Tanzania (including Arumeru, Singida and Kongwa) (Keding *et al.* 2007, Weinberger and Swai 2006). Malnutrition, especially vitamin A and iron deficiencies, have been found to be a problem in the area (Mulokozi *et al.* 2003).

FIGURE 1 *Map of the East Usambara Mountains with surveyed households who reported having visiting a forest in the last month (marked with black triangles) and those who did not report a trip to the forest (marked with white dots). Villages marked at location of village office*



A study in the East Usambara lowlands[1] in 1994 found 60% of children between 7–12 years old to be stunted (Height-for-Age Z score ≤–2), 35% wasted (Weight-for-Height Z score≤ –2), and 49% of children to be anaemic (Hb≤110g/L), with high rates of parasite infection (Beasley *et al.* 2000).

Six rural villages in Muheza district (southern East Usambaras) were selected for this study using stratified sampling based on road access and two elevation categories – upland (>500m) and lowland (<500 m) (Figure 1). Villages consists of hamlets or clusters of houses made mostly of poles and mud, mud brick and occasionally cement, with thatched or tin roofs. In the lowlands, Bombani village, 13.5km from the urban centre – Muheza Town – and at a junction of the main road leading into the uplands and a smaller one to the lowlands, has regular public transit and significant opportunity for wage labour (especially in the timber industry due to the near-by Lunguza Teak Plantation). Tongwe, and further Kiwanda, villages are spread-out along the secondary road from Bombani. Only one or two public transit vehicles travel this road per day, less in the rainy season, but because Tongwe is close, markets and wage labour are still quite accessible. Kiwanda is significantly more isolated, with households spread across a large area. Down Sigi River valley from Kiwanda lies Kwatango village. Kwatango has a even lower population density (although still high compared to some other tropical forests at 21 people per square kilometre) (Tanzania 2002) and limited accessibility by a different road coming from the plains to the east (at the time of research this road was in extremely poor condition and frequently impassable during the rains). Public transit leaves Kwatango once or twice a week in good weather; most produce is taken at least part of the way to market on foot. Misalai and Shambangeda, on the Amani plateau (between 800 and 1100m elevation), were surveyed as the two upland villages. Although over 15km up the mountain from Bombani, they benefit from a road which is maintained by the government to ensure access

[1] Villages of Misongeni, Ubembe and Kilometa Saba in Muheza District

to tea estates and the Amani Research Station. Public transit leaves twice a day, in virtually all weather, as well as vehicles carrying crops to markets. Both villages have high population density (Tanzania 2002), with hamlets squeezed between tea estates and protected government forests. Many inhabitants in both villages engage in wage labour on the tea estates as their only source of income, or in addition to agricultural activities.

Data Collection

Dietary assessment: Approximately 45 households from each of 6 villages were selected using systematic sampling from a lists of households with children under 5 provided by village governments (in this case every 2nd or 3rd household was selected, or ~50% of eligible households, total N=270). Dietary intake information was collected for pairs of mothers and children between the ages of 2 and 5 years; the youngest child within the age range in the household was selected with their mother or primary caregiver (henceforth referred to as mothers). Women of childbearing age and young children are the most nutritionally sensitive members of a household both due to higher requirements and inadequate intake (Gibson 2005). The dietary data presented here was collected during the long rainy season from March to May 2009. Dietary data was also collected at the end of the dry season (September to October 2009), in three of the six villages. This paper presents only the data from the wet seasons because it was the period of the year with the highest rates of food insecurity, and highest use of wild and forest foods (Powell *et al.* forthcoming), and because it allowed for larger sample sizes. Mothers responded to a qualitative 7 day food use questionnaire for their own and their child's dietary intake (from memory, with mothers consulting older child during interview). Nutrient intake information was collected for each child using two 24 hour recalls on non-consecutive days. A Mean Adequacy Ratio (MAR) for 11 nutrients (Protein, Thiamine, Riboflavin, Niacin, B12, Vitamin A, Vitamin C, Calcium, Iron, Zinc and Magnesium) and a score of nutrient density across 12 nutrients (above plus fat) was calculated (Dubois *et al.* 2000). Despite the error associated with human memory, most dietary information is collected by recall; for preschool children data is collected from a caregiver (Livingstone and Robson 2000). The source of each food item consumed was recorded and the relative contribution of foods from each source (forest, farm, purchased, etc) to dietary diversity calculated. Dietary diversity is defined here as the number of unique foods consumed in a given period (here 7 days), although it has been measured many different ways (Ruel 2003). Dietary diversity is believed to be a strong marker of diet quality because diversity enhances the likelihood that sufficient quantities of all nutrients are consumed and decreases the likelihood that large quantities of any one potential toxin are consumed (Gibson *et al.* 2000, Johns and Sthapit 2004). Dietary diversity has been linked to higher nutritional status of children and adults, higher micronutrient intake and adequacy and improved food security (Arimond and Ruel 2004, Ruel 2003, Torheim *et al.* 2004).

Forest Cover and Biophysical variables: The location of each household was recorded using a hand held GPS 60CSX (Garmin™). Geographic Information Systems (ArcGIS9.2) was used to analyze aspects of the landscape in proximity to each household. Tree cover was determined using a Landsat eTM+ gap filled image (30 m resolution, Row 166, path 064, Feb. 23, 2006) and a SPOT satellite image (10m resolution, Feb. 17, 2007). Classification of the image was performed using a supervised maximum likelihood algorithm using ERDAS imagine software in 2008 by Jaclyn Hall in association with the CIFOR-ICRAF Landscapes Mosaics project (Hall 2009). A Normalized Difference Vegetation Index (NDVI) of photosynthetic activity was created using the Landsat red and near infrared spectral data. NDVI is commonly used to represent productivity and is significantly related to the phosynthetically active leaf area across different land covers (Carlson and Pripley 1997, Jensen 1996). NDVI is a measure of growing season productivity, which is different from forest. Total area of tree cover and average NDVI value (Average Leaf Area) for the area in proximity to each household was determined for circular areas around each household with radii of 1.0, 1.5 and 2.0km.

Forest use and other household variables: Questionnaires conducted with the head of each household covered education, assets, source of income, participation in wage labour, land use, forest use and agricultural practices of the entire household. Household wealth was assessed using community-based ranking in which a group of community leaders were asked to reach consensus on the wealth rank of each of the households in the study (based on their own set of criteria including: livelihood, housing, health and diet, education, clothing, travel, among others). This measure of wealth was chosen over asset based ranking because it was holistic and better able to incorporate more diverse and nuanced factors than the asset based ranking.

Data analysis: Survey data were analyzed using SPSS Student Pack 18. Groups were compared using Chi-squared and Independent t-tests. Multivariate analysis compared groups using logistic regression.

RESULTS

Wild and forest foods in the diet

Sources of food

A total of 202 unique food items were used by all households in the six villages, including 10 staples (including maize, cassava, banana), 38 species of fruit, 53 species of vegetables, 9 mushrooms (identified only by vernacular name), 45 animal sources foods (including fish) and 41 other items (mostly purchased items such as salt, sugar, oil, spices, drinks and snacks). The mean dietary diversity (number of food items consumed within the last 7 days) was 38.4 for mothers and 39.3 for children (with normal distributions and no

FIGURE 2 *Sources of all food items (average of mothers and children)*

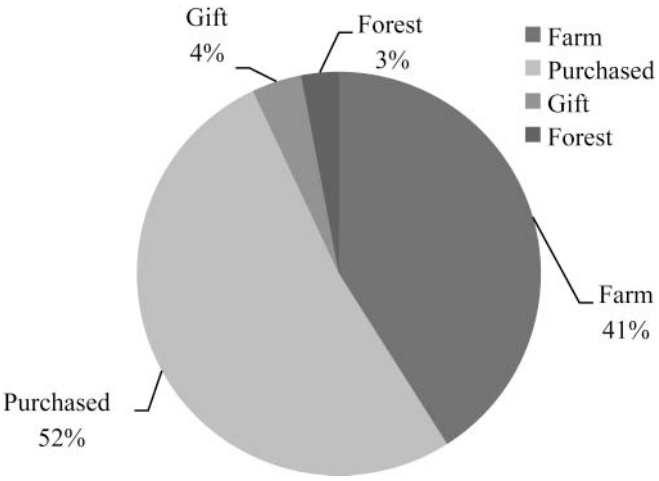
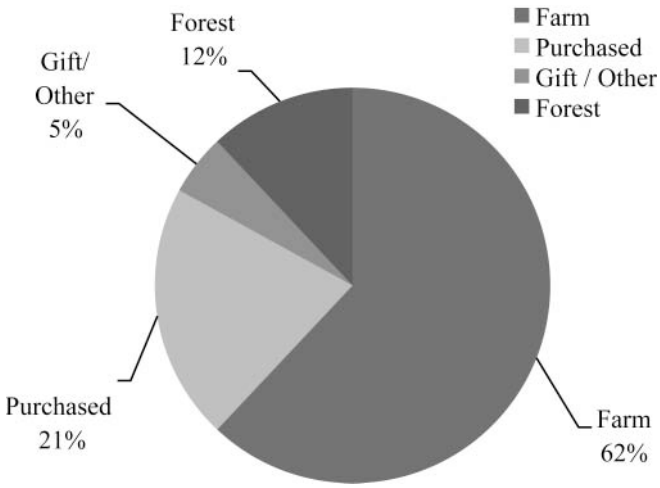


FIGURE 3 *Sources of wild food species (average of mothers and children)*



differences between children and mothers). Sources of food recorded included: purchased foods (store, market, vendor, local restaurant); farm, garden and fallow (combined because use of these terms and their definitions were inconsistent across informants); gift (including foods consumed at a friend's house or a funeral); and foods from forest or non-farm land (river, forest, bush).

An average of 51.9% of food items were purchased, 41.1% were obtained on farm and only 2.6% were obtained from forest (and un-cultivated land) (Figure 2). However, wild or uncultivated species (regardless of reported source) accounted for a much higher percentage of the diet (15.4%) than foods that respondents reported were obtained from the forest / non-farm land. Many (61.7%) of these wild species were obtained from areas considered part of farmland, rather than areas considered forest (Table 1, Figure 3). Of the 53 species of vegetables consumed, 41.5% of them were cultivated (domestic) and 58.5% were wild uncultivated species.

Figure 4 presents the differences in wild species foods vs. foods obtained from forest / non-farm land by food type; while the majority of wild bird (83.3%) and mammal (80%) species consumed are obtained from the forest, most of the wild species of vegetables (70%), mushrooms (62.5%) and fruit (50%) were obtained within farm land (including fallow and agroforests). Data for figure 4 was calculated from the list of all food items consumed, by counting the number of wild species and the number of items that respondents reported as obtained from the forest (>10% of the time).

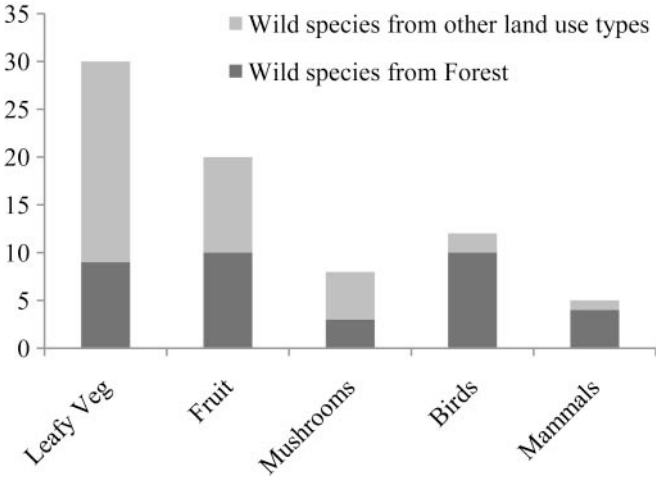
Percent of diversity used

Community level diversity (Table 2) was defined as the total number of food items used by the community as a whole (represented by all individuals included in the survey). The 'primarily source' of each food item was determined as the most common source reported for each food item (used because most food items were obtained from different sources

TABLE 1 *Dietary diversity, mean percent of food items from forest, purchased, gifts, farm and wild species, and sources of wild species food items for mothers and children*

	Mother (N=269)		**Child (N=269)**	
	Mean±SD	**Min-Max**	**Mean±SD**	**Min-Max**
Dietary Diversity (number of items)	38.4±11.6	14-81	39.3±11.7	15-80
Percent- Reporting ≥1 items from the **FOREST** (%)	44.6	-	45.4	-
Percent of Food Items **PURCHASED** (%)	51.4±12.9	25.8-91.7	52.4±12.5	25.8-91.7
Percent of Food Items from **GIFTS** (%)	4.6±6.3	0-45.0	4.9±6.8	0-50.0
Percent of Food Items from **FARM** (%)	41.6±12.2	5.0-68.3	40.5±12.2	5.0-66.7
Percent of Food Items from **FOREST** (%)	2.6±4.0	0-23.9	2.5±3.7	0-22.8
Percent of Food Items from **WILD SPECIES** (%)	15.4±5.4	-	15.3±5.2	-
Percent of **WILD SPECIES**: **PURCHASED** (%)	22.1±22.5	0-100	20.7±21.2	0-100
Percent of **WILD SPECIES**: **from GIFTS** (%)	2.5±7.8	0-50	3.8±10.4	0-80
Percent of **WILD SPECIES**: **from FARM** (%)	61.6±24.7	0-100	61.9±25.2	0-100
Percent of **WILD SPECIES: from FOREST** (%)	12.5±16.8	0-61.5	12.0±16.3	0-63.6

FIGURE 4 *Total number of wild species from the forest and other land use types used by all surveyed households, by different food types*



by different households and wild species came from many sources). The *percent of diversity used* for food from each source was calculated as the mean individual dietary diversity from that source divided by the community level diversity of foods primarily obtained from that source, and is assumed to be approximately equal to the percent of available diversity used.

The higher the *percent of diversity used*, the more similar individuals were to each other in terms of food items consumed from that source. Table 2 shows that the *percent of diversity used* was 30% for purchased foods and 15% for food from the farm, indicating that individuals used many of the same purchased foods, but were less similar in their use of foods from the farm. *Percentage of diversity used* was very low for wild species (6.7%) and foods from forests (3.8%) indicating large variation from one individual to the next in terms of species used from these sources (few food items in common).

Diet, Forest Use and Forest Cover

Forest food use

Only 44.6% of mothers and 45.6% of children were reported to have consumed one or more foods obtained from the forest in the past 7 days (Table 1). Compared to those not reporting

TABLE 2 *Community level diversity, mean individual dietary diversity and percent of (available) diversity used for all foods and different types of foods*

Source	Community level diversity	Mean individual dietary diversity	Percent of diversity used
TOTAL (All sources)	202	39	19.3%
Purchased	69	20	29.0%
From Farm	106	16	15.1%
From Forest	26	1	3.8%
Wild Species	91	6	6.7%

TABLE 3 *Differences in characteristics for mothers and children using and not using foods from the forest for lowland villages*

Characteristics	Mothers		Children	
	Using Forest Foods (N=93)	Not using Forest Foods (N=91)	Using Forest Foods (N=92)	Not using Forest Foods (N=92)
Dietary Diversity (Count)	39.5±11.6	36.0±11.3*	40.2±11.5	37.1±11.0(1)
Number of Animal Foods Used	6.3±2.7	5.2±2.6*	6.3±2.6	5.3±2.6*
Percent of diet from Animal Foods	15.7±4.4	14.1±4.9*	15.5±4.5	13.8±4.4*
Percent of diet from Purchased Food	44.5±10.1	54.3±12.3**	46.2±9.6	54.8±11.6**
Percent of diet from Wild Species	18.6±6.0	13.3±5.1**	19.0±5.4	13.4±4.8**
Leaf Area 200m (Average)	3.09±0.35	2.82±0.46**	3.07±0.35	2.79±0.47**
Tree cover 1.0km (ha)	236.7±169.3	158.6±123.1**	233.0±169.1	163.1±126.5*
Tree cover 1.5km (ha)	793.7±527.3	527.3±304.7**	788.7±515.3	535.3±308.0**
Tree cover 2.0km (ha)	1785.8±1044.0	1343.4±595.6**	1768.9±1045.1	1365.1±614.0*

* statistically significant in an independent t-test $p<0.05$

** statistically significant in an independent t-test $p<0.001$

(1) $p=0.061$. When both upland and lowland villages are included in the analysis, children reported to have used forest foods had significantly higher dietary diversity than those not using forest foods

use of forest foods, those reporting use of foods from forest / non-farm land had higher tree cover within 1km, 1.5km and 2km radii around their homes. The percent of mothers and children reporting use of foods from the forest was significantly higher in the lower elevations[2]. Table 3 displays only results for the four lowland villages.

Mothers and children who used foods from the forest had significantly higher dietary diversity, consumed a greater number of animal source food items, obtained a lower percentage of their food by purchasing and a higher percentage of their food from wild species (Table 3). Children who consumed forest foods had a higher nutrient density score (Student's t-test p=0.045, 39.0 vs. 36.2 for those not using forest foods), and a higher but statistically insignificant mean nutrient adequacy ratio (MAR) (Student's t-test p=0.114, 0.781, vs. 0.753 for those not using forest foods).

Those who reported use of forest foods were not different from those reporting no use in terms of wealth[3], wage labour participation, acres owned, age of mother, education, size of household or ethnicity (all elevations and low elevation only). However, in addition to elevation, a couple of other potential confounding variables were identified. There was a trend for individuals reporting use of forest foods to be more likely to come from a male headed household (Chi squared test for low elevation villages mothers p=0.48 and children p=0.057). The percentage of mothers and children who reported using foods from the forest was significantly different among villages [higher in Kiwanda (71%) and Kwatango (81%) than in Misalai (30%) and Shambangeda (39%), Bombani (24%) and Tongwe (25%)]. It is impossible to determine which of the differences between villages are responsible for the observed differences in forest food use; however a number of characteristics of Kiwanda and Kwantango merit consideration, including their greater isolation, lower access to wage labour and lower population densities (Tanzania 2002). In multivariate logistic regression analyses with forest food use by mothers or children as the dependant variables, controlling for village and elevation, amount of tree cover within 1.5km from the house made a significant addition to the model but gender of the head of household and wealth did not (for mothers using forest foods to those not $R^2 = 0.324$, $p<0.01$ (of change from adding tree cover), N=260; and for children using forest foods to those not $R^2 = 0.297$, $p<0.05$ (of change from adding tree cover), N=254).

Trips to the forest

Of household heads in all 6 villages, 67.4% reported having visited the forest within the last year, 46.4% within the last month and 33.8% within the last week. The average number of trips for respondents who had gone to the forest in the last month was 8.1±8.6 and the last week was 3.0±2.0. Household heads from upland villages reported significantly more trips to the forest than households from lowland villages (past year 75% upland vs. 63% lowland, past month 60% upland vs. 40% lowland, and past week 45% upland vs. 30% lowland).

In the lowland villages, households reporting trips to the forest had lower tree cover within a distance of 1.0, 1.5 and 2.0km from their homes, but greater area of teak plantation. They also had significantly less unprotected forest within a 0.5km radius of their homes (Table 4). These relationships can be seen clearly on the map (Figure 1). These findings are likely linked to the interpretation of the word *forest*, as explained below.

TABLE 4 *Differences between households visiting the forest and those not for tree cover, teak plantation cover, unprotected forest and leaf area for lowland villages only*

Land cover Characteristics	Forest in last year		Forest in last month		Forest in last week	
	YES (N=116)	NO (N=68)	YES (N=74)	NO (N=110)	YES (N=56)	NO (N=128)
Leaf Area 200m (Average)	2.88	3.02*	2.73	3.06*	2.70	3.03*
Tree Cover 1.0km (ha)	163.0	256.3**	146.6	231.7**	133.5	225.5**
Tree Cover 1.5km (ha)	550.2	849.3**	512.3	760.6**	470.8	743.9**
Tree Cover 2.0km (ha)	1341.4	1946.7**	1237.6	1785.4**	1144.9	1749.0**
Teak Cover 1.0km (ha)	194.9	38.7**	253.9	58.6**	275.1	76.8**
Teak Cover 1.5km (ha)	614.6	180.2**	782.3	233.2**	832.1	288.6**
Teak Cover 2.0km (ha)	1371.0	443.9**	1665.2	600.0**	1755.5	710.3**
Unprotected Forest 500m (ha)	2.38	4.60**	1.72	4.19**	1.61	3.89**

* statistically significant in an independent Student's t-test $p<0.05$

** statistically significant in an independent Student's t-test $p<0.001$

[2] Likely in part due to the ecological differences between the dense humid upland forest and more open the lowland forest types

[3] Using asset based wealth ranking there is a trend for children who had used forest foods to be from less wealthy households (but not mothers)

Dietary intake was related to reported trips to the forest in a number of unexpected ways. In the lowlands, individuals from households who reported visiting the forest had significantly lower dietary diversity than those that did not report visiting the forest. Individuals from households who visited the forest obtained a lower percentage of their diet from the farm and a higher percentage from purchased sources. Additionally, individuals from households who visited the forest consumed fewer types of animal foods and borrowed food more often than those from households who had not visited the forest. Those from households who reported trips to the forest (across most time periods) also obtained a lower percentage of fruit, fish and animal foods from the forest, consumed fewer wild species and tended to be less likely to use forest foods. This is likely due to the strong relationship between trips to the forest, wage labour and wealth in the lowlands. The 50 year old mature teak plantation is considered forest by local people and was being actively harvested during the study period.

Individuals from households who had visited the forest in the previous week or month were significantly less wealthy than those who had not (high and low elevation). Chi squared tests showed that those who reported trips to the forest were more likely to engage in wage labour (for high and low elevation, in the last week, month and year $p<0.005$). In the upland, those who engaged in labour on the tea estates were more likely to report trips to the forest (for all time frames). In the lowland, those who engaged in wage labour in the timber industry were more likely to report trips to the forest in the last week and month. Compared to households who did not report trips to the forest (at all elevations), those reporting trips to the forest tended to be less likely to have been born locally (possibly because most immigrants to the area engage in wage labour), to own fewer acres of land and spend fewer hours in the farm; however, there were no differences between ethnic groups nor male and female headed households. In logistic regressions with 'visited the forest in the last year or month' as the dependant variables, controlling for elevation and wage labour in the tea or timber industry, tree cover within 2km from the house and whether the household members had been born locally made significant contributions to the model. With 'visited the forest in the last week' as the dependant variables, wealth and tree cover within 2km were the variables added to the model in forward (stepwise) conditional analysis.

DISCUSSION

Limitations of the study: The complexity of the data and the many potential confounding variables meant that this study was only able to identify associations between variables. The collinearity between variables and the cross-sectional study design (rather than longitudinal), prohibit conclusions about causality. While the methodology section notes limitations of dietary assessment methods, alternatives such as anthropometric and biochemical measures of nutrition can be even more problematic in settings where parasitic infection rates are high, such as the East Usambara Mountains (Semba and Bloem 2008). Given the local history of forest policy and governance, reporting may have been biased by hesitancy to disclose illegal forest use / activities. The fact that this study only describes relationships in the wet season, the season with the greatest use of wild and forest foods, could mean that they differ during other times of the year. Further research, especially longitudinal studies examining the impact of changes in forest cover and access over time on the use of forest foods and nutrition would improve the current state of knowledge. Although the relationships described herein remain unsubstantiated their potential implications for policy and practice provide food for thought for conservation researchers and practitioners.

The importance of forests and wild foods in contemporary diets: Although the Shambaa people historically obtained much of their starchy staple food items from agriculture, Feierman (1974) and Fleuret (1979) suggest that much of the leafy vegetables and meat in the traditional diet were obtained from wild sources. Over 30 years later, wild foods, accounting for 15% of the items in the diet, still make a significant contribution.

Of the wild species consumed (from any source) 40% were vegetables, 27% were fruit, 23% were small mammals and birds, and 11% were mushrooms. Of the items obtained from the forest 39% were birds and small mammals, 28% were fruit and 25% were leafy vegetables (figures and total do not include wild fish species / fish from wild sources, e.g. rivers) (Figure 4). Because fruits, vegetables and animal source foods are important sources of micronutrients, even in small amounts they make an important contribution to local diets. These types of foods, compared to starchy staples and snack foods obtained through agriculture or purchasing, have higher density of most micronutrients relative to energy, carbohydrates and sugars. Data on the nutrient composition of wild foods are lacking so direct comparison between wild and non-wild fruits or vegetables is difficult (and impossible for animal source foods). Moreover, nutrient content of all fruits and vegetables can be extremely variable depending on variety, climate, ecology, harvest and storage factors. Msuya and colleagues (2008) found high variation in iron, zinc and beta-carotene content of wild vegetables harvested from different regions in Tanzania. In the East Usambaras they found high levels of these 3 nutrients in wild vegetables (compare for example the three most commonly consumed wild vegetables *Launaea cornuta*, *Corchorus olitorius* and *Bidens pilosa* with beta-carotene 6800, 6310, 2320 µg/100g, iron 9.9, 4.2, 12.05 mg/100g and zinc 0.579, 0.196, 0.484 mg/100g values respectively to the three most commonly consumed cultivated vegetables *Amaranthus* spp., sweet potato leaves and pumpkin leaves with beta-carotene 5716, 5870 and 3600 µg/100g, iron 2.3, 0.5, 0.6 mg/100g and zinc 0.6, 0.2, 0.1 mg/100g values respectively).

Rural African diets are notorious for the high percent of energy obtained from staples such as maize and cassava and low intake of animal source foods (Stephenson *et al.* 2010). The low intake of the latter leads not only to a low intake of

protein but also to inadequate intake and low bioavailability of many micronutrients (Murphy and Allen 2003). Consumption of animal source foods (from domesticated animals or sustainably harvested wild mammals, birds or fish) is a preferred strategy for improving micronutrient status and therefore children's growth and cognitive development in developing countries (Murphy and Allen 2003). It is important to note that the wild animal species consumed in this study included two types of small antelope and two types of rodent[4]. Of the 16 reports of wild animal consumption, 10 were for *Thryonomys* spp. (a common small rodent). In another part of the Eastern Arc, the Udzungwa Mountains, populations of all mammals except *Thryonomys* spp. were found to be so depleted that the author felt that no level of hunting could be sustainable (Nielsen 2006). It seems very likely that in the East Usambaras, faunal resources are similarly depleted and overexploited (possibly with the exception of *Thryonomys* spp.).

In this study population Powell et al. (forthcoming) report that wild species contribute an average of 2% of daily energy intake, 2% of fat intake, 7.4% of protein intake, 19.2% or iron intake, 20% of vitamin C intake and 31% of vitamin A (in Retinol Activity Equivalents) intake. The finding here that, compared to those who had not, children who had consumed forest foods had higher nutrient adequacy (not statistically significant) and nutrient density across multiple nutrients further supports the contribution of wild and forest foods to nutrition.

Uncultivated food species from cultivated land: Although the results of this study do not allow for conclusions about the net trade-offs between agricultural intensifications vs. maintaining biodiverse agricultural systems[5], they do show that biodiversity within agricultural land makes an important contribution to the local diet by way of the significant amount of uncultivated foods being collected on-farm (62%). Other research has similarly found a large portion of wild species obtained from agricultural land, coining these foods "the hidden harvest" (Bishop and Scoones 1994).

Wild species from farm land included fruit from trees and shrubs growing in field margins and fallows, mushrooms from recently cleared fields, leafy vegetables from field margins and fallow areas, and many leafy vegetables which would otherwise be considered weeds growing among (and often competing with) newly planted maize and other crops. Micro-climates provided by diversity of land use on farms provide for a diversity of wild plant foods. A recent review of wild foods in agricultural systems by Bharucha and Pretty (2010) highlights the fact that labels of hunter-gather vs. agricultural imply a false dichotomy in which wild foods are of limited importance in agricultural livelihoods. Most rural human populations engage in active management of useful wild species; in fact many farmers do not make clear distinctions between cultivated and uncultivated (Bharucha and Pretty 2010). In the East Usambaras people tolerate (do not clear while weeding) wild leafy vegetables, such as *mchunga* (*Launaea cornuta*), in their fields and teach their daughters to harvest in a manner that ensures regeneration (Powell *et al.* 2010). Human activity in forested landscapes tends to increase the density, diversity and/or value of plant, but not animal, species useful to humans (Ambrose-Oji 2003, Parry *et al.* 2009, Toledo and Salick 2006).

The importance of agricultural biodiversity for agriculture and conservation has been established (Sunderland this issue); although further substantiation is needed, the results of this study suggest that the maintenance of farms with biodiverse fallows, field margins and agro- and working forests could benefit human health and nutrition as well, through the provisioning of wild foods. Less than 25% of households in this survey reported having fallow land in the last 12 months (of those the average area was 1.8 acres for 1.5 years). Conservation efforts should focus on the landscape scale approaches; encouraging mosaics of forest, agroforest, fields and fallow within agricultural landscapes surrounding protected areas will likely enhance biodiversity and human health simultaneously (CBD 2006, Dudley *et al.* 2005, Hall *et al.* 2010).

Wealth, time, proximity of forests and other constraints on use of forest species: Wild and forest foods are often suggested to be more important to poorer households (Colfer *et al.* 2006, Harris and Mohammed 2003), although these relationships are not always consistent (Ambrose-Oji 2003, Bharucha and Pretty 2010). In this study there were no significant quantitative associations between forest food use and wealth (assessed by community-based ranking); however, qualitative evidence suggests that cash availability is a contributing factor in the use of wild and forest foods: "*Those leafy vegetables are in the farm and if today I do not have money it will force me to leave home and waste time and go to look for that vegetable so that it can fill that gap.*" Beatrice Akida (single mother and farmer in Tongwe village).

In many contexts, it is access, rather than availability that limits use of wild and forest foods. One important constraint on access is the free time required to collect wild and forests foods (Kuhnlein and Receveur 1996), mediated by travel time to reach the harvesting site and efficiency of harvesting. Although wild foods are free, they can be inaccessible when daily chores, livelihood efforts and / or wage labour take all of person's time and energy. In Cameroon, Koppert *et al*. (1993) found that due to women's time-demanding daily

[4] Two households reported *digi digi* or *paa* (said to be the same species, *Rhynchotragus* spp.) and two households reported *funo* (probably a species of Duiker, *Cephalophus* spp.), all from the forest without specification (because hunting in reserved forests is illegal all informants would presumablely claim to obtained animals from unprotected forests only). The exact species of antelope is impossible to determine due to error in informant identification, and importantly inaccurate reporting. The other species of rodent was kuhe (*Cricetomys gambianus*)

[5] Agricultural shifts towards specialized, intensified systems are often touted as key to development, however improved income does not always translate to improved diet and nutrition (see Kennedy 1989 and Dewey 1989).

tasks, wild or forest foods had to be close to forest camps and in sufficient quantities to be included in the diet. In the East Usambaras wild and forest foods are used by many households when there is not enough available cash to purchase cultivated vegetables, dry fish or legumes. The period just before and during the rains is one of the most agricultural labour intensive (land preparation, planting and early weeding), but is also the period when higher wild food use was recorded. Conversely, despite low labour inputs in the post harvest period at the end of the dry season (when cash is readily available), households reported less use of wild and forest food resources at that time (Powell *et al.* forthcoming). Although many species of wild foods, especially wild leafy greens, are less available in the dry season, there are many which persist in shaded field margins and wet areas (as well as many wild fruits which ripen in the dry season). This might suggest that free time and availability of wild and forest foods are not strong factors determining use in the East Usambaras. Of course if a household lacks available cash to purchase foods, but also has constraints on access to wild and forest foods (e.g. is far from the forest or has limited free time), this could preclude any increased use of wild and forest foods, even if the low *percent of diversity used* for wild and forest foods used suggests that these foods could make greater contributions to the diet. Lack of free time may underpin the finding that female headed households were less likely to use forest foods than male headed households (with a reduced adult work force they may not have the time needed to collect forest foods).

Other research has suggested that wild and forest foods are important as a 'safety-net' in times of hardship (Colfer 2008, Johns and Maundu 2006, Vinceti *et al.* 2008). In the East Usambara Mountains, this importance seems to be mediated by forest proximity (as households far from forests require more travel time to access forest foods). These findings suggest that maintaining forest cover around villages and homes may be necessary if forest foods are to remain in the diet, with important implications for village and household level land management.

Interpretation of questions about forest: In part due to the long and complicated history of forest research and conservation in the East Usambaras, local people have sensitivities to questions about forests and forest use (Vihemäki 2005). Rantala (2010) notes ". . . whenever a tree-dominated area is privately owned, even if it is left to regenerate as forest, it is still called shamba (farm), not msitu (forest). . . . it is common that 'msitu' is only used to refer to a reserved area" such as a government or a village forest reserve. The conservation history in the region has created significant hesitation to admit use of forests; however, this varies from person to person (Vihemäki 2005). The vegetation cover local people refer to as forest (or non-farm land) when women report where a food product has been obtained is likely more closely related to scientific definitions based on vegetation structure or canopy cover. Conversely, questions about 'visiting a forest' conjure ideas about places that are reserved or officially protected, similar to Rantalla's (2010) description. The strong association between wage labour and reported trips to the forest in this study may be related to the fact that wage labour provided legitimate reasons to visit government owned forests. In the lowlands the timber industry provided the majority of wage labour, and in the uplands the tea industry workers often passed through tea estate or reserved forests to reach harvest locations. Had harvesting of the mature teak forest not been underway at the time this study was conducted, results may have been quite different. Vihemäki and colleagues (forthcoming) suggest that historic forest management practices, in which local people had restricted access to forests and no involvement in management and decision making, led to local peoples' unwillingness to use forest products (forests are seen as a place where illegal activities are undertaken), and that this an important factor in the limited forest food use in the area. Vihemäki and colleagues (forthcoming) describe the current forest management regimes (including joint forest management and community based forest management of village forests) in the area and the use rights to forest foods associated with each, and note that despite efforts to decentralization forest management local people perceive a major decrease in the importance of the forest as a source of food. Within the frame-work of these local definitions, two possible conclusions can be drawn from the finding that those who reported visits to the forest had lower area of tree cover and less unprotected forest within a close proximity of their houses. Firstly, the relationship could simply be an artefact of the fact that lowland households who engaged in wage labour lived in areas with less unprotected forest cover nearby[6]; alternatively (or additionally) this finding could suggest that households in areas with greater area of tree cover within the agricultural mosaic obtained subsistence products from treed land which they did not consider forest (such as agroforests, farms and fallows). Households in the uplands, where there was significantly greater tree cover, were more likely to report visiting the forest and yet fewer of them used forest foods. The significantly higher average leaf area and amount of unprotected forest around households not visiting the forest compared to those that did reported visiting the forest lends support to the latter conclusion (see Table 4).

CONCLUSIONS

The food-security and nutrition situation in Tanzania remains discouraging. Recent improvements in children's growth rates have not changed the fact that rates of stunting in Tanzania are still among the highest in the world and that micronutrient deficiency remain a major problem (UN-SCN 2004). Globally, Tanzania is one of the lowest ranked countries in

[6] Not including teak forests. Households involved in wage labour had a greater area of teak cover around their homes. In the uplands there is no difference in tree cover around the home between households that engage in wage labour and those which do not

terms of percent caloric intake from fats and simple sugars (Millstone and Lang 2003); however a nutrition transition from a traditional diet to a diet high in processed foods, salt, sugar and fat has begun. Because of this, communities may face increased rates of obesity and chronic diseases (such as type II diabetes and hypertension) before overcoming food insecurity and micronutrient deficiency (Maletnlema 2002). Research from the 1970's suggested that at the time a transition had begun (Fleuret and Fleuret 1980), and the high percentage of foods purchased in this study (even in Kwatango, the most remote village) demonstrates that this trend may be becoming ubiquitous. Overcoming micronutrient malnutrition and mitigating the nutrition transition simultaneously will require diets rich in micronutrients but without excess energy, fat, sugar or salt. Many forest and wild foods, especially those of plant origin, meet these criteria and could play an important role, especially if appropriate and timely nutrition education can ensure that they are consumed in place of increasingly accessible processed and fried foods. The contribution of wild and forests foods to dietary diversity may support local people's nutritional resilience in the face of social-cultural, economic and environmental change.

The findings of this study show that in the East Usambaras use of forests for food resources by local people is currently limited, but use of wild species is higher, primarily obtained from the farm. Households with greater tree cover in close proximity are more likely to consume wild and forest foods even while reporting fewer visits to protected forests, underscoring the importance of tree cover and fallow within the agricultural mosaic.

Food plays a central role in cultural and personal identity and fulfils multiple symbolic and cultural functions (Khare 1980, Kuhnlein and Receveur 1996); promoting the cultural importance as well as health and nutrition benefits of forests foods (and the maintenance of the traditional food system) may provide impetus for conservation-positive actions by local communities, people and governments. As population densities in the rural landscapes of Africa continue to increase forest remnants are being reduced and eliminated, as are fallow length and area in the agricultural landscape. Health is one of the strongest motivators for people; the health of their families is a particularly high priority for women, who bear the burden of care of ill family members (Wan *et al.* this issue). In a setting where participatory strategies for engaging local people in conservation have been only partially successful (Vihemäki 2005), the results of this study linking forest cover, forest food use and nutrition offer potential motivation for local people to maintain forest cover within the landscape mosaic. As paradigms in forest conservation shift, it is important to not lose sight of the importance of forests for human diet and nutrition.

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REFERENCES

AMBROSE-OJI, B. 2003. The contribution of NTFPs to the livelihoods of the 'forest poor': evidence from the tropical forest zone of south-west Cameroon. *International Forestry Review* **5**(2): 106–117.

ARIMOND, M. and RUEL, M.T. 2004. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *Journal of Nutrition* **134**(10): 2579–2585.

BEASLEY, N., HALL, A., TOMKINS, A., DONNELLY, C., NTIMBWA, P., KIVUGA, J., KIHAMIA, C., LORRI, W. and BUNDY, D. 2000. The health of enrolled and non enrolled children of school age in Tanga, Tanzania. *Acta Tropica* **76**: 223–229.

BHARUCHA, Z. and PRETTY, J. 2010. The roles and values of wild foods in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences* **365**(1554): 2913–2926.

BISHOP, J. and SCOONES, I. 1994. *The hidden harvest: the role of wild foods in agricultural systems. IIED Research Series Vol. 3, No. 1.* London: International Institute for Environment and Development. 49 p.

BROOKS, T., MITTERMEIER, R., MITTERMEIER, C., DA FONSECA, G., RYLANDS, A., KONSTANT, W., FLICK, P., PILGRIM, J., OLDFIELD, S., MAGIN, G. and HILTON-TAYLOR, C. 2002. Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* **16**(4): 909–992.

BURGESS, N.D., BUTYNSKI, T.M., CORDEIRO, N.J., DOGGART, N.H., FJELDSA, J., HOWELL, K.M., KILAHAMA, F.B., LOADER, S.P., LOVETT, J.C., MBILINYI, B., MENEGO, M., MOYER, D.C., NASHANDA, E., PERKIN, A., ROVERO, F., STUART, W.T. and STANLEY, S.N. 2007. The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation* **134**: 209–231.

CARLSON, T. and PRIPLEY, D. 1997. On the relation between NDVI, fractional vegetation cover and leaf area index. *Remote Sensing of Environment* 62: 241–262.

CBD. 2006. *COP 8 Decision VIII/23: Agricultural biodiversity, Cross-cutting initiative on biodiversity for food and nutrition.* The Convention on Biological Diversity, http://www.cbd.int/decision/cop/?id=11037 (Accessed Jan 29th, 2011).

CHOMITZ, K.M. 2007. *At loggerheads? Agricultural expansion, poverty reduction, and environment in the tropical forests.* Washington, DC.: Wold Bank Policy Report.

CINCOTTA, R., WISNEWSKI, J. and ENGELMAN, R. 2000. Human population in the biodiversity hotspots. *Nature* **404**: 990–992.

COLFER, C.J.P. 2008. *Human health and forests: Global overview of issues, practice and policy.* London, UK: Earthscan.

COLFER, C.J.P., SHEIL, D., KAIMOWITZ, D. and KISHI, M. 2006. Forests and human health in the tropics: some important connections. *Unasylva* **224**(57).

DEWEY, K.G. 1989. Nutrition and the commoditation of food systems in Latin America and the Caribbean. *Social Science & Medicine* **28**(5): 415–424.

DEWI, S. and EKADINATA, A. 2010. *Landscape dynamics over time and space from ecological perspective. Working paper number 103.* Bogor, Indonesia: The World Agroforestry Centre (ICRAF). 81 p.

DUBOIS, L., GIRARD, M. and BERGERON, N. 2000. The choice of a diet quality indicator to evaluate the nutritional health of populations. *Public Health Nutrition* **3**(3): 357–365.

DUDLEY, N., BALDOCK, D., NASI, R. and STOLTON, S. 2005. Measuring biodiversity and sustainable management in forests and agricultural landscapes. *Phil Trans R Soc B.* **360**: 457–470.

FA, J.E., CURRIE, D. and MEEUWIG, J. 2003. Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. *Environmental Conservation* **30**(1): 71–78.

FALCONER, J. 1990. "Hungry season" food from the forest. *Unasylva* **160**.

FEIERMAN, S. 1974. *The Shambaa Kingdom.* Madison, WI, USA: The University of Wisconson Press.

FLEURET, A. 1979. The role of wild foliage plants in the diet: A case study from Lushoto, Tanzania. *Ecology of Food and Nutriton* **8**: 87–93.

FLEURET, P. and FLEURET, A. 1980. Nutritional implications of staple food crop successions in Usambara, Tanzania. *Human Ecology* **8**(4): 311–327.

GIBSON, R. 2005. *Principles of Nutritional Assessment* Oxford: Oxford University Press.

GIBSON, R., HOTZ, C., TEMPLE, L., YEUDALL, F., MTITIMUNI, B. and FERGUSON, E. 2000. Dietary strategies to combat deficiency of iron, zinc and vitamin A in developing countries: Development, Implementation, Monitoring and Evaluation. *Food and Nutrition Bulletin* **21**(2): 219–223.

HALL, J., BURGESS, N.D., LOVETT, J., MBILINYI, B. and GEREAU, R.E. 2009. Conservation implications of deforestation across an elevational gradient in the Eastern Arc Mountains, Tanzania. *Biological Conservation* **142**: 2510–2521.

HALL, J.M. 2009. Irreversible loss of high biodiversity forest in the East Usambara Mountains. *The Arc Journal* **4**: 21–23.

HALL, J.M., GILLESPIE, T.W. and MWANGOKA, M. 2010. Comparison of agroforests and protected forests in the East Usambara Mountains, Tanzania. *Environmental Management*.

HARRIS, F.M. and MOHAMMED, S. 2003. Relying on nature: wild foods in northern Nigeria. *Ambio* **32**(1): 24–29.

JENSEN, J.R. 1996. *Introductory digital image processing: A remote sensing perspective.* New Jersey: Prentice Hall.

JOHNS, T. and MAUNDU, P. 2006. Forest biodiversity, nutrition and population health in market-oriented food systems. *Unasylva* **224**(57).

JOHNS, T. and STHAPIT, B. 2004. Biocultural diversity in the sustainability of developing country food systems. *Food and Nutrition Bulletin* **25**(2): 143–155.

KEDING, G., WEINBERGER, K., SWAI, I. and MNDINGA, H. 2007. *Diversity, traits and use of traditional vegetables in Tanzania, Technical Bulletin No. 40.* Shanhua, Taiwan: AVRDC, The World Vegetable Center.

KENNEDY, E. 1989. *The effects of sugarcane production on food security, health and nutrition on Kenya: a longitudinal analysis.* In: Research report. Washington, DC.: International Food Policy Research Institute.

KESSY, J. 1998. *Conservation and utilization of natural resources in the east Usambara forest reserves: conventional views and local perspectives. Tropical Resource Management Papers, no. 18.* the Netherlands: Wageningen Agricultural University.

KHARE, R.S. 1980. Food as nutrition and culture, Notes towards an anthropological methodology. *Social Science Information* **19**(3): 519–542.

KOPPERT, G.J.A., DOUNIAS, E., FROMENT, A. and P.PASQUET. 1993. *Food consumption in three forest populations of the southern coastal areas of Cameroon: Yassa – Mvae – Bakola.* In: Tropical Forests, People and Food. Biocultural Ineractions and Applications to Development. Paris, France: Man and Biosphere Seriers #13, UNESCO: The Parthenon Publishing Group.

KUHNLEIN, H.V. and RECEVEUR, O. 1996. Dietary change and traditional food systems of indigenous peoples. *Annual Review of Nutrition* **16**: 417–442.

LIVINGSTONE, M.B.E. and ROBSON, P.J. 2000. Measurement of dietary intake in children. *Proceedings of the Nutrition Society* **59**(2): 279–293.

MALETNLEMA, T.N. 2002. A Tanzanian perspective on the nutrition transition and its implications for health. *Public Health Nutrition* **5**(1A): 163–168.

MILLSTONE, E. and LANG, T. 2003. *The Penguin Atlas of Food: Who eats what, where and why.* Middlesex, England: Penguin Books.

MSUYA, J.M., MAMIRO, P. and WEINBERGER, K. 2008. *Iron, zinc and β-carotene nutrient potential of non-cultivated indigenous vegetables in Tanzania.* In: International Symposium on Underutilized Plants. Arusha, Tanzania: ISHS, Acta Hort.

MULOKOZI, G., LIETZ, G., SVANBERG, U., MUGYABUSO, J., HENRY, J. and TOMKINS, A. 2003. Plasma levels of retinol, carotenoids, and tocopherols in relation

to dietary pattern among pregnant Tanzanian women. *Int J Vitam Nutr Res.* **73**(5): 323–333.

MURPHY, S.P. and ALLEN, L.A. 2003. Nutritional Importance of Animal Source Foods. *Journal of Nutrition* **133**: 3932S–3935S.

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.B.D. and KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.

NASI, R., BROWN, D., WILKIE, D., BENNETT, E., TUTIN, C., VAN TOL, G. and CHRISTOPHERSEN, T. 2008. *Conservation and use of wildlife-based resources: the bushmeat crisis.* Bogor: Technical Series no. 33, Secretariat of the Convention on Biological Diversity, Montreal, and Center for International Forestry Research (CIFOR). 50 p.

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

PARRY, L., BARLOW, J. and PERES, C.A. 2009. Hunting for sustainability in tropical secondary forests. *Conservation Biology* **23**(5): 1270–1280.

PFUND, J.-L. 2010. Landscape-scale research for conservation and development in the tropics: fighting persisting challenges. *Current Opinion in Environmental Sustainability* **2**(1–2): 117–126.

POWELL, B., MAUNDU, P., KUHNLEIN, H.V. and JOHNS, T. forthcoming. Wild and forest foods in the local food system of Tanzania's East Usambara Mountains.

POWELL, B., WATTS, J., BOUCARD, A., URECH, Z., FEINTRENIE, L., LYIMO, E., ASAHA, S. and SUNDERLAND-GROVES, J. 2010. *The role of wild species in the governance of tropical forested landscapes, Chapter 7*. In: Collaborative Governance of Tropical Landscapes. Colfer C.J.P., Pfund J.-L., eds. London: Earthscan.

RANTALA, S. 2010. *Changing landscapes, transforming institutions: local management of natural resources in the East Usambara Mountains, Tanzania (Chapter 5)*. In: Collaborative Governance of Tropical Landscapes. Colfer C.J.P., Pfund J.-L., eds. London: Earthscan.

RUEL, M.T. 2003. Operationalizing dietary diversity: a review of measurement issues and research priorities. *Journal of Nutrition* **133**(11 Suppl 2): 3911S-3926S.

SAYER, J., CAMPBELL, B., PETHERAM, L., ALDRICH, M., PEREZ, M.R., ENDAMANA, D., DONGMO, Z.-L.N., DEFO, L., MARIKI, S., DOGGART, N. and BURGESS, N. 2007. Assessing environmental and developmental outcomes in conservation landscapes. *Biodiversity and Conservation* **16**(9): 2677–2694.

SEMBA, R.D. and BLOEM, M.W. 2008. *Nutrition and health in developing countries, 2nd ed.* New York: Humana Press.

STEPHENSON, K., AMTHOR, R., MALLOWA, S., NUNGO, R., MAZIYA-DIXON, B., GICHUKI, S., MBANASO, A. and MANARY, M. 2010. Consuming cassava as a staple food places children 2–5 years old at risk for inadequate protein intake, an observational study in Kenya and Nigeria. *Nutrition Journal* **9**: 9.

SUNDERLAND, T.C.H. 2011. Food security: why is biodiversity important? *International Forestry Review* this issue.

TANZANIA, GOVERNMENT OF 2002. *Census.* Dar es Salam: National Bureau of Statistics

TOLEDO, M. and SALICK, J. 2006. Secondary succession and indigenous management in semideciduous forest fallows of the Amazon Basin. *Biotropica* **38**(2): 161–170.

TORHEIM, L.E., OUATTARA, F., DIARRA, M.M., THIAM, F.D., BARIKMO, I., HATLOY, A. and OSHAUG, A. 2004. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. *European Journal of Clinical Nutrition* **58**(4): 594–604.

UN-SCN. 2004. *Fifth report on the world nutrition situation.* Geneva, Switzerland: United Nations, Standing Committee on Nutrition and International Food Policy Research Institute.

VAN VLIET, N. and NASI, R. 2008. Hunting for livelihood in Northeast Gabon: Patterns, Evolution, and Sustainability. *Ecology and Society* **13**(2).

VIHEMÄKI, H. 2005. Politics of Participatory Forest Conservation: Cases from the East Usambara Mountains, Tanzania. *The Journal of Transdisciplinary Environmental Studies* **4**(2).

VIHEMÄKI, H., RANTALA, S. and POWELL, B. forthcoming. Forbidden Fruit? Forest governance and the maintenance of traditional food systems in Tanzania's East Usamabara Mountains.

VINCETI, B., EYZAGUIRRE, P. and JOHNS, T. 2008. *The nutritional role of forest plant foods for rural communities, Chapter4*. In: Human health and forests: a global overview of issues, practice and policy. Colfer C.J.P., ed. London, UK.: Earthscan.

WAN, M., COLFER, C.J.P. and POWELL, B. 2011. Forests, women and health: opportunities and challenges for conservation. *International Forestry Review* this issue.

WEINBERGER, K. and SWAI, I. 2006. Consumption of traditional vegetables in central and northeastern Tanzania. *Ecology of Food and Nutrition* **45**(2): 87–103.

WIENS, J. 2009. Landscape ecology as a foundation for sustainable conservation. *Landscape Ecology* **24**(8): 1053–1065.

WILLIS, J. 1992. The Makings of a tribe: Bondei identities and histories. *The Journal of African History* **33**(2): 191–208.

YEAGER, R. 1989. *Tanzania, an African experiment* Boulder, Colorado, USA: Westview Press.

When formal and market-based conservation mechanisms disrupt food sovereignty: impacts of community conservation and payments for environmental services on an indigenous community of Oaxaca, Mexico

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SUMMARY

The impacts of Payments for Environmental Services (PES) and creation of formal Voluntary Conserved Areas (VCAs) on local diets, agricultural practices, subsistence hunting and livelihoods, were assessed in a Chinantec community of southern Mexico. The community has set aside VCAs covering 4 300 ha of its 5 928 ha of communal lands and forests, and has received over $769 245 in PES for protection of 2 822 ha of watersheds roughly overlapping the VCAs. Community members attribute decreased maize and other subsistence crop yields, reduction of area available for agriculture, and shortened fallow cycles to the new conservation policies. Meat consumption has decreased after a hunting ban, accompanied by increases in purchasing meat still consumed. By agreeing to conservation measures that restrict their use of ancestral agricultural land and prohibit hunting, villagers have seen local food security become less stable, leading to greater dependency on external food supplies. Continued strict preservation measures under the guise of community conservation could lead to losses of agrobiodiversity, dietary diversity, hunting skills and associated environmental knowledge. Appropriate application of the precautionary principle is essential to avoid structural displacement of local peoples and to ensure the success of community conservation initiatives.

Keywords: Community conservation areas, nutritional transition, precautionary principle, shifting cultivation, traditional food systems

Quand les mécanismes de conservation formelle et basée sur le marché dérangent la souveraineté des aliments: impacts sur la conservation de la communauté et les paiements pour services environnementaux dans une communauté d'Oaxaca au Mexique

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Les impacts des paiements pour services environnementaux (PES) et la création de zones de conservation volontaires formalisées (VCAs) sur la nutrition locale, les pratiques de l'agriculture, la chasse de subsistance et les revenus ont été évalués dans une communauté Chinantec du Mexique du sud. La communauté a mis à part des VCAs recouvrant 4300 ha de ses 5928 ha de terres et forêts communautaires et a reçu plus de 769 245$ de PES pour sa protection de 2822 ha de bassins versants dont la superficie coïncide en gros avec celle des VCAs. Les membres de la communauté attribuent une décroissance des récoltes de maïs et d'autres cultures de subsistance, la réduction de la surface disponible pour l'agriculture, et les périodes réduites de jachère aux nouvelles politiques de conservation. La consommation de viande a décru depuis un interdit de chasse, accompagné d'une augmentation de quantité viande qu'il faut maintenant acheter pour consommer. En acceptant des mesures de conservation restreignant l'utilisation des terres arables ancestrales et interdisant la chasse, les villageois ont vu la sécurité de leurs aliments locaux devenir moins stable, les conduisant à une dépendance plus grande sur vis à vis des fournisseurs extérieurs. La continuation de mesures de conservation strictes sous le couvert de conservation de la communauté pourrait conduire à des pertes de l'agrobiodiversité, de la diversité nutritionnelle, de l'habileté à chasser et de la connaissance environnementale associée. Une application appropriée du principe de précaution est essentielle pour éviter un déplacement structurel des populations locales et pour assurer le succès des initiatives de conservation communautaires.

Cuando mecanismos de conservación formales y de Mercado perturban la soberanía alimentaria: Impactos de la conservación comunitaria y de los pagos por servicios ambientales en una comunidad indígena de Oaxaca, México

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Se evaluaron los impactos de los Pagos por Servicios Ambientales (PSA) y de la creación de Áreas de Conservación Voluntaria (ACVs) formales, sobre la dieta local, prácticas agrícolas, cacería de subsistencia y sustento local de una comunidad chinanteca del sur de México. La comunidad ha asignado 4 300 ha de sus 5 928 de tierras comunitarias y bosques a ACVs, y ha recibido más de $769 245 en PSA por la protección de 2 822 ha de cuencas que se traslapan con las ACVs. Miembros de la comunidad atribuyen disminuciones en la producción de maíz y otros cultivos de subsistencia, una reducción del área disponible para agricultura y un acortamiento del período de descanso de las tierras agrícolas, a las nuevas políticas de conservación. El consumo de carne ha disminuido luego de una prohibición de cacería, acompañado de un aumento en la compra de carne que aún se consume. Estando de acuerdo en estas medidas de conservación que restringen el uso de tierras agrícolas ancestrales y que prohíben la cacería, los pobladores han visto que la seguridad alimentaria local se ha vuelto menos estable, llevando a una mayor dependencia por suministros alimenticios externos. La continuidad de medidas de preservación estrictas, bajo la apariencia de una conservación comunitaria, podrían llevar a pérdidas de agrobiodiversidad, diversidad dietaria, habilidades de caza y el conocimiento ambiental asociado. La aplicación apropiada del principio de precaución es esencial para evitar el desplazamiento estructural de comunidades locales y asegurar el éxito de las iniciativas de conservación comunitaria.

INTRODUCTION

Payments for Environmental Services (PES) to local communities have been touted nationally and internationally as a market-based mechanism to reward the protection of biodiversity, forests and watersheds on communally owned land. In Mexico, financial subsidies that are part of a national PES programme (McAfee and Shapiro 2010) have been provided to some communities that have Indigenous and Community Conserved Areas (ICCAs), including ones that are certified Voluntary Conserved Areas (Martin *et al*. 2010). Internationally, ICCAs are seen a possible solution to multiple problems associated with conservation practices that exclude local communities (Borrini-Feyerabend and Kothari 2008).

There is a growing interest in exploring the ways in which these financial subsidies and new trends in community conservation are evolving and affecting various aspects of local rights and livelihoods, including food sovereignty.

Food sovereignty

Food sovereignty is broadly conceived to include the diverse rights that people exercise to protect domestic agricultural production, maintain nutritious diets and regulate market access, all as part of a quest to achieve sustainable development. As Pimbert (2009: 5) notes, food sovereignty is an alternative agricultural and food policy framework that "aims to guarantee and protect people's space, ability and right to define their own models of production, food distribution and consumption patterns." He characterises food sovereignty as a process that seeks to regenerate autonomous food systems that are equitable, socially just and ecologically sustainable.

Key to food sovereignty are traditional food systems (TFS), which incorporate a wealth of acquisition, production, processing, distribution and recycling techniques (Kuhnlein and Receveur 1996, Pimbert 2009). These localised food systems, laden with social meanings and ecological realities, are an integral part of people's cultural identities, knowledge systems, health and economies throughout the world (Johns and Sthapit 2004, Kuhnlein *et al.* 2009). TFS provide edible plants, animal protein and animal micronutrients from traditional agroecosystems, agroforestry and livestock grazing. In addition, they incorporate foods derived from gathering, fishing and hunting as well as exchange with other communities.

Many peoples throughout the world are increasingly distanced from self-sufficiency, as they abandon local dietary traditions and increase their dependence on industrialised foods (Kuhnlein *et al*. 2004, Uauy *et al*. 2001). These changes, part of a complex process referred to as nutritional transition, generally have adverse impacts on local subsistence, food quality and variety, and ultimately public health (Damman *et al*. 2008, Kuhnlein *et al*. 2007, Popkin 2003, 2004). Transitions in various aspects of food sovereignty have occurred with industrialisation, urbanisation, economic development and the globalisation of markets (Damman *et al.* 2008, Pimbert 2009). Dietary changes are a non-directed consequence of other environmental or external forces, and they appear to be accelerating especially in low- and middle-income countries (Kuhnlein and Receveur 1996). These dietary changes are generally promoted by national policies or international programmes that are influenced by global economic and political priorities, rather than responding to local concerns (López and Mariano 2008).

The emergence of community conservation

International and national laws and policy require the protection of not only the biodiversity that provides sustenance for the entire world's population, but also the traditional systems of knowledge, management and use of this biodiversity that meet the basic needs of local people. In the quest to achieve biodiversity conservation, the global tendency has privileged an approach which excludes people in protected areas (West

and Brockington 2006), leading to displacement of communities and restrictions on their access to resources (Agrawal and Redford 2009). By ignoring the role of local cultures in resource management, this trend has promoted a disarticulation between human populations and their environments (López and Mariano 2008). This has resulted in negative impacts such as the disruption of livelihood opportunities, increase in damages to crops by wild animals, and alteration of local economies (Hough 1988, Igoe 2006, Mishra 1982).

The increasing appreciation of the interdependence of diverse environments and local communities and the roles they play in conserving biological diversity and agrobiodiversity has inspired community-based conservation approaches around the world (Gibson and Marks 1995). ICCAs and other modes of community conservation have become important alternatives to government protected areas. In 2004, the IUCN included ICCAs as a distinct category of governance of protected areas (Martin *et al.* 2010), and they have now been recognised in diverse ways throughout the world, including in Africa (Metcalfe 1994, Wainwright and Wehrmeyer 1998), Asia (Bajracharya *et al.* 2005), and Latin America (Camacho *et al.* 2010, Ellis and Porter-Bolland 2008, Toledo 2003).

There is little information about the effectiveness and consequences of this new approach to conservation (Berkes 2009), especially when community protected areas receive external support guided by market mechanisms. Empirical analysis of these arrangements is especially important when ICCAs are linked to new paradigms such as enterprise-based and payments-based conservation (Lele *et al*. 2010). These neo-liberal approaches have spread globally as influential environmental and economic institutions act on the premise that environmental degradation is due to market malfunction or to a lack of financial incentives to protect the services that ecosystems provide (Turner *et al.* 1994). Gómez-Baggethun *et al*. (2010) posit that the shift toward monetisation of ecosystem services marks a conceptual swing from economic recognition of the use value of nature toward a focus on the exchange value of resources.

Food sovereignty and community conservation in Mexico

The majority of indigenous peoples in Mexico base their food consumption on small-scale agricultural and livestock production, complemented by hunting and gathering of wild foods. The agricultural system is centred on the *milpa*, a traditional Mesoamerican polyculture in which maize and many other food plants are cultivated or available as spontaneous semi-domesticates (Hernández X 1977).

In tropical forested areas, the *milpa* forms part of swidden cultivation in which a section of forest is cut and burned for cultivation as part of the agricultural cycle (Ávila 2010). The parcel is then left fallow for several years enabling regeneration of herbs, shrubs, and later trees. The cultivation of *milpas* in forest ecosystems generates a mosaic of landscapes, biotic communities, species and genetic diversity that are intimately linked to local TFS (Vandeermer and Perfecto 2007) and the maintenance of broader patterns of biological and cultural diversity. For indigenous peoples, biodiversity within and around *milpas* is essential in order to achieve a complete and healthy diet (Johns and Sthapit 2004).

In Mexico, many ICCAs are community initiatives closely related to local systems of management of natural resources, lifestyles, political organisation and land tenure security (Martin *et al.* 2010). Civil society and governmental institutions have supported these local initiatives in recent years. Beginning in 2003, the National Forestry Commission (Conafor; Comisión Nacional Forestal) established PES to support local landowners – if they maintain areas of forest cover – through a series of subsidies (compensatory payments) paid out over periods of five years to avoid changes in land use (Anta 2007). Other governmental programmes, in conjunction with the National Commission of Natural Protected Areas (Conanp, Comisión Nacional de Áreas Naturales Protegidas), have supported the establishment and certification of ICCAs. In May 2008, the General Environmental Law of Mexico (LGEEPA, Ley General del Equilibrio Ecológico y Protección al Medio Ambiente) was modified to allow inclusion of certified ICCAs as a new category of Protected Natural Areas, called Voluntary Conservation Areas (Camacho *et al.* 2010).

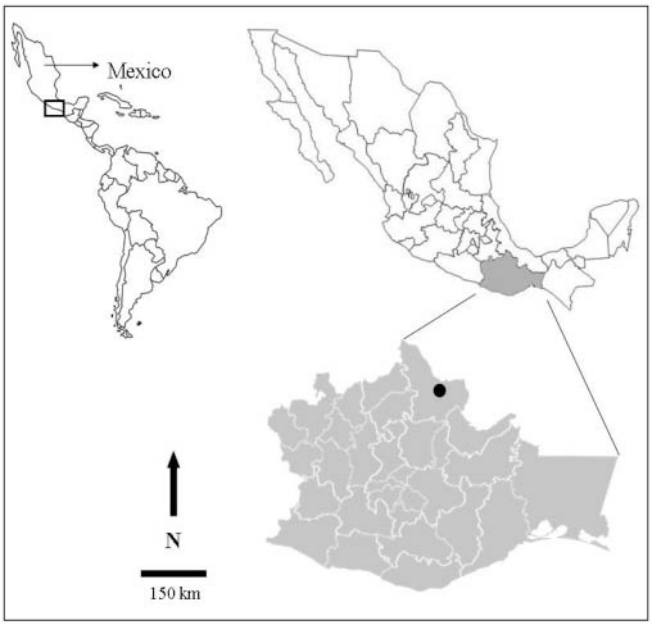
Despite these new policies, official state views continue to characterise human disturbance as a threat to forests. For example, in December 2010 during the celebration of World Forest Day, as part of the 16th Conference of the Parties to the UN Framework Convention on Climate Change in Cancun, Mexican President Felipe Calderón blamed traditional forms of agriculture of indigenous peoples and peasants for deforestation in Mexico (Presidencia de la República 2010). In addition, he stated that one of the nation's priorities is to approve and promote financial mechanisms for reducing deforestation, allowing peasants to receive economic compensation instead of continuing to cultivate the land.

The study presented here – conducted in a Chinantec community in Oaxaca, a biologically and culturally diverse state of southeast Mexico – explores the consequences of external support for ICCAs that follow official conservation policies and receive financial subsidies. To better understand the interactive impacts, the study specifically examines the consequences of PES and the creation of certified VCAs for food sovereignty in a broad socio-ecological context, including food acquisition, dietary patterns, domestic economy, and socio-cultural significance.

STUDY AREA

The Chinantla, defined culturally by the presence of Chinantec indigenous people, is located in northeast portion of the State of Oaxaca, Mexico (Figure 1). It forms part of the Papaloapan hydrological region and the "*Sierras del Norte de Oaxaca-Mixe*" Priority Area for Biodiversity Conservation (Conabio 2008). The zone exhibits one of the highest levels of biodiversity and encompasses the third largest and best conserved tropical humid forest in Mexico (Hernández 2007).

FIGURE 1 *Map of Mexico, showing the State of Oaxaca (in gray). Study area was located in the Chinantla area (black dot; 17°33′N 95°31′W) of Oaxaca*



The study took place in Santiago Tlatepusco, a Chinantec community of 591 residents[1] who have a communal territory of 5 928 ha located between 250 and 2 800 m of elevation in the Municipality of San Felipe Usila. The territory encompasses a mosaic of different habitat types including tropical evergreen, cloud and pine-oak forests, active swidden agricultural areas, coffee plantations, and secondary vegetation (GeoConservación 2006). There are approximately 536 vertebrate species, including jaguar, jaguarondi, margay, tapir, owls, woodpeckers, toucans and other fauna, most of them endemic to Mesoamerica and some rare and endangered (Martin 1996). In addition, there are hundreds of plant species that have not yet been fully inventoried.

Residents combine the *milpa* agricultural system with agroforestry (including shade coffee plantations), extraction of non-timber forest products, subsistence hunting, fishing and, recently, fish production in ponds (Pérez *et al*. 2006). The *milpa* system allows the integration of cultivation of maize, beans, chilli, manioc and squash, among other species, with the collection of other edible plants that complement local diets (Anta and Mondragón 2006). Hunting of birds and mammals in *milpas*, fallow fields and forests, along with fishing, has historically been the main animal protein source in the Chinantla (Weitlaner and Castro 1973).

Santiago Tlatepusco is part of the Regional Committee for Chinantla Alta Natural Resources (CORENCHI), an organisation comprised of six Chinantec communities formed in 2004 by a regional accord with the objective of improving natural resource control, strengthening conservation efforts and obtaining more economic benefits from resource management (Bray *et al.* 2008, Mondragon n.d., Pérez *et al.* 2006).

Between 2003 and 2006, the communities conducted community territorial planning with the help of a non-governmental organisation, which subsequently advocated for a revision of community-level statutes concerning natural resource use and management and the demarcation of different land use zones, including conservation areas to protect biodiversity and ecosystem health (Martin *et al.* 2010).

Large expanses of well-conserved cloud forest and tropical rainforest in the CORENCHI communities are *prima facie* evidence of the adequacy of traditional management practices. As in other parts of the Chinantla (Robson 2009), there has been reduced agriculture and increased fallow forest in Santiago Tlatepusco over the last twenty years (Edward A. Ellis, personal communication, May 16, 2011), a trend not readily attributable to community conservation efforts alone. Because the area is relatively isolated due to limited communication facilities and poor accessibility (Pérez *et al*. 2006), there is no broad commercialisation of bush meat, non-timber forest products or timber species at present (Anta *et al.* 2008), although some small-scale local trade exists. In 2004, Conanp officially certified the communities' conserved areas, promising increased visibility, financial support, and certification of agricultural and non-timber forest products. The certified area included 4 300 ha in Santiago Tlatepusco, putting 72.5% of the communal lands under protection. The community obtained its certification at the same time as three others belonging to CORENCHI, giving a combined area of 22 148 ha certified in 2004 for the four communities.

Processes of community conservation were further supported by Conafor's programme of payment for hydrological environmental services (PES-H), financed by the World Bank (McAfee and Shapiro 2010). The communities were able to access these funds because of the hydrological value of the Chinantla, one of the areas of highest rainfall in the country. Its watersheds benefit many rural and urban areas in the State of Oaxaca, as well as the hydroelectric and other diverse manufacturing industries (Mondragon n.d.).

In 2004, Santiago Tlatepusco submitted 1 969 ha for PES-H, for which Conafor approved 3 938 000 MXN (345 349 USD at the 2004 average exchange rate) for a period of five years (Conafor 2004). In 2007, the community submitted a proposed expansion of the PES-H area that included an additional 853 ha, leading to approval by Conafor of a second payment of 1 401 311 MXN (129 392 USD at the 2007 average exchange rate) for another full five-year period. Finally, in 2009 they recommitted 1 716 ha of the original assigned area to extend the PES-H for an additional five-year period, receiving in exchange 3 786 171 Mexican pesos (294 415 USD at the 2009 average exchange rate). In sum, a total area of 2 822 ha – 47.6% of communal lands – are covered by PES-H payments, totalling $769 245 at the

[1] Demographic statistics from the Centre for Rural Health of Santiago Tlatepusco, belonging to Health Jurisdiction Nº3 of Tuxtepec, Health Services of Oaxaca, Mexico.

summed average exchange rates. To receive these funds, the community – and others in CORENCHI – agreed to maintain vegetation cover, avoid land use change (including conversion to grazing) and pollution in the conserved area, as well as to monitor the territory over time (Conafor 2010, Mondragón n.d.). In Santiago Tlatepusco, these measures were incorporated into a restrictive agreement that prohibits a broad range of activities in the community conserved areas, including: (a) deforestation or damage to vegetation for agricultural, animal husbandry or other purposes; (b) hunting; and (c) extraction of any plants, animals, fruits seeds, or wood.

Most of the payments (97.5%) received are divided among community members and their families, and the other portion (2.5%) has been used for CORENCHI activities and infrastructure (Anta *et al.* 2008). Each family receives an average PES contribution of US $1.48/day, or US $44.40/month, equivalent to 27.2% of the basket of consumer goods per year across the four communities (Mondragon n.d.).

METHODS

Methodological considerations: The ideal way to determine the presence of cultural changes is through diachronic analysis in which socio-ecological phenomena from two different time periods – such as before and after a particular intervention – are directly compared (Balée 1994). As no systematic data on food sovereignty are available from before the advent of the establishment of PES and certification of VCAs, research relied on asking informants to recall the time prior to the PES and VCA programmes, an indirect means for documenting changes in the recent past.

By maximising the number of people interviewed and triangulating information collected through diverse methods, substantial data were collected on how these initiatives have affected the community. Methods included participant observation, informal interviews and semi-structured interviews, which are among the best ways to learn about common and divergent perspectives held by community members (Bernard 2005). In addition to these approaches, formal elicitation techniques such as freelist exercises and structured interviews were used to examine patterning of environmental knowledge (Puri 2011a) and then interpret if these patterns are attributable to the aforementioned conservation initiatives.

Free Prior informed consent (FPIC): Following best practice as defined by professional codes of ethics and international conventions – including the United Nations Declaration on the Rights of Indigenous Peoples – FPIC was obtained from local authorities and the General Assembly of the community after explaining the scope of the project, and clearly stating the potential benefits and risks of our presence and proposed study. This built on community research agreements established with the Global Diversity Foundation, an international non-governmental organisation which has been active in the communities since 2008. Additional consent, rapport and willingness to participate in the study were gained after participating in diverse community events and work activities.

Participant observation: Participant observation (Puri 2011b) was conducted in the community between 2008 and 2011. Participation in community events and agricultural activities included firewood gathering, sowing, weeding, measuring agricultural productivity, identification of pest damage, participatory mapping, and community labour (*tequio*). Informal interviews were carried out during these activities with individuals or groups of people, with a total interaction of over 150 individuals (Table 1). Notes relevant to the research were made during these conversations and later developed in field notes recorded daily (Bernard 2005).

While the researchers were working in the community, local authorities arranged for them to have three meals per day with different families on a rotating basis. Families were encouraged to serve foods eaten daily and not to prepare special dishes, as is customary when receiving visitors. In order to assess household dietary patterns, the ingredients of every dish given to researchers were recorded during two months. These data were compared with statements by community members about dietary patterns at the household level (White *et al.* 2005).

Freelists: Women (n=30) were asked (in Spanish or Chinantec) to freelist the most common foods available in the household (Atran *et al*. 2002) in order to elicit information about household diets. Later, *Smith's index of saliency* (Smith's S), which is based on order and frequency of mention of items on a freelist, was used to measure the relative importance of the foods (Smith 1993). The index predicts that foods mentioned first and most frequently are more salient and, therefore, more important to individual women, as compared to foods mentioned last and least often (Smith 1993, Smith and Borgatti 1997).

Semi-structured and structured interviews: An interview question set was designed and piloted with a subsample of

TABLE 1 *Breakdown of informants according to major subsistence occupation, age, and gender*

Method used	Number of participants	Major subsistence occupation	Age range	Gender
Informal interviews	± 150	Farmers, hunters or ex-hunters and local authorities	16–55	± 100 male ± 50 female
Freelists	30	Farmers and housewives	20–46	All female
Semi-structured and structured interviews	76	Farmers, hunters or ex-hunters, local authorities and traditional healers	18–59	21 female 55 male

people from the villages (n=20) allowing researchers to minimise the possibility of errors in the data in later interviews (Bernard 2005, White *et al.* 2005). Afterwards, the interview was applied at the household level with married women and men (n=76; Table 1). Interviews consisted in a first semi-structured part of open-ended questions, and a second structured part of pre-determined questions. Together they revealed socio-economic information, dietary patterns, meat consumption, agricultural practices, productivity and pest species, foraging knowledge and attitudes towards conservation initiatives (Ibarra 2010).

RESULTS

Diet overview: Women mentioned a total of sixty-two common foods in the freelist exercises. Ranked by Smith's S, black beans, rice, noodles and chicken were the most salient foods currently consumed. Among mentioned meat resources, game animals such as the collared peccary, nine-banded armadillo, red brocket deer, and white-nosed coati were mentioned, but rarely. Meat from domestic animals, such as chicken, steak and pork, showed greater saliency than game (Appendix 1).

The most salient items were regularly consumed by families, as noted during participant observation. Based on meals actually consumed by local families, hand-made tortillas of maize were present in 99% of meals, including breakfast, lunch and dinner. As noted in Figure 2, black beans (39%) were the second most consumed, followed by onions (37%), hen's eggs (33%), tomatoes (29%), noodles (25%), and rice (18%). The main animal protein sources consumed were hen's eggs (33%), chicken (15%), ray-finned fish (0.07%) and canned tuna fish (0.02%). Armadillo, pork and canned herring occurred at a frequency of only 0.01% (Figure 2).

Purchased items were slightly more commonly consumed than foods locally obtained (Figure 3). As confirmed during participant observation, less than half of the most salient food items (such as black beans, squash vine, chayote fruits, nightshade and chayote vine) are still gathered or produced – including in small home-gardens – by local farmers. Of the animal protein sources consumed during participant observation, only chicken and ray-finned fish are locally produced, and armadillo is hunted. Several villagers have stopped raising poultry because of increased frequency of disease, especially during the dry season. Buying of hen's eggs and chicken – and almost all other meat sources – has increased.

Both men and women reported a change in the consumption of meat. Men stated that meat consumption has decreased from 1.75 ± 0.89 times/week before the hunting ban, to 0.83 ± 0.41 after the ban. Women reported a change from 1.50 ± 0.71 to 1.10 ± 0.32 times/week. Aggregated figures showed a perceived change from 1.61 ± 0.78 to 1.00 ± 0.37 times/week (Figure 4). In order to improve animal protein consumption, ray-finned fish production is increasing. Several families engage in this complementary activity, although the high cost of pellet fish food limits further expansion of fish farming.

During interviews, 90% of informants noted that the consumption of previously common food items has decreased after the implementation of the PES and VCA programmes. Although these changes were attributed the new conservation initiatives and financial subsidies, many respondents noted

FIGURE 2 *Frequency of food items present in meals (n=87) consumed during two months with different families one Chinantec community. Black bars show the four most salient foods, according to the* Smith's Index of Saliency *(Smith'S), currently used among Chinantecs (based on freelists). Black arrows show the animal protein sources consumed (note that hen eggs were the most important animal protein source consumed, and the others were never present in more than 15% of meals). Dashed arrow shows the only game meat (nine-banded armadillo), consumed once, among the meals documented*

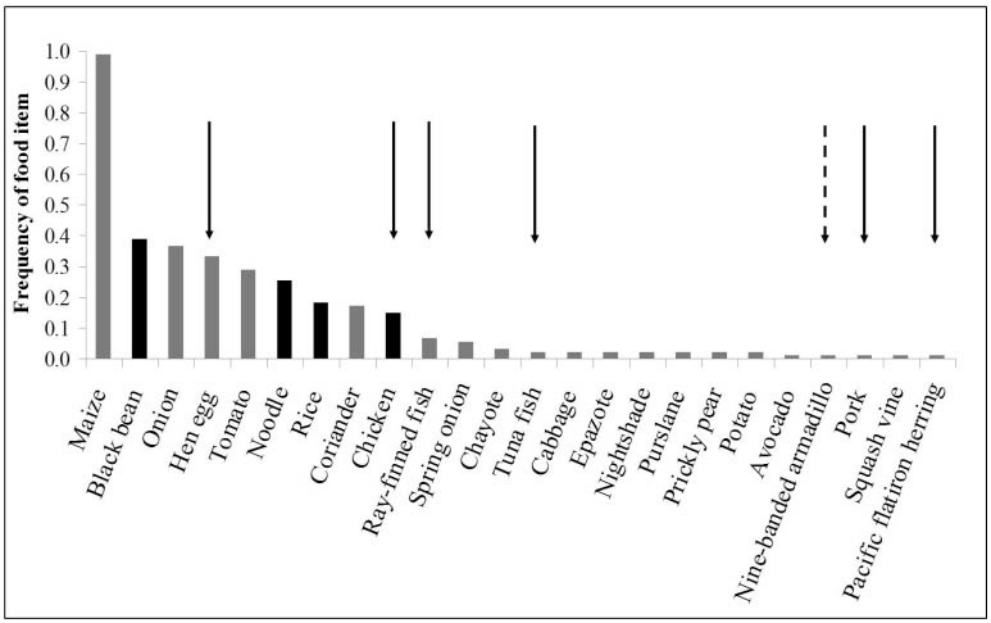
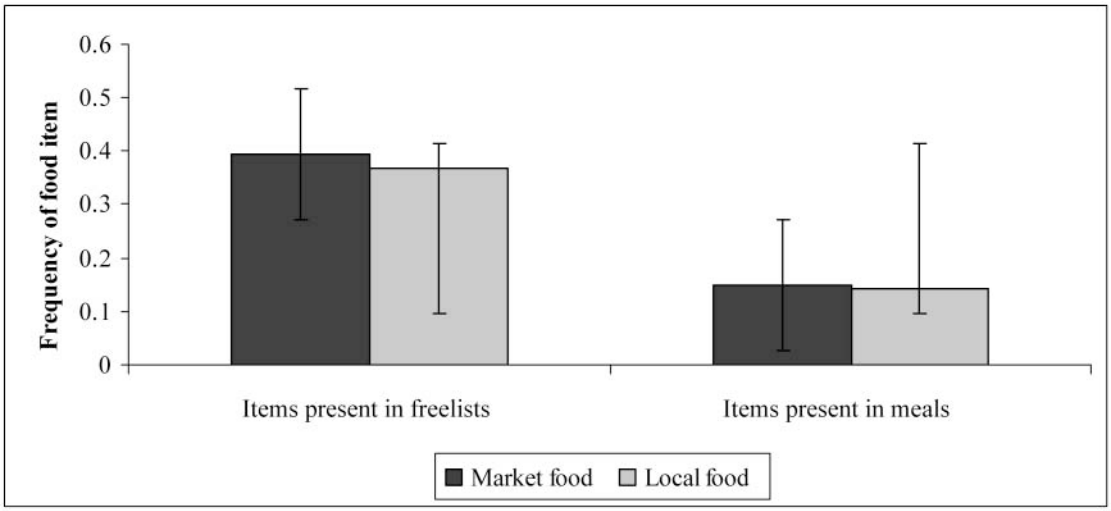


FIGURE 3 *Mean market purchased food item frequencies and mean locally obtained (through cultivation, gathering or hunting) food item frequencies in freelist exercises and in meals consumed by local Chinantec families (and researchers). According to* t*-tests, frequencies of market food items and local food items were not significantly different in both freelist exercises (*t = *0.178, df = 58, P = 0.859) and in meals actually consumed by families (*t = *0.042, df = 20, P = 0.967). Error bars (95% CI) are shown*

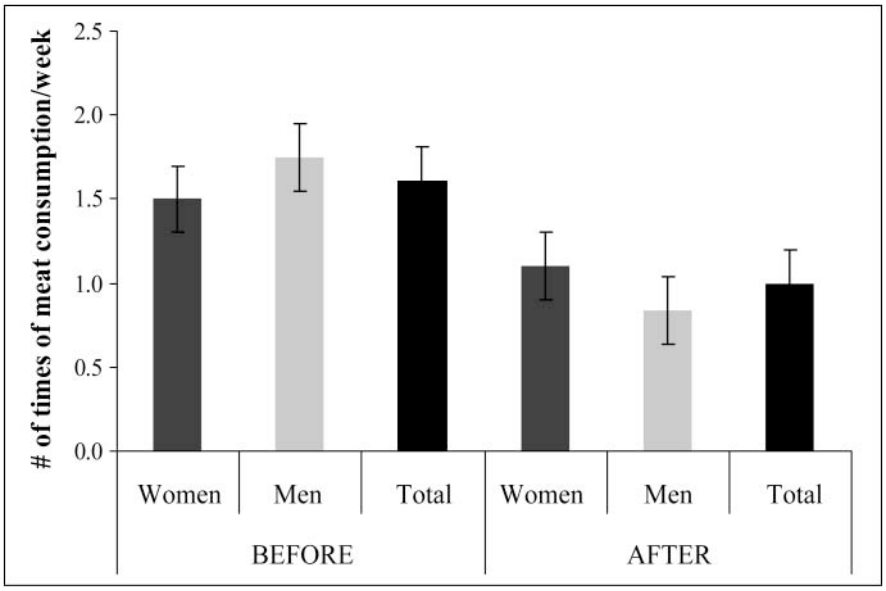


that the availability of local freshwater food (e.g. prawn, crayfish and trout) obtained from the river declined beginning in the 1980s, after the construction of the Miguel Alemán-Cerro de Oro dam on the Usila River during the 1970s.

Sixty-five per cent of informants said that they have incorporated new food items since the implementation of the PES and VCA programmes. The most common recently incorporated food items in local diets were rice, noodles, canned beans, steak, canned sardines, canned tuna fish, and soft drinks. According to informants, consumption of these foods increased after implementation of the PES because villagers were able to purchase these new goods with their annual income from this programme.

Agricultural production, meat consumption and domestic economy: Maize production has reportedly dropped from 31.08 ± 10.17 *zontles*[2] of maize/year before, to 20.63 ± 7.41 *zontles* of maize/year after the advent of the PES and VCA

FIGURE 4 *Reported incidence of meat consumption/week, before and after the implementation of hunting prohibitions in the Community Conservation Area. Error bars (95% CI) are shown*



[2] Area maize yields are measured in zontles: one zontle contains 400 well-formed ears, equivalent to 35 kg grain, equivalent to 87.5 g per ear (Van der Wal *et al*. 2006).

initiatives. Similarly, farmers reported that the production of black beans, which are typically cultivated in higher elevation fields that are now in the community conservation area, has almost disappeared.

In addition, harvest of semi-cultivated edible greens is diminished. A local farmer[3] attributed this in part to shortened fallow cycles and the use of agricultural chemicals: "*Ahora la tierra descansa sólo dos años, cuando antes descansaba 15 años. Ahora se usa más líquido químico, y eso acaba con las semillas de los quelites... Imagínate cuánta semilla de quelites hay en los acahuales viejos...*". [Now the land is left to fallow only for two years, whereas before a fallow was left for 15 years. Now more chemicals are used, and they eliminate seeds of leafy greens (quelites)... Imagine how much quelite seed there is in the old fallows...].

Seventy-six per cent of interviewees associated the diminishing productivity in the area with the PES and VCAs programmes, and they evoked three main reasons. First, informants pointed out that since a large proportion of the territory is currently under conservation designation, areas for agriculture have been reduced and, as a consequence, fallowing is diminished to only two to three years, which potentially lowers productivity in the long term. Preceding the PES and VCAs programmes, respondents reported that fallows used to rest for 15–20 years before they were again slashed and burned to reinitiate the agricultural cycle. Second, interviewees indicated that because of the hunting prohibition, pest animals are currently multiplying and adversely affecting agricultural production (Table 2). Finally, there is an impression that the annual payment had reduced the incentive to cultivate, because they no longer needed to produce enough food to last the entire year as was necessary prior to the establishment of the payments.

Villagers interviewed reportedly spent US $268.75 ± 220.87 dollars/year in order to complement the shortfall of maize and black bean production. In addition, there has been a change in patterns of purchasing meat. Sixty-five per cent of respondents noted they did not purchase meat before the hunting prohibition (because meat could be obtained by hunting), while 35% had occasionally purchased meat. Currently only 10% of respondents do not purchase market meat whereas the other 90% of respondents spend an average of US $30.97 ± 24.48 dollars/month to purchase meat.

Although villagers receive an annual payment from the PES programme, most interviewees (80%) stated that they now have to spend a greater proportion of their income purchasing food, since both agricultural productivity and meat procurement have decreased locally. Seventy-nine per cent of households stated that their families could not now survive without buying external goods. Respondents reported that the approximately US$ 500/year that households currently receive from the PES programme is less than the amount spent annually purchasing maize and meat alone.

In the words of one community member[4], "*Trabajo ahora en Santa Teresa pero antes trabajaba arriba de Arroyo Colmena. Ahora tengo problemas con la tuza y muy baja producción. Compro 700 kg de maíz este año a 4 200 pesos más 104 kg de frijol a 1 976 pesos. Recibo 4 000 pesos de pago por PSA. No alcanza ni para comprar todo lo que necesito*". [I work now in Santa Teresa (outside the conservation area) but before I worked above Arroyo Colmena (now inside the conservation area). Now I have problems with

TABLE 2 *Most significant vertebrate pests as reported by Chinantec farmers, Oaxaca, Mexico*

English name (Scientific name)	Milpa (maize)	Manioc	Pineapple	Sugar cane	Bananas	Coffee	Black bean
MAMMALS							
Lowland paca *(Agouti paca)*	#				# (Ø)		
Mexican agouti *(Dasyprocta mexicana)*	#	#					
Squirrel *(Sciurus* spp.*)*	○	#					
Pocket gopher *(Orthogeomys hispidus)*	•	•	Δ	Δ	#	Δ	
Rats (more than one species)	Δ						
White-nosed coati *(Nasua narica)*	•	•			#		
Raccoon *(Procyon lotor)*	#	#			Δ		
Tayra *(Eira barbara)*							
Collared peccary *(Pecari tajacu)*	•	○			Δ (Ø)		
Red brocket deer *(Mazama americana)*							Δ
BIRDS							
Parakeet *(Aratinga* sp.*)*	#						
Yellow-billed cacique *(Amblycercus holosericeus)*	#						
Montezuma oropendula *(Psarocolius montezuma)*	Δ						

[3] S.M.A., 58 years old (The initials of key informants quoted in the text have been changed to protect their anonymity).
[4] B.S.P., 38 years old.

TABLE 2 *Continued*

English name (Scientific name)	Squash	Jicama	Sweet potato	Cacao	Mamey sapote	Chayote
MAMMALS						
Lowland paca *(Agouti paca)*	Δ					Δ (Ø)
Squirrel *(Sciurus* spp.*)*				#		
White-nosed coati *(Nasua narica)*	Δ	#	#			
Tayra *(Eira barbara)*					Δ (Ø)	
Collared peccary *(Pecari tajacu)*	Δ					

• = primary pest (i.e. those reported by 80–100% of respondents); ○ = secondary pest (i.e. those reported by 50–79% of respondents); # = tertiary (i.e. those reported by 20–49% of respondents); Δ = marginal (i.e. those reported by at least 10–19% of respondents); Ø = eats fallen fruit.

Note 1: This list does not consider one bat species (*Desmodus rotundus*), which was reported as a pest by 40% of respondents because it would attack mules, chickens and donkeys.

pocket gophers and a very low production. I am buying 700 kg of maize this year for 4 200 pesos plus 104 kg of beans for 1 976 pesos. I receive 4 000 pesos from PES. It isn't enough to buy all that I need].

Subsistence hunting and culture: According to interviewees, at least 32 vertebrate species were used prior to the implementation of the hunting prohibition (Table 3). Species mentioned were used primarily as a source of food (84.4% of mentioned species), medicines (15.6%), handcrafts (12.5%), ornamentation (9.4%), pets (6.3%), or tools (3.1%). Formerly, 75% of the birds and mammals used by Chinantec villagers were hunted in the forest, 62.5% in fallows, 34.4% in *milpas*, and 18.8% within or near the community (Table 3). For local hunters, the main reasons for hunting before the prohibition were to control pest species (52.6%), and obtain meat for families and kin (47.4%). From the total, only 26.3% of hunters noted that, on rare occasions, they sold meat to neighbours or friends. Hunters who reported gathering useful plants and mushrooms while hunting said this was mainly a complementary activity to the hunt, and not worthwhile as a separate endeavour.

Permission is still granted to hunt 10 species (31.3% of those formerly hunted) exclusively in *milpas*, as they are considered harmful to agriculture. Nevertheless, even this practice is disappearing, since hunters are afraid that sanctions – especially withholding annual PES annual allocations – could be imposed by local or national authorities because of unsubstantiated concerns that any hunting could be considered harmful to wildlife. As one farmer and hunter[5] from Santiago Tlatepusco stated "*Hoy en día nadie va armado a la milpa. . . No es bien visto que andes con un arma"*. [Today no one goes to the milpa armed . . . it is not well accepted that you carry a gun].

Furthermore, a prohibition on keeping hunting dogs has further reduced hunting success. Before the prohibition, the principal strategies were stationary hunting from blinds or bushy vegetation (recognised by 57.9% of informants as their main practice), followed by hunting with dogs (36.8%) and opportunistic hunting (5.3%). As one hunter[6] stated: "*Antes ibas a la milpa con tus perros y ellos empezaban a ladrar hacia el bosque. Después salían ladrando, persiguiendo al animal. Tú solo tenías que seguirlo hasta alcanzarlo. . . A veces lo encontrabas ladrando bajo un árbol hacia un tejón en sus ramas o a la entrada de una guarida de armadillo*". [Before you would go to the *milpa* with your dogs and they would start to bark towards the forest. Then they venture out barking, following the animal. You would only have to follow to capture it . . . sometimes you would find your dog barking beneath a tree at a white-nosed coati on its branches or at the entrance of an armadillo den].

The hunting prohibition is also leading to a progressive deskilling among hunters. The people who demonstrated the greatest knowledge about animals were the hunters who would go accompanied by their dogs on hunting expeditions that could last for days, now a practice of the past. As one community member expressed[7], "*Un cazador es nada sin su perro. . . Ya no hay cazadores en Santiago porque los perros están prohibidos. Con la pérdida de los perros, los cazadores también nos estamos perdiendo*". [A hunter is nothing without his dog . . . Now there are no more hunters in Santiago because dogs are prohibited. With the loss of the dogs, we hunters are also disappearing].

Hunting was also one means by which socio-cultural ties, such as friendship and kinship, were maintained in the community before the ban was implemented. Villagers used to go hunting with their relatives, sharing what they obtained from a hunting trip and thereby maintaining relationships. Hunting

[5] S.T.J., 38 years old.
[6] R.N.L., 49 years old.
[7] M.I.S. 39 years old.

TABLE 3 *Reported terrestrial vertebrates used by Chinantec villagers, before the implementation of a hunting prohibition in the area (Note: * indicates those species for which permission is still granted for hunting)*

Family	Scientific name	English name	Uses[1]	Part used[2]	Site[3]
MAMMALS					
Didelphidae	*Didelphis marsupialis*	Common opossum	M, F (-)	T, M	V
	Didelphis virginiana	Virginia opossum	M, F (-)	T, M	V
Dasypodidae	*Dasypus novemcinctus*	Nine-banded armadillo	F, O (-)	M, Ar	F, Fa, B
Myrmecophagidae	*Tamandua Mexicana*	Northern tamandua	F (-), M (-)	M	F, Fa
Eretizonthidae	*Coendu Mexicana*	Mexican porcupine	M	S	V, F, Fa
Dasyproctidae	*Cuniculus paca**	Lowland paca	F, P, Pe (-)	M, C	F, Fa, M, R, C
	Dasyprocta Mexicana	Mexican agouti	F, P	M	M, F, Fa
Sciuridae	*Sciurus* spp.*	Gray squirrel	F, P	M	M, F, Fa
Geomydae	*Orthogeomys hispidus**	Pocket gopher	P	-	M
Echimyidae, Muridae	- *	Rats	P	-	M, V
Procyonidae	*Nasua narica**	White-nosed coati	F, P	M	M, F, Fa
	*Procyon lotor**	Raccoon	F, P	M	M, F, Fa
Mephitidae	*Conepatus mesoleucus*	Skunk	M (-), F (-)	M	F, Fa
Mustelidae	*Eira Barbara*	Tayra	F (-), P (-)	M	F, Fa
Felidae	*Panthera onca*	Jaguar	F (-), H (-)	M, S, C	F
	Leopardus wiedii	Margay	F (-), H (-)	M, S, C	F, Fa
	Leopardus pardalis	Ocelot	F (-), H (-)	M, S, C	F, Fa
Tayassuidae	*Pecari tajacu**	Collared peccary	F, P, H (-)	M, C	M, F, Fa, C
Cervidae	*Mazama Americana*	Red brocket deer	F, P (-), T (-)	M, A	F, Fa, R
BIRDS					
Tinamidae	*Tinamus major*	Great tinamou	F	M	F, Fa
Cracidae	*Ortalis* sp.	Chachalaca	F	M	F, Fa
	Crax rubra	Great curassow	F	M	F
Columbidae	*Columba* spp.	Pigeons (several species)	F, Pe (-)	M	F, Fa, V
Psittacidae	*Aratinga* sp.*	Parakeet	P, F(-)	M	M
Ramphastidae	*Pteroglossus torquatus*	Collared aracari	F (-), O (-)	M, B	F, Fa
	Ramphastos sulfuratus	Keel-billed toucan	F (-), O (-)	M, B	F, Fa
Picidae	*Melanerpes aurifrons*	Golden-fronted woodpecker	F (-)	M	F, Fa
	Campephilus guatemalensis	Pale-billed woodpecker	F (-)	M	F
	Dryocopus lineatus	Lineated woodpecker	F (-)	M	F
Icteridae	*Quiscalus quiscula*	Common grackle	P (-)	-	V
	*Amblycercus holosericeus**	Yellow-billed cacique	P	-	M
	*Psarocolius montezuma**	Montezuma oropendula	P (-)	-	M

On the basis of interviews with informants, (-) means that use is marginal or not practiced anymore.
[1] F = food, H = handcraft, M = medicinal, T = tool, Pe = pet. This column includes "P", which refers to those species considered agricultural pests.
[2] M = meat, S = skin, C = canines, A = antlers, T = tail, B = bill, Ar = armour, S = spines.
[3] Preferred site where species is hunted: V = village (in the case of Opossum species they are caught close to poultry), F = forests, Fa = fallows, M = *milpa* or other crop fields, R = river, C = cave, B = burrow.

was an avenue for adolescent Chinantecs to gain environmental skills, including hunting *per se* as well as identification of wildlife and useful plants. Hunting was also a means of enjoying free time and forgetting daily preoccupations and problems.

Agricultural activities and hunting were also mechanisms for transmission of traditional beliefs, environmental knowledge and skills. Interviewees pointed out that young boys and men, by the ages of 12–20 years old, should be able to perform most subsistence related tasks competently, including hunting at least to protect their *milpas*. Hunters reported that they learned to hunt at age 17.4 ± 5.1 years (n=19); 58.2% of hunters were taught by their parents or grandparents, while the others were taught by an older sibling or a friend.

Informants expressed concern that the younger generation is losing the knowledge and skills of their fathers and grandfathers. As one farmer noted[8], "*Ahora, mi hijo más chico (10 años) no conoce los acahuales de Arroyo Quelite, y mi hijo del medio (14 años) ni quiere caminar hasta allá cuando lo invito. Los jóvenes se están acostumbrando a no caminar y a trabajar menos"*. [Now, my youngest son (10 years old) doesn't know the fallows of Arroyo Quelite, and my middle son (14 years old) doesn't even want to walk there when I ask him. The youngsters are getting used to non-walking and working less].

DISCUSSION

Payments for Environmental Services (PES) and the formalisation of community conservation efforts may entail unintended consequences, including alterations of traditional resource management and declines in the health and nutrition of relatively isolated indigenous communities. By providing financial subsidies linked to environmental services, the Mexican government has initiated an exchange mechanism based on agreements concerning the bundle of rights inherent in community governance of the forest. In these agreements, a large subset of the services the forest provides to the communities (including long-fallow agricultural sites, hunting and gathering grounds, and related opportunities for locally sourcing nutritional foods) are abrogated or diminished in exchange for cash payments. These changes may be initiated or exacerbated by the designation of Voluntary Conserved Areas (VCAs) if the community members are not fully in control of the process of delimiting and monitoring these local protected areas.

Several scholars have called for rigorous empirical studies on the impact of the market economy on the well-being of indigenous peoples and their use of natural resources (Godoy *et al*. 2005, Gómez-Baggethun *et al.* 2010, Lu 2007, Reyes-García *et al.* 2005). While noting that deficiencies and discrepancies in methodology limit the general conclusions that can be drawn from available case studies, they generally conclude that current evidence suggests market exposure has mixed effects on the subsistence, health, nutritional status, social capital, and traditional ecological knowledge of indigenous peoples.

The preliminary results of research on PES, community conservation and food sovereignty in the Chinantla contribute additional insights into these issues. Chinantec communities are facing a transition in (a) dietary patterns and food acquisition, (b) household economies and food security, and (c) socio-cultural significance of subsistence activities. This study has considered if these changes are partially driven by preservationist approaches inherent in the establishment of PES and VCAs.

Dietary patterns and food acquisition

Many indigenous groups around the globe are going through a transition of lifestyles and diets (Damman *et al.* 2008, Creed-Kanashiro *et al.* 2009, Huamán-Espino and Valladares 2006), which often poses a threat to their health and nutrition. This decline usually goes hand in hand with processes of acculturation – particularly the degradation of local knowledge of, and pride in, traditional agricultural practices – and of increasing consumption of Western foods of low nutritional quality, especially soft drinks and refined flour (Correal *et al.* 2009). This new dietary pattern, which includes dependence on nutrient-deficient market items such as noodles, rice and fried foods, can contribute to insufficient intake of vitamins and minerals.

The results of this study suggest that Chinantec traditional food systems have been altered by limitations on shifting agriculture, a hunting ban, the construction of a river dam, and new income received by villagers from PES and other sources, which allows them economic access to new industrialised food items. Purchased foods (rice, noodles, steak, canned beans, sardines and tuna fish and bottled soft drinks) are becoming more frequent in the local diets. The important proportion of external market foods in meals, together with the loss of traditional foods, attests to changes in Chinantec food sovereignty.

Among Mesoamerican indigenous peoples, the *milpa* is the most critical element of a diversified traditional food system (Alcorn and Toledo 1998), and is the key agricultural and economic component of local livelihoods in the Chinantla. Shifting cultivation associated with the *milpa* is only one component of a much larger agroecosystem that includes agriculture, hunting, and gathering (Warner 1991).

As revealed by this study, decreases in *milpa* productivity are associated with the implementation of the PES and VCAs programmes, mainly via three avenues. First, land-use change is now prohibited in approximately three quarters of the territory, which reduces the availability of agricultural land, shortens cycles of sowing and fallowing, affects soil quality, and decreases productivity. Second, since villagers receive annual payments through the PES-H scheme and other government subsidies, they are working their fields less and are harvesting

[8] J.P.B., 38 years old.

reduced food stocks that do not last the entire year. Finally, nuisance animals are reportedly multiplying and there is a constant escalation of pest attacks affecting agricultural fields. Increasing negative effects of nuisance animals have been associated with the implementation of conservation initiatives elsewhere (Mishra 1982, Chhangani *et al.* 2008), and could become a major source of conflict between local communities and VCA management if not properly addressed (Bajracharya *et al.* 2005).

Swidden cultivation has long proven a flashpoint for development scholars and practitioners, including those who characterise it as a backward and destructive practice linked to deforestation and poverty (FAO Staff 1957 in Mertz *et al.* 2009). Conklin (1957, 1963) contested this assessment, and recent empirical work substantiates his assertion that swidden agriculture is adaptive, economically rational, and sustainable. For example, Diemont and Martin (2009) found high indices of sustainability and low environmental impact in Lacandon Maya swidden agroforestry systems. Mertz *et al.* (2009) have argued that a deeper understanding of agroecosystem dynamics is needed before declaring that shifting cultivation is unsustainable and proposing alternative land uses. Despite these new insights, there were no efforts on the part of the governmental and civil society proponents of conservation efforts in Santiago Tlatepusco to conduct baseline studies or implement monitoring of the impact of preservationist measures on swidden agriculture, dietary diversity and other aspects of food sovereignty.

Villagers frequently pointed out that meat consumption patterns changed after the hunting prohibition. Similar to other shifting cultivators in Mexico (Naranjo *et al.* 2004, Quijano-Hernández and Calmé 2002, Ramírez and Naranjo 2007) and elsewhere in the Neotropics (Smith 2005), Chinantec community members used to obtain animal protein partly by hunting in adjacent forests, fallows and fields while they protected their *milpas*. According to Neusius (1996), hunting of animals that frequent fields and fallows provides high-quality protein and effective reduction of competition for crops.

Robinson and Bennett (2004) have argued that the sustainability of subsistence hunting, which is critical to the livelihoods of people around the world, depends in part on the ecological conditions that affect wildlife supply and demand. They provide empirical evidence that the supply of game is greater in secondary forests and forest–farm–fallow mosaics than in undisturbed forests. They recommend that empirical studies of the impact of hunting in various ecosystem types and degrees of human disturbance be conducted before land is zoned for protected areas or resource management. Unfortunately, there has been no such analysis of the viability of wildlife populations in the Chinantec communities before and after the implementation of hunting prohibitions. In addition, there was little consideration of customary forms of governing and managing the territory and sustaining hunting yields, elements that are closely linked to the institutions and cosmology of Chinantec communities (Ibarra 2010, Oliveras de Ita 2005).

Decreases in the proportion of game versus livestock meat in the diet reflect changes in traditional livelihoods and lifeways among indigenous peoples (Hawkes *et al.* 2001, Spielmann and Eder 1994, Vázquez and Godínez 2005). This tendency, currently experienced by Chinantecs, is common among indigenous groups in Mexico. Furthermore, local efforts to establish poultry to compensate for diminished animal protein have been limited by diseases, preventing year-round consumption, and an increase in grazing livestock raises concerns about erosion and landslides near settlements. These changes in local procurement of protein exacerbate the impact of the Miguel Alemán-Cerro de Oro dam, which decreased local access to aquatic resources in favour of regional hydropower development (cf. Arthur and Friend 2011).

Domestic economy: food for health and security

Increased income in rural areas does not translate directly into increased or higher quality food consumption (Dewey 1981, DeWalt 1983). Poor and market-dependent individuals tend to purchase cheap and filling industrially processed foods and drinks, high in refined carbohydrates and saturated fats rather than good quality food (Kuhnlein *et al.* 2004), due to affordability, which in turn affects the amount of time and energy committed to harvesting and preparing traditional foods (Kuhnlein and Receveur 1996). When alternative foods are available at low cost in local markets, local farmers tend to reduce the time spent working in traditional agroecosystems when they can afford to buy processed products.

The current challenges of food acquisition in Chinantec communities could arguably be ameliorated by the PES income each family receives annually. However, villagers currently spend a high proportion of these revenues to purchase externally produced, lower-quality food. Following the implementation of PES and VCAs, they are increasingly dependent on external markets for industrialised foods, meat, black beans and maize, historically the pivotal element of their diversified subsistence system strategy. With greater distance from regional markets, PES cash payments buy relatively fewer goods and services for members of remote communities because food prices are augmented by transport costs. For these reasons, economic benefits of the transition in food sovereignty are unlikely to accrue locally.

A diet based on processed food can result in health problems, especially for indigenous communities who are predisposed to certain health conditions. This has been demonstrated in Mexico where a decrease in food quality has increased the prevalence of chronic degenerative diseases like diabetes mellitus, cancer, and arterial hypertension (Chávez *et al.* 2003). In South America, Uauy *et al.* (2001) documented the extent of obesity and metabolic complications among rural and urban Mapuche and Aymara indigenous people in Chile after they became dependent on external markets and increasing incomes. A wide range of literature, summarised by Fleuret and Fleuret (1980), consistently documents nutritional declines, called transitional malnutrition, associated with new income strategies. Further studies in the Chinantla

are necessary to test whether current changes in food sovereignty are yielding measurable changes in nutritional status and health.

For indigenous peoples, global economic drivers have contributed to redirecting land and resources away from traditional modes of securing household subsistence and toward cash cropping, conservation, or industrial development (Kuhnlein and Receveur 1996). While making greater numbers of people secure in terms of caloric energy, industrialised food also drives the nutritional transition and can undermine the self-sufficiency and economic viability of local systems (Kuhnlein and Receveur 1996, Diaz-Bonilla and Robinson 2001).

In the Chinantla, by agreeing to restrict use of their ancestral agricultural land and prohibit hunting as conservation measures, food security has become less stable, leading to greater community dependency on external supplies for food. If market food of sufficient quality (meat, low-fat dairy items, vegetables, whole grains) is not available to replace essential nutrients from traditional meat, fish and produce, the nutrition of the entire community is at risk (Kuhnlein *et al.* 2004). Compromising food security is questionable at best: "food is so fundamental to human well-being that it is hard to envisage a situation in which it could be traded-off for some other good" (Arthur and Friend 2011: 219).

Socio-cultural significance of Chinantec food acquisition

Swidden agriculture and hunting represent more than a food quest for Chinantecs. The *milpa* has an essential function as a major food source (DeWalt 1983), but also a socio-cultural role in defining land tenure and various social interactions (Alcorn and Toledo 1998). Garden hunting in *milpas*, fallows, and forests links natural and social environments, agricultural practices, custom and cosmology (Ibarra 2010). Chinantec hunting is related to eliminating nuisance animals, but also to providing protein, medicine and tools. Traditional environmental knowledge related to farming, hunting and gathering is both vertically and horizontally transmitted. Hunting previously provided an opportunity to learn about the environment, reaffirm traditional beliefs, gather plants and socialise. The socialisation involved processes by which individuals became hunters, embodying in their own experience and acting out in their learned behaviour part of Chinantec swidden maintenance and hunting culture (Oliveras de Ita 2005).

With the prohibition of hunting, not only meat consumption, but also other traditional uses of wildlife and socio-cultural meanings of hunting and gathering have been disrupted (Ibarra 2010). PES appear to have created new forms of self- and community policing (Foucault 1977): community members relate that they avoid shooting animals in agricultural areas for fear other community members will report them, leading to loss of their PES allocation. If this is the case, then the influence of the PES over certain spaces in the community has been extended beyond the officially protected areas. A formalised commons has rules governing membership and access to resources. By monetising and effectively closing the Chinantec communities' commons, PES and VCA certification have generated a new set of rules about resource management on community land, including areas not set aside to provide environmental services or conserve biodiversity.

CONCLUSIONS

Programmes to protect food sovereignty can provide strategies to combat malnutrition while ensuring sustainable development (Murcott 1992). With the current focus on advocating and assessing the impact of policy shifts that seek to directly foster food sovereignty (Pimbert 2009), much less attention has been paid to the influence of a broader web of policy, law and regulations, especially related to nature conservation (Martin *et al*. 2010). A central concern is that new uses of land, ranging from large-scale agriculture to biodiversity conservation, and financial subsidies, including market-based mechanisms such as PES, may disrupt the resource access, production, consumption and distribution that are at the heart of localised food systems. This is part of a gradual structural displacement of indigenous peoples and local communities, a process of restricting access to and use of communal lands that eventually limits the ability of community members to meet their basic needs.

Traditional food systems, once lost, are hard to recreate, underlining the imperative for documentation, compilation, and dissemination of knowledge of biodiversity and its uses, especially when it is eroding in the face of acculturation and globalisation (Johns and Sthapit 2004). For indigenous peoples and local communities, it is not just a loss of food items *per se* that matters, but also deskilling, such as the loss of fishing and hunting practices, and the impoverishment of the knowledge related to recognising, harvesting, preparing, and consuming traditional foods that contribute to maintaining healthy diets and social relations.

Agrawal and Redford (2009) have summarised contemporary critiques of biodiversity conservation programmes, noting they have been faulted for distressing ". . .human populations, especially those who are less powerful, politically marginalised, and poor" (2009:1). They highlight in particular the impact of physical dispossession of peoples from their lands, restrictions on access to resources, loss of livelihoods and diminished opportunities for future income that often accompanies the establishment of protected areas. Lele *et al*. (2010) explore alternative forms of biodiversity conservation that are intended to rectify these difficulties, with a focus on inclusive approaches such as community-based conservation, enterprise-based conservation and PES. Indigenous and Community Conserved Areas (ICCAs) are considered to show particular promise (Borrini-Feyerabend and Kothari 2008), although there are concerns about assessing their conservation benefits, ensuring they integrate traditional ecological knowledge and finding appropriate governance regimes, among other challenges (Berkes 2009).

In order to be successful, ICCAs will have to avoid the pitfalls of previous approaches to biodiversity conservation. Lele *et al*. (2010: 1) have already raised a red flag on enterprise-based conservation, noting that it "offers some

potential if design flaws, poor implementation, assumptions about homogeneous communities, and inattention to tenurial change and security are addressed". They equally urge caution on payments-based programmes, suggesting the need for more insightful and detailed studies of their "economic efficiency, and simplified assumptions regarding the nature of rights, biological information, monitoring costs, and state interventions" (Lele *et al*. 2010: 1).

The precautionary principle applied to community conservation

The caveats detailed in this paper highlight the importance of applying a precautionary principle when implementing the increasingly diverse set of measures and practices that are currently included under the broad rubric of community conservation.

Since the early 1990s, environmental scientists have recognised the importance of the precautionary principle as an essential guideline in environmental policy and practice (Kriebel *et al*. 2001). A consensus definition from Raffensperger and Tickner (1998), cited in Kriebel *et al*. (2001: 871), summarizes the principle: "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." Four specific components of the principle, all specifically relevant to community conservation, have been proposed: (1) preventive action should be taken in the face of uncertainty; (2) the burden of proof should be shifted to the proponents of an intervention; (3) a wide range of alternatives to possibly harmful actions should be explored; and (4) public participation in decision making should be increased (Kriebel *et al*. 2001: 871).

Cooney (2004) notes that the precautionary principle should not be used to support protectionist approaches to conservation, without considering the potential impacts of these policies. Furthermore, she argues that scientific assessments should incorporate indigenous, traditional and local resource user knowledge, and should examine the broader socio-economic and political contexts which affect the impact of conservation decisions. The precautionary principle is particularly relevant to ICCAs, many of which have been managed by local peoples over long periods of time.

Conservationists should shoulder the responsibility of proving that changes in landscape or resource use are needed, and they should actively engage community researchers in their environmental assessments. Absence of evidence of environmental degradation on a landscape scale should be a strong incentive to block preservationist measures whose impacts are uncertain. Above all, a wide range of alternatives – many of them based on the knowledge, innovations and practices of indigenous and local communities – should be explored before implementing extensive protected areas, hunting bans and other restrictions on customary resource use. Articles 8(j) and 10(c) of the Convention on Biological Diversity, and well as Article 8.2(b) and Article 26 of the United Nations Declaration on the Rights of Indigenous Peoples, support this approach.

The preliminary results presented here provide initial evidence that dietary diversity, agricultural practices, household economies and livelihoods may be negatively affected by strict preservation measures imposed under the guise of community conservation, especially when subsidised through financial incentives. Although PES and VCAs schemes in the Chinantla maintain community ownership of lands and resources and are putatively community-led, they still represent avenues for government and civil society policies to permeate local institutions and customary governance of commons, and to drive changes in food acquisition and consumption. This results in a *de facto* structural displacement of Chinantec people from their communal lands.

These drivers of change are intertwined with other factors – such as migration, large scale development projects and various other trends associated with the market economy – that affect local livelihoods and modes of social reproduction. Although it can be conceptually and empirically difficult to distinguish the impact of one driver from the others, this study has identified some consequences that local people attribute to the prohibition of hunting, the reduction of swidden agriculture and the effects of financial subsidies linked to conservation initiatives.

The people of Santiago Tlatepusco are not alone in questioning the impact of preservationist measures implemented in the name of community conservation (Schmidt 2010). Concerned about the impact of conservation measures on subsistence production, the General Assembly of Santiago Lachiguiri, a Zapotec community in the Isthmus of Oaxaca, voted in May 2010 to cancel the certification of its VCA, originally delimited in 2003 as the first indigenous VCA in Mexico. In addition, the community opted unanimously to reject any further PES. Instead, it decided to rewrite the municipal statutes to explicitly recognise the responsibility of all inhabitants to manage and protect the natural resources of Santiago Lachiguiri in an equitable way (Schmidt 2010: 23). The new statues recognise that swidden farming is "un sistema de agricultura tradicional milenario que mantiene el equilibrio entre la producción de alimentos y el cuidado de la montaña, bosque y selva" [an ancient traditional agricultural system that maintains the equilibrium between food production and caring for the mountain, woods and tropical forests].

An important question is whether market-based mechanisms like PES can ever be made compatible with food sovereignty. Answers are urgently needed, as these mechanisms already form part of national and international biodiversity conservation policies, and some indigenous and local communities see them as a viable source of income even as others reject them. This study suggests that taking socio-cultural context and ecological parameters into account is essential in any analysis of the impact of nature conservation and financial incentives on food sovereignty. This requires a detailed understanding of local production systems and wild food harvesting that can inform any restrictions on resource access or use, ensuring they are sensitive to local livelihood needs. This is consistent with international recognition of the importance of reviving and rebuilding food sovereignty in developing

countries to reap health and environmental benefits (Johns and Sthapit 2004).

In order to achieve a deeper analysis of these complex issues, the tentative results and preliminary methodology of this study will need to be expanded in more comprehensive and comparative socio-ecological studies (Lele *et al*. 2010) which heed calls for more rigorous methodology (Godoy *et al*. 2005). Danielsen *et al*. (2009) have demonstrated the diverse ways in which local peoples can be involved in monitoring of trends in the conservation status of species or habitats. A community-based participatory approach will be an essential element of any deeper analysis of conservation, market mechanisms and food sovereignty.

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REFERENCES

AGRAWAL, A. and REDFORD, K. 2009. Conservation and displacement: An overview. *Conservation and Society* **7**: 1–10.

ALCORN, J. and TOLEDO, V.M. 1998. Resilient resource management in Mexico's forest ecosystems: the contribution of property rights. In: BERKES, F. and Folke, C. (eds.) *Linking social and ecological systems*. Cambridge University Press, Cambridge, U.K. 476 p.

ANTA, S. and MONDRAGÓN, F. 2006. El ordenamiento territorial y los estatutos comunales: El caso de Santa Cruz Tepetotutla, Usila, Oaxaca. In: ANTA, S. *et al.* (eds.) *Ordenamiento Territorial Comunitario.* INE-SEMARNAT, Idesmac, GAIA, GEA, Methodus, SAED. México, D.F. 253 p.

ANTA, S. 2007. Áreas Naturales de Conservación Voluntaria. Estudio elaborado para la iniciativa Cuenca. CCMSS. Unpublished manuscript.

ANTA, S., MONDRAGÓN, F. and LAVÍN, D. 2008. El manejo de los Recursos Naturales y el Pago de Servicios Ambientales Hidrológicos en la Chinantla Alta, Oaxaca: El Caso de CORENCHI, A.C. In: PARÉ, L. e*t al* (coord.). *Gestión de Cuencas y Servicios Ambientales. Perspectivas comunitarias y ciudadanas.* SEMARNAT, INE, Itaca, Raises, Sendas, A.C., WWF, GAIA, D.F. México. 304 p.

ARTHUR, R.I. and FRIEND, R.M. 2011. Inland capture fisheries in the Mekong and their place and potential within food-led regional development. *Global Environmental Change* **21**: 219–226.

ATRAN, S., MEDIN, D., ROSS, N., LYNCH, E., VAPNARSKY, V., UCAN EK', E., COLEY, J., TIMURA, C. and BARAN M. 2002. Folkecology, cultural epidemiology, and the spirit of the commons: A garden experiment in the Maya lowlands, 1991–2001. *Current Anthropology* **43**: 421–451.

ÁVILA BELLO, C.H. 2010. La agricultura tradicional y la conservación de los recursos naturales en México. *Este país* **226**.

BAJRACHARYA, S.B., FURLEY, P.A. and NEWTON, N.A. 2005. Effectiveness of community involvement in delivering conservation benefits to the Annapurna Conservation Area, Nepal. *Environmental Conservation* **32**: 239–247.

BALÉE, W. 1994. *Footprints of the forest*. Columbia University Press, New York, U.S.A. 416 p.

BERKES, F. 2009. Community conserved areas: policy issues in historic and contemporary context, *Conservation Letters* **2**: 19–24.

BERNARD, R.H. 2005. *Research methods in anthropology: qualitative and quantitative approaches*. 4th Edition. Altamira Press, Oxford, U.K. 824 p.

BOEGE, E. 2008. El patrimonio biocultural de los pueblos indígenas de México. INAH, Comisión Nacional para el Desarrollo de Pueblos Indígenas. México, D.F. 344 p.

BORRINI-FEYERABEND, G. and KOTHARI, A. 2008. *Recognizing and supporting indigenous and community conservation – ideas and experiences from the grassroots*. IUCN CEESP Briefing Note 9, September. 28 p.

BRAY, D.B., DURÁN, E., ANTA, S. MARTIN, G.J. and MONDRAGÓN, F. 2008. A New Conservation and Development Frontier: Community Protected Areas in Oaxaca, Mexico. *Current Conservation* **2**: 7–9.

CAMACHO-BENAVIDES, C., MARTIN, G.J. and DEL CAMPO, C. 2010. Fortalecimiento de áreas de conservación comunitarias e indígenas a través de la etnobiología. In: MORENO FUENTES, A., PULIDO-SILVA, M.T., MARIACA-MÉNDEZ, R., VALDEZ-AZÚA, R., MEJÍA-CORREA, P. and GUTIÉRREZ-SANTILLÁN, T.V. (eds.) *Sistemas Biocognitivos Tradicionales*. Asociación Mexicana de Etnobiología, D.F., México. 486 p.

CHHANGANI, A.K., ROBBINS, P. and MOHNOT, S.M. 2008. Crop raiding and livestock predation at Kumbhalgarh Wildlife Sanctuary, Rajasthan India. *Human Dimensions of Wildlife* **13**: 305–316.

CHÁVEZ, M.C., MADRIGAL FRITSCH, H., VILLA, A. and GUARNEROS SOTO N. 2003. Alta prevalencia de desnutrición en la población infantil indígena mexicana. Encuesta Nacional de Nutrición 1999. *Revista Española de Salud Pública* **77**: 245–255.

CONABIO. 2008. *Regiones Terrestres Prioritarias de México*. Available at: http://www.conabio.gob.mx/conocimiento/regionalizacion/doctos/terrestres.html. Last accessed December 2010.

CONAFOR. 2004. Padrón de beneficiarios de pagos por servicios ambientales. 2004–2010. Non-published data base.

CONAFOR. 2010. *Términos de referencia para la formulación del programa de mejores prácticas de manejo (PMPM) en el concepto de servicios ambientales en su modalidad de apoyo B2.1 Servicios ambientales hidrológicos correspondiente al Área 1 y 2*. Available at: http://www.conafor.gob.mx:8080/documentos/docs/6/860T%C3%A9rminos%20de%20Referencia%20para%20la%20formulaci%C3%B3n%20del%20Programa%20de%20Mejores%20Pr%C3%A1cticas%20de%20Manejo%20%28PMPM%29%202010.pdf. Last accessed July 2011.

CONKLIN, H.C. 1957. *Hanunoo agriculture. A report on an integral system of shifting cultivation on the Philippines*. FAO, Rome, Italy. 209 p.

CONKLIN, H.C. 1963. *The Study of Shifting Cultivation*. Routledge & Kegan Paul, London, U.K. 229 p.

COONEY, R. 2004. *The Precautionary Principle in Biodiversity Conservation and Natural Resource Management: An issues paper for policy-makers, researchers and practitioners*. IUCN, Gland, Switzerland and Cambridge, U.K. 51 p.

CORREAL, C., ZULUAGA, G., MADRIGAL, L., CAICEDO, S. and PLOTKIN, M. 2009. Ingano traditional food and health: Phase 1, 2004–2005. In: KUHNLEIN, H.V., ERASMUS, B. and SPIGELSKI, D. (eds.) *Indigenous Peoples' food systems: the many dimensions of culture, diversity and environment for nutrition and health.* FAO, Centre for Indigenous Peoples' Nutrition and Environment, Rome, Italy. 350 p.

CREED - KANASHIRO, H., ROCHE, M., TUESTA CERRÓN, I. and KUHNLEIN, H.V. 2009. Traditional food system of an Awajun community in Peru. In: KUHNLEIN, H.V., ERASMUS, B. and SPIGELSKI, D. (eds.) *Indigenous Peoples' food systems: The many dimensions of culture, diversity and environment for nutrition and health.* FAO, Centre for Indigenous Peoples' Nutrition and Environment, Rome, Italy. 350 p.

DAMMAN, S., BARTH EIDE, W. and KUHNLEIN, H.V. 2008. Indigenous peoples' nutrition transition in a right to food perspective. *Food Policy* **33**: 135–155.

DANIELSEN, F., BURGESS, N.D. and BALMFORD, A. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* **14**: 2507–2542.

DEWALT, K.M. 1983. *Nutritional strategies and agriculture changes in a Mexican community*. Ann Arbor, University of Michigan, Michigan, U.S.A. 232 p.

DEWEY, K. 1981. Nutritional consequences of the transformation from subsistence to commercial agriculture in Tabasco, Mexico. *Human Ecology* **9**: 151–187.

DIAZ-BONILLA, E. and ROBINSON, S. 2001. *Shaping globalization for poverty alleviation and food security*. Focus Briefs–International Food Policy Research Institute (IFPRI). International Food Policy Research Institute, Washington, DC, U.S.A. 26 p.

DIEMONT, S.A.W. and MARTIN, J.F. 2009. Lacandon Maya ecosystem management: Sustainable design for subsistence and environmental restoration. *Ecological Applications* **19**: 254–266.

ELLIS, E.A. and PORTER-BOLLAND, L. 2008. Is community-based forest management more effective than protected areas? A comparison of land use/land cover change in two neighboring study areas of the Central Yucatan Peninsula, Mexico. *Forest Ecology and Management* **256**: 1971–1983.

FLEURET, P. and FLEURET, A. 1980. Nutrition, consumption, and agricultural change. *Human Organization* **39**: 250–60.

FOUCAULT, M. 1977. *Discipline and punish: The birth of the prison*. Random House of Canada. Vintage/Random House, New York, U.S.A. 352 p.

GEOCONSERVACIÓN. 2006. *Ordenamiento territorial comunitario de Santiago Tlatepusco*. Informe Técnico Final, Santiago de Juárez, Oaxaca, México. 89 p.

GIBSON, C.C. and MARKS, S.A. 1995. Transferring rural hunters into conservationists: an assessment of community-based wildlife management in Africa. *World Development* **23**: 941–957.

GODOY, R., REYES-GARCIA, V., BYRON, E., LEONARD W.R. and VADEZ, V. 2005. The Effect of Market Economies on the Well-Being of Indigenous Peoples and on Their Use of Renewable Natural Resources. *Annual Review of Anthropology* **34**: 121–38.

GÓMEZ-BAGGETHUN, E. DE GROOT, R. LOMAS, P.L. and MONTES, C. 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics* **69**: 1209–1218.

GÓMEZ-BAGGETHUN, E., MINGORRÍA, S., REYES-GARCÍA, V., CALVET, L., and MONTES, C. 2010. Traditional ecological knowledge trends in the transition to a market economy: Empirical study in Doñana natural areas. *Conservation Biology* **24**: 721–729.

HAWKES, K., O'CONNELL, J.F. and BLURTON JONES, N.G. 2001. Hunting and nuclear families: some lessons from the Hadza about men's work. *Current Anthropology* **42**: 681–709.

HERNÁNDEZ, J.L. 2007. *La Chinantla, fuente de agua, fuente de vida*. La Jornada. August. Available at: http://www.agua.org.mx. Last accessed June 2011.

HERNÁNDEZ X, E. 1977. *Agroecosistemas de México: Contribuciones a la enseñanza, investigación y divulgación agrícola*. Colegio de Postgraduados-ENA, Chapingo, México. 335 p.

HUAMÁN-ESPINO, L. and VALLADARES, C. 2006. Estado nutricional y características del consumo alimentario de la población Aguaruna. Amazonas, Perú. *Revista Peruana de Medicina Experimental y Salud Pública* **23**: 12–21.

HOUGH, J.L. 1988. Obstacles to effective management of conflicts between national parks and surrounding human communities in developing countries. *Environmental Conservation* **15**: 129–136.

IBARRA, J.T. 2010. *The transition from local hunting to external meat dependency: Ethnoecological and sociocultural effects of a hunting prohibition in the Chinantla*

Alta Community-based Conservation Area, Oaxaca, Mexico. Master Thesis in Environmental Anthropology, University of Kent, U.K. 83 p.

IGOE, J. 2006. Measuring the costs and benefits of conservation to local communities. *Journal of Ecological Anthropology* **10**: 72–77.

JOHNS, T. and STHAPIT, B.R. 2004. Biocultural diversity in the sustainability of

developing-country food systems. *Food and Nutrition Bulletin* **25**: 143–155.

KRIEBEL, D., TICKNER, J., EPSTEIN, P. LEMONS, LEVINS, J.R., QUINN, M. RUDEL, R. SCHETTLER, T. and STOTO, M. 2001. The Precautionary Principle in Environmental Science. *Environmental Health Perspectives* **109**: 871–876.

KUHNLEIN, H.V. and RECEVEUR, O. 1996. Dietary change and traditional food systems of indigenous peoples. *Annual Review of Nutrition* **16**: 417–442

KUHNLEIN, H.V., RECEVEUR, O., SOUEIDA, R. and EGELAND, G.M. 2004. Arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. *Journal of Nutrition* **134**: 1447–1453.

KUHNLEIN, H.V., RECEVEUR, O., SOUEIDA, R. and BERTI, P.R. 2007. Unique patterns of dietary adequacy in three cultures of Canadian Arctic indigenous peoples. *Public Health Nutrition* **11**: 349–360.

KUHNLEIN, H.V., ERASMUS, B., and SPIGELSKI, D. 2009. *Indigenous Peoples' food systems: The many dimensions of culture, diversity and environment for nutrition and health.* FAO, Centre for Indigenous Peoples' Nutrition and Environment, Rome, Italy. 350 p.

LELE, S., WILSHUSEN, P., BROCKINGTON, D., SEIDLER, R. and BAWA, K. 2010. Beyond exclusion: Alternative approaches to biodiversity conservation in the developing tropics. *Current Opinion in Environmental Sustainability* **2**: 1–7.

LÓPEZ, J. and MARIANO, L. 2008. Cultura, derecho a la alimentación e (in) seguridad alimentaria. In: *Derecho a la alimentación y soberanía alimentaria.* Cátedra de estudios sobre hambre y pobreza, Córdoba, Argentina. 450 p.

LU, F. 2007. Integration into the market among indigenous peoples: A cross-cultural perspective from the Ecuadorian Amazon. *Current Anthropology* **48**: 593–602.

MCAFEE, K. and SHAPIRO, E. 2010. Payments for Ecosystem Services in Mexico: Nature, Neoliberalism, Social Movements, and the State. *Annals of the Association of American Geographers* **100**: 579–599.

MARTIN, G.J. 1996. *Comparative Ethnobotany of the Chinantec and Mixe of the Sierra Norte, Oaxaca, Mexico.* Doctoral Dissertation, Anthropology Department, University of California at Berkeley. 960 p.

MARTIN, G.J. DEL CAMPO, C., CAMACHO, C., ESPINOZA SAUCEDA, G. and ZOLUETA JUAN, X. 2010. Negotiating the web of law and policy: community designation of indigenous and community conserved areas in Mexico. *Policy Matters* **17**: 195–204.

MERTZ, O., MBOW, C., REENBERG, A. and DIOUF, A. 2009. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management* **43**: 804–816.

METCALFE, S. 1994. The Zimbabwe communal areas management programme for indigenous resources (CAMPFIRE). In: WESTERN, D., and WRIGHT, R.M. (eds.) *Natural connections: perspectives in community-based conservation*. Island Press, Washington DC, U.S.A. 600 p.

MISHRA, H. 1982. Balancing human needs and conservation in Nepal's Royal Chitwan National Park. *Ambio* **11**: 246–251.

MONDRAGÓN, F. N/d. *La protección comunitaria de las cuencas de los ríos Perfume y Santiago; el aprovisionamiento y negociación para el cobro y pago de los servicios ambientales hidrológicos en las comunidades del Comité de Recursos Naturales de la Chinantla Alta, México*. GeoConservación, FAO-facility. Unpublished manuscript.

MURCOTT, A. 1992. Cultural perceptions of food and eating: obstacles to change? *Ecology of food and nutrition* **27**: 283–90.

NARANJO, E.J., GUERRA, M.M., BODMER, R.E. and BOLANOS, J.E. 2004. Subsistence hunting by three ethnic groups of the Lacondon Forest, Mexico. *Journal of Ethnobiology* **24**: 384–395.

NEUSIUS, S.W. 1996. Game procurement among temperate horticulturalists: The case for garden hunting by the Dolores Anasazi. In Reitz, E.J., Newsom, L.A. and Scudder S.J. (eds.) *Case studies in environmental archaeology*. Plenum Press, New York, U.S.A. 380 p.

OLIVERAS DE ITA, D. 2005. *Cosmovisión y territorio entre los Chinantecos de Tlatepusco*. Bachelor Thesis in Ethnology, Escuela Nacional de Antropología e Historia, INAH-SEP, Oaxaca, México. 167 p.

PÉREZ, P., ANTA, S. and MONDRAGÓN, F. 2006. *Los ordenamientos Territoriales en las Comunidades de la Chinantla Alta, Oaxaca. Seminar "Análisis Metodológico del Ordenamiento Comunitario del Territorio"*. COINBIO, D.F., México. 15 p.

PÉREZ LUSTRE, M., CONTRERAS DÍAS, R.G. and SÁNTOS MORENO, A. 2006. Mamíferos del bosque mesófilo de montaña del municipio de San Felipe Usila, Tuxtepex, Oaxaca, México. *Revista Mexicana de Mastozoología* **10**: 29–40.

PIMBERT, M. 2009. *Towards food sovereignty*. Gatekeeper 141. International Institute for Environment and Development, London, U.K. Available at: http://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/5851/14855IIED.pdf?sequence=1. Last accessed April 2011.

POPKIN, B.M. 2003. The nutrition transition in the developing world. *Development Policy Review* **21**: 581–597.

POPKIN, B.M. 2004. The nutrition transition: An overview of world patterns of change. *Nutrition Reviews* **62**: 140–143.

PRESIDENCIA DE LA REPÚBLICA. 2010. *Discurso del Presidente Felipe Calderón en el día mundial de los*

bosques. Available at: http://www.presidencia.gob.mx/?DNA=42&Contenido=61880. Last accessed December 2010.

PURI, R.K. 2011a. Documenting local environmental knowledge and change. In: Newing H. (ed.) *Conducting research in conservation: A social science perspective*. Routledge, London and New York. 376 p.

PURI, R.K. 2011b. Participant observation. In: Newing, H. (ed.) *Conducting research in conservation: A social science perspective*. Routledge, London and New York. 376 p.

QUIJANO-HERNÁNDEZ, E. and CALMÉ, S. 2002. Patrones de cacería y conservación de la fauna silvestre en una comunidad Maya de Quintana Roo, México. *Etnobiología* **2**: 1–18.

RAFFENSPERGER, C. and TICKNER, J. 1999. *Protecting Public Health and the Environment: Implementing the Precautionary Principle.* Island Press, Washington, DC, U.S.A. 441 p.

RAMÍREZ, P.J. and NARANJO, E.J. 2007. La cacería de subsistencia en una comunidad de la zona Maya, Quintana Roo, México. *Etnobiología* **5**: 65–85.

REYES-GARCIA, V., VADEZ, V., BYRON, E., APAZA, L., LEONARD, W.R., PEREZ, E. and WILKIE, D. 2005. Market Economy and the loss of folk knowledge of plant uses: Estimates from the Tsimane' of the Bolivian Amazon. *Current Anthropology* **46**: 651–656.

ROBINSON, J.G. and BENNETT, E.L. 2004. Having your wildlife and eating it too: An analysis of hunting sustainability across tropical ecosystems. *Animal Conservation* **7**: 397–408.

ROBSON, J.P. 2009. Out-migration and commons management: social and ecological change in a high biodiversity region of Oaxaca, Mexico. *International Journal of Biodiversity Science & Management* **5**: 21–34.

SCHMIDT, G. 2010. *Territorios indígenas y áreas protegidas: Tres casos y sus conclusiones.* Bonn, Germany: Servicio de las Iglesias Evangélicas en Alemania para el Desarrollo. 30 p.

SMITH, J.J. 1993. Using ANTHROPAC 3.5 and a spreadsheet to compute a free-list salience index. *Cultural Anthropology Methods* **9**: 8–12.

SMITH, J.J. and BORGATTI, S.P. 1997. Salience counts-and so does accuracy: Correcting and updating a measure for free-list-item salience. *Journal of Linguistic Anthropology* **7**: 208–209.

SMITH, D.A. 2005. Garden game: Shifting cultivation, indigenous hunting and wildlife ecology in western Panama. *Human Ecology* **33**: 505–537.

SPIELMANN, K.A. and EDER, J.F. 1994. Hunters and farmers: Then and now. *Annual Review of Anthropology* **23**: 303–323.

TOLEDO, V.M. 2003. Los pueblos indígenas, actores estratégicos para el Corredor biológico mesoamericano. *Biodiversitas* **47**: 8–15.

TURNER, R., PEARCE, D. and BATEMAN, I. 1994. *Environmental economics: An elementary introduction.* Harvester Wheatsheaf, Hertfordshire, U.K. 328 p.

UAUY, R., ALBALA, C. and KAIN, J. 2001. Obesity trends in Latin America: Transiting from under- to overweight. *Journal of Nutrition* **131**: 839–899.

VAN DER WAL, H., GOLICHER, D., CAUDILLO-CAUDILLO, S. and VARGAS-DOMÍNGUEZ, M. 2006. Plant densities, yields and area demands for maize under shifting cultivation in the Chinantla, Mexico. *Agrociencia* **40**: 449–460.

VANDERMEER, J. and PERFECTO, I. 2007. The agricultural matrix and future paradigm for conservation. *Conservation Biology* **21**: 274–277.

VÁZQUEZ, V. and GODÍNEZ, M.L. 2005. Cambio social y estatus masculino en la cacería indígena: Un estudio de caso del sureste veracruzano. *Relaciones* **26**: 134–167.

WARNER, K. 1991. *Shifting cultivators: local technical knowledge and natural resource management in the humid tropics*. Publications Division, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 80 p.

WAINWRIGHT, C. and WEHRMEYER, W. 1998. Success in integrating conservation and development? A study from Zambia. *World Development* **26**: 933–944.

WEITLANER, R. 1952. Sobre la alimentación Chinanteca. *Anales del Museo Nacional de México* **5**: 177–195.

WEITLANER, R. and CASTRO, C.A. 1973. Usila, morada de colibríes. *Papeles de la Chinantla VII*, Serie Científica 11. INAH. D.F., México. 268 p.

WEST, P. and BROCKINGTON, D. 2006. An anthropological perspective on some *unexpected consequences of protected areas. Conservation Biology* **20**: 609–619.

WHITE, P.C.L., JENNINGS, N.V., RENWICK, A.R. and BARKER, N.H.I. 2005. Questionnaires in ecology: A review of past use and recommendations for best practice. *Journal of Applied Ecology* **42**: 421–430.

APPENDIX 1 *Food items mentioned by Chinantec women during freelists exercises. Items are shown in descending order according to the* Smith's Index of Saliency. ** shows the rarely mentioned game resources*

English name	Spanish name	Scientific name	Response frequency	Smith's S Index
Black bean	Frijoles	*Phaseolus vulgaris*	1	0.93
Rice	Arroz	*Oryza sativa*	0.9	0.73
Noodle	Sopa	-	0.9	0.62
Chicken	Pollo	*Gallus domesticus*	1	0.60
Squash vine	Guía de calabaza	*Cucurbita moschata*	0.8	0.56
Chayote vine	Guía de chayote	*Sechium edule*	0.7	0.50
Chayote	Chayote	*Sechium edule*	0.9	0.49
Mint	Hierbabuena	*Mentha viridis*	0.3	0.48
Hen egg	Huevo de gallina	*Gallus domesticus*	0.8	0.46
Steak	Res	*Bos taurus*	0.8	0.45
Manioc	Yuca	*Manihot esculenta*	1	0.43
Squash	Calabaza	*Cucurbita moschata*	0.8	0.39
Maize	Maíz	*Zea mays*	0.7	0.35
Banana	Plátano	*Musa cuminata*	0.9	0.34
Ray-finned fish	Mojarra	*Aequidens latifrons*	0.6	0.27
Tomato	Tomate	*Solanum lycopersicon*	0.6	0.26
Night-blooming jasmine	Huele de noche	*Cestrum nocturnum*	0.3	0.25
Potato	Papa	*Solanum tuberosum*	0.4	0.24
Pacific flatiron herring	Sardina	*Harengula thrissina*	0.4	0.23
Prickly pear	Nopal	*Opuntia cochenillifera*	0.7	0.21
Sweet potato	Camote	*Ipomoea batatas*	0.5	0.19
Early beans	Ejote	*Phaseolus vulgaris*	0.3	0.18
Apple	Manzana	*Malus domesticus*	0.3	0.17
Carrot	Zanahoria	*Daucus carota*	0.3	0.16
Nightshade	Hierba mora	*Solanum nigrescens*	0.8	0.16
Freshwater prawn	Camarón	-	0.3	0.15
Papaya	Papaya	*Carica papaya*	0.3	0.14
Orange	Naranja	*Citrus x aurantium*	0.4	0.12
Pork	Cerdo	*Sus scrofa*	0.2	0.12
Corn	Elote	*Zea mays*	0.3	0.10
Lime	Lima	*Citrus aurantifolia*	0.2	0.09
Pineapple	Piña	*Ananas cosmosus*	0.3	0.09
Onion	Cebolla	*Allium cepa*	0.2	0.09
Pacaya	Tepejilote	*Chameadora tepijilote*	0.2	0.09
Watermelon	Sandía	*Citrullis vulgaris*	0.2	0.09
Chilli	Chile	*Capsicum annuum*	0.4	0.08
Coral tree	Hoja de corazón	*Erythrina* sp.	0.1	0.07
Mango	Mango	*Mangifera indica*	0.3	0.07
Coriander	Cilantro	*Coriandrum sativum*	0.2	0.07
Cheese	Queso	-	0.3	0.06
Lemon	Limón	*Citrus limon*	0.2	0.06
Melon	Melón	*Cucumis melo*	0.1	0.05

APPENDIX 1 *Continued*

English name	Spanish name	Scientific name	Response frequency	Smith's S Index
Coconut	Coco	*Cocos nucifera*	0.2	0.05
Avocado	Aguacate	*Persea americana*	0.2	0.04
Ice cream bean	Jinicuil	*Inga jinicuil*	0.1	0.04
Grape	Uva	*Vitis vinifera*	0.1	0.04
Plum	Ciruela	*Spondias purpurea*	0.2	0.04
Spring onion	Cebollín	*Allium cepa*	0.2	0.03
Collared peccary *	Jabalí	*Tayassu tajacu*	0.1	0.02
Mushroom	Hongo	?	0.1	0.02
Turkey	Guajolote	*Meleagris gallopavo*	0.1	0.02
Cacao	Cacao	*Theobroma cacao*	0.1	0.02
Nance	Nanche	*Byrsonima crassifolia*	0.1	0.02
Mamey sapote	Sapote mamey	*Pouteria sapota*	0.1	0.02
Red brocket deer *	Mazate	*Mazama americana*	0.1	0.01
Guava	Guayaba	*Psidium guajava*	0.1	0.01
Yam bean	Jícama	*Pachyrhizus erosus*	0.1	0.01
Nine-banded armadillo *	Armadillo	*Dasypus novemcinctus*	0.1	0.01
Sugar cane	Caña de azúcar	*Saccharum officinarum*	0.1	0.01
White-nosed coati *	Tejón	*Nasua narica*	0.1	0.01
Guachipilin	Huachepil	*Diphysa robinioides*	0.1	0.00
Garlic	Ajo	*Allium sativum*	0.1	0.00

Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders' agroforestry systems: a review

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SUMMARY

The cultivation of indigenous and exotic fruits for sub-Saharan Africa's domestic markets can bring increased revenues for smallholders and improve the diets of local consumers. There are, however, many bottlenecks which need to be addressed so that wider benefits from such activities are realised. Here, we describe key interventions being taken to address current constraints. For indigenous fruit trees, it is necessary to set priorities for which species to promote and to engage in participatory domestication for the improvement of yield, quality and germplasm delivery to farmers. For exotic fruits, 'south-south' transfer of advanced cultivars and the development of small-scale commercial suppliers of planting material are required to reinvigorate production. For both indigenous and exotic species, a focus on improving market value chains to bring greater benefits to producers is needed. We describe where further work is required to increase efficiency in the sector and to favour smallholder involvement.

Keywords: indigenous and exotic fruits, African smallholders, market value chains, participatory domestication, 'south-south' transfer

Amélorier le niveau de vie et la nutrition dans l'Afrique sub-saharienne à l'aide de la promotion de la production des fruits locaux et exotiques dans les systèmes d'agroforesterie de petite taille: une étude

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La culture de fruits exotiques et locaux pour les marchés domestiques de l'Afrique sub-saharienne peut être une source de revenus pour les petis producteurs et améliorer la nutrition des consommateurs locaux. Plusieurs empêchenments existent cependant et doivent être pris en compte pour permettre à des bénéfices plus larges de se réaliser. Nous décrivons ici les interventions les plus importantes en place actuellement pour faire face à ces contraintes. Pour les arbres fruitiers indigènes, il est nécessaire de donner priorité aux espèces à promouvoir et à engager dans une domestication participationnelle pour l'amélioration de la production, de la qualité et du germplasm fournis aux cultivateurs. Pour les fruits exotiques, le transfert "sud-sud" des cultivars avancés, et le développement des petits producteurs commerciaux de matériel de plantation sont nécessaires pour renvigorer la production. Pour les espèces indigènes et exotiques, une concentration sur l'amélioration des chaînes de valeurs de marché est nécessaire pour offrir de plus grands bénéfices aux producteurs. Nous décrivons les zones où un travail plus poussé est nécessaire pour accroître l'éfficacité du secteur et favoriser la participation des petits producteurs.

Mejora en los medios de subsistencia y la nutrición en el África subsahariana mediante la promoción de la producción de frutas nativas y exóticas en sistemas agroforestales de pequeños productores: una revisión

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El cultivo de frutas nativas y exóticas para los mercados domésticos subsaharianos puede aportar ingresos a los pequeños productores y mejorar la dieta de los consumidores locales. Sin embargo, existen muchos problemas que hace falta superar para poder alcanzar estos beneficios.

Aquí describimos las acciones clave que se están implementando para superar las restricciones actuales. Para árboles frutales nativos, es necesario establecer prioridades sobre qué especies promocionar, así como llevar a la práctica una domesticación participativa para el aumento de la producción y la mejora de la calidad y el suministro de germoplasma a los productores. Para frutales exóticos, son necesarias la transferencia de 'sur-a-sur' de cultivares avanzados y la aparición de proveedores comerciales de pequeña escala de material de plantación para dar vigor a la producción. Tanto para especies nativas como exóticas es necesario un enfoque centrado en mejorar las cadenas de valor del mercado para atraer así mayores beneficios para los productores. Describimos dónde se requieren mayores esfuerzos para aumentar la eficiencia del sector y dar prioridad a la participación de los pequeños productores.

INTRODUCTION

Sub-Saharan Africa's efforts to mitigate malnutrition are lagging behind the rest of the world, with 30% of the population under-nourished (FAO 2005a). Indeed, eight of the 20 nations with the highest burden of under-nutrition worldwide are in the region (Bryce *et al*. 2008). A lack of micronutrients, or 'hidden hunger', leads to poor health consequences for millions of Africans (Saka and Msonthi 1994, Saka *et al*. 2007, www.nap.edu, www.purdue.hort.edu). For example, around 50 million African children are at risk of vitamin A deficiency, the continent's third greatest public health problem after HIV/AIDS and malaria (Black *et al*. 2008, www.worldmapper.org). Nutritionists agree that solving malnutrition requires a range of interconnected approaches (Bhutta *et al*. 2008). These include the bio-fortification through conventional breeding or genetic modification (GM) of staple crops (the first option has generally been preferred because of societal resistance to the second, although GM approaches have become more acceptable in developing countries in the last few years, Dawson *et al*. 2009a), further spending on food supplementation programmes, and greater use of a wide range of edible plants for more diverse diets (Leakey 1999, World Bank 2006, UNICEF 2007, Negin *et al*. 2009). The further promotion of indigenous fruits and vegetables is an attractive option, as it allows consumers to take responsibility over their diets in culturally relevant, and therefore potentially more sustainable, ways (Keatinge *et al*. 2010). Furthermore, the nutritional profiles of these indigenous species in supplying micronutrients, fat, fibre and protein are often better than staple foods (Leakey 1999).

Current nutritional deficiencies in sub-Saharan Africa are exacerbated by a number of factors, including declining soil fertility and lack of water that limit the yields of staple crops, and anthropogenic climate change that restricts the range of crops that can be grown (Costello *et al*. 2009, Keatinge *et al*. 2010, Müller *et al*. 2011). In addition, continued deforestation, currently estimated at 3.4 million hectares annually for Africa as a whole (FAO 2010), means that many communities can no longer gain easy access to natural stands of fruits, nuts and other edible non-timber forest products (NTFPs) that they once collected to supplement their diets. In these circumstances, agroforestry, the practice of integrating a range of trees with annual crop cultivation and other farm activities, is an approach adopted by farmers to meet their needs for essential resources and improved livelihoods (Garrity 2004). At the same time, farmland tree planting provides valuable environmental services (Scherr and McNeely 2008, Nair *et al*. 2009, Leakey 2010). Indeed, worldwide, it is estimated that more than 1.2 billion people practise agroforestry in some form, and that approximately 560 million people live in farm landscapes that have more than 10% tree cover, many of which are found in the sub-Sahara region (Zomer *et al*. 2009).

By providing on-farm resources, the cultivation of trees for NTFPs, now known as agroforestry tree products (AFTPs) to distinguish them from common property resources (Simons and Leakey 2004), has the potential to reduce pressure on extraction from natural forest (Simons *et al*. 2000, Jamnadass *et al*. 2010). Furthermore, planting AFTPs with other crops improves the resilience of smallholders' agricultural systems (Steffan-Dewenter *et al*. 2007) and can bring significant revenues (Weinberger and Lumpkin 2007, Akinnifesi *et al*. 2010, Asaah *et al*. 2011). Rural women in particular can benefit, as markets for fruits, vegetables and other AFTPs have a lower capital threshold for involvement than other sectors of the economy (Awono *et al*. 2002, Akinnifesi *et al*. 2006, Kadzere *et al*. 2006). In Africa, special potential for cultivation lies in the great biological diversity of indigenous fruits, nuts and other edible products found in the forests of the continent (IPGRI *et al*. 2005, Akinnifesi *et al*. 2008). There are hundreds of indigenous fruit tree species (IFTs) that, although relatively unknown in global markets, are important locally. These are now the focus of domestication initiatives which could contribute significantly more to the livelihoods and nutrition of local people (Leakey 1999, Leakey *et al*. 2005, Degrande *et al*. 2006b, Schreckenberg *et al*. 2006, Pye-Smith 2009, Ræbild *et al*. 2011, Box 1). At the same time, the cultivation of IFTs allows valuable genetic resources to be conserved outside threatened forests (Dawson *et al*. 2009b). Planting also provides opportunities for carbon credit sales as non-destructive harvesting of fruits should not materially reduce sequestration (Nair *et al*. 2009), although current payment mechanisms are generally inefficient and further attention to approaches is required if farmers are to benefit significantly (Jack *et al*. 2008).

In this review, we consider the promotion of fruit tree cultivation on smallholdings, of both indigenous species and exotics that have traditionally been grown in the region, often for centuries, as one means of improving nutritional security in sub-Saharan Africa. We describe key areas where measures are being taken to address current constraints (Box 2) for the involvement of small-scale growers in production and markets, and indicate where further action is required to make

Box 1 Indigenous fruit and nut trees identified through priority-setting exercises as targets for promotion in Cameroon, Kenya and/or Malawi (see Table 1 for particular countries where a priority; the same species may also be important in other nations)

Allanblackia A genus of nine species found in the humid forests of Central, East and West Africa, the tree grows to 40 m tall and produces a large fruit that contains between 14 and 90 seeds. The seed produces an edible oil of interest to the global food industry as well as for local use in cooking and soap production (www.allanblackia.info). Oil from two species, *A. parviflora* and *A. stuhlmannii*, has received the approval of the European Union Novel Food Regulations that certify safe usage as a foodstuff in European markets.

Baobab *Adansonia digitata*, a tree with a large swollen trunk that can have a diameter of up to 10 m, is a very long-lived species (specimens found up to 2 000 years old) located in arid and semi-arid savannah in sub-Saharan Africa. The edible white, powdery pulp found in the fruit is very rich in vitamin C and vitamin B2 and is used to make a refreshing drink. Young leaves are also rich in vitamin C and are in high demand in West Africa as a soup vegetable.

Ber *Ziziphus mauritiana*, a spiny evergreen shrub or small tree up to 15 m high, is native to drylands in Africa and Asia. Fruit is eaten fresh or dried and can be made into a floury meal, butter, or a cheese-like paste, used as a condiment. The fruit is a good source of carotene, vitamins A and C, and oils. A refreshing drink is prepared by macerating the fruit in water. The use of ber in India can be traced back as early as 1 000 BC.

Bitter cola *Garcinia kola*, native to the moist lowland tropical forests of Central and West Africa, is a medium-sized evergreen tree. The bitter kernels are highly valued in Central Africa and are chewed as a stimulant. The kernels are also used for the treatment of coughs, bronchitis and liver disorders. Split stems and twigs are used as chewing sticks. A recent inventory revealed that the species, which is currently harvested mainly from the wild, is close to commercial extinction in Ghana.

Bush mango *Irvingia gabonensis* and *I. wombolu*, collectively known as bush mango or dika nut, are economically important long-lived fruit trees native to moist lowland tropical forest in Central and West Africa. The fruit mesocarp of *I. gabonensis*, sweet bush mango, is appreciated as a fresh fruit snack. Ground kernels of both species are used to thicken and flavour soups, although those of *I. wombolu*, bitter bush mango, are most valued and fetch high prices in cross-border trade, contributing significantly to local economies.

Desert date *Balanites aegyptiaca*, a spiny shrub or tree up to 10 m high, is a species with a wide ecological distribution across Africa. The fleshy pulp of both unripe and ripe fruit is eaten dried or fresh. The fruit is processed into drinks in West Africa and is used as a soup ingredient in East Africa. Young leaves and tender shoots are used as a vegetable, which are boiled, pounded and fried.

Kola nut *Cola nitida*, an under-storey evergreen tree that generally grows to 9 to 12 m tall, is native to lowland tropical forests in Central and West Africa. Nuts, which contain caffeine, kolatine and theobromine, are chewed as a stimulant. The nuts taste bitter when chewed at first but they leave a sweet taste in the mouth later. Chewing cola nuts before drinking water thus helps to render the water sweeter. The nut is widely used for social ceremonies.

Marula The long-lived tree *Sclerocarya birrea* has an extensive distribution across dryland savannah habitats in the sub-Sahara. The fruit pulp of *S. birrea* subsp. *caffra*, widely distributed in southern Africa, is used to produce jam, juice, beer and, in South Africa, the internationally available liqueur Amarula Cream, while the oily kernels are consumed raw, roasted and in sauces. In addition to current use, archaeological evidence indicates human harvesting of fruit extending back 10 000 years.

Njansang *Ricinodendron heudelotii*, a fast-growing tree reaching up to 50 m in height, is found primarily in Central and West Africa, often in secondary forest. A spicy sauce made from the kernels is widely used in stews, and the high oil content of the seeds makes them suitable for use in the soap industry. In Cameroon, it is also valued for its medicinal properties and is used to treat constipation, dysentery, eye infections and female sterility, and also as an antidote to poison.

Safou *Dacryodes edulis* is a medium-sized evergreen tree found in the humid tropical zone of Central and West Africa. It has been cultivated by farmers in southern Nigeria and Cameroon for many years, and is considered 'semi-domesticated' in some areas, based on planters' selective seed sampling. Widely sold in local markets, the highly nutritious fruits have an oily texture similar to avocado and are eaten boiled or roasted. The fruit pulp is rich in vitamins and amino acids.

Star apple *Chrysophyllum albidum*, a long-lived tree which grows to 35 m tall, is a canopy species of lowland mixed rainforest that is distributed from West Africa to western Kenya. The fleshy and juicy fruits are popularly eaten, and can be fermented and distilled for the production of wine and spirits.

Tamarind *Tamarindus indica*, a tree growing to 30 m tall, has an extensive distribution through much of the tropics, but is believed to have originated in Africa, where it is found across dryland savannah regions. The species was cultivated in Egypt as early as 400 BC. The fruit pulp is used to prepare juice and jam, and is an ingredient in curries, chutneys and sauces. The ripe fruits of 'sweet' types are eaten fresh as a snack.

Box 1 *Continued*

Wild loquat *Uapaca kirkiana*, a small- to medium-sized evergreen or semi-deciduous tree, is found in the miombo woodlands of southern Africa. The fruit of *U. kirkiana* is highly regarded and is eaten fresh as well as being used to prepare jams and beverages. Harvesting of fruit from wild stands is an important coping strategy during times of extreme hunger.

For further information on species see ICRAF's Agroforestree Database (AFTD), from which the majority of the above was taken (www.worldagroforestry.org/Sites/TreeDBS/aft.asp). The AFTD contains data on the use, ecology and management of more than 600 tree species planted by smallholders in the tropics.

Box 2 Current constraints to smallholder involvement in fruit production in sub-Saharan Africa

The lack of cultivars bred specifically for African smallholders There has been a lack of investment in the development of new fruit tree varieties – of high quality, with wider production seasons and highly marketable products – of both indigenous and exotic species that are specifically suited to African farmers' circumstances. In particular, the great potential for improvement of a wide range of IFTs, the 'Cinderella' species, has until the last 20 years been under-recognised, with most species being little researched to help guide cultivation and domestication.

The inability of farmers to access superior cultivars developed outside the region Many sub-Saharan African smallholders grow old varieties of exotic fruit trees that were introduced into the region over the last thousand years from Asia and elsewhere. Since introduction, breeding work in other continents has produced cultivars with higher yields and better quality characteristics, but planting material of these varieties has not reached small-scale African producers.

Use of poor farm management practices Smallholders in sub-Saharan Africa are frequently unaware of, or cannot afford to practice, the management methods that are needed to make fruit production more efficient and profitable. Better practices applied by small-scale farmers in other continents, for propagation, pest control, irrigation and harvesting, etc., have not yet reached them. In common with small-scale farming in the sub-continent generally, the possible role of the private sector in supplying products and services that could improve current practices has been under-valued.

Inadequate post harvest practices Smallholders and other small- and medium-scale enterprises often do not have access to the information and equipment they need for the proper storing, grading, packing, processing, preserving and transporting of fruit, which often has a short shelf life. As a result, wastage is high, the quality of product in the market is often low and sales are therefore limited.

Weak marketing systems Existing markets to deliver fruit to urban consumers are poorly structured and coordinated, resulting in high prices of fruit for consumers and low and unstable returns to farmers. From the producers' perspective, problems frequently cited include an absence of collective bargaining, lack of transparency, poor transport infrastructure, and the involvement of multiple value-robbing brokerage layers that reduce farm-gate prices. It is as a result of prevailing low produce prices that farmers struggle to afford inputs to improve their current sub-optimal management practices. Traders face many problems as well, including poor roads, corrupt officials and the costs of collecting produce from geographically scattered producers.

For discussion of the constraints listed here, see Leakey and Newton (1994), Poulton and Poole (2001), FAO (2004), Weinberger and Lumpkin (2007), Graudal and Lillesø (2007), Akinnifesi *et al*. (2008), Ham *et al*. (2008), Jordaan *et al*. (2008), Jamnadass *et al*. (2009), Tschirley *et al*. (2010).

greater progress towards their inclusion. By outlining appropriate interventions, our objective is that African smallholder producers and domestic consumers will benefit from greater and better directed government and commercial investment in the sector. Indigenous and exotic fruits both have a role to play and no 'ideological' attribution of value based on whether a fruit is of local or introduced origin should be made. Origin is however of importance when considering the different types of intervention that are needed for promotion. Below, we draw illustrations from relevant research carried out by the World Agroforestry Centre (ICRAF, www.worldagroforestry.org), its partners and other organisations over the last decades.

PROMOTING THE CULTIVATION OF INDIGENOUS FRUITS

Priority-setting for promotion

Since there is a very large range of IFTs that could potentially be cultivated, the first intervention is to decide on which species to focus attention. Guidelines for species priority-setting have been developed by ICRAF and partners that take into account the interests of local farmers, markets and consumers, as well as the knowledge of scientists (Franzel *et al*. 1996, Maghembe *et al*. 1998). Important factors for scientists to consider include the potential for rapid yield and/or

nutritional quality improvements and whether a species is easy to grow by smallholders (Franzel *et al*. 2008, Mng'omba *et al*. 2008). Priority-setting must also take into account the different interests of male and female producers and consumers, since gender is a key factor in determining which species, cultivars and products are deemed valuable (ICUC 2003). Using these guidelines, priority-setting exercises led by ICRAF have been undertaken at different times in over a dozen countries in sub-Saharan Africa; the same guidelines could, in principle, be applied in other nations in the region.

Typical results, for Cameroon, Kenya and Malawi, are given in Table 1, while more information on the priority IFTs identified is given in Box 1. Results for these three countries illustrate that some species have been found to be important in several nations; for example, baobab (*Adansonia digitata*), ber (*Ziziphus mauritiana*) and tamarind (*Tamarindus indica*) were priorities in both Kenya and Malawi. In other instances, favoured species were specific to a nation or sub-region due to climatic restrictions or traditional use. In the case of marula (*Sclerocarya birrea*), which is found throughout dry sub-Saharan Africa, the species was important in Kenya but not in Malawi, as only in the latter nation has the fruit been traditionally used in beverage production (Hall *et al*. 2002, Wynberg *et al*. 2003). Priorities not only vary between countries but also within them; for example, in Kenya exotic fruits are preferred in high rainfall areas, while indigenous fruits are more popular in low rainfall districts (Muok *et al*. 2001, Simitu *et al*. 2009). Based on priority-setting it is possible to determine if international trials are appropriate for identifying superior cultivars and/or management methods, or if local approaches, such as the participatory domestication method described below, are the best for cultivar development and delivery. Since producer and consumer preferences change with time, priority-setting needs to be repeated at regular intervals. It should seek out species that are likely to be priorities for long enough for promotion activities to deliver genuine impact in terms of improved livelihoods, etc., within an appropriate time frame (Franzel *et al*. 2008).

The participatory domestication approach

One way to undertake fruit tree breeding is to use a 'formal', centralised approach involving on-station field trials, controlled crosses and, in some cases, biotechnological breeding methods (Ray 2002). These techniques have been successfully applied to temperate fruits and a smaller number of popular, widely-grown tropical fruits such as avocado (*Persea americana*), orange (*Citrus sinensis*) and mango (*Mangifera indica*) (Samson 2003). A 'formal' strategy for breeding is relatively easy to coordinate and allows advanced methods to be applied to combine multiple important traits into single cultivars, but can be expensive, may not be able to reach farmers with improved germplasm and can become disconnected from growers' key requirements (Clement *et al*. 2008).

TABLE 1 *Ten fruit and nut trees identified through priority-setting exercises as targets for promotion in each of three African countries (Cameroon, Kenya and Malawi chosen as representative nations from Central, East and southern Africa, respectively). The same species may also be important in other nations*

	Fruits and nuts ranked highly for promotion (alphabetical order)		
Country	**Indigenous**	**Exotic**	**Methods used to set priorities**
Cameroon	• *Allanblackia* species • Bitter cola (*Garcinia kola*) • Bush mango (*Irvingia gabonensis*/*I. wombolu*) • Kolanut (*Cola nitida*) • Njansang (*Ricinodendron heudelotii*) • Safou (*Dacryodes edulis*) • Star apple (*Chrysophyllum albidum*)	• Avocado (*Persea americana*) • *Citrus* species (e.g., orange, *C. sinensis*) • Mango (*Mangifera indica*)	Participatory priority-setting exercises, household surveys, market value data, future market predictions
Kenya	• Baobab (*Adansonia digitata*) • Ber (*Ziziphus mauritiana*) • Desert date (*Balanites aegyptiaca*) • Tamarind (*Tamarindus indica*)	• Avocado (*Persea americana*) • *Citrus* species (e.g., orange, *C. sinensis*) • Macadamia nut (*Macadamia tetraphylla*) • Mango (*Mangifera indica*) • Papaya (*Carica papaya*) • Passion fruit (*Passiflora edulis*)	Horticultural Crops Development Authority market value data, indigenous species survey in drylands
Malawi	• Baobab (*Adansonia digitata*) • Ber (*Ziziphus mauritiana*) • Marula (*Sclerocarya birrea*) • Tamarind (*Tamarindus indica*) • Wild loquat (*Uapaca kirkiana*)	• Avocado (*Persea americana*) • *Citrus* species (e.g., orange, *C. sinensis*) • Macadamia nut (*Macadamia tetraphylla*) • Mango (*Mangifera indica*) • Papaya (*Carica papaya*)	Participatory priority-setting exercises of smallholders and markets, household surveys, future market predictions

For further information on priority-setting exercises, see Maghembe *et al*. (1998), Muok *et al*. (2001), Franzel *et al*. (2008) and Faulkner *et al*. (2009). Information on the IFTs listed here is given in Box 1.

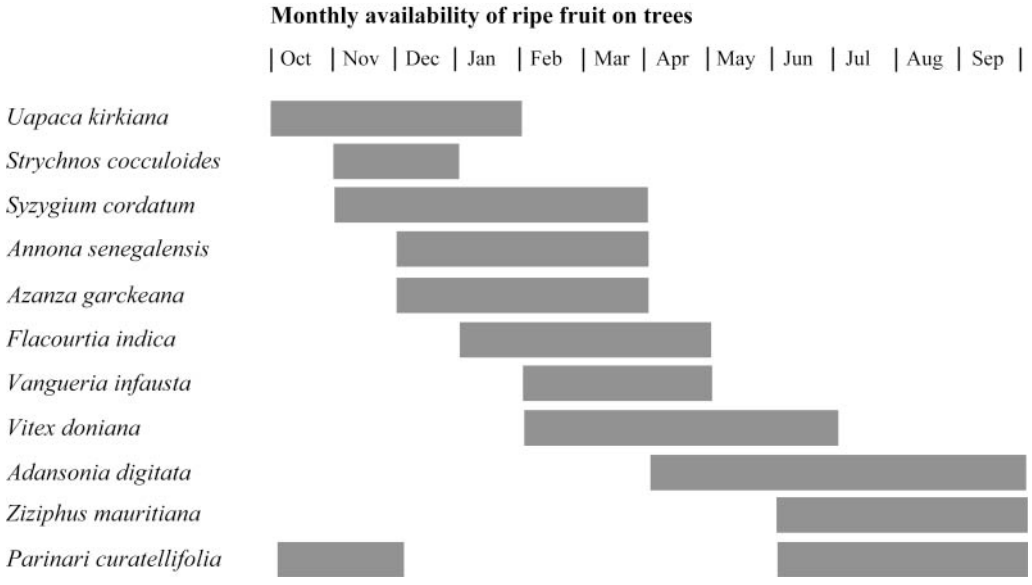
Alternatively, a decentralised, participatory strategy can be employed that involves local people and builds on their existing knowledge on fruit tree use and cultivation (Tchoundjeu *et al*. 2006, Miller and Nair 2006, Asaah *et al*. 2011). The participatory domestication approach, as developed by ICRAF and partners, involves combining communities' traditional knowledge with scientific advances in germplasm collection, selection and vegetative propagation. Farmers are trained in appropriate techniques for handling germplasm and are then encouraged to apply newly-acquired skills to the fruit trees that they find growing naturally in the landscapes they inhabit (Leakey *et al*. 2005). At some locations, then, farmers are being updated in methods of management that they have already been practising sub-optimally; at other sites, the concept of participating in domestication activities may be completely novel (Leakey *et al*. 2003).

Key advantages of the participatory approach are that it empowers communities to manage local resources themselves and promotes greater and more rapid adoption (Degrande *et al*. 2006a, Lombard and Leakey 2010, Tchoundjeu *et al*. 2010). Furthermore, it provides farmers with the strategic skills they need to domesticate a range of different species and therefore supports diversification that buffers production and market risks (Tchoundjeu *et al*. 2010). If the diverse species (or cultivars within a species) being domesticated have different ripening times – see Fig. 1 for an example of a fruit tree 'portfolio' containing species that fruit in different months – this helps to provide nutrients across the year, including during times when hidden hunger is most prevalent (Dawson *et al*. 2007). Spreading the time period of production also allows for the more efficient use of labour during harvesting and of equipment for processing (Axtell and Fellows 2008).

The relevance of the participatory domestication approach has been researched in southern (Akinnifesi *et al*. 2006, 2008) and dry zone West Africa (Kalinganire *et al*. 2008, Jensen *et al*. 2011) over the last decade, but the method has been most intensively applied in the humid forest margins of Central Africa where IFTs are highly valued in the local economy, as described in more detail elsewhere (Leakey *et al*. 2005, 2007, Tchoundjeu *et al*. 2006, 2008, Box 1 lists some of the species involved). The participatory approach has been used in Central Africa where farmers can still gain relatively easy access to populations of high value tree species that interest them; where such stands are harder to access, for example, due to extensive deforestation and agricultural intensification, the method is clearly less appropriate. In this second situation, a more formal approach based on the introduction of germplasm from outside is obviously required.

Significant success of the participatory domestication approach has been achieved through the 'Food for Progress' project in Cameroon. A recent survey there (Tchoundjeu *et al*. 2010) demonstrated that smallholders achieved increased incomes from the sale of fruits from locally selected, clonally propagated cultivars and from selling nursery stock of selected trees to other growers. Around 50% of local adopters included more indigenous fruit in their own diets, having a direct impact on their own nutrition, whilst participatory domestication also contributed to a reduction in human migration from rural to urban areas. Again indicating success, Tadjo (2008) found that tree nurseries in Cameroon that had received support from the participatory tree domestication initiative supplied a wider range of fruit trees, propagated in more appropriate ways, and with higher purchaser satisfaction, than those nurseries that had not received assistance. Asaah *et al*. (2011) determined that Cameroonian tree nurseries applying participatory domestication methods were transforming farmers' lives and generating thousands of US Dollars annually (income depending on nursery size). The

FIGURE 1 *A fruit tree 'portfolio' consisting of species fruiting at different times of the year. The example given here is based on underutilised fruits found in southern Africa (FA, personal observations)*



propagation methods being taught as part of the participatory domestication approach for IFTs were also being applied to exotic fruits.

In order to further promote the participatory domestication approach in Central Africa, rural resource centres (RRCs) managed by local communities are now being established (Tchoundjeu *et al*. 2010). These centres train farmers in how to collect and propagate germplasm, host small field trials to demonstrate effective horticultural methods, hold stockplants of selected trees for vegetative multiplication, and link with satellite nurseries to provide germplasm and knowledge at a wider range of locations. Centres also provide processing facilities, business training, and act as venues for farmers, wholesalers and service providers (e.g., of fertiliser, credit) to meet, so that they can share market information and undertake transactions (Asaah *et al*. 2011). Trials established at RRCs will in future allow communities to gather the data they need to gain Plant Breeders Rights over their best cultivars, an important issue if these types are to be more widely disseminated or adopted in 'formal' improvement programmes (Lombard and Leakey 2010). The RRC approach, integrating participatory tree domestication with a broader set of services, is recognised as an important example of multifunctional agricultural development in the tropics (Leakey 2010), and as such was awarded an Equator Prize for livelihood improvement and biodiversity conservation in 2010 (www.equatorinitiative.org/).

Yield and quality improvements through vegetative propagation and selection

The time taken between planting and fruiting is a key factor determining the profitability of fruit tree planting and farmers' interest in it (Waibel *et al*. 2005). To realise early yields, the participatory domestication approach has applied vegetative techniques for propagation (Leakey 2004) that result in accelerated fruit production compared to tree establishment from seed. In this way, for example, the period between planting and first fruiting of baobab can be reduced from more than 10 years to around 4 years, in safou (*Dacryodes edulis*) from 5 to 2 years, in sheanut (*Vitellaria paradoxa*) from 20 to 5 years or less, and in wild loquat (*Uapaca kirkiana*) from 12 to 4 years (Sidibe and Williams 2002, Sanou *et al*. 2004, Leakey and Akinnifesi 2008). Another advantage of vegetative propagation is that the material collected is a clone of the mother tree and it is therefore easier to capture genetic gain through selection when compared to sampling by seed, where the paternal parent of the progeny is unknown when a species is outbreeding, as are most trees (Petit and Hampe 2006, Leakey and Akinnifesi 2008). Vegetative propagation also allows female, fruit-bearing trees to be cloned specifically for species such as *Allanblackia* and safou that are dioecious and thus have separate male and female plants (Jamnadass *et al*. 2010).

The most common approaches promoted for vegetative propagation have been the rooting of leafy stem cuttings, grafting and air layering. Rooting of leafy stem cuttings is practiced in non-mist propagators that communities can build for themselves based on a simple design (Leakey *et al*. 1990). In addition, micropropagation protocols for rapid multiplication have been devised for a few IFTs, though it is not yet clear how such micro-propagules can be delivered to growers for planting, as the technology required to generate clones goes beyond what can be handled directly by farmers (Mng'omba *et al*. 2007a, b). Although vegetative propagation has many attractive features, the collection of too few clones and/or too narrow a genetic base could result in losses in performance through inbreeding depression that leads to low fruit set (Leakey and Akinnifesi 2008). In the worst case situation, multiplication of only a single clone may lead to no fruit being produced if the tree is an obligate outbreeder and can therefore reproduce only through mating with a genetically different individual. The possibility for inbreeding amongst clonally propagated individuals can be minimised by maintaining wide sampling of source plants and supporting pollinator presence (Dawson *et al*. 2009b). Another issue is that the level of acceleration in fruiting of vegetative propagules depends on the level of ontogenetic maturity. This is determined by the origin of the scion, marcot or cutting within the tree crown/stockplant, which also affects the level of success of propagation (Leakey, 2004). This determines the approach to multiplication that should be employed; research to optimise methodology may be needed on a species-by-species basis.

An essential part of the participatory domestication approach is to deliver quality and yield improvements through the selection of superior germplasm with the right combinations of traits. Developing effective selection strategies requires understanding how genetic variation is structured within and between fruit tree populations through phenotypic observations and other methods for characterisation such as molecular genotyping (Jamnadass *et al*. 2009). Ideally, species should have high genetic diversity at a local geographic scale, providing farmers with the opportunity to select superior 'ideotypes' (Leakey and Page 2006, Jamnadass *et al*. 2009). Determining the proportion of genetic variation within an IFT that occurs within local stands is therefore an important topic for research: if high for important characteristics, a participatory strategy is appropriate; if low, a more centralised breeding approach, in which varieties are developed outside the local area and some method is then found to bring them to farmers, may be better.

Evidence collected from a range of African fruit trees shows that large variation in yield, fruit size, shape and composition, among other important characteristics, is found within natural stands and farmers' existing populations, which is very encouraging for the participatory approach. For example, in *Allanblackia*, a more than four-fold difference in average seed yield per fruit has been observed between trees within natural stands (Peprah *et al*. 2009), a difference mirrored by high molecular genetic variation (Atangana *et al*. 2009, Russell *et al*. 2009) and the different fatty acid profiles found within populations (Atangana *et al*. 2011). Similarly, in safou, it is estimated that local selection from within natural and/or farmers' stands could result in a five-fold increase in the economic value of material (Waruhiu *et al*. 2004). Again, greater than two-fold variation between trees in the vitamin C

content of fruit pulp has been observed in natural populations of marula (Thiongo and Jaenicke 2000), which accords with the high molecular genetic variation also noted in populations (Kadu *et al*. 2006).

The targeted sampling of superior phenotypes during participatory domestication will, however, only be effective for characters of medium to high heritability, because of the environmental heterogeneity of collection sites (White *et al*. 2007). Research suggests that heritability in characters such as fruit yield and quality may be reasonably high compared to other tree traits (Ræbild *et al*. 2011 and references therein, although see Atangana *et al*. 2011). That this is the case for particular species can however only be confirmed through controlled field trials in which different selections are brought together into a uniform environment. Even using the participatory domestication approach, therefore, a degree of centralised activity to compare genotypes, as one might do when undertaking 'formal' breeding, is necessary to understand the potential genetic gains that are achievable through farmer selection (Cornelius *et al*. 2006, Weber *et al*. 2009). Such studies are required on a wide range of IFTs (Ræbild *et al*. 2011), possibly based at RRCs. More research is also needed on within-population genetic variation in the chemical composition of different fruits (Leakey 1999).

EXOTIC FRUITS TO COMPLEMENT THE CULTIVATION OF INDIGENOUS SPECIES

The 'south-south' transfer of cultivars

During exercises to determine which IFTs are the farmers' priorities, exotics such as avocado, mango and orange are often also mentioned (Table 1). Often, these exotics were introduced into Africa many centuries ago. For example, mango and banana from Asia were already present in the sub-Sahara in the 14th Century according to the Arabian traveller Ibn Battuta (Vinceti *et al*. 2009). Farmers often now think of these species as indigenous. Many of the cultivars now grown by African smallholders are derived from these ancient introductions, but they do not perform well when compared to more modern cultivars developed elsewhere. For example, various local mango varieties in Kenya are considered stringy in texture and are not well matched to current consumer preferences (FAO 2004, Kehlenbeck *et al*. 2010).

To revitalise sub-Saharan smallholder production of these long-present species, two approaches are possible. The first is to breed new cultivars within the sub-Sahara based on the existing 'landrace' gene pool, while the second is to renew 'south-south' linkages to bring in superior cultivars developed outside the region. Taking advantage of new cultivars developed elsewhere is likely to be the more cost effective approach because local landraces in Africa may be based on a very narrow genetic base with limited potential for gain, and there seems little benefit in duplicating breeding efforts already undertaken in other locations (Ray 2002, Samson 2003). However, the 'transfer' approach requires that introduced material be compared with existing local cultivars under African conditions, so that the level of potential gain in yield and/or quality is quantified. A recent example of the success of south-south transfer has been the introduction of new varieties of ber from Asia into Sahelian countries (Danthu *et al*. 2004). In this case, the species is in fact indigenous to both the sub-Sahara and Asia, but varieties developed in Asia perform significantly better when introduced and tested against local types in West Africa (Kalinganire *et al*. 2008, Ræbild *et al*. 2011). There is also great potential for renewed transfers of fruits such as guava (*Psidium guajava*), tamarind, pomegranate (*Punica granatum*), papaya (*Carica papaya*), custard apple (*Annona squamosa*) and jackfruit (*Artocarpus heterophyllus*) (www.fao.org/hortivar/index.jsp).

Undertaking the international exchange of planting material is however complicated by a lack of effective coordination amongst relevant legislations, such as the Convention on Biological Diversity (CBD), Plant Breeders Rights and phytosanitary import requirements. Although current rules that control transfers were devised with the best of intentions (e.g., to protect the rights of those that have domesticated the species), their net effect has in recent decades been to significantly restrict exchange that could benefit farmers and consumers more widely. At the same time, a situation in which unregulated germplasm exchange out of Africa resulted in the cultivation of African indigenous fruits in other continents and the out-competition of African smallholders is clearly not desirable, such as happened in the past with oil palm, *Elaeis guineensis* (Simons and Leakey 2004). The harmonisation of regulations to remove unintended hindrances while providing the right level of protection is therefore crucial (Gepts 2004, Koskela *et al*. 2009). Members of the Consultative Group on International Agricultural Research, of which ICRAF is one, may have an important role to play in facilitating harmonisation and transfer.

Supporting small-scale commercial suppliers of planting material

Once superior exotic fruit cultivars have been introduced into Africa, they need to be delivered to smallholders to plant them, along with the new management methods needed to assure maximum performance. These apparently simple steps require greatly improved national-level tree germplasm delivery systems (Dawson *et al*. 2009b). The problem is that national-level suppliers, such as tree seed centres and horticultural research institutes, are unable to reach smallholders because of the high costs involved in dealing with widely dispersed clients that each requires only a small number of individuals of a particular tree species (Graudal and Lillesø 2007). This difficulty in access is one reason (amongst others described above) why the participatory domestication approach has been favoured when promoting indigenous fruit cultivation, as germplasm delivery to farmers is assured by their being directly involved in genetic improvement; in the case of exotic cultivars developed internationally, an alternative approach to farmer delivery is clearly required (Koskela *et al*. 2009).

Graudal and Lillesø (2007) have suggested that small-scale, decentralised, private nursery operators with low investment overheads provide the best basis for ensuring

reach and sustainability in delivering healthy plants of new exotic fruit tree cultivars to farmers (see also Muriuki 2005). These entrepreneurs are currently being supported through training in successful propagation methods and business management, and through the provision of 'starter' germplasm for stockplant blocks. Greater support is however required to introduce new policies to discourage the common NGO practice of providing subsidised tree planting material to farmers, since this discourages the involvement of small-scale entrepreneurial suppliers (Brandi *et al*. 2007).

Lessons on what type of support to these entrepreneurs is likely to work best can be gleaned from the crop sector, which is generally more advanced (Graudal and Lillesø 2007, Lillesø *et al*. 2011). Innovations there are being tested in the Programme for Africa's Seed Systems (PASS, www.agra-alliance.org/section/work/seeds), the Vegetable Breeding and Seed Systems programme (vBSS, www.avrdc.org) and in other initiatives. PASS is concerned with broadening smallholder access to a range of agricultural inputs including improved staple crop seed, while vBSS involves supporting small African seed companies to supply new indigenous and exotic vegetable cultivars. Possibly, the delivery of tree germplasm can be made to 'piggyback' on crop seed delivery (Nathan *et al*. 2005). At some level, linkages also need to be established between the RRCs designed to promote the participatory domestication of IFTs (see above) and the delivery systems for exotic fruit trees, in a manner that supports the livelihoods of the people involved in both; this remains an important topic for research.

EXPANDING AND IMPROVING MARKETS AND MARKETING SYSTEMS FOR INDIGENOUS AND EXOTIC FRUITS

Market supply and demand

The recommended daily consumption of fruit and vegetables is a minimum of 400 g per person (World Health Organization [WHO] guidelines) but in sub-Saharan Africa it is significantly lower (Ruel *et al*. 2005, FAOSTAT at www.fao.org). Figures for fruit consumption in a range of countries in the region illustrate this (Table 2): in East Africa, for example, mean consumption is only 35g per person per day, one of the lowest levels in the world. One reason why current consumption is so low is that households with limited incomes focus on purchasing staples that provide relatively cheap and 'concentrated' sources of carbohydrate to meet basic energy needs, leaving only a small fraction of the family budget to spend on other foods such as fruit and vegetables (Ruel *et al*. 2005).

Domestic markets for fruit are, however, predicted to grow rapidly in the next two decades in sub-Saharan Africa as economies grow and provide local consumers more income to spend on fruit, and as human populations increase and a trend to urbanisation continues (IMF 2008, Bill and Melinda Gates Foundation, personal communication). This raises the issue of how much extra fruit in total needs to be consumed within African nations to meet WHO guidelines. Calculations show that, for example, more than a million tonnes annually would be required in each of Ethiopia, Ghana, Kenya, Mozambique, Tanzania and Uganda (Table 2). This provides some indication of the potential incomes for farmers, in the order of hundreds of millions of US Dollars annually, in supplying domestic markets in the future, if fruit can be produced and delivered to consumers more effectively.

A particular opportunity to develop domestic markets and influence child nutrition involves consideration of 'home grown school feeding' (HGSF). Traditionally, school feeding programmes in food-insecure areas of the sub-Sahara have relied on foods of limited nutritional quality and variety that have often been sourced from outside the region (Bundy *et al*. 2009, WFP 2009). In contrast, HGSF initiatives seek to link schools with local agricultural producers to promote a more diverse, nutritionally-balanced range of foods (WFP 2008). These programmes are currently in the pilot stage, with the New Partnership for Africa's Development (NEPAD) and the World Food Programme inviting twelve countries[1] to test implementation, but political support for HGSF is expected to grow in future years (WFP 2009). Another notable opportunity is to supply the rapidly developing supermarket sector in sub-Saharan Africa, although these retailers may favour linkages with medium- or large-scale farmers rather than smallholders, in order to operate greater control over the supply chain (Neven and Reardon 2004).

Export markets for smallholders' produce should also not be neglected, though these are currently much smaller in volume and value than local sales (Table 2, www.worldmapper.org). For example, mango exports are around 4% of total production only for sub-Saharan African countries for which data are available[2] (FAO 2005b), the rest of the crop being consumed locally. South Africa, where the export value of exotic fruits exceeds domestic markets (~ 65% of revenues from export, South Africa Agricultural Research Council figures for 2005), is an exception. It is unlikely that other nations will be able to replicate South Africa's success that is based on good infrastructure and large commercial fruit production enterprises rather than smallholders. Niche markets have developed, however, for various indigenous fruits among expatriate African communities and these could be more widely promoted to benefit small producers (Awono *et al*. 2002). In addition, new markets for indigenous fruits may develop as consumers in high-income nations experiment with new tastes. Entering these markets, however, requires that non-tariff barriers to trade, such as the European Union (EU) Novel Foods Regulation (which requires costly safety checks on 'new' foods) and importing countries' stringent phytosanitary requirements for fresh fruits, be addressed (Hermann 2009, www.phytotradeafrica.com).

[1] Angola, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Senegal, Uganda and Zambia.
[2] Average figures for Cote d'Ivoire, Kenya, Mali and Sudan, for the years 1996 to 2004 inclusive.

TABLE 2 *Characteristics of domestic consumption and international fruit markets for 10 countries in sub-Saharan Africa*

Country	Average domestic fruit consumption (g/person/day)*	Average % family food budget spent on fruit*	Human population (millions)[φ]	Annual national deficit in fruit consumption (thousands of tonnes)[$]	Average annual value of the fruit export market (thousands of US Dollars)[^]	Average annual percentage of all exports[^]
Burundi	41	1.8	8.2	476	12	< 0.1
Ethiopia	4	0.4	81.0	5 795	2 049	0.3
Ghana	64	2.1	23.0	1 142	116 654	2.9
Guinea	103	3.7	9.2	326	3 012	0.3
Kenya	71	1.9	36.6	1 723	41 179	1.5
Malawi	30	1.9	13.6	844	7 697	1.6
Mozambique	23	1.2	21.0	1 357	24 998	1.7
Rwanda	41	4.2	9.5	551	73	< 0.1
Tanzania	55	2.5	39.5	2 091	53 411	4.2
Uganda	34	1.1	29.9	1 812	1 305	0.2

* Data taken from Ruel *et al*. (2005) and based on home production, local collection, purchase and barter. According to Food and Agriculture Organization figures (for 2004, FAOSTAT at www.fao.org), average consumption worldwide is ~ 130 g/person/day, 210 g/person/day in developed countries and 110 g/person/day in developing countries. Africa has the lowest consumption of any continent, with East Africans for example consuming on average only ~ 35 g/person/day.

[φ] United Nations Statistics Division's estimates for 2006 (http://unstats.un.org/unsd/).

[$] Implied deficit based on average domestic fruit consumption/person and total population, and assuming that half of the World Health Organization's recommended intake of fruit and vegetables of 400g/person/day is met by eating fruit.

[^] Information taken from the trade performance statistics of the International Trade Centre (www.intracen.org/). Shown is the average annual value of the export market for the years 2002 to 2006 inclusive for edible fruit, nuts, peel of citrus fruit and melons (for most countries the majority represents fresh fruit). Data are likely to be underestimates because informal flows within regions (markets between neighbouring countries) are difficult to account for; nevertheless, the total value of exports is low. Also given for the same period is the average annual value of the market as a percentage of all exports. Over the same period, the equivalent average annual export value for South Africa was approximately 1 billion US Dollars, which represented around 2.5% of all exports from that nation.

Improving value chains to bring greater benefits to producers

Smallholder fruit producers have traditionally been 'price takers' rather than 'price makers' in markets (Ham *et al*., 2008, Jordaan *et al*. 2008). Value chain analysis, which seeks to characterise the processes by which products are brought from production to consumption (*via* harvesting, processing, storage, transport, marketing, etc.) and understand how value is created, has been carried out to identify and overcome bottlenecks in delivery (KIT *et al*. 2006). In Cameroon, for example, value chain analysis indicated important areas for intervention in the njansang (*Ricinodendron heudelotii*) nut market (Tchoundjeu *et al*. 2008). Key issues were the need for better harvest and post-harvest techniques to improve product quality based on market requirements, the need for storage facilities to allow sales to be scheduled to avoid market gluts, the need to strengthen farmers' producer groups to allow direct negotiations with wholesalers, and the need to introduce market information and credit facilities (Facheux *et al*. 2007). Support in these areas resulted in farmers receiving a 31% increase in price for njansang kernels.

TechnoServe (www.technoserve.org) undertook a similar approach to that applied to njansang to analyse the banana market in Kenya and Uganda, where multiple brokerage levels were found to deprive farmers of significant revenues (Milder 2008). Based on this analysis, smallholders were organised into producer business groups (PBGs) linked directly to wholesale banana buyers, which resulted in farmers' incomes rising by over 80% during the project. By 2008, more than 7 000 farmers had been trained to participate in more than 145 PBGs that used text messaging to exchange market information. As a result of the project, participating farmers have become increasingly interested in producing fruit of other species that can also be sold to the same wholesalers (Milder 2008). TechnoServe is applying the lessons from this project to a new initiative to link smallholder producers of mango and passion fruit (*Passiflora edulis*) in Kenya and Uganda to Coca-Cola's supply chain for locally-processed and consumed juices (substituting for imported fruit juice concentrate). Greater application of these lessons is required in other countries and on other fruit value chains to bring smallholders more effectively into markets.

FINAL REMARKS

Significant gaps in knowledge on the productivity, market value, net returns and other features of smallholder fruit production and markets in sub-Saharan Africa need to be filled to properly guide future investments by private enterprise, governments and development donors (Leakey *et al*. 2005, Schreckenberg *et al*. 2006, Akinnifesi *et al*. 2008). According to the Agricultural Science and Technology Indicators website, public research capacity on fruit promotion (breeding, horticulture, nutrition, pomology, value chain development, processing, market monitoring, etc.) in sub-Saharan Africa is low compared to other regions in the tropics, with only a fifth as many scientists engaged in research per unit area of production as in Asia (www.asti.cgiar.org). This deficit in human capacity must be addressed to continue developing appropriate solutions to current constraints. There is, for example, a need to understand how best to educate consumers on the benefits of eating fruit, and how to respond to the opportunities and challenges presented by climate change. In the first case, it is well known that children can be effective agents of change in societies and teaching them about agriculture and nutrition is considered a wise investment (Sherman 2003). In Kenya, for example, the Education for Sustainable Development initiative includes a Healthy Learning programme aimed at school children that is resulting in attitudinal and behavioural changes in communities (Vandenbosch *et al*. 2009). The effectiveness of such initiatives for fruit promotion in Kenya and elsewhere needs to be explored.

In the case of anthropogenic global warming, tree growth can be more resilient to climate change than annual crop growth (Dawson *et al*. 2011). However, for many fruits, pollination is dependent on specific environmental conditions and on animal vectors that may be adversely affected by change (Bazzaz 1998, FAO 2008, Jamnadass *et al*. 2009). It is important to match both tree and pollinator to newly prevailing environments resulting from climate change at specific locations. To do so involves mathematical modelling based on current species distributions and the predictions of future temperature and rainfall profiles (Kindt *et al*. 2008, Dawson *et al*. 2011). The starting point – information on the ecogeographic range over which species currently grow – is, however, often lacking for indigenous fruits (www.lifemapper.org). This deficiency is currently being addressed through the creation of detailed vegetation maps for Africa; these will become available for Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia later in 2011 (en.sl.life.ku.dk/upload/forestday3.pdf). Multilocational field trials that compare the performance of a range of populations/cultivars across different ecological zones are also required to determine the relative roles of germplasm transfer and local adaptation as strategies for agroforestry production to respond to climate change (Dawson *et al*. 2011).

In conclusion, we recommend that, in the future, particular attention be given to the following eight points:

- Fruit tree portfolios of indigenous and exotic species that spread farmers' production risks and can provide nutrients to consumers year-round should be devised and promoted across sub-Saharan Africa. To do so, more information is required on species distributions, the priorities of farmers and consumers, genetic variability, fruiting phenology and nutritional composition.
- The expansion of rural resource centres as training, communication and infrastructure hubs for implementing both production and market activities for indigenous fruit trees should be accelerated, scaling up the successful model of the 'Food for Progress' project in Cameroon. The boundaries (under what conditions and involving what partners?) for the successful operation of these centres need to be established.
- Methods are required for applying intellectual property protection to farmer-derived indigenous fruit tree cultivars, in order to ensure farmers benefit from the wider distribution of the varieties they develop. Ensuring tree domestication issues are included in the pan-African intellectual property agenda, for resolution within global plant variety rights negotiations, is an important requirement.
- An improvement in yield and quality of exotic fruit trees already grown in the sub-Sahara region is required. This involves the introduction of improved varieties, farm management methods and processing approaches from Asia in particular. Liaising with breeders and regulatory authorities in China, India and Sri Lanka will be essential for bringing in new cultivars and methods.
- Greater emphasis should be placed on developing commercial, decentralised methods for delivering exotic fruit tree planting material to African smallholders, rather than relying on existing 'formal' suppliers that do not have adequate reach. Lessons on what works best from ongoing research on crop germplasm delivery to farmers need to be adapted and applied to fruit trees.
- The opportunities presented by home grown school feeding programmes and initiatives to educate school children in the importance of nutrition should receive more attention. Education should include the role of fruit in improving diet, methods for preparation and consumption, and appropriate agroforestry practices for growing fruit and other products and services.
- Constraints to market development for both indigenous and exotic fruits should be identified and overcome by promoting wider adoption of the value chain approach to analysis.
- The likely impacts of climate change on indigenous and exotic fruit production should be explored in greater detail so that appropriate species, cultivars and farm management methods can be adopted to increase resilience and adapt to change.

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REFERENCES

AKINNIFESI, F.K., AJAYI, O.C., SILESHI, G., MATAKALA, P., KWESIGA, F.R., HAM, C., KADZERE, I., MHANGO, J., MNG'OMBA, S.A., CHILANGA, T. and MKONDA, A. 2008. Creating opportunities for domesticating and commercializing indigenous fruit trees in southern Africa. In: AKINNIFESI, F.K., LEAKEY, R. R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 137–170.

AKINNIFESI, F.K., KWESIGA, F., MHANGO, J., CHILANGA, T., MKONDA, A., KADU, C.A.C., KADZERE, I., MITHÖFER, D., SAKA, J.D.K., SILESHI, G., RAMADHANI, T. and DHLIWAYO, P. 2006. Towards the development of miombo fruit trees as commercial tree crops in southern Africa. *Forests, Trees and Livelihoods* **16**: 103–121.

AKINNIFESI, F.K., SILESHI, G.W., AJAYI, O.C., AKINNIFESI, A.I., DE MOURA, E.G., LINHARES, J.F.P. and RODRIGUES, I. 2010. Biodiversity of urban homegardens of Sao Luis city, northeastern Brazil. *Urban Ecosystem* **13**: 129–146.

ASAAH, E.K., TCHOUNDJEU, Z., LEAKEY, R.R.B., TAKOUSTING, B., NJONG, J. and EDANG, I. 2011. Trees, agroforestry and multifunctional agriculture in Cameroon. *International Journal of Agricultural Sustainability* **9**: 110–119.

ATANGANA, A.R., BEAULIEU, J. and KHASA, D.P. 2009. Wild genetic diversity preservation in a small-sized first generation breeding population of *Allanblackia floribunda* (Clusiaceae). *Tree Genetics and Genomes* **6**: 127–136.

ATANGANA, A.R., VAN DER VLIS, E., KHASA, D.P., VAN HOUTEN, D., BEAULIEU, J. and HENDRICKX, H. 2011. Tree-to-tree variation in stearic and oleic acid content in seed fat from *Allanblackia floribunda* from wild stands: potential for tree breeding. *Food Chemistry* **126**: 1579–1585.

AWONO, A., NDOYE, O., SCHRECKENBERG, K., TABUNA, H., ISSERI, F. and TEMPLE, L. 2002. Production and marketing of safou (*Dacryodes edulis*) in Cameroon and internationally: market development issues. *Forests, Trees and Livelihoods* **12**: 125–147.

AXTELL, B. and FELLOWS, P.J. (eds.). 2008. *Opportunities in fruit and vegetable processing*. Opportunities in food processing series. The African, Caribbean and Pacific-European Union (ACP-EU) Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands.

BAZZAZ, F.A. 1998. Tropical forests in a future climate: changes in biological diversity and impact on the global carbon cycle. *Climate Change* **39**: 317–336.

BHUTTA, Z.A., AHMED, T., BLACK, R.E., COUSENS, S., DEWEY, K., GUIGLIANI, E., HAIDER, B.A., KIRKWOOD, B., MORRIS, S.S., SACHDEV, H.P.S. and SHEKAR, M. 2008. What works? Interventions for maternal and child under-nutrition and survival. *The Lancet* **371**: 417–440.

BLACK, R.E., ALLEN, L.H., BHUTTA, Z.A., CAULFIELD, L.E., DE ONIS, M., EZZATI, M., MATHERS, C. and RIVERA, J. 2008. Maternal and child under-nutrition: global and regional exposures and health consequences. *The Lancet* **371**: 243–260.

BRANDI, E., LILLESØ, J.-P.B., MOESTRUP, S. and KISERA, H.K. 2007. *Do organisations provide quality seed to smallholders? - A study on tree planting in Uganda, by NGOs and CBOs*. Working Paper No. 8-2007, Development and Environment, Forest and Landscape Denmark, Hørsholm, Denmark.

BRYCE, J., COITINHO, D., DARNTON-HILL, I., PELLETIER, D. and PINSTRUP-ANDERSEN, P. 2008. Maternal and child under-nutrition: effective action at national level. *The Lancet* **371**: 510–526.

BUNDY, D., BURBANO, C., GROSH, M.E., GELLI, A., JUKE, M. and DRAKE, L. 2009. *Rethinking school feeding: social safety nets, child development, and the education sector*. The World Bank, Washington DC, USA.

CLEMENT, C.R., CORNELIUS, J.P., PINEDO-PANDURO, M.H. and YUYAMA, K. 2008. Native fruit tree improvement in Amazonia: an overview. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 100–119.

CORNELIUS, J.P., CLEMENT, C.R., WEBER, J.C., SOTELO-MONTES, C., VAN LEEUWEN, J., UGARTE-GUERRA, L.J., RICSE-TEMBLADERA, A. and AREVALO-LOPEZ, L. 2006. The trade-off between genetic gain and conservation in a participatory improvement programme: the case of peach palm (*Bactris gasipaes* Kunth). *Forests, Trees and Livelihoods* **16**: 17–34.

COSTELLO, A., ABBAS, M., ALLEN, A., BALL, S., BELL, S., BELLAMY, R., FRIEL, S., GROCE, N., JOHNSON,

A., KETT, M., LEE, M., LEVY, C., MASLIN, M., MCCOY, D., MCGUIRE, B., MONTGOMERY, H., NAPIER, D., PAGEL, C., PATEL, J., DE OLIVEIRA, J.A.P., REDCLIFT, N., REES, H., ROGGER, D., SCOTT, J., STEPHENSON, J., TWIGG, J., WOLFF, J. and PATTERSON, C. 2009. Managing the health effects of climate change. The Lancet Commissions. *The Lancet* **373**: 1693–1733.

DANTHU, P., TOURÉ, M.A., SOLOVIEV, P. and SAGNA, P. 2004. Vegetative propagation of *Ziziphus mauritiana* var. Gola by micrografting and its potential for dissemination in the Sahelian zone. *Agroforestry Systems* 60: 247–253.

DAWSON, I.K., GUARINO, L. and JAENICKE, H. 2007. *Underutilised plant species: impacts of promotion on biodiversity*. International Centre for Underutilised Crops Position Paper No. 2. International Centre for Underutilised Crops, Colombo, Sri Lanka.

DAWSON, I.K., HEDLEY, P., GUARINO, L. and JAENICKE, H. 2009a. Does biotechnology have a role in the promotion of underutilised crops? *Food Policy* **34**: 319–328.

DAWSON, I.K., LENGKEEK, A., WEBER, J.C. and JAMNADASS, R. 2009b. Managing genetic variation in tropical trees: linking knowledge with action in agroforestry ecosystems for improved conservation and enhanced livelihoods. *Biodiversity and Conservation* **18**: 969–986.

DAWSON, I.K., VINCETI, B., WEBER, J.C., NEUFELDT, H., RUSSELL, J., LENGKEEK, A.G., KALINGANIRE, A., KINDT, R., LILLESØ, J.-P.B., ROSHETKO, J. and JAMNADASS, R. 2011. Climate change and tree genetic resource management: maintaining and enhancing the productivity and value of smallholder tropical agroforestry landscapes. A review. *Agroforestry Systems* **81**: 67–78.

DEGRANDE, A., FACHEUX, C., MFOUMOU, C., MBILE, P., TCHOUNDJEU, Z. and ASAAH E. 2006a. Feasibility of farmer-managed vegetative propagation nurseries in the Cameroon. *Forests, Trees and Livelihoods* **16**: 181–190.

DEGRANDE, A., SCHRECKENBERG, K., MBOSSO, C., ANEGBEH, P., OKAFOR, V. and KANMEGNE J. 2006b. Farmers' fruit tree-growing strategies in the humid forest zone of Cameroon and Nigeria. *Agroforestry Systems* **67**: 159–175.

FACHEUX, C., TCHOUNDJEU, Z., FOUNDJEM-TITA, D., DEGRANDE, A. and MBOSSO, C. 2007. Optimizing the production and marketing of NTFPs. *African Crop Science Conference Proceedings* **8**: 1249–1254.

FAO. 2004. *Value chain analysis: a case study of mangoes in Kenya*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2005a. *The state of food insecurity in the world*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2005b. *Tropical fruits compendium*. Commodities and Trade Division, Food and Agriculture Organization of the United Nations, Rome, Italy. Available at www.fao.org/es/esc/common/ecg/218/en/partcomp_2005.pdf

FAO. 2008. *Rapid assessment of pollinators' status: a contribution to the International Initiative for the Conservation and Sustainable Use of Pollinators*. Global Action on Pollination Services for Sustainable Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2010. *Global forests resources assessment*. FAO Forestry Paper No. 163. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAULKNER, L., HARRINGTON, J., LEVY, D. and THE, K. 2009. *Commercial opportunities for fruit in Malawi*. ICRAF Working Paper No. 86. The World Agroforestry Centre, Nairobi, Kenya.

FRANZEL, S., AKINNIFESI, F.K. and HAM, C. 2008. Setting priorities among indigenous fruit tree species in Africa: examples from southern, eastern and western Africa regions. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 1–27.

FRANZEL, S., JAENICKE, H. and JANSSEN, W. 1996. *Choosing the right trees: setting priorities for multipurpose tree improvement*. ISNAR Research Report No. 8. International Service for National Agricultural Research, The Hague, The Netherlands.

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

GEPTS, P. 2004. Who Owns Biodiversity, and How Should the Owners Be Compensated? *Plant Physiology* **134**: 1295–1307.

GRAUDAL, L. and LILLESØ, J.-P.B. 2007. *Experiences and future prospects for tree seed supply in agricultural development support – based on lessons learnt in Danida supported programmes, 1965–2005*. The Ministry of Foreign Affairs of Demark, Copenhagen, Denmark.

HALL, J.B., O'BRIEN, E.M. and SINCLAIR, F.L. (eds.). 2002. Sclerocarya birrea*: a monograph*. School of Agricultural and Forest Sciences Publication No. 19. University of Wales, Bangor, United Kingdom.

HAM, C., AKINNIFESI, F.K., FRANZEL, S., JORDAAN, D. DU P.S., HANSMANN, C., AJAYI, O.C. and DE KOCK, C. 2008. Opportunities for commercialization and enterprise development of indigenous fruits in southern Africa. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 254–272.

HERMANN, M. 2009. The impact of the European Novel Food Regulation on trade and food innovation based on traditional plant foods from developing countries. *Food Policy* **34**: 499–507.

ICUC. 2003. *Improvement of tropical underutilised fruits in Asia*. International Centre for Underutilised Crops, Southampton, United Kingdom.

IMF. 2008. *Coping with food price increases in sub-Saharan Africa*. The International Monetary Fund, Washington DC, USA. Available at www.imf.org/external/pubs/ft/survey/so/2008/CAR032008A.htm

IPGRI, GFU and MSSRF. 2005. *Meeting the Millennium Development Goals with agricultural biodiversity*. Bioversity International (formerly the International Plant Genetic Resources Institute), Rome, Italy, the Global Facilitation Unit for Underutilized Species, Rome, Italy and the MS Swaminathan Research Foundation, Chennai, India.

JACK, B.K., KOUSKY, C. and SIMS, K.R.E. 2008. Designing payments for ecosystem services: lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences of the USA* **105**: 9465–9470.

JAMNADASS, R., DAWSON, I.K., ANEGBEH, P., ASAAH, E., ATANGANA, A., CORDEIRO, N., HENDRICKX, H., HENNEH, S., KADU, C.A.C., KATTAH, C., MISBAH, M., MUCHUGI, A., MUNJUGA, M., MWAURA, L., NDANGALASI, H.J., NJAU, C.S., NYAME, S.K., OFORI, D., PEPRAH, T., RUSSELL, J., RUTATINA, F., SAWE, C., SCHMIDT, L., TCHOUNDJEU, Z. and SIMONS, T. 2010. *Allanblackia*, a new tree crop in Africa for the global food industry: market development, smallholder cultivation and biodiversity management. *Forests, Trees and Livelihoods* **19**: 251–268.

JAMNADASS, R., LOWE, A. and DAWSON, I.K. 2009. Molecular markers and the management of tropical trees: the case of indigenous fruit. *Tropical Plant Biology* **2**: 1–12.

JENSEN, J.S., BAYALA, J., SANOU, H., KORBO, A., RÆBILD, A., KAMBOU, S., TOUGIANI, A., BOUDA, H-N., LARSEN, A.S. and PARKOUDA, C. 2011. A research approach supporting domestication of Baobab (*Adansonia digitata* L.) in West Africa. *New Forests* **41**: 317–335.

JORDAAN, D. DU P.S., AKINNIFESI, F.K., HAM, C. and AJAYI, O.C. 2008. The feasibility of small-scale indigenous fruit processing enterprises in southern Africa. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 273–287.

KADU, C.A.C., IMBUGA, M., JAMNADASS, R. and DAWSON, I.K. 2006. Genetic management of indigenous fruit trees in southern Africa: a case study of *Sclerocarya birrea* based on nuclear and chloroplast variation. *South African Journal of Botany* **72**: 421–427.

KADZERE, I., WATKINS, C.B., MERWIN, I.A., AKINNIFESI, F.K., SAKA, J.D.K. and MHANGO, J. 2006. Harvesting and post-harvesting handling practices and characteristics of *Uapaca kirkiana* (Muell. Agr.) fruits: a survey of roadside markets in Malawi. *Agroforestry Systems* **68**: 133–142.

KALINGANIRE, A., WEBER, J.C., UWAMARIYA, A. and KONE, B. 2008. Domestication, utilization and marketing of indigenous fruit trees in West and Central Africa. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 171–185.

KEATINGE, J.D.H., WALIYAR, F., JAMNADASS, R.H., MOUSTAFA, A., ANDRADE, M., DRECHSEL, P., HUGHES, J.A., KADIRVEL, P. and LUTHER, K. 2010. Relearning old lessons for the future of food – by bread alone no longer: diversifying diets with fruit and vegetables. *Crop Science* **50**: S51–S62.

KEHLENBECK, K., ROHDE, E., NJUGUNA, J.K., OMARI, F., WASILWA, L. and JAMNADASS, R. 2010. Mango cultivar diversity and its potential for improving mango productivity in Kenya. In: *Transforming agriculture for improved livelihoods through agricultural product value chains*. Proceedings of the 12th KARI biennial scientific conference, Kenya Agricultural Research Institute, Nairobi, Kenya, pp. 657–665.

KINDT, R., LILLESØ, J.-P.B., VAN BREUGEL, P., NZISA, A., ORWA, C., GRAUDAL, L., NYABENGE, M. and JAMNADASS, R. 2008. *Potential natural vegetation of south-western Kenya for selection of indigenous tree species: CD-ROM with electronic versions of the map, species selection tool and detailed descriptions for a subset of species*. The World Agroforestry Centre, Nairobi, Kenya.

KIT, FAIDA MALI and IIRR. 2006. *Chain empowerment: supporting African farmers to develop markets*. Royal Tropical Institute, Amsterdam, The Netherlands, Faida Market Link, Arusha, Tanzania and the International Institute of Rural Reconstruction, Nairobi, Kenya.

KOSKELA, J., VINCETI, B., DVORAK, W., BUSH, D., DAWSON, I., LOO, J., KJAER, E.D., NAVARRO, C., PADOLINA, C., BORDÁCS, S., JAMNADASS, R., GRAUDAL, L. and RAMAMONJISOA, L. 2009. *The use and movement of forest genetic resources for food and agriculture*. Background Study Paper No. 44. The Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations, Rome, Italy.

LEAKEY, R.R.B. 1999. Potential for novel food products from agroforestry trees. *Food Chemistry* **64**: 1–14.

LEAKEY, R.R.B. 2004. Physiology of vegetative reproduction. In: BURLEY, J., EVANS, J and YOUNGQUIST, J.A. (eds.) *Encyclopaedia of forest sciences*. Academic Press, London, UK, pp. 1655–1668.

LEAKEY, R.R.B. 2010. Agroforestry: a delivery mechanism for multi-functional agriculture. In: KELLIMORE, L.R. (ed.) *Handbook on agroforestry: management practices*

and environmental impact. Environmental Science, Engineering and Technology Series. Nova Science Publishers, Hauppauge, USA, pp. 461–471.

LEAKEY, R.R.B. and AKINNIFESI, F.K. 2008. Towards a domestication strategy for indigenous fruit trees in the tropics. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 28–49.

LEAKEY, R.R.B., MESÉN, J.F., TCHOUNDJEU, Z., LONGMAN, K.A., DICK, J., NEWTON, A.C., MATIN, A., GRACE, J., MUNRO, R.C. and MUTHOKA, P.N. 1990. Low-technology techniques for the vegetative propagation of tropical trees. *Commonwealth Forestry Review* **69**: 247–257.

LEAKEY, R.R.B. and NEWTON, A.C. 1994. Domestication of 'Cinderella' species as the start of a woody-plant revolution. In LEAKEY, R.R.B. and NEWTON, A.C. (eds.) *Tropical trees: the potential for domestication and the rebuilding of forest resources*. HMSO, London, UK, pp. 3–4.

LEAKEY, R.R.B. and PAGE, T. 2006. The 'ideotype concept' and its application to the selection of 'AFTP' cultivars. *Forests, Trees and Livelihoods* **16**: 5–16.

LEAKEY, R.R.B., SCHRECKENBERG, K. and TCHOUNDJEU, Z. 2003. The participatory domestication of West African indigenous fruits. International Forestry Review **5**: 338–347.

LEAKEY, R.R.B., TCHOUNDJEU, Z., SCHRECKENBERG, K., SHACKLETON, S.E. and SHACKLETON, C.M. 2005. Agroforestry tree products (AFTPs): targeting poverty reduction and enhanced livelihoods. *International Journal of Agricultural Sustainability* **3**: 1–23.

LEAKEY, R.R.B., TCHOUNDJEU, Z., SCHRECKENBERG, K., SIMONS, A.J., SHACKLETON, S., MANDER, M., WYNBERG, R., SHACKLETON, C. and SULLIVAN, C. 2007. Trees and markets for agroforestry tree products: targeting poverty reduction and enhanced livelihoods. In: GARRITY, D., OKONO, A., PARROTT, M. and PARROTT, S. (eds.) World agroforestry into the future. The World Agroforestry Centre, Nairobi, Kenya, pp. 11–22.

LILLESØ, J-P.B., GRAUDAL, L., MOESTRUP, S., KJÆR, E.D., KINDT, R., MBORA, A., DAWSON, I., MURIUKI, J., RÆBILD, A. and JAMNADASS, R. 2011. Innovation in input supply systems in smallholder agroforestry: seed sources, supply chains and support systems. *Agroforestry Systems* (Still in press).

LOMBARD, C. and LEAKEY, R.R.B. 2010. Protecting the rights of farmers and communities while securing long term market access for producers of non-timber forest products: experience in southern Africa. *Forests, Trees and Livelihoods* **19**: 235–249.

MAGHEMBE, J.A., SIMONS, A.J., KWESIGA, F. and RARIEYA, M. (eds.). 1998. *Selecting indigenous fruit trees for domestication in southern Africa: priority setting with farmers in Malawi, Tanzania, Zambia and Zimbabwe*. The World Agroforestry Centre, Nairobi, Kenya.

MILDER, B. 2008. Closing the gap: reaching the missing middle and rural poor through value chain finance. *Enterprise Development and Microfinance* **19**: 301–316.

MILLER, R.P. and NAIR, P.K.R. 2006. Indigenous agroforestry systems in Amazonia: from prehistory to today. *Agroforestry Systems* **66**: 151–164.

MNG'OMBA, S.A., AKINNIFESI, F.K., SILESHI, G., AJAYI, O.C., CHAKEREDZA, S. and MWASE, W.F. 2008. A decision support tool for propagating miombo indigenous fruit trees of southern Africa. *African Journal of Biotechnology* **7**: 4677–4686.

MNG'OMBA, S.A., DU TOIT, E.S., AKINNIFESI, F.K. and VENTER, H.M. 2007a. Effective preconditioning methods for *in vitro* propagation of *Uapaca kirkiana* Müell Arg. tree species. *African Journal of Biotechnology* **6**: 1670–1676.

MNG'OMBA, S.A., DU TOIT, E.S., AKINNIFESI, F.K. and VENTER, H.M. 2007b. Repeated exposure of jacket plum (*Pappea capensis*) micro-cuttings to indole-3-butyric acid (IBA) improved *in vitro* rooting capacity. *South African Journal of Botany* **73**: 230–235.

MÜLLER, C., CRAMER, W., HARE, W.L. and LOTZE-CAMPEN, H. 2011. Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences of the USA* **108**: 4313–4315.

MUOK, B.O., OWUOR, B., DAWSON, I. and WERE, J. 2001. The potential of indigenous fruit trees: result of a study in Kitui District, Kenya. *Agroforestry Today* **12**: 13–15.

MURIUKI, J.K. 2005. *Informal agroforestry tree seed quality and supply systems: a case of peri-urban Nairobi, Meru and western Kenya*. MSc thesis, Kenyatta University, Nairobi, Kenya.

NAIR, P.K.R., KUMAR, B.M. and NAIR, V.D. 2009. Agroforestry as a strategy for carbon sequestration. *Journal of Plant Nutrition and Soil Science* **172**: 10–23.

NATHAN, I., SHRESTHA, K.B., JHA, P.K. and SUVEDI, S. 2005. *Commercial distribution of tree seed in small bags: results from a pilot and action research project in Nepal*. Development and Environment Working Paper No. 9-2005. Forest and Landscape Denmark, Hørsholm, Denmark.

NEGIN, J., REMANS, R., KARUTI, S. and FANZO, J.C. 2009. Integrating a broader notion of food security and gender empowerment into the African Green Revolution. *Food Security* **3**: 351–360.

NEVEN, D. and REARDON, T. 2004. The rise of Kenyan supermarkets and the evolution of their horticulture product procurement systems. *Development Policy Review* **22**: 669–699.

PEPRAH, T., OFORI, D.A., SIAW, D.E.K.A., ADDO-DANSO, S.D., COBBINAH, J.R., SIMONS, A.J. and JAMNADASS, R. 2009. Reproductive biology and characterization of *Allanblackia parviflora* A. Chev. in Ghana. *Genetic Resources and Crop Evolution* **56**: 1037–1044.

PETIT, R.J. and HAMPE, A. 2006. Some evolutionary consequences of being a tree. *Annual Review of Ecology, Evolution, and Systematics* **37**: 187–214.

POULTON, C. and POOLE, N. 2001. *Poverty and fruit tree research*. Issues and Options Paper. Agricultural Economics and Business Management Research Group, Imperial College at Wye, Ashford, UK.

PYE-SMITH, C. 2009. Chocolate berries! Gingerbread plums! *New Scientist* **2733**, 53–55.

RÆBILD, A., LARSEN, A.S., JENSEN, J.S., OUEDRAOGO, M., DE GROOTE, S., VAN DAMME, P., BAYALA, J., DIALLO, B.O., SANOU, H., KALINGANIRE, A. and KJAER, E.D. 2011. Advances in domestication of indigenous fruit trees in the West African Sahel. *New Forests* **41**: 297–315.

RAY, P.K. 2002. *Breeding tropical and subtropical fruits*. Springer-Verlag, Berlin, Germany.

RUEL, M.T., MINOT, N. and SMITH, L. 2005. *Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa: a multi-country comparison*. International Food Policy Research Institute, Washington DC, USA.

RUSSELL, J.R., KADU, C.A.C., JAMNADASS, R., BOOTH, A., CORDEIRO, N.J., WOODHEAD, M. and DAWSON, I.K. 2009. AFLP and SSR diversity in the African fruit tree *Allanblackia*: implications for management of a genus newly subject to domestication for the edible oil industry. *Tree Genetics and Genomes* **5**: 517–527.

SAKA, J.D.K. and MSONTHI, J.D. 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. *Forest Ecology and Management* **64**: 245–248.

SAKA, J., RAPP, I., AKINNIFESI, F., NDOLO, V. and MHANGO, J. 2007. Physicochemical and organoleptic characteristics of *Uapaca kirkiana*, *Strychnos cocculoides*, *Adansonia digitata* and *Mangifera indica* fruit products. *International Journal of Food Science and Technology* **42**: 836–841.

SAMSON, J.A. 2003. *Tropical fruits*. Second edition. Blackwell Publishing, Oxford, United Kingdom (reprint from 1986).

SANOU, H., KAMBOU, S., TEKLEHAIMANOT, Z., DEMBÉLÉ, M., YOSSI, H., SINA, S., DJINGDIA, L. and BOUVET J-M. 2004. Vegetative propagation of *Vitellaria paradoxa* by grafting. *Agroforestry Systems* **60**: 93–99.

SCHERR, S.J. and MCNEELY, J.A. 2008. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. *Philosophical Transactions of the Royal Society B* **363**: 477–494.

SCHRECKENBERG, K., AWONO, A., DEGRANDE, A., MBOSSO, C., NDOYE, O. and TCHOUNDJEU, Z. 2006. Domesticating indigenous fruit trees as a contribution to poverty reduction. *Forests, Trees and Livelihoods* **16**: 35–51.

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

SIDIBE, M. and WILLIAMS, J.T. 2002. *Baobab*. Adansonia digitata. International Centre for Underutilised Crops, Southampton, UK.

SIMITU, P., JAMNADASS, R., KINDT, R., KUNGU, J. and KIMIYWE, J. 2009. Consumption of dryland indigenous fruits to improve livelihoods in Kenya. The case of Mwingi District. *Acta Horticulturae* **806**: 93–98.

SIMONS, A.J., JAENICKE, H., TCHOUNDJEU, Z., DAWSON, I., KINDT, R., OGINOSAKO, Z., LENGKEEK, A. and DE GRANDE, A. 2000. The future of trees is on farm: tree domestication in Africa. In: KRISHNAPILLAY, B., SOEPADMO, E., LOTFY ARSHAD, N., WONG, A., APPANAH, S., WAN CHIK, S., MANOKARAN, N., LAY TONG, H. and KEAN CHOON, K. (eds.) *Forests and society: the role of research*. Proceedings of the XXI[st] IUFRO World Congress, held in Kuala Lumpur, Malaysia, August 2000, Sub-plenary Sessions vol. 1. IUFRO Secretariat, Vienna and the Forest Research Institute Malaysia, Malaysia, pp. 752–760.

SIMONS, A.J. and LEAKEY, R.R.B. 2004. Tree domestication in tropical agroforestry. *Agroforestry Systems* 61: 167–181.

STEFFAN-DEWENTER, I., KESSLER, M., BARKMANN, J., BOS, M.M., BUCHORI, D., ERASMI, S., FAUST, H., GEROLD, G., GLENK, K., GRADSTEIN, S.R., GUHARDJA, E., HARTEVELD, M., HERTEL, D., HOHN, P., KAPPAS, M., KOHLER, S., LEUSCHNER, C., MAERTENS, M., MARGGRAF, R., MIGGEKLEIAN, S., MOGEA, J., PITOPANG, R., SCHAEFER, M., SCHWARZE, S., SPORN, S.G., STEINGREBE, A., TJITROSOEDIRDJO, S.S., TJITROSOEMITO, S., TWELE, A., WEBER, R., WOLTMANN, L., ZELLER, M. and TSCHARNTKE, T. 2007. Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences of the USA* **104**: 4973–4978.

TADJO, P. 2008. *Evaluation de l'efficacité des pépinières rurales des zones d'intervention de l'ICRAF dans la distribution des plants d'arbres agroforestiers: cas des provinces de l'Ouest et du Nord-Ouest Cameroun*. MSc thesis, University of Dschang, Cameroon.

TCHOUNDJEU, Z., ASAAH, E.K., ANEGBEH, P., DEGRANDE, A., MBILE, P., FACHEUX, C., TSOBENG, A., ATANGANA, A.R., NGO-MPECK, M.L. and SIMONS, A.J. 2006. Putting participatory domestication into practice in West and Central Africa. *Forests, Trees and Livelihoods* **16**: 53–69.

TCHOUNDJEU, Z., ATANGANA, A., ASAAH, E., TSOBENG, A. and FACHEUX, C. 2008. Domestication, utilisation, and marketing of indigenous fruit trees in West and Central Africa. In: AKINNIFESI, F.K., LEAKEY, R.R.B., AJAYI, O.C., SILESHI, G., TCHOUNDJEU, Z., MATAKALA, P. and KWESIGA, F.R. (eds.) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. CAB International, Wallingford, UK, in association with the World Agroforestry Centre, Nairobi, Kenya, pp. 137–170.

TCHOUNDJEU, Z., DEGRANDE, A., LEAKEY, R.R.B., NIMINO, G., KEMAJOU, E., ASAAH, E., FACHEUX, C., MBILE, P., MBOSSO, C., SADO, T. and TSOBENG, A. 2010. Impacts of participatory tree domestication on

farmer livelihoods in West and Central Africa. *Forests, Trees and Livelihoods* **19**: 217–234.

THIONGO, M.K. and JAENICKE, H. 2000. Preliminary nutritional analysis of marula (*Sclerocarya birrea*) fruits from two Kenyan provenances. *Acta Horticulturae* **531**: 245–249.

TSCHIRLEY, D., AYIEKO, M., HICHAAMBWA, M., GOEB, J. and LOESCHER, W. 2010. *Modernizing Africa's fresh produce supply chains without rapid supermarket takeover: towards a definition of research and investment priorities*. International Development Working Paper No. 106, Michigan State University, Michigan, USA.

UNICEF. 2007. The state of the world's children 2008. Child survival. The United Nations Children's Fund, New York, USA.

VANDENBOSCH, T.E., OUKO, B.A., GULEID, N.J., WERE, R.A., MUNGAI, P.P., MBITHE, D.D., NDANYI, M., CHESUMO, J., LAENEN-FOX, L., SMETS, K., KOSGEI, C.K. and WALEMA, B. 2009. Integrating food and nutrition, health, agricultural and environmental education towards education for sustainable development: lessons learned from the Healthy Learning Programme in Kenya. In: *Sustainable initiatives in the decade of education for sustainable development: where are we?* Proceedings of the July 2009 Environmental Education Association of Southern Africa (EEASA) conference. Available at worldagroforestry.org/publications/publicationsdetails?node=52930

VINCETI, B., DAWSON, I., KOSKELA, J. and JAMNADASS, R. 2009. Tree genetic resources: international interdependence in the face of climate change. In: FUJISAKA, S., HALEWOOD, M. and WILLIAMS, D. (eds.) *The impact of climate change on countries' interdependence on genetic resources for food and agriculture*. Background Study Paper No. 48. The Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 18–26.

WAIBEL, H., WESSELER, J. and MITHÖFER, D. 2005. R&D and private investment: how to conserve indigenous fruit biodiversity of Southern Africa. Proceedings of the German Development Economics Conference, held in Kiel, Germany, 2005, paper 35. Available at http://econstor.eu/bitstream/10419/19826/1/Waibel.pdf

WARUHIU, A.N., KENGUE, J., ATANGANA, A.R., TCHOUNDJEU, Z. and LEAKEY, R.R.B. 2004. Domestication of *Dacryodes edulis*: 2. Phenotypic variation of fruit traits in 200 trees from four populations in the humid lowlands of Cameroon. *Food, Agriculture and Environment* **2**: 340–346.

WEBER, J.C., SOTELO-MONTES, C., UGARTE, J. and SIMONS, T. 2009. Phenotypic selection of *Calycophyllum spruceanum* on farms in the Peruvian Amazon: evaluating a low-intensity selection strategy. *Silvae Genetica* **58**: 172–179.

WEINBERGER, K. and LUMPKIN, T.A. 2007. Diversification into horticulture and poverty reduction: a research agenda. *World Development* **35**: 1464–1480.

WFP. 2008. *Ghana: home grown school feeding case study*. World Food Programme, Rome, Italy.

WFP. 2009. *Home grown school feeding: a framework to link school feeding with local agricultural production*. World Food Programme, Rome, Italy.

WHITE, T.L., ADAMS, W.T. and NEALE, D.B. 2007. *Forest genetics*. CAB International, Wallingford, UK.

WORLD BANK. 2006. *Repositioning nutrition as central to development. A strategy for large-scale action*. The World Bank, Washington DC, USA.

WYNBERG, R.P., LAIRD, S.A., SHACKLETON, S., MANDER, M., SHACKLETON, C., DU PLESSIS, P., DEN ADEL, S., LEAKEY, R.R.B., BOTELLE, A., LOMBARD, C., SULLIVAN, C., CUNNINGHAM, T. and O'REGAN, D. 2003. Marula commercialisation for sustainable and equitable livelihoods. *Forests, Trees and Livelihoods* **13**: 203–215.

ZOMER, R.J., TRABUCCO, A., COE, R. and PLACE, F. 2009. *Trees on farm: analysis of global extent and geographical patterns of agroforestry*. Working Paper No. 89. The World Agroforestry Centre, Nairobi, Kenya.

Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins

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SUMMARY

Protein from forest wildlife is crucial to rural food security and livelihoods across the tropics. The harvest of animals such as tapir, duikers, deer, pigs, peccaries, primates and larger rodents, birds and reptiles provides benefits to local people worth millions of US$ annually and represents around 6 million tonnes of animals extracted yearly. Vulnerability to hunting varies, with some species sustaining populations in heavily hunted secondary habitats, while others require intact forests with minimal harvesting to maintain healthy populations. Some species or groups have been characterized as ecosystem engineers and ecological keystone species. They affect plant distribution and structure ecosystems, through seed dispersal and predation, grazing, browsing, rooting and other mechanisms. Global attention has been drawn to their loss through debates regarding bushmeat, the "empty forest" syndrome and their ecological importance. However, information on the harvest remains fragmentary, along with understanding of ecological, socioeconomic and cultural dimensions. Here we assess the consequences, both for ecosystems and local livelihoods, of the loss of these species in the Amazon and Congo basins.

Keywords: bushmeat, livelihoods, forest, Amazon, Congo

Forêts vides, estomacs vides? Viande de brousse et condition de vie dans les bassins du Congo et de l'Amazone.

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Les protéines tirées de la faune sauvage sont cruciales pour la sécurité alimentaire et les conditions de vie des populations tropicales. Le prélèvement d'animaux comme tapirs, céphalophes, cochons sauvages, pécaris, primates, gros rongeurs, oiseaux et reptiles représente des bénéfices valant plusieurs millions de US$ par an et approximativement 6 millions tonnes extraites annuellement. La vulnérabilité vis-à-vis de la chasse varie avec certaines espèces qui se maintiennent dans des zones très chassées ou secondarisées et d'autres qui nécessitent des forêts intactes et des prélèvement minimaux pour maintenir des populations viables. Certaines des espèces chassées sont considérées comme des espèces clé de voute, sortes "d'ingénieurs" des écosystèmes. Elles jouent un rôle primordial dans la distribution des plantes et la structure des écosystèmes au travers de la dispersion ou la prédation des semences, le broutage, la pollinisation, etc. Leur perte est l'objet de l'attention générale au travers des débats sur la crise de la viande de brousse, le syndrome des "forêts vides" et leur importance écologique. Cependant les informations sur la récolte restent fragmentaires, de même que notre compréhension de ses dimensions écologiques, socio-économiques et culturelles. Dans ce texte nous évaluons les conséquences, pour les écosystèmes et les conditions de vie locales, de la perte de ces espèces dans les bassins de l'Amazone et du Congo.

¿Bosques vacíos, estómagos vacíos? Caza y medios de subsistencia en las cuencas del Congo y el Amazonas

R. NASI, A. TABER y N. VAN VLIET

La proteína obtenida de la fauna salvaje del bosque es crucial para la seguridad alimentaria en zonas rurales y para los medios de subsistencia en los trópicos. La explotación cinegética de animales como el tapir, duiker, cerdo salvaje, pecarí, primates, grandes roedores, aves y reptiles, aporta millones de dólares anuales en ingresos a las comunidades locales y representa un total de 6 millones de toneladas de animales aprovechados anualmente. La vulnerabilidad a la actividad de la caza varía con la especie: algunas mantienen sus poblaciones en hábitats secundarios intensamente explotados mientras que otras requieren bosques intactos y una presión cinegética mínima para poder mantener poblaciones saludables. Algunas especies o grupos han sido caracterizadas como ingenieras de ecosistemas y especies clave ("*keystone*") ecológicamente hablando ya que afectan a la distribución de especies vegetales y estructuran ecosistemas por dispersión y predación de semillas, herbivoría, ramoneo, al alimentarse de raíces o por otros mecanismos. Globalmente se ha prestado mucha atención a la pérdida de estas especies en debates relacionados con la caza en el bosque, el "síndrome del bosque vacío" y su importancia ecológica. Sin embargo, la información en cuanto a su aprovechamiento se encuentra fragmentada, junto con la comprensión de sus dimensiones ecológicas, socio-económicas y culturales. En este artículo evaluamos las consecuencias que tiene la pérdida de estas especies en los ecosistemas y los medios de subsistencia locales de las cuencas del Congo y el Amazonas.

INTRODUCTION

There is ample and diverse evidence (see Nasi *et al.* 2008 for a review) that the scale of current hunting is a serious threat to many forest species and ecosystems in the Amazon and Congo Basin, the two largest and least populated dense forest areas of the world. In two seminal pieces using data from the end of the 1990's, Fa and Peres (2001) and Fa *et al.* 2002, concluded that "*over 5 million tons of meat feed millions in Neotropical (0.15 million tons) forests and Afrotropical (4.9 million tons) forests annually*". Local extirpation of hunted species is widespread, with West and Central Africa particularly hard hit (Milner-Gulland *et al.* 2003).

Despite this evidence and increased international attention, more than ten years later information on the bushmeat harvest and trade is still fragmentary and our understanding of the complex interactions between ecological, socio-economic and cultural dimensions of the issue remains limited. Studies are frequently limited to single sites, using a multiplicity of research approaches, limiting prospects for comparisons. Further, results are frequently disseminated in unpublished reports or peer-reviewed articles that are not easily accessible to key audiences. As a result, governments and other stakeholders have limited objective information at national and regional levels to inform and support policy or management decisions.

The present synthesis aims to draw renewed attention to the ecological and livelihood impacts of defaunation by updating and contrasting relevant information from both the Amazon and Congo Basins. We first provide an overview of the ecological consequences of overhunting. Then we analyse the impacts in terms of food security and local livelihoods. We conclude by pointing to key actions needed to fill information gaps and set the use of wildlife in these two regions on a more sustainable course.

HUNTED SPECIES AND ECOLOGICAL IMPACTS OF UNSUSTAINABLE HUNTING

Composition of the catch

In both basins a wide variety of taxa are hunted for food. In Gabon alone, 114 species have been recorded in hunter catches, household consumption and markets (Abernethy and Ndong Obiang 2010). In Latin America over 200 species of mammals, *ca.* 750 bird species (including over 530 species for the pet trade), more than 60 species of reptiles and a minimum of 5 species of amphibians have been registered as harvested for household consumption and for markets (Ojasti 2000). Mammals make up the bulk of the catches both in number and biomass terms, with ungulates and rodents representing more than two thirds of the carcasses sold in urban markets or recorded from hunter off takes in both Congo and Amazon Basin (Table 1).

In both basins medium-sized species between 2 and 50 kg are the most frequently hunted, though hunters will not shy from killing larger taxa when encountered (e.g., tapirs, wild pigs, forest buffalo, large antelopes, great apes). Monkeys are hunted in large numbers in some areas but because of their generally small body size they usually represent a small part of the harvested biomass. Brush-tailed porcupine *(Atherurus africanus),* pouched rat (*Cricetomys eminii*), blue (*Cephalophus monticola*) and red duikers (other *Cephalophus* spp.), represent the majority of the catch in the Congo Basin with blue duikers alone accounting often for about a third of the harvest (Kümpel 2006a, van Vliet 2008). Similarly, in the Amazon Basin, large rodents (*Dasyprocta* spp. and *Cunniculus paca*) and medium-sized ungulates such as brocket deer (*Mazama* spp.) and peccaries (*Tayassu pecari* and *Pecari tajacu*. 12–45 kg) typically make up the bulk of the harvest, although the hunting of a few tapir (*ca.* 200 kg) can be very important in biomass terms (Bodmer and Lozano 2001, Bodmer *et al.* 2004, Ojasti 2000, Peres 2000b, Robinson and Bennett 2000).

Differing hunting methods target particular species in both basins. Rifles and shotguns are typically used for larger animals and arboreal species (Coad 2007, Kümpel 2006a, van Vliet 2008), although some native people still use blow pipes and or bows and arrows where constrained by the availability of fire arms and the cost of ammunition. Dogs are frequently used to find and corner prey (Noss *et al.* 2004). Netting and trapping were traditionally carried out using a variety of specialized techniques (Dounias 1999, Smith 2010); but the use of steel wire snares is now prominent in Africa, although often "illegal", as the material is inexpensive, durable and strong enough to capture large animals. Steel leg hold traps have been used extensively to hunt furbearers such as ocelots and jaguars (Swank and Teer 1989). Hunting in high forest with snares and traps appears more frequent in the Congo Basin, but in both basins "garden hunting" is common using traps for relatively small game (mainly rodents) to protect farming plots (Naughton-Treves *et al.* 2003, Smith 2005).

The majority of mammal species (70%) hunted in the Congo Basin is not listed as threatened on the IUCN Red List of Threatened Species. Average extraction rates calculated for African forest mammals within each Red List category indicate that non-threatened species have the highest extraction rates. In Gabon, 23 of the partially protected species and 24 of the totally protected species were found to be used as bushmeat, but rare and vulnerable species such as great apes and elephants usually represent a small proportion (often less than 5%) of the total catch (Abernethy and Ndong Obiang 2010, van Vliet and Mbazza 2011). The situation in the Amazon Basin is similar with 19 of 30 commonly hunted prey species not being listed in any of the threatened categories of the IUCN Red List (Vulnerable or Endangered), while a further four are data deficient. This contrasts with the 21% of all mammal species which are considered threatened globally (IUCN 2008). This should however be qualified by the fact that where overhunting has occurred over long periods, larger and more vulnerable species (often endangered) have already disappeared with smaller, generally non-threatened species, becoming prevalent in the harvest (Altrichter 2006, Bennett and Robinson 2000, Cowlishaw *et al.* 2005, Stearman 2000).

TABLE 1 *Percentage of carcasses from ungulates, primates, rodents and other species in different hunting sites in the Congo and Amazon Basins (including some tropical forests sites from elsewhere in Latin America)*

Country	Location	Ungulates	Primates	Rodents	Other	Source
		CONGO				
DRC	Ituri forest	60–95	5–40	1	1	Hart 2000b
Gabon	Makokou	58	19	14	9	Lahm 1993
	Dibouka, Baniati	51.3	10.6	31		Starkey 2004
	Dibouka, Kouagna	27	8.3	48.7		Coad 2007
	Ntsiete	65	23.5	9		van Vliet 2008
Congo	Diba, Congo	70	17	9	4	Delvingt *et al.* 1997
	Oleme, Congo	62	38			Gally and Jeanmart 1996
	Ndoki and Ngatongo	81–87	11–16	2–3		Auzel and Wilkie 2000
CAR	Dzanga-Sangha	77–86	0	11–12	2–12	Noss 1995
Equatorial Guinea	Bioko and Rio Muni	36–43	23–25	31–37	2–4	Fa *et al.* 1995
	Sendje	30	18	32		Fa and Yuste 2001
	Sendje	35	16	43		Kümpel 2006b
Cameroon	Dja	88	3	5	4	Dethier 1995
	Ekim	85	4	6	5	Delvingt *et al.* 1997
	Ekom	87	1	6	6	Ngnegueu and Fotso 1996
		AMAZON				
Guyana	Rupununi Region	32		27		Read *et al.* 2010
Brazil	Japuaranã, Nova Bandeirantes, Brazil	72		12	16	Trinca and Ferrari 2007
	Agrovila Nova Fronteira, Para	56	1	15	28	Smith 1976
	Agrovila Leonardo da Vinci, Para	61	0	18	20	Smith 1976
	Agrovila Coco Chato, Para	6	1	51	42	Smith 1976
Latin America	Native Americans - 7 communities	25	23	26	26	Ojasti 1996
Latin America	Colonists - 6 communities	50	9	24	16	Ojasti 1996

Impacts on hunted populations

Hunting (like other human extractive activities in tropical forests) is, depending on the scale, a disruptive process. It can and does trigger numerous indirect effects, which in turn alter both (i) the hunted populations and (ii) the functioning, structure and composition of the ecosystem (Nasi *et al.* 2010).

Empirical studies in both basins show that population densities are lower in hunted versus un-hunted areas, implying a potential decline in stocks (Table 2). Not all species respond equally to hunting pressure. This is especially the case because central place foragers typically deplete large bodied species close to their base camps. As a result a common trend is to see the density of large bodied species increasing with distance from hunter settlements.

Some taxa appear highly vulnerable while others seem unaffected, and populations of a few taxa may even be enhanced by hunting (Bodmer *et al.* 1997, Cullen *et al.* 2000, Hurtado-Gonzales and Bodmer 2004, Isaac and Cowlishaw 2004, Salas and Kim 2002) – typically as a function of their ecological adaptability and population biology. Irrespective of the region, larger-bodied longer-lived species with low intrinsic rates of population increase, such as apes, other large primates, carnivores and antelopes as well as tapirs, buffaloes or elephants are less resistant to intensive hunting than species with high intrinsic rates of population increase such as rodents or small- to medium-sized ungulates (Robinson and Redford 1991). Primates and large carnivores appear extremely vulnerable and their populations plummet with intense hunting (Henschel 2009, Oates 1996). Hunting is the major cause for a reported 50% decline in apes in Gabon within two decades (Walsh *et al.* 2003). Hunted populations of Black colobus (*Colobus satanas*) in the Congo Basin, spider (*Ateles* sp.) and Woolly monkeys (*Lagothrix* sp.) in the Amazon basin have declined precipitously (Bodmer *et al.* 1994, Kümpel *et al.* 2010a, Robinson and Redford 1994).

In areas where larger species have been significantly depressed, the abundance of small and medium-sized species can remain unaffected or even increase. For example, in

TABLE 2 *Decrease in population densities in hunted areas compared to unhunted areas. Modified from Nasi et al. 2008*

Country	Location	Percentage by which mammal densities are lower in moderately to heavily hunted forests than in un-hunted forest	Reference
	AMAZON		
Brazil	23 Amazonian sites	80.8	Peres 2000b
Ecuador	Quehueiri-ono	35.3	Mena *et al.* 2000
Paraguay	Mbaracayu	53.0	Hill and Padwe 2000
Paraguay	Mbaracayu	0 to 40	Hill *et al.* 2003
Brazil	Mata de Planalto	27 to 69	Cullen *et al.* 2000
	CONGO		
D.R. of Congo	Ituri I	42.1	Hart 2000
D.R. of Congo	Ituri II	12.9	Hart 2000
C. African Republic	Mossapoula	43.9	Noss 2000
Gabon	Makokou	43.0 to 100	Lahm 2001

Gabon, the small Blue duiker is significantly less abundant in remote forests within the boundaries of the Ivindo National Park than in hunted areas with similar vegetation cover close to the town of Makokou, while the larger Peter's (*Cephalophus callipygus*) and Bay duiker (*C. dorsalis*) are less abundant or even depleted (van Vliet 2008, van Vliet *et al.* 2007). Similar patterns have been recorded in the Amazon with declining White-lipped peccary (*Tayassu pecari*) populations being accompanied by increasing density and larger group sizes for Collared peccaries (*Pecari tajacu)* (Fragoso 1994). This is highly suggestive of density compensation (Peres and Dolman 2000) processes where the abundance of resilient species rises if their more vulnerable competitors for resources (space, food, etc.) are removed. Source-sink effects (Novaro *et al.* 2000, Salas and Kim 2002), spatial heterogeneity (Kümpel *et al.* 2010a, van Vliet *et al.* 2010a) or high dispersal (Hart 2000a) can also help maintain populations in hunted areas, masking or compensating for hunting driven population decline.

Impacts on ecosystems

The loss of wildlife from forest ecosystems can lead to the disruption of ecological and evolutionary processes, changes in species composition within ecosystems and probably a general reduction in biological diversity (Emmons 1989, Redford 1992) creating "Empty Forests". Most ecosystem processes are driven by the combined activities of many species. Plant regeneration (affected by pollinators, seed dispersers and predators) and plant diversity (affected by a change in herbivory patterns or pest increase) are often dependent upon the presence of specific species or groups of species (Beck 2006, 2008, Keuroghlian and Eaton 2009, Nuñez Iturri and Howe 2007, Terborgh *et al.* 2008, Vanthomme *et al.* 2010, Wright *et al.* 2007b). Reviews and discussion on ecological impacts of defaunation in general are covered elsewhere (Bennett and Robinson 2000, Şekercioğlu *et al.* 2004, Stoner *et al.* 2007, Wright 2003, Wright *et al.* 2007b).

The disappearance, or even extreme reduction, of populations of 'keystone species', 'ecosystem engineers', or other species or groups of importance in ecological communities is expected to have a disproportionate impact on the ecosystem compared to the loss of other species (Campos-Arceiz and Blake 2011, Fragoso 1997, Keuroghlian and Eaton 2009). Hunters preferentially target large animals whenever they are available and these are often keystone species. Top predators (e.g. large cats, raptors, crocodiles) impact biodiversity by providing resources that would otherwise be scarcely available to other species (e.g. carrion) or by initiating trophic cascades (Sergio *et al.* 2008, Terborgh 2010). Local extinction of these predators can trigger major changes in prey populations, which in turn can dramatically alter browsing or grazing by herbivorous species to the point where large regime shifts or ecosystem collapse happen. Elephants (Campos-Arceiz and Blake 2011), but also ungulates such as tapirs and peccaries (Beck 2006, Fragoso 1997, Keuroghlian and Eaton 2009), can play major roles in modifying vegetation structure, composition and dynamic through their feeding habits and movements in the forest. Tapirs, peccaries, wild pigs, deer, duikers and the larger rodents are among the most active seed dispersers or predators; thus a significant change in their population densities will have a major effect on seedling survival and forest regeneration (Beck 2005, Bodmer 1991, Fragoso 1997).

BUSHMEAT IN LOCAL PEOPLE'S LIVELIHOODS

The importance of bushmeat in the diets of rural and urban populations

Bushmeat consumption by rural and urban populations

Bushmeat consumption by rural communities has been reported in a number of studies (Table 3) for the two basins. Rigorous comparison across sites is not possible as ratios are

TABLE 3 *Average daily wild meat consumption (kg/person/year) in rural communities and indigenous people settlements*

Indigenous group (or site) and country	Annual consumption of bushmeat based on deadweight (kg/person/year)	Source
	AMAZON	
Bari, Colombia	35.8	Ojasti 1996
Cuiba, Colombia	191.6	Ojasti 1996
Jivaro, Peru and Ecuador	101.5	Ojasti 1996
Kainsang, Brazil	34.7	Ojasti 1996
Transamazon highway, Brazil	2.1–15.8	Smith 1976
Japuaranã, Nova Bandeirantes, Brazil	73	Trinca and Ferrari 2007
Sharanahua, Peru	99.6	Ojasti 1996
Shipibo, Peru	17.2	Ojasti 1996
Siona, Secova, Ecuador	74.8	Ojasti 1996
Trio, Suriname	47.5	Ojasti 1996
Sirino, Bolivia	79.9	Ojasti 1996
Yanomano, Venezuela	52.2	Ojasti 1996
Yékwana, Venezuela	58	Ojasti 1996
Yukpa, Venezuela	10.2	Ojasti 1996
	CONGO	
Ituri Forest, DRC	58.4	Bailey and Peacock1988
Ituri Forest, DRC	43.8	Aunger 1992
Ogoué Ivindo, Gabon	36.5–62.05	Lahm 1993
Mossapoula, CAR	18.3	Noss 1995
Dja Reserve, Cameroon; Ngotto CAR and Odzala National Park, Congo	29.2–58.4	Delvingt 1997
Campo Man Reserve	69.4	Dounias *et al.* 1995 reported in Dethier 1995
Mvae, Cameroon	67.0	Bahuchet and Ioveva 1999
Kola, Cameroon	79.0	
Northern Congo (forest villages)	33.0	Auzel 1997
Northern Congo (forestry camp)	53.0	
Badjoué, Cameroon	16.4–35.9	Delvingt *et al.* 2001
Azande, DRC	14.6	De Merode *et al.* 2004
Dibouka and Baniati villages, Gabon	97.8	Starkey 2004
Forest villages near Okondja, Gabon	94.9	
Coastal villages near Omboué, Gabon	18.3	

based on varying parameters (whole carcass, dressed, or boned-out weights; per capita or using Average Male Equivalents). The range of values does not seem, however, to differ significantly for the two basins: for the Amazon (average: 63 ± 25 kg/capita/year; range: 10–190 kg/capita/yr; n = 14) and for the Congo Basin (average: 51 ± 14kg/capita/year; range: 7–110 kg/capita/yr; n = 15).

Data on bushmeat consumption by urban dwellers is especially scarce for the Amazon Basin (see however the case of Iquitos in the following section). Rushton *et al*. (2005) consider urban bushmeat consumption in South America is negligible because of the existence of one of the most important livestock production systems in the world – but we would need some updated reviews to confirm anecdotal evidence. A relatively low percentage of the population consumes bushmeat (mostly indigenous and the smaller rural communities). When they become "richer" the non-indigenous people turn generally to alternative sources of protein. As South America has some of the most important livestock production systems (beef, pork and poultry) in the world the authors suggest that bushmeat is likely to be slowly replaced by domestic sources of protein: "*Bushmeat in South America is not of*

great importance in terms of either of the proportion of people in a population who eat bushmeat nor in terms of its contribution to the livestock and fisheries economy". Though the income elasticity of demand for bushmeat is still poorly understood, it seems that bushmeat in South America stops being an economic necessity as household income increases. Note also that Rushton *et al*. (2005) emphasize that though only a small percentage of people in South America consume bushmeat – they are typically the poorest and most marginalized. We note that for wealthier sectors of society bushmeat is harvested, sometimes heavily, for sports hunters (many hunting and fishing clubs in small towns across the Amazon) as well as a novelty food for tourists in high-end restaurants in the region. However, the volume and impact of these latter uses are essentially unstudied.

In the Congo Basin the situation is totally different and urban bushmeat consumption is significant. Chardonnet *et al*. (1995) report that urban populations in Gabon, DRC and CAR consumed on average 4.7 kg/person/year; consumption in Libreville (Gabon) is estimated at 7.2 kg/person/year (Wilkie *et al*. 2005), in Bangui (CAR) at 14.6 kg/person/year (Fargeot and Dieval 2000), in Mbanjock (Cameroon) at 2 kg/person/year, etc. Although urban bushmeat consumption per capita appears significantly lower than in rural areas according to most available studies, the contribution of urban areas to the overall bushmeat consumption is high and likely to become higher as the population of Central African countries becomes more urbanised. Given the very significant urban and rural consumption and the either inexistent (e.g. Gabon, DRC, Congo) or pretty limited (Cameroon, CAR) domestic livestock sector, bushmeat remains a crucial component of food security for the Congo Basin.

Using consumption data gathered in this work (Table 3) and updated population figures we can provide updated estimates of bushmeat consumption and wildlife extraction (considering a 0.7 meat/live animal ratio) for the Amazon and Congo Basins in 2010. Our estimates for the Amazon Basin are ten times higher than Fa *et al*. 2002 and similar for the Congo Basin. It would be very dangerous to jump to the conclusion that bushmeat consumption has increased in the Amazon and stabilized in the Congo Basin. Fa *et al*. (2002) estimates for the Amazon were very low, equating to a consumption of 35 g/capita/day, largely below any published data (even contradicting their own data). As for the Congo Basin, data (e.g. population) are notoriously unreliable and consumption patterns very variable.

We can reasonably estimate that our figures are of the right order of magnitude and that annually 6 million tonnes of wildlife in the two basins.

Reasons behind the consumption of bushmeat

In remote forest areas of Central Africa and the Amazon basin bushmeat is often the main source of animal protein available and plays an essential role in people's diets especially where livestock husbandry is not a feasible option and wild fish not available. Eating bushmeat is therefore a matter of survival with few if any alternatives. When wild fish is available it can outweigh the importance of bushmeat in the diet of forest dwellers (Rushton *et al.* 2005 in Peru or Wilkie *et al.* 2005 in Gabon). The consumption of fish and/or bushmeat seems to be closely linked to both availability and/or price of substitutes. Overall, people who depend on wild protein will substitute wild fish and wild meat for one another, depending on the price and availability of each. This means that a decline in one wild resource tends to drive up unsustainable exploitation of the other (Brashares *et al.* 2004). There are also incidences where fish is either or not preferred to bushmeat. This further complicates the understanding of the feedback loop between fish and meat catches (Nasi *et al.* 2008). The other possible wild substitute invertebrates, represents an important traditional habit and also, considering their nutritional composition, a substantial contribution to the human diet (Marconi *et al.* 2002, Vantomme *et al.* 2004) but they are generally seasonal and cannot fully substitute for meat and fish.

Unlike rural or forest dwellers, urban consumers usually have a choice of several sources of protein but may opt for bushmeat for a variety of reasons (e.g. cost, taste or preference) that vary between regions. In such context, bushmeat consumption level can vary according to variations in prices of alternative foods, such as fish (Wilkie *et al.* 2005). In several African cities, bushmeat is still the cheapest source of protein and represents a crucial source of meat for the poorest urban households. In Kisangani, Democratic Republic of Congo (DRC) and Bangui, Central African Republic (CAR), bushmeat is cheaper than many other alternative sources of protein (Fargeot 2010, van Vliet *et al.* in press) or essentially perceived as a 'lower cost' protein as it can be captured rather than purchased (Kümpel 2006a). By contrast, in large cities of Equatorial Guinea, Gabon and Cameroon, bushmeat is more of a luxury product. Although preferred for its taste, it is less frequently consumed than frozen mackerel, chicken or pork due to their lower cost (Kümpel *et al.* 2007, Abernethy and

TABLE 4 *Estimated bushmeat consumption and wildlife extraction in the two Basins in 2010*

Basin	Dense Forest (km^2)	Population (×1 000)		Consumption (tonne/meat/yr)			Extracted (tonne/yr)
		Rural	Urban	Rural	Urban	Total	
Amazon[1]	3 938 000	14 425	24 352	909 000	Negligible	909 000	1 299 000
Congo[2]	1 612 000	57 046	41 199	2 909 000	289 000	3 198 000	4 569 000

[1]: Environment Outlook in Amazonia – GEO Amazonia; UN Population Division databases
[2]: State of the Forest 2008; UN Population Division databases

Ndong Obiang 2010). Analysis of taste choices in Gabon indicated that consumers differentiate amongst bushmeat species and that wildlife cannot be treated as a generic food source (Knights 2008, Schenck *et al.* 2006). In Latin America, fruit eating species are preferred over folivores, the meat of which is frequently described as "sweet". These include primates of the genera *Ateles* and *Lagothrix*, rodents such as Agoutis and Pacas, and the tropical forest ungulates which tend to be more frugivorous than open country species.

We must finally recognize the cultural significance of bushmeat use, particularly for traditional indigenous peoples confronting major societal and socioeconomic change. In Gabon, bushmeat is associated with the village, with rituals and with ceremonies, such as men's circumcision ceremonies (Angoué *et al.* 2000, van Vliet and Nasi 2008). The traditional role of bushmeat has also been shown in Equatorial Guinea, where some species are considered to have magical or medicinal properties that increase their value and others are taboo (Kümpel 2006a). Taboos on certain foods are widespread in parts of Central Africa (Okouyi 2006, van Vliet and Mbazza in press). Similarly in the Amazon Basin, various key bushmeat species have significant importance within native culture. For instance different Native American groups in the Amazon believe that shamans may reincarnate as peccaries, and these species may even be worshipped as deities in traditional belief systems (Donkin 1985). There are also prohibitions or taboos on hunting some of the species as well, for instance for brocket deer by the Ayoreo People of Bolivia and Paraguay. We have been unable however to find evidence that these taboos play a significant role in regulating harvests.

Sale or self-consumption: trade and income generated by bushmeat

Local trade

Even where bushmeat is used to satisfy basic subsistence requirements, many families also hunt wild game for sale to meet short term cash needs (Table 5). For hunters, the distinction between subsistence and commercial use is often blurred, with meat from the forest supplementing both diets and incomes (e.g. Bodmer and Lozano 2001, Bodmer *et al.* 2004, Kümpel *et al.* 2010b, 2010c).

It is important to understand to what extent rural people depend on bushmeat and would therefore suffer if the resource diminished. Many depend on wildlife resources as a buffer to see them through times of hardship (e.g. unemployment, illness of relatives, crop failure), or to gain additional income for special needs (e.g. school fees, festivals, funerals) (Fa and Brown 2009), and this 'safety net' is often more important for the more vulnerable members of a community (Allebone-Webb 2009, de Merode *et al.* 2004). In South America, for small holders it buffers domestic livestock such as goats and cattle, key economic reserves that can be easily converted into cash for poor country dwellers (Altrichter 2006). In a similar way, bushmeat can further subsidize large ranch owners economically since they often resist providing livestock meat for their workmen, who are encouraged to hunt instead. Bushmeat can also be differentially important during times of stress for local people, such as when crops fail. In some cases it tends to be relied on more by community members who practice seasonal migrant labour (e.g., to participate in agribusiness harvests), and hence have less time to plant family gardens or for livestock husbandry (Noss 1999, Noss and Cuellar 2001). Another factor in South America is that as household wealth has increased in some rural communities wild game consumption has increased, in part due to greater availability of firearms (Espinosa 2008, Godoy *et al.* 2009).

Commercial trade is probably the primary driver of the increasing levels of bushmeat off take in the Congo Basin (Bennett *et al.* 2007, Davies 2002). On average per capita urban consumption across the region appears an order of magnitude smaller than rural consumption but while per capita urban consumption of bushmeat is lower than per capita rural consumption, aggregate urban consumption is usually higher than aggregate rural consumption due to the size of the urban population (Chardonnet *et al.*1995, Starkey 2004). In the Congo Basin, bushmeat trade occurs in established markets together with the commercialisation of other agricultural products. However, since much bushmeat is also sold through informal channels such as from rural hunters directly to urban consumers, established bushmeat markets channel only a portion (probably 50–60%) of the total urban consumption (Bahuchet and Ioveva 1999, Starkey 2004, Trefon and de Maret 1999). Starkey (2004) estimated that a total of 161 tonnes of bushmeat was sold per year in five markets in Gabon. Similarly, Fa *et al.* (1995) suggested that the volume of bushmeat traded annually in Equatorial Guinea's two main markets is of the order of 178 tons. An inventory in 1995–96 of the four main markets in the Cameroon capital, Yaoundé, estimated sales of 840–1 080 tons of bushmeat per year (Bahuchet and Ioveva 1999). In Yaoundé, Edderai and Dame (2006) identified 15 markets and 145 restaurants and cafeterias selling bushmeat and providing an occupation for 249 people, of whom 84.3% are women. Fargeot and Dieval (2000) estimate annual consumption in Bangui, Central African Republic, to be of the order of 9 500 tons per year.

In the Amazon Basin commercialisation occurs in largely hidden markets and bushmeat consumption in urban areas is unevenly studied. Here, the scale of the bush meat trade is less well-known than in the Congo Basin and appear highly variable. Bodmer *et al.* (2004) estimated the number of animals hunted annually in the Peruvian Amazon (Loreto region) as above 110 000 but how much of this catch is sold through open-markets is almost impossible to estimate. The best known and largest wild game market is in Iquitos Peru where for instance in the 1990s bush meat prices could reach $4 per kg (e.g., for meat from the highly prized paca *Cunniculus paca*) and the meat from an individual large peccary could be worth as much as US$60 with the hide bringing in an additional $10 to the hunter (Bodmer and Lozano 2001, Claggett 1998). This market arose due to the lack of cattle ranching in this part of the lowland Amazon.

TABLE 5 *Wild meat use (self consumption and sold) in various communities*

Country	Locally consumed (% biomass)	Sold (% biomass)	Source
		CONGO	
DRC	10	90	de Merode *et al.* 2004
CAR	27	73	Noss 1995
	65	35	Delvingt 1997
Equatorial Guinea	57	34	Fa and Yuste 2001
	10	90	Kümpel 2006a
Gabon	41	59	Starkey 2004
	60	40	van Vliet and Nasi 2008
	56	44	Carpaneto *et al.* 2007
Cameroon	36	64	Wright and Priston 2010
	44	56	Solly 2004
	34	40	Delvingt 1997
	63	15	Takforyan 2001
	59	28	Takforyan 2001
	68	14	Dounias 1999
Congo	28	68	Delvingt 1997
	42	54	Delvingt 1997
	45	35	Delvingt 1997
		AMAZON	
Brazil	100		Trinca and Ferrari 2007
	100		Parry *et al.* 2009
	100		Fragoso *et al.* 2000
Peru	14	86	Bodmer *et al.* 1994
	59	41	Claggett 1998
	54	46	Claggett 1998
	42	58	Claggett 1998

Another special example of such use is the commercial harvest of Capybara meat for lent in Venezuela (Hoogesteijn and Chapman 1997, Ojeda 1997) although cash benefits from this tend to accrue to large ranch owners rather than benefit poor rural livelihoods because the remaining land available for capybaras tends to be on extensive land holdings as opposed to small farms. Elsewhere, bush meat may be sold in cities and on road side stands across the region, but typically not commanding higher prices than for domestic livestock such as cattle.

International trade

There is very scarce quantitative data concerning the international trade of bushmeat and almost nothing on the Amazon Basin where the problem seems to relate more to the international exotic pet trade, as well as the hide trade as is the case for peccaries. Bushmeat trade across borders is frequent in the Congo Basin, especially in forest blocks located close to national borders where civil unrest and war have increased the availability of ammunitions and the demand for bushmeat. Bushmeat trade to Western countries also exists. A recent study at Roissy-Charles de Gaulle airport, in France, researchers identified eleven bushmeat species from confiscated luggage, including primates, crocodiles and pangolins and estimated that around 270 tonnes of bushmeat passing unchecked through a single European airport per year (Chaber *et al.* 2010) The Central African Republic, Cameroon and the Democratic Republic of Congo were identified as the main sources of bushmeat.

CONCLUSION: EMPTY FORESTS AND EMPTY STOMACHS?

Increased hunting pressure has tangible effects on wildlife and is likely to have long term impacts on forest ecosystems. As it is expected in hunted areas, the abundance and composition of mammal assemblages differ from un-hunted areas.

Many vulnerable species such as elephants, tapirs and great apes, although not representing high percentages in the hunter's catch, have declined or become locally depleted due to hunting. Very little is known however for the majority of Central African hunted species that are partially or totally protected. Knowledge on the ecology of major bushmeat species in the Amazon is better but four of some 30 such species are in the data deficient category of the IUCN Red List. The effects of hunting on these species need further investigation, with a particular focus on the impacts of hunting at varying spatial and temporal scales and under different hunting techniques, to provide objective information for sustainable wildlife management.

On the other hand, despite long and continuous sustained heavy harvesting, some bushmeat species continue to thrive in natural and modified habitats. The most resilient species are often able to adapt to hunting pressure, either by modifying their biological parameters and their ecology or by taking the niches left empty by the most vulnerable species. Thus, high harvesting pressure should not always be equated with local extinction. As a result, and because bushmeat plays a crucial role in the diets and livelihoods of people, options for sustainable harvest need to be investigated. Indeed, rural and urban people in Central Africa and indigenous people and part of the rural poor in the Amazon, use bushmeat as a major source of protein and income or to serve multiple social roles.

The level of dependency on bushmeat is however different in both basins: In the Amazon Basin, a relatively small number of indigenous people depend on bushmeat for their everyday life and hunt at sustainable levels for most species. As the rural non-indigenous or pioneer population becomes wealthier it looks more towards alternative protein sources (livestock, poultry). The urban population has access to one of the most active livestock sector of the world and therefore does not depend on bushmeat for protein intake. Urban trade in bushmeat is limited in size and location - though not very well known – and is not a major driver. With urbanization, wealth, and the availability of other meat sources, bushmeat harvest is likely to decline sharply in the future. The flip side of the coin is that the production of the main alternative source of protein (e.g. cattle) is also the main driver of deforestation in the Amazon basin, with well known negative effects on wildlife and ecosystems. The policy approach in the Amazon could well be inspired by Sarawak, Malaysia (Bennett *et al.* 2000), where A Master Plan for Wildlife has been developed. In Sarawak a strictly enforced law bans trade in wild animals and their parts, ensures strict control of shotgun cartridge availability and of hunting in logging concessions, and provides for broad education programs and involvement of local communities in the management of protected areas. This was enacted in 1998 through a "Wild Life Protection Ordinance" put into effect through intensive programmes of education and enforcement combined with strong support from rural community leaders as a means to conserve the resources on which the rural constituents depend (Bennett and Madhu Rao 2002). This success was possible in Sarawak because the commercial wildlife trade mainly supplies a luxury, urban market with plenty of alternative protein sources available. This situation has some similarities to prevailing circumstances in most urban areas in the Amazon Basin, and might be a useful model to adapt or replicate.

In the Congo Basin, increasing population and trade from rural to urban areas compounded with the lack of any sizeable domestic meat sector are the main drivers of unsustainable levels of hunting. Even where urban consumers have access to domesticated sources of meat they are imported and/or expensive and bushmeat remains an important part of their diet. With an estimated yearly extraction rate in the Congo Basin of 4.5 million tonnes, we would need to transform large areas of tropical forests or savannas into pasture to replace bushmeat by cattle. As comparison, the Brazilian beef production (8.6 million tonnes in 2005[1]) is considered responsible of about 50 million ha of deforestation. If bushmeat consumption in the Congo Basin was to be replaced by locally produced beef, an area as large as 25 million hectares might have to be converted to pastures. Pigs and chickens have much higher feed conversion rates than do cattle and both can thrive on kitchen scraps and crop residues. Focusing on pig or chicken husbandry rather than cattle ranching would then make more sense in the Congo Basin, but managing wildlife resoures will remain a necessity for decades to come.

Achieving sustainable harvest of bushmeat is therefore a necessity and by far, the best available option compatible with biodiversity conservation, local livelihoods, food security and food self sufficiency. Banning and strictly enforcing the sale of endangered or at risk species in urban markets but allowing the continued sale of resilient species would be a good step in Central Africa. If banned species where confiscated in the market and publically incinerated (to demonstrate that the police were not simply going to resell the meat elsewhere) market sellers would quickly see no profit in selling these species and would stop buying then from traders. At least that is the theory. Furthermore, as much of the commercial bushmeat that is consumed in urban households comes from logging concessions that represent the single largest landuse in the Congo Basin, increasing certification and forcing logging companies to halt hunting and export of bushmeat from their concessions would do much to reduce urban consumption (see Nasi *et al.* 2011 for examples).

Multidisciplinary approaches are needed to combine a better knowledge of the use and trade of bushmeat, the strengthening of legal frameworks, the provision of food and livelihood alternatives and the sustainable use of wildlife. None of these alone appear to be able to solve the so-called "bushmeat crisis", but combined and incorporated into solid national and regional bushmeat strategies, there is potential to achieve a more sustainable use of wildlife for food in the Congo Basin.

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[1] FAOStat database

REFERENCES

ABERNETHY, K. and NDONG OBIANG, A.M. 2010. *Bushmeat in Gabon/La viande de Brousse au Gabon*. Technical Report to the Directeur Général des Eaux et Forets, Président du Comité Inter-ministériel de la Stratégie Nationale de Gestion de la Viande de Brousse. Ministère des Eaux et Forêts, Gabon.

ALLEBONE-WEBB, S. 2009. *Evaluating dependence on wildlife products in rural Equatorial Guinea*. University of London, London, United Kingdom.

ALTRICHTER, M. 2006. Wildlife in the life of local people of the semi-arid Argentine Chaco. *Biodiversity and Conservation* **15**: 2719–2736.

ANGOUÉ, C., ASSOKO NDONG, A., BINOT, A., CARETTE, S., DE MARET, P. and TREFON, T. 2000. *Gabon.* In: BAHUCHET, S. and MARET, P.D. (eds.) *Les peuples des forêts tropicales aujhourd'hui: Volume III Région Afrique Central*. Programme Avenir des Peuples des Forêts Tropicales (APFT), Université Libre de Bruxelles, Brussels, Belgium.

AUNGER, R. 1992. *An ethnography of variation: food avoidance among horticulturalists and foragers in the Ituri forest, Zaire*. PhD, University of California, Los Angeles.

AUZEL, P. 1997. *Exploitation du milieu et émergence de nouvelles maladies virales : le cas de la faune sauvage dans les forêts d'Afrique Centrale*. Mémoire de DEA ETES : Orléans. 184 p + annexes.

AUZEL, P. and WILKIE, D.S. 2000. *Wildlife use in Northern Congo: hunting in a commercial logging concession*. 413–454 p. In: ROBINSON, J.G. and BENNET, E.L. (eds.) *Hunting for sustainability in tropical forests*. Columbia University Press, New York.

BAHUCHET, S. and IOVEVA, K. 1999. *De la forêt au marché: le commerce du gibier au sud Cameroun*. In: BAHUCHET, S., BLEY, H., PAGEZY, D. And VERNAZ-ZA-LICHT, N. (eds.) *L'homme et la forêt tropicale*. Editions de Bergier.

BAILEY, R.C. and PEACOCK, N.R. 1988. *Efe pygmies of northeast Zaire: subsistence strategies in the Ituri forest*. In: DE GARINE, I. And HARRISON, G.A. (eds.) *Uncertainty in the food supply*. Cambridge University Press, Cambridge. 88–117 p.

BECK, H. 2005. *Seed predation and dispersal by peccaries throughout the Neotropics and its consequences: a review and synthesis*. 77–115 p. In: FORGET, P.M., LAMBERT, J.E., HULME, P.E. and VANDER WALL, S.B. (eds.) *Seed fate: predation, dispersal, and seedling establishment*. CABI Publishing, Wallingfort, U.K.

BECK, H. 2006. A review of peccary-palm interactions and their ecological ramifications across the Neotropics. *Journal of Mammalogy* **87**: 519–530.

BECK, H. 2008. *Tropical ecology*. 3616–3624 p. In: JØRGENSEN, S.E. and FATH, B.D. (eds.) *General ecology, encyclopedia of ecology*. Elsevier, Oxford.

BENNETT, E.L. and ROBINSON, J.G. 2000. *Hunting of wildlife in tropical forests: implications for biodiversity and forest peoples*. 42 p. Environment Department Papers: Biodiversity Series - Impact Studies. World Bank, Washington, D.C.

BENNETT, E.L. and RAO, M. 2002. *Wild meat consumption in Asian tropical forest countries: is this a glimpse of the future for Africa?* In: MAINKA, S. And TRIVEDI, M. (eds.) *Links between biodiversity, conservation, livelihoods and food security: the sustainable use of wild species for meat.* IUCN. 39–44 p.

BENNETT, E.L., NYAOI, A.J. and SOMPUD, J. 2000. *Saving Borneo's bacon: the sustainability of hunting in Sarawak and Sabah*. In: ROBINSON, J.G. and BENNETT, E.L. (eds.) *Hunting for sustainability in tropical forests*. Columbia University Press, New York. 305–324 p.

BENNETT, E.L., BLENCOWE, E., BRANDON, K., BROWN, D., BURN, R.W., COWLISHAW, G.C., DAVIES, G., DUBLIN, H., FA, J., MILNER-GULLAND, E.J., ROBINSON, J.R., ROWCLIFFE, J.M., UNDERWOOD, F. and WILKIE, D. 2007. Hunting for consensus: a statement on reconciling bushmeat harvest, conservation and development policy in west and central Africa. *Conservation Biology* **21**: 884–887.

BODMER, R.E. 1991. Strategies of seed dispersal and seed predation in amazonian ungulates. *Biotropica* **23**: 255–261.

BODMER, R.E., FANG, T.G. and MOYA, I. 1994. Managing wildlife to conserve Amazonian forests: population biology and economic considerations of game hunting. *Biological Conservation* **67**: 29–35.

BODMER, R.E., EISENBERG, J.F. and REDFORD, K.H. 1997. Hunting and the likelihood of extinction of Amazonian mammals. *Conservation Biology* **11**: 460–466.

BODMER, R.E. and LOZANO, E.P. 2001. Rural development and sustainable wildlife use in Peru. *Conservation Biology* **15**: 1163–1170.

BODMER, R.E., LOZANO, E.P. and FANG, T.G. 2004. *Economic analysis of wildlife use in the Peruvian Amazon*. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press, New York.

BODRIE, J.F. and GIBBS, H.K. 2009. Bushmeat hunting as climate threat. *Science* **326**: 364–365.

BRASHARES, J.S., ARCESE, P., SAM, M.K., COPPOLILLO, P.B., SINCLAIR, A.R.E. and BALMFORD, A. 2004. Bushmeat hunting, wildlife declines and fish supply in West Africa. *Science* **306**: 1180–1183.

CAMPOS-ARCEIZ, A. and BLAKE, S. 2011. Megagardeners of the forest – the role of elephants in seed dispersal. *Acta Oecologica*.

CARPANETO, G.M., FUSARI, A. and OKONGO, H. 2007. Subsistence hunting and exploitation of mammals in the Haut-Ogooué province, south-eastern Gabon. *Journal of Anthropological Sciences* **85**: 183–193.

CBD. 2009. Report of the liaison group on bushmeat meeting. UNEP/CBD/LG-Bushmeat/1/2, Buenos Aires.

CHABER, A.-L., ALLEBONE-WEBB, S., LIGNEREUX, Y., CUNNINGHAM, A.A. and ROWCLIFFE, J.M. 2010. The scale of illegal meat importation from Africa to Europe via Paris. *Conservation Letters* **3**(5): 317–321.

CHARDONNET, P., editor. 1995. Faune sauvage Africaine: la ressource oubliée. International Game Foundation, CIRAD-EMVT, Luxembourg.

CLAGGETT, P.R. 1998. *The spatial extent and composition of wildlife harvests among three villages in the Peruvian Amazon*. 1998 meeting of the Latin American Studies Association, The Palmer House Hilton Hotel, Chicago, Illinois.

COAD, L. 2007. *Bushmeat hunting in Gabon: socio-economics and hunter behaviour.* University of Cambridge, Cambridge.

COWLISHAW, G., MENDELSON, S. and ROWCLIFFE, J.M. 2005. Evidence of post-depletion sustainability in a mature bushmeat market. *Journal of Applied Ecology* **42**: 460–468.

CULLEN, L., BODMER, R.E. and PADUA, C.V. 2000. Effects of hunting in habitat fragments of the Atlantic forests, Brazil. *Biological Conservation* **95**: 49–56.

DAVIES, G. 2002. Bushmeat and international development. *Conservation Biology* **16**: 587–589.

DE MERODE, E., HOMEWOOD, K. and COWLISHAW, G. 2004. The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. *Biological Conservation* **118**: 573–581.

DELVINGT, W. 1997. *La chasse villageoise synthèse régionale des études réalisées durant la première phase du programme ECOFAC au Cameroun, au Congo et en République Centrafricaine*. ECOFAC/AGRECO-CTFT, Brussels, Belgium.

DELVINGT, W., DETHIER, M., AUZEL, P. and JEANMART, P. 2001. *La chasse villageoise Badjoué, gestion coutumière durable ou pillage de la ressource gibier ?* 65–92 p. In: DELVINGT, W. (ed.) *La forêt des hommes : Terroirs villageois en forêt tropicale africaine*. Les Presses Agronomiques de Gembloux, Gembloux.

DETHIER, M. 1995. *Etude chasse*. Rapport ECOFAC, Composante Cameroun. AGRECO-CTFT, Bruxelles.

DONKIN, R.A. 1985. *The peccary - with observations on the introduction of pigs to the new world*. The American Philosophical Society, Philadelphia.

DOUNIAS, E. 1999. *Le câble pris au piège de la conservation. Technologie du piégeage et production cynégétique chez les Mvae du sud Cameroun forestier*. 281–300 p. In: BAHUCHET, S., BLEY, D., PAGEZY, H. and VERNAZZA-LICHT, N. (eds.) *L'homme et la forêt tropicale*. Travaux Société Ecologie Humaine, Paris.

EDDERAI, D. and DAME, M. 2006. A census of the commercial bushmeat market in Yaoundé, Cameroon. *Oryx* **40**(40): 472–475.

EMMONS, L.H. 1989. Jaguar predation on Chelonians. *Journal of Herpetology* **23**: 311–314.

ESPINOSA, M. 2008. What has globalization to do with wildlife use in the remote Amazon? Exploring the links between macroeconomic changes, markets and community entitlements. *Journal of Developing Societies* **24**: 489.

FA J.E. and PERES, C.A. 2001. *Game vertebrate extraction in African and neotropical forests: an intercontinental comparison*. In: REYNOLDS, J.D., MACE, G.M., REDFORT, K.H. and ROBINSON, J.G. (eds.) *Conservation of exploited species*. Cambridge University Press, Cambridge. 203–241 p.

FA, J. and YUSTE, J. 2001. Commercial bushmeat hunting in the Monte Mitra forests, Equatorial Guinea: extent and impact. *Animal Biodiversity and Conservation* **24**: 31–52.

FA, J.E. and D. BROWN. 2009. Impacts of hunting on mammals in African tropical moist forests: a review and synthesis. Mammal Review **39**: 231–264.

FA, J.E., YUSTE, J., PEREZ DEL VAL, J. and CASTRO-VIEJO, J. 1995. Impact of market hunting on Mammalian species of Equatorial Guinea. *Conservation Biology* **9**: 1107–1115.

FA, J.E., PÉRES, C.A. and MEEUWIG, J. 2002. Bushmeat exploitation in tropical forests: an international comparison. *Conservation Biology* **16**(1): 232–237.

FARGEOT, C. 2010. *Bushmeat consumption in Central African Republic*. XXIII IUFRO Congress, 23rd–28th of August 2010, Seoul, South Korea.

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

FRAGOSO, J.M.V. 1994. *Large mammals and the community dynamics of an Amazonian rain forest*. Zoology. University of Florida, Gainesville, Florida.

FRAGOSO, J.M.V. 1997. Tapir-generated seed shadows: scale-dependent patchiness in the Amazon rain forest. *Journal of Ecology* **85**: 519–529.

FRAGOSO, J.M.V., SILVIUS, K.M. and VILLA-LOBOS, M. 2000. *Wildlife management at the Rio das Mortes Xavante Reserve, MY, Brazil: integrating indigenous culture and scientific method for conservation*. World wildlife Fund-Brazil, Brasilia, Brazil.

GALLY, M. and JEANMART, P. 1996. *Etude de la chasse villageoise en forêt dense humide d'Afrique Centrale (Cameroun, Congo, République Centrafricaine)*.

GODOY, R., UNDURRAGA, E., WILKIE, D., REYES-GARCIA, V., HUANCA, T., LEONARD, W., MCDADE, T., TANNER, S. and VADEZ, V. 2009. The effect of wealth and real income on wildlife consumption among native Amazonians in Bolivia: estimates of annual trends with longitudinal household data (2002–2006). *Animal Conservation 9999*.

HART, J. 2000a. *Impact and sustainability of indigenous hunting in the Ituri Forest, Congo-Zaire: a comparison of unhunted and hunted duiker populations*. 106–153 p. In: ROBINSON, J.G. and BENNETT, E.L. (eds.) *Hunting for sustainability in tropical forests*. Columbia University Press, New York.

HART, J. 2000b. *Impact and sustainability of indigenous hunting in the Ituri Forest, Congo-Zaire: a comparison of unhunted and hunted duiker populations. Hunting for sustainability in tropical forests*. 106–153 p.

HENSCHEL, P. 2009. *The status and conservation of leopards and other large carnivores in the Congo Basin, and the potential role of reintroduction*. Reintroduction of Top-Order Predators. HAYWARD, M.W. and SOMERS, M.(eds.) Blackwell Publishing, Oxford.

HOOGESTEIJN, R. and CHAPMAN, C. 1997. Large ranches as conservation tools in the Venezuelan llanos. *Oryx* **31**: 274–284.

HURTADO-GONZALES, J.L. and BODMER, R.E. 2004. Assessing the sustainability of brocket deer hunting in the Tamshiyacu-Tahuayo Communal Reserve, northeastern Peru. *Biological Conservation* **116**: 1–7.

ISAAC, N.J.B. and COWLISHAW, G. 2004. *How species respond to multiple extinction threats*. Proceedings of the Royal Society B: Biological Sciences **271**: 1135.

IUCN 2008. IUCN Red List of Threatened Species.

KEUROGHLIAN, A. and EATON, D. 2009. Removal of palm fruits and ecosystem engineering in palm stands by white-lipped peccaries (Tayassu pecari) and other frugivores in an isolated Atlantic Forest fragment. *Biodiversity and Conservation* **18**: 1733–1750.

KNIGHTS, K. 2008. *Who ate all the crocodiles? An investigation of trends and patterns in trade and consumption of bushmeat in Gabon*. Conservation Science. Imperial College, London.

KÜMPEL, N.F. 2006a. *Incentives for sustainable hunting of bushmeat in Río Muni, Equatorial Guinea*. PhD thesis, Institute of Zoology, Zoological Society of London and Imperial College London, University of London. 247 p. Available at http://www.iccs.org.uk/thesis/KumpelPhD.pdf.

KÜMPEL, N.F. 2006b. *Incentives for sustainable hunting of bushmeat in Río Muni, Equatorial Guinea*. Institute of Zoology. University of London, London.

KÜMPEL, N.F., EAST, T., KEYLOCK, N., ROWCLIFFE, J.M., COWLISHAW, G. and MILNER-GULLAND, E.J. 2007. *Determinants of bushmeat consumption and trade in Río Muni, Equatorial Guinea: an urban-rural comparison*. 73–91 p. In: DAVIES, G. and BROWN, D. (eds.) *Bushmeat and livelihoods: wildlife management and poverty reduction*. Blackwell Publishing, Oxford.

KÜMPEL, N., MILNER-GULLAND, E., COWLISHAW, G. and ROWCLIFFE, J. 2010a. Assessing sustainability at multiple scales in a rotational bushmeat hunting system. *Conservation Biology* **24**: 861–871.

KÜMPEL, N., MILNER-GULLAND, E., COWLISHAW, G. and ROWCLIFFE, J. 2010b. Incentives for hunting: the role of bushmeat in the household economy in rural Equatorial Guinea. *Human Ecology* **38**: 251–264.

LAHM, S. 1993. *Ecology and economics of human/wildlife interaction in northeastern Gabon*. New York University.

MARCONI, S., MANZI, P., PIZZOFERRATO, L., BUSCARDO, E., CERDA, H., HERNANDEZ, D.L., PAOLETTI, M.G. 2002. Nutritional evaluation of terrestrial invertebrates as traditional food in Amazonia. *Biotropica* **34**(2): 273–280.

MILNER-GULLAND, E.J., BENNETT, E.L. and S.A.M.W.M. GROUP. 2003. Wild meat: the bigger picture. *TRENDS in Ecology and Evolution* **18**: 351–357.

MOCKRIN, M. 2010. Duiker demography and dispersal under hunting in Northern Congo. *African Journal of Ecology* **48**: 239–247.

NASI, R., CHRISTOPHERSEN, T. and BELAIR, C. 2010. Ending empty forests: management and sustainable use of wildlife in tropical production forests. *ITTO Tropical Forest Update* **20**: 19–21.

NASI, R., BROWN, D., WILKIE, D., BENNETT, E., TUTIN, C., VAN TOL, G. and CHRISTOPHERSEN, T. 2008. *Conservation and use of wildlife-based resources: the bushmeat crisis*. Secretariat of the Convention on Biological Diversity and Center for International Forestry Research (CIFOR), Bogor, Indonesia and Montreal, Canada.

NASI, R., BILLAND, A. and VAN VLIET, N. 2011. Managing for timber and biodiversity in the Congo Basin. *Forest Ecology and Management* DOI:10.1016/j.foreco.2011.04.005.

NAUGHTON-TREVES, L., MENA, J.L., TREVES, A., ALVAREZ, N. and RADELOFF, V.C. 2003. Wildlife survival beyond park boundaries: the impact of slash-and-burn agriculture and hunting on mammals in Tambopata, Peru. *Conservation Biology* **17**: 1106–1117.

NGNEGUEU, P. and FOTSO, R. 1996. *Chasse villageoise et conséquences pour la conservation de la biodiversité dans la réserve de biosphere du Dja.*. COFAC Yaoundé, Cameroon.

NOSS, A. 1995. *Duikers, cables, and nets: a cultural ecology of hunting in a central African forest*. University of Florida, Gainesville, Florida.

NOSS, A. 1999. *La sostenibilidad de la caceria de subsistencia Izoceña*. 535–543 p. In: CABRERA, E., MERCOLLI, C. and RESQUIN, R. (eds.) *Manejo de fauna silvestre en Amazonıa y Latinoamerica*. CITES Paraguay, Fundacion Moises Bertoni, University of Florida, Asuncion, Paraguay.

NOSS, A.J. 2000. *Cable snares and nets in the Central African Republic*. 282–304 p. In: ROBINSON, J.G. and BENNETT, E.L. (eds.) *Hunting for sustainability in tropical forests*. Columbia University Press., New York.

NOSS, A.J. and CUELLAR, R.L. 2001. Community attitudes towards wildlife management in the Bolivian Chaco. *Oryx* **35**: 292–300.

NOSS, A., CUELLAR, E. and CUÉLLAR, R. 2004. An evaluation of hunter self-monitoring in the Bolivian Chaco. *Human Ecology* **32**: 685–702.

NOVARO, A.J., REDFORD, K.H. and BODMER, R.E. 2000. Effect of hunting in source-sink systems in the neotropics. *Conservation Biology* **14**: 713–721.

NUÑEZ ITURRI, G. and H. HOWE. 2007. Bushmeat and the fate of trees with seeds dispersed by large primates in a lowland rain forest in western Amazonia. *Biotropica* **39**: 348–354.

OATES, J. 1996. *African primates: status survey and conservation action plan*. IUCN, Gland, Switzerland.

OJASTI, J. 1996. *Wildlife utilization in Latin America: current situation and prospects for sustainable management*. FAO Conservation Guide no. 25, Rome, Italy. 237 p.

OJASTI, J. 2000. *Manejo de fauna silvestre neotropical*. 290 p. In: DALLMEIER, F. (ed.) SI/MAB Series. Smithsonian Institution/MAB Biodiversity Program, Washington D.C.

OJEDA, M.M. 1997. Wildlife management in Venezuela: experiences and future perspectives. *Wildlife Society Bulletin* **25**: 49–56.

OKOUYI, J. 2006. Savoirs locaux et outils modernes cynégétiques : développement de la filière commerciale de viande de brousse à Makokou (Gabon). Université Orléan, France.

PARRY, L., BARLOW, J. and PERES, C.A. 2009. Hunting for sustainability in tropical secondary forests. *Conservation Biology* **23**: 1270–1280.

PERES, C.A. 2000a. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. *Conservation Biology* **14**: 240–253.

PERES, C.A. 2000b. *Evaluating the impact and sustainability of subsistence hunting at multiple Amazonian forest sites*. 31–57 p. In: ROBINSON, J. and BENNETT, E. (eds.) *Hunting for sustainability in tropical forests*. Columbia University Press, New York, USA.

PERES, C.A. and DOLMAN, P. 2000. Density compensation in neotropical primate communities: evidence from 56 hunted and nonhunted Amazonian forests of varying productivity. *Oecologia* **122**: 175–189.

READ, J., FRAGOSO, J., SILVIUS, K., LUZAR, J., OVERMAN, H., CUMMINGS, A., GIERY, S. and DE OLIVEIRA, L. 2010. Space, place, and hunting patterns among indigenous peoples of the Guyanese Rupununi region. *Journal of Latin American Geography 9*.

REDFORD, K.H. 1992. The empty forest. *Bioscience* **42**: 412–422.

ROBINSON, J. and REDFORD, K. 1991. Sustainable harvest of neotropical forest mammals. *Neotropical wildlife use and conservation* 415–429 p.

ROBINSON, J. and REDFORD, K. 1994. *Community-based approaches to wildlife conservation in neotropical forests*. In: WESTERN, D. and WRIGHT, R. (eds.) Natural Connections. Island Press.

ROBINSON, J.G. and BENNETT, E.L. (eds.) 2000. *Hunting for sustainability in tropical forests*. Columbia University Press, New York.

RUSHTON, J., VISCARRA, R., VISCARRA, C., BASSET, F., BAPTISTA, R. and BROWN, D. 2005. *How important is bushmeat consumption in South America: now and in the future?* ODI Wildlife Policy Briefing, Number 11, February 2005, ODI, United Kingdom.

SALAS, L.A. and KIM, J.B. 2002. Spatial factors and stochasticity in the evaluation of sustainable hunting of tapirs. *Conservation Biology* **16**: 86–96.

SCHENCK, M., NTSAME EFFA, E., STARKEY, M., WILKIE, D., ABERNETHY, K., TELFER, P., GODOY, R. and TREVES, A. 2006. Why people eat bushmeat: Results from two-choice, taste tests in Gabon, Central Africa. *Human Ecology* **34**: 433–445.

ŞEKERCIOĞLU, Ç.H., DAILY, G.C. and EHRLICH, P.R. 2004. Ecosystem consequences of bird declines. *Proceedings of the National Academy of Sciences of the United States of America* 101:18042–18047.

SERGIO, F., CARO, T., BROWN, D., CLUCAS, B., HUNTER, J., KETCHUM, J., MCHUGH, K. and HIRALDO, F. 2008. Top predators as conservation tools: ecological rationale, assumptions, and efficacy. *Annual review of ecology, evolution, and systematics* **39**: 1–19.

SMITH, N.J.H. 1976. Utilization of game along Brazil's transamazon highway. *Acta Amazonia* **6**: 455–66.

SMITH, D.A. 2005. Garden game: shifting cultivation, indigenous hunting and wildlife ecology in Western Panama. *Human Ecology* 33:505–537.

SMITH, D.A. 2010. The harvest of rain-forest birds by indigenous communities in Panama. *Geographical Review* **100**: 187–203.

SOLLY, H. 2004. Bushmeat hunters and secondary traders: making the distinction for livelihood improvement. *ODI Wildlife Policy Briefing 8.*

STARKEY, M. 2004. *Commerce and subsistence: the hunting, sale and consumption of bushmeat in Gabon*. Fitzwilliam College. Cambridge University, Cambridge, United Kingdom.

STEARMAN, A.M. 2000. *A pound of flesh: Social changes and modernization as factors in hunting sustainability*. 233–250 p. In: ROBINSON, J. and BENNETTE, E. (eds.) *Hunting for Sustainability in Tropical Forests*. Columbia University Press, New York.

STONER, K.E., RIBA-HERNANDEZ, P., VULINEC, K. and LAMBERT, J.E. 2007. *The role of mammals in creating and modifying seedshadows in tropical forests and some possible consequences of their elimination*. 316–327 p.

SWANK, W. and TEER, J. 1989. Status of the jaguar – 1987. *Oryx* **23**: 14–21.

TAKFORYAN, A. 2001. *Chasse villageoise et gestion locale de la faune sauvage en Afrique: Une étude de cas dans une forêt de l'Est-Cameroun*. Thèse de l'EHESS, Paris, 467 p.

TERBORGH, J. 2010. *Trophic Cascades*. Duke University Press.

TERBORGH, J., NUÑEZ-ITURRI, G., PITMAN, N.C.A., VALVERDE, F.H.C., ALVAREZ, P., SWAMY, V., PRINGLE, E.G. and PAINE, C.E.T. 2008. Tree recruitment in an empty forest. *Ecology* **89**: 1757–1768.

TREFON, T. and DE MARET, P. 1999. *Snack nature dans les villes d'Afrique Centrale*. In: BAHUCHET, S., BLEY, D., PAGEZY, H. and VERNAZZA-LICHT, N. (eds.) *L'homme et la forêt tropicale*. Editions de Bergier.

TRINCA, C.T. and FERRARI, S.F. 2007. Game populations and hunting pressure on a rural frontier in Southern Brazilian Amazonia. *Biologia Geral e Experimental, Universidade Federal de Sergipe* **7**: 5–16.

VANTOMME, P.D., GÖHLER and N'DECKERE-ZIANGBA, F. 2004. *Contribution of forest insects to food security and forest conservation: The example of caterpillars in Central Africa*. Wildlife Policy Briefing no 3, ODI, London.

VAN VLIET, N. 2008. *Spatial and temporal variability within the "hunter-animal-village territory" system – towards a geographical approach to hunting sustainability in*

Central Africa- case study on duikers in north-east Gabon. Faculté de Géographie. Université Toulouse le Mirail, Toulouse, France.

VAN VLIET, N. and NASI, R. 2008. Hunting for livelihood in Northeast Gabon: patterns, evolution, and sustainability. *Ecology and Society* **13**: 33.

VAN VLIET, N. and MBAZZA, P. 2011. Recognizing the multiple reasons for Bushmeat consumption in urban areas: a necessary step towards the sustainable use of wildlife for food in Central Africa. *Human Dimensions of Wildlife* **16**(1): 45–54.

VAN VLIET, N., NASI, R., EMMONS, L., FEER, F., MBAZZA, P. and BOURGAREL, M. 2007. Evidence for the local depletion of bay duiker, *Cephalophus dorsalis*, within the Ipassa Man and Biosphere Reserve, north-east Gabon. *African Journal of Ecology* **45**: 440–443.

VAN VLIET, N., MILNER-GULLAND, E., BOUSQUET, F., SAQALLI, M. and NASI, R. 2010. Effect of small-scale heterogeneity of prey and hunter distributions on the sustainability of bushmeat hunting. *Conservation Biology* **24**: 1327–1337.

VAN VLIET N., NEBESSE, C., GAMBALEMOKE, S., AKAIBE, D. and NASI, R. (in press). The bushmeat market in Kisangani, Democratic Republic of Congo: implications for conservation and food security. *Oryx.*

VANTHOMME, H., BELLE, B. and FORGET, P.M. 2010. Bushmeat hunting alters recruitment of large-seeded plant species in central Africa. *Biotropica* **42**: 320–326.

WALSH, P., ABERNETHY, K., BERMEJO, M., BEYERS, R., DE WACHTER, P., AKOU, M., HUIJBREGTS, B., MAMBOUNGA, D., TOHAM, A. and KILBOURN, A. 2003. Catastrophic ape decline in western equatorial Africa. *Nature* **422**: 611–614.

WILKIE, D., STARKEY, M., ABERNETHY, K., NTSAME, E., TELFER, P. and GODOY, R. 2005. Role of prices and wealth in consumer demand for bushmeat in Gabon, Central Africa. *Conservation Biology* **19**: 268–274.

WRIGHT, S.J. 2003. The myriad consequences of hunting for vertebrates and plants in tropical forests. *Perspectives in Plant Ecology, Evolution and Systematics* **6**: 73–86.

WRIGHT, S.J., STONER, K.E., BECKMAN, N., CORLETT, R.T., DIRZO, R., MULLER-LANDAU, H.C., NUNEZ-ITURRI, G., PERES, C.A. and WANG, B.C. 2007b. The plight of large animals in tropical forests and the consequences for plant regeneration. *Biotropica* **39**: 289–291.

WRIGHT, J.H. and PRISTON, N. 2010. Hunting and trapping in Lebialem Division, Cameroon: bushmeat harvesting practices and human reliance. *Endang. Species Res. Vol.* **11**: 1–12.

Forests, women and health: opportunities and challenges for conservation

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SUMMARY

Health issues of forest women in developing countries merit more serious attention. This paper reviews existing literature on the interface of women, health and forests to highlight conservation opportunities and challenges. Most women in forests are collectors and users of forest species. However, existing conservation efforts, deforestation, poor health services and household responsibilities can intensify health and safety concerns for forest dependent women. Women are likely to bear the strenuous burden of carrying fuelwood (and other forest products) long distances and inhaling smoke while cooking. The burden of unintended childbearing, diseases and cultural issues can compound their health problems. To improve local livelihoods and environments, some organisations have initiated activities that integrate conservation and human health objectives, including family planning. This article provides project examples, where the involvement of women has been identified as a key component in effectively meeting both conservation and development goals.

Keywords: women, human health, forest conservation, fuelwood, integrated projects

Forêts, femmes et santé: défis et opportunités pour la conservation

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Les questions de santé des femmes vivant dans la forêt dans les pays en voie de développement méritent une attention sérieuse. Cet article examine la littérature existante sur les questions liées des femmes, de la santé et de la forêt, pour souligner les opportunités et les défis qu'elles lancent à la conservation. La plupart des femmes vivant dans les forêts récoltent et utilisent les espèces forestières. Cependant, les efforts existants de la conservation, la déforestation, les services de santé faibles et les responsabilités de ménage peuvent intensifier les soucis quant à la sécurité et à la santé des femmes dépendantes de la forêt. Il est probable que ce soient les femmes qui doivent soutenir le fardeau écrasant du transport du bois de combustion et d'autres produits forestiers sur leur dos sur de longues distances, ainsi que l'inhalation des fumées durant la combustion et la cuisine. Le fardeau des grossesses non prévues, des maladies et des questions culturelles peut aggraver leurs problèmes de santé. Pour améliorer l'existence et l'environnement, certaines organisations ont créé des activités intégrant les objectifs de conservation et de santé, en incluant le planning familial. Cet article fournit des exemples de projets où la participation des femmes a été identifiée comme étant un élément clé pour parvenir à atteindre efficacement les buts de conservation et de développement.

Bosque, mujer y salud: oportunidades y retos para la conservación

M. WAN, C.J.P. COLFER y B. POWELL

El tema de la salud de la mujer que trabaja en el bosque en países en vías de desarrollo merece ser considerado más seriamente. Este artículo es una revisión de la literatura existente sobre la interacción de la mujer, la salud y el bosque con la que poner de relieve oportunidades para la conservación y los retos existentes. La mayoría de mujeres que trabajan en el bosque son recolectoras o utilizan las especies forestales. Sin embargo, los esfuerzos de conservación actuales, la deforestación, los servicios de salud deficientes y las responsabilidades del hogar pueden aumentar la preocupación existente sobre la salud e higiene de las mujeres que dependen del bosque. Las mujeres sufren habitualmente la carga agotadora del acarreo de leña (y otros productos forestales) a largas distancias y el respirar humos al cocinar. Sus problemas de salud pueden agravarse con la responsabilidad de hijos no planeados, las enfermedades o por razones culturales. A fin de mejorar los medios de subsistencia y el medio ambiente local, algunas organizaciones ya han iniciado esfuerzos que integran los objetivos de conservación con los de la salud humana, incluyendo la planificación familiar. Este artículo proporciona ejemplos de proyectos en los que se ha identificado la participación de la mujer como un componente clave para alcanzar de manera efectiva tanto los objetivos de conservación como los de desarrollo.

INTRODUCTION

Although a number of gender-related issues have garnered the attention of policy makers and researchers, health issues of forest-reliant women in developing countries merit more serious attention. Within forestry particularly, the multiple forest functions that intersect with women's lives have been comparatively ignored. The literature discussed here comes from divergent fields and represents the tip of a substantial knowledge 'iceberg' fairly inaccessible to foresters.

Here we introduce existing literature on the interface of women,[1] health and forests to highlight conservation opportunities and challenges. Resources important to most forest women include fuelwood, fodder and foods. In many regions, women are the ones responsible for collecting these for their families' subsistence needs and/or cash income. They are likely to bear the arduous burden of carrying firewood long distances,[2] as well as inhaling smoke from cooking. Due to the minimal availability of health services and the burdens of household responsibilities, forest dependence can also intensify specific health and safety concerns for women. Unintended childbearing and expanding family sizes can compound health problems. Women's customary use of fuelwood, forest medicines, fibers, fruits, vegetables and bushmeat makes them repositories of considerable ecological knowledge (see e.g., Boer and Lamxay 2009, Eyzaguirre 2006, Johnson and Grivetti 2002). Relevant traditional knowledge and strong forest-reliance can together provide a compelling rationale for forest conservation; and external acknowledgement of these facts can contribute to better collaborative management of such resources. In an effort to improve local livelihoods and environments, some organisations have begun to integrate conservation and human health objectives, including family planning (e.g., Africa Biodiversity Collaborative Group, Population Action International, WWF; examples in Boxes 2–5).

Women, as half of the human global population, represent a huge potential human resource. Tropical forest women[3] tend to have access to virtually no labour-saving devices and lack the possibility of limiting their reproductive roles. This has meant that huge amounts of female creativity, energy and knowledge have not been accessible to those trying to manage forests more sustainably or protect forest areas more effectively. Additionally, because women tend also to be responsible for the care of sick family members, they have a special interest in improving the health of their communities. Our experience suggests that efforts to provide birth control and to improve local health represent powerful incentives for local women to become involved in conservation efforts.

Here, we first introduce the global relevance of the issue. The second section outlines some examples of issues that affect the health of women in forests (some directly forest-related, some not, but important for those working in forest conservation to be aware of), and the final section explores the links of these realities to conservation, using specific examples.

GLOBAL RELEVANCE

We highlight two related global concerns: the first is the eight Millennium Development Goals (MDGs) identified in September 2000 (see Box 1). Global actors were encouraged to make them a reality by 2015.

Four of the eight goals are directly related to human health (MDG 1, 4, 5 and 6); and two are specifically related to women (MDG 3 and 5). Ten years have passed, yet adult female mortality rates in developing countries are still far higher than in developed countries (Table 1).

BOX 1 *Millennium Development Goals*

MDG 1: Eradicate extreme poverty and hunger
MDG 2: Achieve universal primary education
MDG 3: Promote gender equality and empower women
MDG 4: Reduce child mortality
MDG 5: Improve maternal health
MDG 6: Combat HIV/AIDS, malaria and other diseases
MDG 7: Ensure environmental sustainability
MDG 8: Develop a global partnership for development

TABLE 1 *Female mortality rate per 1,000 females age 15–60 years*

	Mean	Median	Std. Deviation
Developing countries			
1990	213	187	102
2000	216	178	124
2007	209	164	134
Developed countries			
1990	80	75	24
2000	67	62	20
2007	59	54	21

Calculated from: WHO Data 2010

[1] The category 'women' encompasses a huge range of behaviour, knowledge, and interests (see e.g., Leach 2007). Yet there remain sufficient patterns and tendencies among women, vis-à-vis men that some level of generalisation is justified (a level we try not to exceed).

[2] Such a burden varies substantially by forest type and human settlement patterns – greater in dry forests (e.g., East and North Africa, parts of India, eastern Indonesia) and in resettlement areas that cluster people too densely (e.g., parts of Indonesia, Laos).

[3] By 'forest women' we refer to women living in/around forests, whose lives are directly dependent on it and/or have significant impacts on it.

The second global issue of relevance derives from our observations of change in the world's climate. Our emphasis on change has meant that concepts like *dynamism, resilience, uncertainty* and *future trends* have become increasingly common. These are concepts that apply at the global and landscape levels, but also pertain to women's lives. As we examined the literature and our own substantial experience of rural forest women and their lives, we were struck by the repetition of patterns; the specifics, the locations and times may change, but similar patterns frequently recurred elsewhere, later. Although ten year old research might no longer represent the studied reality, its findings were often relevant for women in other areas and at different times. Older studies remained useful in highlighting forest women's problems and

BOX 2 *"A Bagagem das Mulheres da Floresta" of the Secretary of Women Extractivists*

The rubber tappers movement in Brazil helped to catalyse a profound shift in perceiving environmental and human rights goals as inherently intertwined.

Realising the growing importance of women in the social movement, in 1995, the National Council of Rubber Tappers (CNS) created the Secretary of Women Extractivists specifically to treat questions relating to forest-reliant women. Strategically, the Secretariat chose health as its entryway to women's issues, as health issues are generally not perceived as threatening to men. In addition, an extreme lack of basic education and health care in remote areas of Amazonia had left women isolated, ignorant and fearful about basic health issues. Given the strong prior tendency for community meetings to be male-dominated, the mere chance for rural women to meet and discuss health concerns was a huge conquest.

Today, one of the foremost projects of the Secretariat, "Bagagem das Mulheres" (the Baggage of Women) is signifying all the knowledge which women hold as well as the tools in the forms of books, videos and workshops that the project brings to them. Workshops focus on health care, prevention of sexually transmitted diseases, family planning, environment, raising income through forest products and community organisation. From 1995 until 2011, the project has conducted 430 workshops reaching each of the over 80 conservation units in remote regions of Amazonia.

In 2009 the project received the Chico Mendes Award for Health and Environment in Acre, as well as the Award for the Defense of the Human Rights of Women in the United Kingdom. The project has also worked closely with the Ministry of Health in a massive effort in which they successfully amended public health policy and nomenclature to include, "forest populations". Since its founding, female leadership within extractive reserves has grown; seven women are currently Presidents of Conservation Units. And after years of deliberation, the name of the National Council of Rubber Tappers has recently been changed to the National Council of Extractivist Populations, to include not only collectors of all types of forest products, but also – women.

[Courtesy of Fatima Cristina da Silva, CNS]

BOX 3 *Linking Conservation and Human Health in West Kalimantan, Indonesia*

The forests of Gunung Palung National Park in western Borneo, Indonesia, are some of the most biodiverse – and threatened – in the world. Just as tenuous is the health of people living among them. Women, in particular, are vulnerable to lung disease from cooking with wood, and that problem can worsen when human-induced forest fires blanket large areas in smoke. Remote villages and bad roads make it costly and difficult to access health care, whether for routine visits or for emergencies like complicated childbirth. And those emergencies can ruin an extended family's finances. To make money, some people turn to illegal logging. Others burn the rainforest to clear new land for pesticide-laden crops and plantations. But in damaging the forest, people hurt themselves; clean watersheds become contaminated and floods damage fields and roads and accentuate disease. Thus, environmental destruction, poverty, poor access to and high cost of quality health care, lack of knowledge, and transportation problems are all linked in a vicious cycle.

Enter Alam Sehat Lestari (ASRI), an Indonesian NGO whose name means "healthy nature everlasting." Based beside the national park in the town of Sukadana, ASRI seeks to interrupt that cycle and return Gunung Palung's forest and communities to a healthier coexistence. A survey, conducted early on, showed the villagers spending some $145 yearly on food – lower than what they spent on cigarettes ($297) or healthcare ($209). One of the reasons for the high health care costs was the lack of nearby access. Building on the villagers' requests, ASRI first began running a high-quality health clinic and mobile clinic; it offers free birth control and inexpensive diagnostics and medications, as well as ambulance service. Second, it offers people incentives to stop illegally logging, in the form of discounts on health care as well as training in organic farming. Third, ASRI offers eco-friendly and conservation-promoting work opportunities. Patients and their families may pay with non-cash means, such as manure for the clinic's garden or seeds for its reforestation site. Widows are eligible to receive goats, which provide them with manure, and a measure of economic independence.

Environmental destruction and human disease are exceedingly complicated problems, but they are linked. ASRI believes that spotting and protecting those links between people and nature is the key to securing good health for both.

[Prepared by Jenny Blair, ASRI]

opportunities pertaining to health, in providing insights for foresters who struggle to incorporate gender and health into forestry research/management strategies.

Writing this article has demonstrated the degree to which useful materials were spread among diverse literatures, using hugely divergent vocabularies and methods, with vastly different goals. We found, for instance, the health literature to be biased toward urban settings; the forestry literature to be biased toward men's behaviour and knowledge; and many gender studies (like the health research in fact) neglect to indicate the habitat of the study population.

With these concerns and constraints in mind, we selected four topics that are important in the lives of women living in tropical forests. We provide a smattering, a potpourri, of interesting topics, with important real-life implications for human well being and forest management.

Our selection has built on our observations of women's lives, over a combined 45 years of field experience in the forests of Africa, Latin America and Asia. We have not chosen to emphasise *poverty* per se (despite the acknowledged shortage of financial resources among these populations), because of our sense of the disempowering effect of such an emphasis (Escobar 1995), in global discourse. It stresses the weaknesses rather than the strengths in populations under study; and unlike more specific observations, as identified here, an emphasis on poverty provides few insights or hints for constructive action.

We have defined 'forests' broadly, focusing on the forests of the developing world. We include the emblematic tropical rainforests of the Amazon and Congo Basins, of Borneo and New Guinea. But we also address women's lives in the dry forests of eastern and southern Africa, the Sahel, parts of India and eastern Indonesia. From a human perspective, we have looked at the lives of hunter gatherers, swiddeners, frontier dwellers, resettled populations, inhabitants of parks, refugees – any women whose lives depend on and/or affect forests. We have used such a broad brush partly to introduce foresters to the breadth of disciplines with 'something to say'; but also because of the paucity of materials; the issues identified beg for further study and attention.

BOX 4 *Linking Women and Forest Benefits through Improved Stoves*

Improved household energy practice (i.e. using improved stoves) have been linked with the MDGs, including the goals related to betterment of women and forests:

MDG 3: Promote gender equality and empower women

- Alleviating the drudgery of fuel collection and reducing cooking time will free women's time for productive endeavours, education and child care.
- Reducing the time and distance that women and girls need to travel to collect fuel will reduce the risk of assault and injury, particularly in conflict situations.
- Women's involvement in decisions about household energy promotes gender equality.

MDG 5: Improve maternal health

- Reducing indoor air pollution will alleviate chronic respiratory problems among women.
- A less polluted home can improve the health of new mothers who spend time close to the fire after having given birth.
- More accessible fuel sources can reduce women's labour burdens and associated health risks, such as prolapse due to carrying heavy loads.

MDG 7: Ensure environmental sustainability

- Where biomass is scarce, easing the reliance on fuelwood through more efficient cooking practices will lessen pressures on forests.
- Using cleaner, more efficient and convenient fuels (such as natural gas and electricity); and improved stoves can increase energy efficiency and decrease greenhouse gas emissions (Rehfuess 2006).

In Nepal, a Population, Health and Environmental project introducing the use of improved cook stoves reduced consumption of firewood by 4,804 metric tons per year (or about 12,000 trees), and dramatically reduced the number of cases of acute child respiratory infections (D'Agnes 2009).

When women of Bonfi in coastal Guinea use the Chorkor oven, which requires less fuelwood than traditional stoves, to smoke their fish, the women found they had extra time to attend literacy classes, because they spent far less time stoking the fires (Anoko 2008). This oven not only reduces fuelwood and labour requirements, but produces better quality smoked fish that can be stored for a longer time, and thus can also be sold when prices are higher (Kleter 2004, UNDP 2001).

Roy (2008) reported that women around Chunati Wildlife Sanctuary (Bangladesh) who used improved stoves which created less indoor air pollution and increased energy efficiency collected forest fuelwood less often and in smaller amounts, compared to those who used traditional stoves.

A SAMPLING OF ISSUES LINKING WOMEN, HEALTH AND FORESTS

Although many of the problems discussed here also affect women beyond forests, remoteness and shortages of household resources tend to increase the severity of any particular problem *in* forests. National health programs prioritise areas where their 'health dollars' will go furthest, making serving sparsely-populated forest areas difficult (e.g., Cunningham *et al*. 2008 for Africa; Ali 2008, Persoon 2008 for Asia; Goicolea 2001, Oliveira 2005 for Latin America). Forest women typically have fewer economic resources, and less control over shared resources, than their husbands, and therefore even less access to any available formal medical care (Allotey *et al*. 2008). Forestry institutions, though in recent years recognising some responsibility for the well being of people living in forests,[4] have traditionally ignored health and food security issues.

We have selected four disparate categories designed to reflect the range of issues that affect women's health in forests. These are forest resources, reproductive matters, diseases and culture.

Forest Resources

This section focuses primarily on the collection and use of fuelwood[5], however the issues are similar for collection of fodder and wild plant food resources. These topics demonstrate how living and working in/near forested areas and the loss of forest resources can adversely affect women. They serve as an entree into a broader range of issues linked to forests and their use – specifically nutritional adequacy, health dangers related to the collection of non timber forest products (NTFPs) for subsistence and sale, and occupation-related health hazards (some parallel to or related to those described below).

Forest resource collection

Most women who live in and around forests in developing countries collect the majority of fuelwood, fodder and wild vegetables used by their households (cf. Agarwal 2009a, Biran *et al.* 2004, Nakro and Kikhi 2006, Nilsson 2006, Robinson and Kajembe 2009, Roy 2008, Tabuti *et al*. 2003). Fuelwood is used for cooking, smoking meat or fish, making charcoal, lighting, mosquito repellent, sometimes heating

BOX 5 *Hand in Hand: Bringing together Health and Environment Sectors in Madagascar*

In Fianarantsoa province in eastern Madagascar, a stunning sliver of biodiverse forest remains, yet those who live on its periphery are unable to access basic health services and markets.

Champion Commune sought to improve access to health services while simultaneously helping rural communities better manage their natural resources and improve their livelihoods. Champion Commune built upon prior multi-sectoral work, and challenged communities to set and achieve health, environment, economic growth and good governance goals.

One community adjacent to Ranomafana National Park surpassed its goals, and found a multi-sectoral approach fit their development needs, saying:

- Even if people use family planning to have healthier children, unless they are able to grow nutritionally good food, their family's health will not improve;
- Improved agricultural techniques that do not rely on herbicides and pesticides are better for the environment and for families;
- Protecting the surrounding area adjacent to water sources helps the environment and provides cleaner water for human consumption;
- One cannot separate the two: healthy people and a healthy environment go hand in hand!

The health sector gained access to underserved populations in areas of high biodiversity, and the project found that people were more receptive to environmental initiatives due to greater community trust (a result of also addressing stated community health needs). In addition, there was an increase in male participation in health initiatives, and a rise in female participation in natural resources management activities.

Like families in developed nations, Malagasy households in isolated villages want to choose when and how many children to have. Children's and mother's lives – as well as forest health and economic growth – are tied to ensuring better access to family planning and health services in remote, biodiverse regions. By working hand in hand, integrated initiatives such as Champion Commune help do just that.

[Courtesy of Kristen P. Patterson, the USAID-funded Kaominina Mendrika (Champion Commune) project]

[4] But compare sets of criteria and indicators for sustainable forest management. Many include concerns about access to resources, community health and worker safety.

[5] Interest in fuelwood as a topic of scientific study has varied over the years, as has scientific interest in women's relations to it. According to Bassam and Maegaard (2004) fuelwood scarcity affects around 60% of rural women in Africa, 80% in Asia and 40% in Latin America.

houses and water for bathing or for earning cash income. Its collection is among the most time-consuming chores undertaken by rural women (Carr and Hartl 2010). Such use of their time reduces their opportunities to pursue education[6] or to participate in other capacity building or income generating activities (Anoko 2008, Population Action International 2000).

Not surprisingly, women often develop useful knowledge about the forest products they regularly use. For example, women may know which firewood burns better (Edmond 2008, Gbadegesin 1996, Godfrey *et al.* 2010), is most suitable for cooking certain type of foods, has longer burning duration, requires less attention, and produces less smoke and ash (Brouwer *et al.* 1996). Women similarly have detailed knowledge of and are sensitive to changing availability of wild plant foods in their local environments (Daniggelis 2003, Johnson and Grivetti 2002).

With forest degradation in developing countries women face increasing difficulty in collecting firewood, fodder and wild vegetables (cf. Adedayo *et al.* 2008, Ayanwuyi *et al.* 2007, Gupta 2008, Kidanu *et al.* 2009, Nakro and Kikhi 2006, Nilsson 2006). Collection and use require the expenditure of more time and energy (Agarwal 2001, Brouwer *et al.* 1996, Gbetnkom 2007). Kitts and Roberts' (1996) 1990 Indian findings of APDC found that before deforestation, women and children had sought fuelwood within a 1–2 km walk. Seven to eight years later, they had to walk 8–10 km every day to get enough fuelwood to cook the evening meal. Such long journeys

> "...[induce] neglect of children at home, meals are skipped, the sick ones are not adequately taken care of and the school is not regularly attended as older children either accompany their mothers in search for firewood or are assigned to take care of the young ones and other domestic chores." (Godfrey *et al*. 2010, p. 847)

Elsewhere Gbetnkom (2007) noted that more time in collection reduces time spent for cooking and income generation. Social and cultural expectations, as well as child care and other time-consuming daily tasks, often means that resource depletion near the home affects women before it affects men, who can venture further to obtain the same resources (Bizzarri 2010, Powell *et al.* 2010). A study by Cooke (1998) in Nepal examines the implications of changing levels of resource availability over a 14 year period, on women and girls in Nepal, finding adverse effects of resource degradation on girls' educational achievement.

Forest closure or forest protection for conservation or prevention of deforestation can also cause hardships for women, especially for poor, landless women (Agarwal 2009b). For example, in Nigeria, some women had to walk more than 4 km to collect firewood in an open access area because of their restricted access to the trees on communal and family land (Adedayo *et al.* 2010). In many cases, women and girls have had no choice, but to collect these forest products illegally from protected areas, their neighbours' forests or tree plantations. Some have been beaten, had their fuelwood confiscated, and been subjected to demands for bribes, verbal (Sarin 2000, Sarin *et al.* 1997) or sexual abuse, rape, even death by forest guards or other forest owners (Gain 2010, Haile 1991). Restricted forest access may also reduce women's access to wild forest foods, many of which provide important micronutrients often scarce in foods from other sources (Powell *et al.* 2011, Vinceti *et al.* 2008).

In facing a scarcity of fuelwood, some women have substituted it with other less efficient fuels such as twigs, leaves, dung, crop residue for fuelwood (Agarwal 2001), even plastic (Lemenih and Kassa 2007). These inferior fuels require more time to light and more effort to keep them burning, thus making cooking more time-consuming and preventing women from simultaneously attending to other work (Agarwal 2007, Brouwer *et al.* 1996, Gbadegesin 1996). Even though cooking with twigs can be faster for a brief time (perhaps 10 minutes), about 2.5 kg more of fuel are required to cook the same meal (Brouwer *et al.* 1996). These inferior fuels also produce more harmful smoke (Brouwer *et al*. 1996, Subba 1999).

Besides the direct problems for women, relating to fuelwood and wild plant food acquisition, fuelwood scarcity can also have indirect adverse effects including changes dietary composition, either by omitting foods and meals (Bizzarri 2010, Cooke *et al*. 2008, Gardner-Outlaw and Engelman 1999) or substituting certain dishes (e.g., for beans, an important source of protein and micronutrients in many rural diets) with less nutritionally beneficial ones (Brouwer *et al.* 1996, 1997). Reductions in cooking time (Cecelski 1995, Ishaya *et al.* 2009) can decrease the nutritional quality of the diet as well as increase the risk of food-borne disease. Some women in refugee camps have been reported to have sold or traded their food rations (dried beans, grain, flour) for fuelwood, since they did not have enough fuel to cook the food (Bizzarri 2010, Patrick 2010). Given the well-established cyclical links between nutrition and infection, the impact of women's decreased access to fuelwood and forest foods can cause health problems for the whole family.

Fuelwood smoke

Combustion of biomass, including fuelwood, releases significant quantities of health-damaging pollutants, including several carcinogenic compounds (Naeher *et al.* 2007). For example, biomass fuels can release 1500–2000 $\mu g/m^3$ of respirable particle indoor pollution, while kerosene and gas produce 76 $\mu g/m^3$ and 101 $\mu g/m^3$, respectively (Rehfuess 2006). Globally, women spend from 3–7 hours per day near stoves, preparing food (WHO 2005a). Compared to men, they are more consistently exposed to the negative health effects of

[6] A UN study (UN 2010) found that "Women who receive an education are less likely to die in childbirth and more likely to have healthy children. The under five mortality rate falls by about half for mothers with primary education and the benefits increase with each additional year at school." (p. 4)

smoke from the firewood and other solid fuels they use for cooking. Poor ventilation of kitchens is common and worsens the situation. Indoor smoke exposure has been found to be responsible for 39% annual deaths due to chronic pulmonary diseases in women, while only 12% in men (Rehfuess 2006).

WHO (2005a) found that "[i]n high-mortality developing countries, indoor smoke is responsible for an estimated 3.7% of the overall disease burden, making it the most lethal killer after malnutrition, unsafe sex and lack of safe water and sanitation," with "59% of all indoor air pollution-attributable deaths thus fall[ing] on females".

Meta analysis by Smith *et al.* (2004) showed strong evidence that smoke from solid fuel usage in households in developing countries was linked to pulmonary diseases in the women. "Women exposed to indoor smoke are three times more likely to suffer from chronic obstructive pulmonary disease (COPD), such as chronic bronchitis or emphysema, than women who cooked with electricity gas or other cleaner fuels." (Rehfuess 2006, p. 10). Similar respiratory effects were noted for their young children since women care for children while cooking (Table 2). Rehfuess (2006) also noted that in Africa and South East Asia annually there were over 600,000 deaths of children under five years caused by pneumonia and other acute respiratory infections due to indoor air pollution.

Cataracts represent another health problem that can be caused by exposure to smoke, including smoke from biomass. Pokhrel *et al.*'s (2005) study in Nepal and India confirmed the causal relationship found in three earlier studies: that the risk of cataracts is increased by indoor exposure to smoke from solid cooking fuel. Smith and Mehta (2003) also noted links between solid fuel use and blindness.

Women's Reproductive Health

Reduction of maternal mortality is one of the core objectives of the 5th MDG, yet in 2008 there were an estimated 358,000 maternal deaths (deaths associated with pregnancy and childbirth) globally, with less than 1% of these deaths occurring in developed countries (WHO *et al.* 2010). Because, malnutrition during childhood can lead to a small birth canal and obstructed labour (a main cause of maternal mortality), one important step towards reducing maternal mortality is to break the intergenerational cycle of chronic under-nutrition (UN-SCN 2004). Achievement of this MDG will require efforts which cut across disciplines and government divisions, including nutrition, food security, agriculture and forestry.

TABLE 2 *Health effects of solid fuel usage in developing country households*

Disease	Population affected	Strength of evidence
Chronic obstructive pulmonary disease	Females >15 years	Strong
	Males >15 years	Intermediate
Lung cancer (coal smoke only)	Females >15 years	Strong
	Males >15 years	Intermediate
Blindness (cataracts)	Females >15 years	Intermediate
Tuberculosis	Females > 15 years	Intermediate
Acute lower respiratory infections	Children < 5 years	Strong

Source: Smith et al. 2004 in Smith 2008 (p. 102)

This section focuses on two recurrent female health problems: uterine prolapse and stillbirth – both of which tend to be overlooked within the field of forestry despite the fact that forest use, management and governance decisions and policies can have an impact on factors associated with their development. Forest women have an elevated risk for these problems due to limited access to medical care and forest-related activities (such as heavy manual labour and malnutrition common in many forest communities).

> The International Labour Organization (ILO) specifies: "No woman should be assigned to manual transport of loads during a pregnancy which has been medically determined or during the ten weeks following [birth] if in the opinion of a qualified physician such work is likely to impair her health or that of her child." (CIS 2007)

The ILO recommendation for maximum weight for manual carrying is 55 kg for men and should be "substantially less" for women (CIS 2007). The ILO further urges care regarding "arduous work involving the manual lifting, carrying, pushing or pulling of loads" for pregnant women (CIS 2007). In many countries the maximum recommended limit for lifting and carrying by women is only about 20 kg (ILO 1988 in Poschen 1993), however many (if not most) women who live in or near tropical forests carry burdens of fuelwood and water far exceeding this amount daily.

Carrying heavy loads for long distance can lead to several health problems such as, musculoskeletal disorders, miscarriage, stillbirth, or uterine prolapse (Messing and Östlin 2006). Haile (1991) found more than 6,000 women working as fuelwood carriers in Addis Ababa, Ethiopia, walking an average of 30 km (an increase from a previous study showing 24 km) up and down rugged hills, round trip, with some carrying up to 77 kg of fuelwood on their backs. The women spent about 7 hours a day doing this work. Women in the village of Chembe, Malawi walked between 0.5 and 4.9 km to their fuelwood source in Lake Malawi National Park (Biran *et al.* 2004). They also had to climb steep hills and descend the hills again, carrying around 29 kg of fuelwood (more than half of their body weight); some also carried their young children (an additional 9 kg on average). Kibera women around Ngong Forest in Kenya similarly earned their income from carrying up to 70 kg of fuelwood (Paula 2009).

Uterine prolapse

Uterine prolapse involves the uterus falling or sliding from its normal position in the pelvic cavity, in extreme cases, out of the vaginal canal (Pradhan 2007). It is one of five types of pelvic organ prolapse.

Unlike in developed countries where this extremely unpleasant condition occurs among postmenopausal women and is unrelated to childbirth, in Nepal it was found in a younger group with a mean age of 28 years (Subedi 2010). For many, prolapse occurs after giving birth to their first child (often at a young age) and is a permanent condition which they live with for life (Bodner-Adler *et al.* 2007, Pradhan 2007, The Advocacy Project n.d.). Ravindran *et al.* (2000) reported 87% of a small sample (N=37) of agricultural labourers from rural India were found to be suffering from uterine prolapse. Data on prevalence and age of onset for uterine prolapsed (and other types of pelvic organ prolapsed) are extremely limited for developing countries, but it seems likely that this condition is widespread, although greatly underreported (Scherf *et al.* 2002, Sherrie Palm pers. comm.). Risk of uterine prolapse is heightened by an arduous work load and carrying heavy loads (such as fuelwood, water, fodder, other NTFPs) during and soon after childbirth, low availability of skilled birth attendants (particularly with difficult births),[7] lack of nutritious food, early or closely-spaced pregnancies (Bodner-Adler *et al.* 2007, Kumari 2009, Pradhan 2007). Bonetti *et al.* (2004) noted that women carrying heavy load daily on their backs or heads could increase pressure on their pelvic organs.

This problem is common in Nepal, where the majority of the rural population[8] depend on forests as part of their subsistence agriculture practices (Gautam 2009). Women reported having to continue collecting wood from the forest and doing other strenuous field and domestic work, despite their pain (Subedi 2010, The Advocacy Project n.d.). A 2006 demographic and health survey showed that the problem has already affected more than 600,000 Nepalese women, and 200,000 are in need of immediate corrective surgery (Kumari 2009).

This maternal health condition, besides causing great physical pain, also disrupts marital and sexual relations. Women suffering from uterine prolapse often receive physical and verbal abuse from their husband and mother-in-law because of the condition, with some husbands leaving or threatening to leave their wives (Bonetti *et al.* 2004, Kumari 2009); others incorrectly consider it indicative of venereal disease (Allotey and Gyapong 2005). Shy and afraid of the consequences, many women who suffer from this disease hide their problem from others for decades (Farkouh 2009).

Stillbirths

Lawn *et al.* (2010) estimated that there are 3.2 million stillbirths globally per year and Fretts (2010) suggests that 98% of these occur in developing countries, indicative of a significant problem. Moreover, maternal mortality and stillbirths are highly correlated, particularly in the developing world. Similar to uterine prolapse, the risk factors for stillbirths include: access to medical care, number or pregnancies, maternal age, multiple births (e.g., twins), untreated maternal infection (such as malaria and syphilis), exposure to pollutants, complications during pregnancy (pre-eclampsia, diabetes, anemia, obstructed labour) and poor foetal growth (IUGR – Inter-Uterine Growth Restriction) (Allotey *et al.* 2008, Fretts 2010). Complications during pregnancy and IUGR are both strongly linked to nutrition, another obstacle faced by forest women. The shortage of resources and reduced availability of formal medical care in remote forested areas suggests that higher rates are likely to be found in such regions.

Although the issue is definitely under-researched, systematic review of four studies[9] on the effect of indoor air pollution from biomass cooking smoke on pregnancy showed a 51% increase in risk of stillbirth for pregnant women exposed to the pollutants (Pope *et al*. 2010, Yakoob *et al.* 2009). One study in India showed that women cooking with biomass fuels (wood, animal dung or crop residues) were twice as likely to have experienced two or more stillbirths as those using cleaner fuels, like electricity, liquid petroleum gas, biogas or kerosene (Mishra *et al*. 2005). Haile's (1991) Ethiopian study reported the incidence of miscarriage among fuelwood carriers – a task performed routinely by rural forest women – as 16% on average, and 44% among those aged 35–44.

Disease

Numerous illnesses that plague forest dwellers have been widely reported (see e.g., Colfer *et al.* 2006).[10] Although most of these diseases are not uniquely found in forested ecosystems, they play a major role in the health and well-being of forest people, and have important implications for forest management and conservation. For example, several authors have linked HIV/AIDS exposure and prevalence in forested parts of Africa to residence near roads (Orubuloye *et al.* 1993), migrant labour (Hunt 1993), and other timber-related infrastructure (e.g., brothels).[11] While some parasites and infectious diseases are more prevalent in men (Zuk and McKean 1996), others (such as malaria) affect women, and particularly pregnant or lactating women, more seriously than men. Additionally, in most developing countries infection and food and nutrition security have a cyclical relationship: poor nutrition impairs immune function and increases risk of infection,

[7] Cunningham *et al*. (2008, p. 36) report mid-1990's data on Swaziland (with a doctor-patient ratio of 1:6,600), Ghana (1:16,100), and Tanzania (1:24,390). Ratios in forested areas are typically lower than such national averages; and we found no evidence to suggest that such ratios have improved significantly in Africa.

[8] In 2009, only 17.7% of Nepal's population lived in urban areas (Asian Development Bank 2011) and women are the primary users of forests (Giri and Darnhofer 2010).

[9] All of which have adjustments for confounding factors.

[10] See Dry and Leach (2010) for a fascinating collection of papers on diseases, many of which are relevant for tropical forest contexts.

[11] The account of women's roles in providing sexual services in large scale plantation agriculture by Enloe (1989) nicely parallels the situation in many timber concessions, each of which may have an associated brothel.

and infection impairs absorption of and increases requirements for many nutrients (Semba and Bloem 2008). In forest communities gender differences in infection rates are likely exacerbated by gender differences in food security and nutrition.

There are a variety of patterned, disease-related advantages that accrue to men (in forests and out) *vis-à-vis* women, including better access to medical facilities (partly through their greater general mobility), higher likelihood of accurate diagnosis and treatment[12], more consistent follow-up, and more extant medical knowledge about men's health than women's (Allotey and Gyapong 2005).

Malaria

Malaria is one of the most common parasitic diseases in tropical forest areas (Allotey *et al.* 2008) and one of the top three killers among infectious diseases (Sachs and Malaney 2002). People become infected through the bites of mosquitoes infected with the plasmodium parasite. Ernst *et al.* (2006) mentioned that incidence of malaria increases as distance to forest decreases. Other studies have demonstrated the links between deforestation and increases in malaria risk (Olson *et al.* 2010, Pattanayak *et al.* 2006, Patz *et al.* 2008, Vittor *et al.* 2006).

WHO (2003) found that "[p]regnant women are particularly vulnerable to malaria as pregnancy reduces a woman's immunity to malaria, making her more susceptible to malaria infection and increasing the risk of illness, severe anaemia and death." Pregnancy and breastfeeding (and menstruation) also increase the body's requirements for many nutrients, increasing the likelihood of deficiency and resulting impaired immunity. Indeed, pregnant women suffer ". . .a two- to three-fold higher risk of severe malarial illness than non-pregnant women" (WHO 2003).

The disease causes more female than male deaths (aged 15 or older) (Allotey *et al.* 2008) and pregnant women are twice as likely as non-pregnant women to contract malaria (Espinosa *et al.* 2000). Pregnant women represent a high risk group, in which malaria can lead to miscarriage, low birth weight, stillbirth (Murphy and Breman 2001, WHO 2005b), premature delivery and neonatal death (WHO 2005b), cerebral malaria, pulmonary oedema (fluid in the lungs), hypoglycaemia (low blood sugar), or renal failure in the mother (summarised in Okoko *et al.* 2003; see also Reuben 1993). The disease kills about 10,000 pregnant women per year in Africa (WHO 2009). Prevalence of infection and parasite density are highest during the first half of a pregnancy and decline gradually during the second half (Okoko *et al.* 2003). The combination of a high pregnancy rate and living in a malaria-endemic area, such as many tropical forests, creates a potent risk of maternal mortality. According to Reuben (1993), cerebral malaria causes 40% mortality in pregnant women: double that of non-pregnant women. Malaria is associated with increased iron requirements and anemia, already a major problem in women of child bearing age (and a major risk factor for maternal mortality) (Semba and Bloem 2008).

Many of the world's forest women live in malaria endemic areas and often have lower access to dietary sources of iron (such as meat) and less access to treatment compared to men (Bentley *et al*. 1999, Gittelsohn *et al.* 1997, Gittelsohn and Vastine 2003, Messer 1997).

'Culture',[13] Food Systems and Health

The links between people's health, food security and their cultures have been extensively examined by anthropologists,[14] and differently, by medical practitioners. The former have typically seen the positive aspects of cultural systems; the latter, beliefs and practices deemed harmful.

Several important features of human food and health systems, including those in forests, should be borne in mind:

- Extreme variability from place to place;
- Integration of health within broader, holistic, and changing cultural systems;
- Mutability of individuals' beliefs, goals and behaviour, as well as of more patterned behaviour;
- Pluralistic ways in which individuals may view health, often combining the 'traditional' with the 'cosmopolitan' in their own health care.

The place of women within such systems varies enormously. Some examples of the unique roles women play related to forests and health include: the central (and culturally mediated) role of women in the maintenance or expansion of human population (Colfer *et al.* 2008); women's greater roles in bringing up children with or without environmental concerns, with or without forest-related knowledge; women's differential forest knowledge, often focused more

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[12] Allotey *et al.* (2008) describe a survey conducted by Simonsen *et al.* (1995) in Tanzania, which found that a physical examination for Filariasis for males included the genitals, arms and legs, whereas examination for females omitted the genital examination.

[13] By culture, we refer to the (somewhat patterned) values, beliefs, behaviour of human beings that are transmitted in some (changeable) form from one generation to the next. These behaviours include the whole spectrum of human behaviour (e.g., politics, kinship, religion, ethics, economics, subsistence, etc.) – *not* simply specific individual beliefs or exotic religious practices. Although the study of 'culture' has become a bit passé in anthropology, due to greater recognition of the mutability and internal diversity among human groups, we still see patterns in human behavior, thus find the concept useful. Here we risk alienating some anthropologists by simplifying some of the human complexity, in recognition of length limitations and the different disciplinary backgrounds of most readers of this journal.

[14] Useful compendia include: Conrad and Gallagher 1993, Landy 1977, McClain 1989, McElroy and Townsend 2004, and Whitaker 2006. Examples of useful overviews include classic texts by Foster and Anderson (1978) and Helman (1984).

on NTFPs (Pérez *et al.* 2002, Porro and Stone 2005, Powell *et al.* 2010), sometimes medicinal plants (Leaman 1996), less on timber (Bolaños and Schmink 2005, Sithole 2005); the roles of select women as healers (Jordan and Davis-Floyd 1993, McClain 1989, Tsing 1993); among others.

One of the most critically important women-forest-health interstices with cultural implications relates to food security and nutrition. Women almost always play major roles in the provision of adequate food to their families – whether cooking, marketing, production and/or gathering – functions key to the ongoing, day-to-day maintenance of forested populations. In or near forests, such foods typically include forest products (e.g., Colfer 2009, Ibarra *et al.* 2011, Laird *et al.* 2011, Ogle *et al.* 2001, Powell *et al.* 2011, Vinceti *et al.* 2008).

A study from the Western Ghats in India found that women hold significant amounts of knowledge about wild plant foods and that spending time with their mothers during collection and processing of wild foods is the primary means by which children learn about such foods (Cruz Garcia 2006). Cultural proscriptions are learnt simultaneously when mothers pass on their knowledge of identification and use of forest products and can have positive or negative health implications. Chotiboriboon *et al.* (2009), for instance, found that among the Karen of northern Thailand, consumption of various nutritious foods, including banana, ripe mango, papaya, pineapple, pomelo, wild pig and wild chicken, was forbidden when ill with fever or malaria. In the East Usambara Mountains, Tanzania, some local people believe that a woman should not consume traditional bitter vegetables (which are mostly wild) after giving birth (Powell *et al.* 2010). Forest women's access to wild plant food species (when and where they are permitted to harvest different species) is also bound by gendered cultural norms (Price 1997).

The reproductive sphere is one arena in which women are uniquely affected, with sometimes very specific cultural injunctions. Traditional beliefs or taboos may restrict women from eating certain food during pregnancy and lactation, reducing their nutritional intake (Creed-Kanashiro *et al.* 2009). Bentley *et al.* (1999), who studied the Lese women of the Democratic Republic of Congo (DRC), found women compensating for their loss of bush meat and other taboo food items, by increasing their consumption of cassava, which they linked to an increase in goitrogenic health problems. Some Karen women (in the Thungyai Naresuan National Wildlife Sanctuary, Thailand) see wild animal meat, including that of reptiles, insects and aquatic animals, as harmful for infants and pregnant and lactating women; after childbirth these women consume only warm water with salted rice for one to two weeks (Chotiboriboon *et al.* 2009) (a time when their requirements for micronutrients found in animal source foods, such as iron, is high); see also Boer and Lamxay (2009), on similar beliefs among the Brou, Saek and Kry of Laos.

On the other extreme, Dounias describes the enviable position of first time (primiparous) mothers among the Ntomba, also of the DRC (Dounias with Colfer 2008):

> "During this long period of seclusion [two to four years], over-feeding and intensive care have beneficial consequences for the health status of both the mother and her firstborn. . .[T]he primiparous mother incarnates the 'true mother' and radiates a symbolic image of purity and good health that is a source of pride and psycho-cultural wellbeing for the whole community." (p. 282)

More importantly, from an anthropological and human perspective, is the integration of such beliefs in a broader cultural system that in many cases depends crucially on the forested environment for its continuation. The interest in maintaining such cultures is not to maintain or create human museums, but rather as a kind of global insurance for the human species. At community and landscape scales, a threshold level of cultural stability is important for the maintenance of human life; and at an individual level, a woman's (and man's) sense of *meaning* in her/his life depends on (varying) threshold levels of cultural continuity. The lives of women who have depended on the forest for food security, subsistence and incomes and who lose such access – through gazettement as a park, the intrusions of a logging, mining or plantation company, or resettlement to a different context – suffer cultural and psychological losses, often even more devastating than the material losses sustained. Better forest management will acknowledge these aspects of health (both physical and mental).

WIN-WIN OPTIONS FOR WOMEN AND FOREST CONSERVATION

Two issues are addressed in this section: the advantages of linking women and conservation efforts, from the perspective of the environment; and the advantages of such links accruing to women.

Linking Women's Health and Forest Conservation – an Environmental View

There are both ethical and pragmatic reasons for addressing health and population issues in efforts to conserve forests. Issues of justice suggest that women, as forest users, should have a say in forest management (see, for instance, Agarwal 2000). The sometimes dire state of women's health in and around forested areas (as seen in much of the information provided so far) – provides ethical rationale. Food and food security, in addition to health, have been designated as a human right (Article 25, The Universal Declaration of Human Rights, the United Nations). Numerous authors have noted the primacy with which communities, and particularly women, tend to view their own food and health needs (cf. Ali 2008, Cronkleton 2005, Rao 2008), particularly in forested areas where formal health care systems are limited. The pragmatic implication of this for conservationists is that people are already motivated to improve their health; the 'health card' can serve as a potent entrée into a community and increase people's willingness to work with conservation

projects.[15] Box 3 provides an example of this practice in West Kalimantan, Indonesia.

Another issue of relevance for conservationists is the generally adverse effects of human population (and particularly population growth) on forests and protected areas. A growing population can create serious pressures on the environment and on local resources. Yet in recent years the topic of human population has been effectively taboo in conservation circles. We concur with Chaudhary (2000), Kidanu *et al.* (2009), Smail (2002), WWF (2002), and others, who believe that the burden of a growing global population can no longer be ignored.[16]

Climate change has strengthened researchers' interests in holistic analyses (cf. the *Millenium Ecosystems Assessments*) – a trend that affords greater likelihood that women, health and forest issues will be effectively addressed. Engelman, who has written extensively on the importance of linking population and environment issues (Engelman 1998, Engelman *et al.* 2006), has recently emphasised the linkage among population, carbon emissions and women's lives (Engelman 2010). The disease-related issue of deforestation has important links to climate change (to wit, the extensive and growing literature on REDD and REDD+, see www.cifor.org). Kidanu *et al.* (2009), in a recent Ethiopian study of the links between climate change and population, argued that increases in population were the major cause of deforestation in their forests, leading in turn to climate change. Women are the logical parties to involve in efforts to address these interlinked issues.[17] Box 4 provides examples of projects that eased both women's health and deforestation problems.

Our extensive experience at the forest management unit level has shown how increases in population – whether due to natural increase or to in-migration – complicate the lives of forest managers (whether formal or 'traditional') and often spell dangers for human health and forest sustainability. Some problematic actions include, for instance,

- Local or in-migrating people need more land for food crops and as their children age,
- Local or in-migrating people yield to temptations to log or perhaps over-harvest NTFPs to fund their children's education or their own health care, and
- Communities increasingly violently resist the actions of external parties that limit their own access to local resources.

A number of environmental and development organisations have begun to include a human health aspect in their conservation projects (e.g., TNC, WWF, CI, USAID). A primary motivation for these organisations has been the recognition that projects without local involvement are less likely to succeed.[18] In the next section, we turn to the implications at the level of the individual woman.

Linking Women's Health and Forest Conservation – some Women's Views

Many daily activities and ailments forest women endure – such as carrying heavy loads, exposure to indoor smoke pollution and forest diseases, and reproduction-related health problems – are often interrelated and exacerbate women's experience of disease. There is a strong need for attention to women's health for their own good, regardless of conservation outcomes. The priority that forest women themselves attribute to health has already been mentioned (see also Freudenberger 2010). Like environmental issues, many of these health problems are further exacerbated by the birth and care of large numbers of children.

Forests usually have low population densities. While this is partly responsible for the health profession's tendency to overlook people in remote areas, the low population densities can be due to low birth rates, but are often due to high mortality rates – related to infectious diseases, decreasing food availability and/or lack of health care services. Both high mortality rates and high rates of out-migration can disguise high birth rates, a topic which the environmental community must overcome the aversions to discussing.

One can imagine that women might consider pregnancy and giving birth to be a unique privilege of women; no [human] male can experience this. Yet this privilege remains one of the leading causes of death among women in developing countries. As noted above, more than 350,000 women die annually from complications of pregnancy and childbirth, almost all of them in developing countries (WHO *et al.* 2010). High fertility rates, combined with under-nutrition and poor

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[15] We are viewing people's involvement in conservation efforts (appropriately designed to take local human rights into account) as beneficial both ecologically and for local people's own lives. Such involvement can also build local skills (negotiation, self-analysis, conflict resolution, leadership, etc.), which can be more broadly useful to them (see Box 2).

[16] Others disagree. In an excellent, international study, Geist and Lambin (2002) examined 152 cases of tropical deforestation, finding population of lesser importance compared to economic, institutional, technological and cultural factors. Rudel's (2005) more nuanced study used 'qualitative comparative analysis' to untangle the factors involved in deforestation and reforestation in 115 cases around the world, demonstrating, among other things, the varying roles of population growth from region to region. The growth of population undeniably has different relevance in different forests, with no simple, linear, positive relationship between population growth and forest loss.

[17] Although controversial, a substantial literature argues for women's greater natural ecological awareness *vis-à-vis* men (see Shiva 1989, Diamond and Orenstein 1990). The latter, for instance, see the devaluation of natural processes as a product of masculine consciousness that ". . .denigrated and manipulated everything defined as 'other' whether nature, women, or Third World cultures" (pp. ix–x). Leach (2007) provides a convincing critique of these views.

[18] Interestingly, a study by Shandra *et al.* (2008) concluded that "high levels of women's and environmental international NGOs per capita are correlated with less deforestation."

health care services in remote areas, also increase women's general morbidity and mortality. An empirical model for rural South Africa showed a positive and significant correlation between wood scarcity (based on longer time taken to access wood resources) and women's fertility (Aggarwal *et al*. 2001).

Colfer *et al.* (2008) use causal loop diagramming to show common interconnections among women's pregnancies, caretaking responsibilities (for children, the elderly and the infirm), income generating and educational opportunities, as well as time and energy to become involved in community action, politics and. . .conservation. These factors carry different value among different groups, intimately affected by cultural propensities and individual difference, but they are likely to be significant for all women. Besides the adverse, global implications of population growth, high fertility rates have adverse health impacts on individual women and their families. Frequent pregnancies and near-continuous childcare can reduce women's and girls' involvement in forest conservation efforts as well as their opportunities for any self-actualisation unrelated to reproduction.[19] Further, repeated childbearing jeopardises women's health. Usually, a lack of time and energy are among the reasons women give when asked why they are not involved in community forest based activities (Agarwal 2000, Bolaños and Schmink 2005, Jewitt 2000). Agarwal (2000), for instance, suggests that ". . .[i]n the face of acute shortage, . . .the very values of nurture and caring for others, especially children, might lead women not toward conservation but its opposite" (p. 298).

Women in forested areas often ask for reproductive health services (Engelman 1998, 2007, Population Action International 2004; see Box 5). Howard *et al*. (2008) describe the positive attitudes of Senegalese refugees toward family planning in their camp in Guinea. Bremner *et al.* (2009), Carr *et al*. (2006) and Goicolea (2001), separately, document the unfulfilled interest of forest women in determining the number of their children in Ecuador. In developing countries, around 215 million women who want to avoid a pregnancy are still not using an effective method of contraception (Singh *et al*. 2009). Knowledge of modern family planning methods may not mean having access to them (particularly in remote forested areas); and it is not uncommon for women in rural areas also not to have the needed knowledge.

Not only women suffer from excessive childbearing (cf. Mavanza and Grossman's (2007) on a dismayed Tanzanian father of 23 children who learned about family planning too late). Bonetti *et al.* (2004) note Nepali men's concerns about the women in their community, who had to return to heavy labour immediately following childbirth. The men recounted a story about a community woman who had recently gone to the forest to have her baby alone – a situation they found very concerning. Similarly Katang men (Laos) expressed their concern about the many women who died in childbirth in their community. Many mothers in this community also gave birth in the forest near the village (Chithtalath and Earth 2001); reported also by Boer and Lamxay (2009), among the Brou, Saek and Kry of Laos.

CONCLUSIONS

Attempts to link the food security and health of women and their forest environments are fairly new, at least in an explicit, purposeful manner. Awareness of the potential for building on such links to produce 'win-win' situations in forests and forest communities has grown over time (see Boxes 2–5). In many forest communities, gender divisions of labour mean that women bear a heavy responsibility of providing and cooking their families daily meals. Women's central role in food acquisition and preparation may mean that, compared to men, they have stronger impetus than men to ensure local food resources are used sustainably. Women's greater global roles in nursing ill family members give women unusually strong motivation to address the health issues of all family and community members, not just their own, effectively. Women's greater focus on food and health is likely a key driver of differences in conservation priorities between men and women.

In moving forward, we agree with the account by Blay *et al.* (2004) of their experience in Tanzania, who attributed their successes to ". . .awareness-raising, community participation and empowerment . . . ." (p. 51). We recognise how difficult these approaches are.[20] But there are several pragmatic reasons that we continue to see them as the most likely to succeed. There is growing awareness of:

- Ecological and cultural diversity globally
- The degree to which 'tribal' and 'cultural' group members differ internally
- The ubiquity of change and the resulting need for continual adaptation
- The inadequacy with which many governments respond to crises and/or provide routine basic services, strengthening the need to empower local communities to deal with these needs themselves and gain a stronger voice in determining their own futures.
- A growing global demand for greater democracy, attention to human rights, and self-determination.

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[19] There are tremendous differences from place to place in women's valuation of childbearing. However, in the Indonesian, US, Iranian (Qashqa'I) and Omani villages where Colfer has conducted long term ethnographic research, there have always been women concerned to both limit childbearing and carve out time for non-reproductive activities. Colfer has also discussed this issue with women in Africa and Latin America, on shorter term visits, who have expressed fatigue at so many children, and the desire to limit childbearing and expand their horizons – within their own cultural frames.

[20] See for instance, Cooke and Kothari (2002) on the 'tyranny' of participation; Manor (2005) on the ineffectiveness of user groups; Mutimukuru-Maravanyika (2010) on political naiveté; Wollenberg (2001) on the need to attend to power politics; and more.

All of these factors make the pre-planned, 'command and control,' unilineal, logframe style of 'development' increasingly anachronistic and improbable of success.

Besides the bullets listed above, another series of constraints applies more dramatically to women: shortages of time and finances, illiteracy, lack of knowledge of the national language, responsibility to care for children and the elderly or ill. Women are particularly affected by the cycle of malnutrition and infection; each of the factors listed here, has the potential to exacerbate this cycle. These factors have functioned in effect to further mute women's voices.

We do not under-estimate the difficulty of addressing women's concerns and approaching health and forest management from holistic, culturally and ecologically sensitive, adaptive/learning perspectives. But we believe that such a paradigmatic shift is needed; and, in fact, is the only approach that will eventually bring a 'development' that forest women might appreciate and that might maintain forests.

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REFERENCES

ADEDAYO, A.G., OYUN, M.B. and KADEBA, O. 2010. Access of rural women to forest resources and its impact on rural household welfare in North Central Nigeria. *Forest Policy and Economics* **12**: 439–450.

ADEDAYO, A.G., SALE, F.A. and KEKEH, O. 2008. Rural household wood energy utilization pattern and its impact on deforestation in Akoko South West LGA, Ondo State, Nigeria. In: ONYEKWELU, J.C., ADEKUNLE, V.A.J. and OKE, D.O. (eds.) *Research for Development in Forestry, Forest Products and Natural Resources Management*. Proceedings of the First National Conference of the Forests and Forest Products society, 16th–18th April, 2008. Federal University of Technology, Akure, Nigeria. 159–164.

AGARWAL, B. 2000. Conceptualising environmental collective action: why gender matters. *Cambridge Journal of Economic* **24**: 283–310.

AGARWAL, B. 2001. The hidden side of group behaviour: a gender analysis of community forestry groups. Queen Elizabeth House Working Paper No. 76. 28 p.

AGARWAL, B. 2007. Gender inequality, cooperaton and environmental sustainability. In: BALLAND, J.-M., BARDHAN, P. and BOWLES, S. (eds.) *Inequality, cooperation and environmental sustainability.* Princeton University Press, Princeton, New Jersey. 274–313.

AGARWAL, B. 2009a. Gender and forest conservation: The impact of women's participation in community forest governance. *Ecological Economics* **68**: 2785–2799.

AGARWAL, B. 2009b. Rule making in community forestry institutions: The difference women make. *Ecological Economics* **68**: 2296–2308.

AGGARWAL, R., NETANYAHU, S. and ROMANO, C. 2001. Access to natural resources and the fertility decision of women: the case of South Africa. *Environment and Development Economics* **6**: 209–236.

ALI, R. 2008. Approaching conservation through health. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 317–332.

ALLOTEY, P. and GYAPONG, M. 2005. The gender agenda in the control of tropical diseases: A review of current evidence. Special Programme for Research and Training in Tropical Diseases. World Health Organization, Geneva, Switzerland.

ALLOTEY, P., GYAPONG, M. and COLFER, C.J.P. 2008. The gender agenda and tropical forest diseases. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 135–160.

ANOKO, J.N. 2008. Gender and equity in the protected areas of West Africa. FIBA and UICN PAPACO. 84 p.

ASIAN DEVELOPMENT BANK. 2011. Asian Development Bank & Nepal: Fact Sheet.

AYANWUYI, E., OLADOSU, O., OGULADE, I. and KUPONIYI, F.A. 2007. Rural women perception of effects of deforestation on their economic activties in Ogbomoso area of Oyo State, Nigeria. *Pakistan Journal of Social Sciences* **4**: 474–479.

BASSAM, N.E. and MAEGAARD, P. 2004. *Integrated renewable energy for rural communities: Planning guidelines, technologies, and applications.* Elsevier, Amsterdam, The Netherlands. 315 p.

BENTLEY, G.R., AUNGER, R., HARRIGAN, A.M., JENIKE, M., BAILEY, R.C. and ELLISON, P.T. 1999. Women's strategies to alleviate nutritional stress in a rural African society. *Social Science & Medicine* **48**: 149–162.

BIRAN, A., ABBOT, J. and MACE, R. 2004. Families and firewood: A comparative analysis of the costs and benefits of children in firewood collection and use in two rural communities in sub-Saharan Africa. *Human Ecology* **32**: 1–24.

BIZZARRI, M. 2010. Safe access to firewood and alternative energy in Kenya: An Appraisal Report. WFP and Women's Refugee Commission. 52 p.

BLAY, D., BONKOUNGOU, E., CHAMSHAMA, S.A.O. and CHIKAMAI, B. 2004. *Ngitili*: A traditional method of land rehabilitation in Shinyanga region, Tanzania. In: WOOD, P. and YAPI, A.M. (eds.) *Rehabilitation of degraded lands in sub-Saharan Africa: Lessons learned from selected case studies.* 48–51. http://www.fornis.net/system/files/synthesis_all.pdf.

BODNER-ADLER, B., SHRIVASTAVA, C. and BODNER, K. 2007. Risk factors for uterine prolapse in Nepal. *International Urogynecology Journal* **18**: 1343–1346.

BOER, H. de and LAMXAY, V. 2009. Plants used during pregnancy, childbirth and postpartum healthcare in Lao PDR: A comparative study of the Brou, Saek and Kry ethnic groups. *Journal of Ethnobiology and Ethnomedicine* **5**: 25.

BOLAÑOS, O. and SCHMINK, M. 2005. Women's place is not in the forest: gender issues in a timber management project in Bolivia. In: COLFER, C.J.P. (ed.) *The equitable forest: Diversity, community and resource management.* Resources for the Future, Washington, DC. 274–295.

BONETTI, T.R., ERPELDING, A. and PATHAK, L.R. 2004. Listening to ''felt needs'': Investigating genital prolapse in Western Nepal. *Reproductive Health Matters* **12**: 166–175.

BREMNER, J., BILSBORROW, R., FELDACKER, C. and HOLT, F.L. 2009. Fertility beyond the frontier: indigenous women, fertility, and reproductive practices in the Ecuadorian Amazon. *Population and Environment* **30**: 93–113.

BROUWER, I.D., HARTOG, A.P.D., KAMWENDO, M.O.K. and HELDENS, M.W.O. 1996. Wood quality and wood preferences in relation to food preparation and diet composition in Central Malawi. *Ecology of Food and Nutrition* **35**: 1–13.

BROUWER, I.D., HOORWEG, J.C. and VAN LIERE, M.J. 1997. When households run out of fuel: Responses of rural households to decreasing fuelwood availability, Ntcheu District, Malawi. *World Development* **25**: 255–266.

CARR, D., PAN, W. and BILSBORROW, R. 2006. Declining fertility on the frontier: the Ecuadorian Amazon. *Population and Environment* **28**: 17–39.

CARR, M. and HARTL, M. 2010. Lightening the load: Labour-saving technologies and practices for rural women. United Kingdom. 76 p.

CECELSKI, E.W. 1995. From Rio to Beijing. *Energy Policy* **23**: 561–575.

CHAUDHARY, R.P. 2000. Forest conservation and environmental management in Nepal: A review. *Biodiversity and Conservation* **9**: 1235–1260.

CHITHTALATH, S.-A. and EARTH, B. 2001. From the forest to the clinic: Changing birth practive among the Katang, Lao. *Reproductive Health Matters* **9**: 99–104.

CHOTIBORIBOON, S., TAMACHOTIPONG, S., SIRISAI, S., DHANAMITTA, S., SMITASIRI, S., SAPPASUWAN, C., TANTIVATANASATHIEN, P. and EG-KANTRONG, P. 2009. Thailand: food system and nutritional status of indigenous children in a Karen community. In: KUHNLEIN, HV., ERASMUS, B. and SPIGELSKI, D. (eds.) *Indigenous peoples' food systems: the many dimensions of culture, diversity and environment for nutrition and health.* Food and Agriculture Organization of the United Nations and Centre for Indigenous Peoples' Nutrition and Environment, Rome. 159–183.

CIS (International Occupational Safety and Health Information Centre). 2007. SafeWork Bookshelf. International Labour Organization. http://www.ilo.org/safework_bookshelf/english/.

COLFER, C.J.P. 2009. *Longhouse of the tarsier: Changing landscapes, gender and well being in Borneo*, Borneo Research Council/ CIFOR/ UNESCO, Philipps, Maine. 433 p.

COLFER, C.J.P., DUDLEY, R.G. and GARDNER, R. 2008. Forest women, health and childbearing. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 113–134.

COLFER, C.J.P., SHEIL, D. and KISHI, M. 2006. Forests and human health: Assessing the evidence. *CIFOR Occasional Paper* 45. 111 p.

CONRAD, P. and GALLAGHER, E.B. (eds.) 1993. *Health and health care in developing countries: Sociological perspectives*. Temple University Press, Philadelphia, PA.

COOKE, B. and KOTHARI, U. (eds.) 2002. *Participation: the New Tyranny?* Zed Books, London.

COOKE, P.A. 1998. The long-term effect of environmental degradation on women in the hills of Nepal* (PRELIMINARY DRAFT). International Food Policy Research Institute, Washington, DC.

COOKE, P., KOHLIN, G. and HYDE, W.F. 2008. Fuelwood, forests and community management – evidence from household studies. *Environment and Development Economics* **13**: 103–135.

CREED-KANASHIRO, H., ROCHE, M., CERRON, I.T. and KUHNLEIN, H.V. 2009. Traditional food system of an Awajun community in Peru. In: KUHNLEIN, H.V., ERASMUS, B. and SPIGELSKI, D. (eds.) *Indigenous peoples' food systems: the many dimensions of culture, diversity and environment for nutrition and health.* Food and Agriculture Organization of the United Nations and Centre for Indigenous Peoples' Nutrition and Environment, Rome. 59–81.

CRONKLETON, P. 2005. Gender, participation and the strengthening of indigenous forest management in Bolivia. In: COLFER, C.J.P. (ed.) *The equitable forest: Diversity, community and resource management.* Resources for the Future, Washington, DC. 256–273.

CRUZ GARCIA, G. 2006. The mother – child nexus. Knowledge and valuation of wild food plants in Wayanad, Western Ghats, India. *Journal of Ethnobiology and Ethnomedicine* **2**: 39.

CUNNINGHAM, A.B., SHANLEY, P. and LAIRD, S. 2008. Health, habitats and medicinal plant use. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 35–62.

D'AGNES, L. 2009. The population, health and environment (PHE) pathway to livelihoods improvement: Lessons and best practices from Nepal. USAID, Nepal. 27 p.

DANIGGELIS, E. 2003. Women and 'wild' foods: Nutrition and household security among Rai and Sherpa forager-farmers in eastern Nepal. In: HOWARD, P.L. (ed.) *Women and Plants: Gender relations in Biodiversity Management and Conservation*. Zed Books, London. 83–97.

DIAMOND, I. and ORENSTEIN, G. (eds). 1990. Reweaving the world: the emergence of ecofmenism.: Sierra Club Books, San Francisco.

DOUNIAS, E.W. with COLFER, C.J.P. 2008. Sociocultural dimensions of diet and health in forest-dwellers' systems. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 275–292.

DRY, S. and LEACH, M. (eds.) 2010. *Epidemics: Science, Governance and Social Justice*. Earthscan, London. 299 p.

EDMOND, J. 2008. Incorporating gender into PHE strategies: Experiences from Conservation International. Conservation International and USAID. 25 p.

ENGELMAN, R. 1998. *Plan & conserve: A source book on linking population and environmental services in communities*. Population Action International, Washington, DC.

ENGELMAN, R. 2007. Sustainability from the ground up – Working on reproductive health and the environment in communities. http://www.populationaction.org/Issues/Population_and_Environment/Sustainability_from_the_Ground_Up/Summary.shtml.

ENGELMAN, R. 2010. Population, climate change, and women's lives. Worldwatch Report, Washington, DC. 43 p.

ENGELMAN, R., BREMNER, J., DESOUZA, R.-M. and MOGELGAARD, K. 2006. Indigenous population, fertility, and reproductive intention in the lowland neotropics: Response to McSweeney. *Conservation Biology* **20**: 1315–1317.

ENLOE, C. 1989. *Bananas, beaches and bases: Making feminist sense of international politics.* University of California Press, Berkeley, CA.

ERNST, K.C., ADOKA, S.O., KOWUOR, D.O., WILSON, M.L. and JOHN, C.C. 2006. Malaria hotspot areas in a highland Kenya site are consistent in epidemic and non-epidemic years and are associated with ecological factors. *Malaria Journal* 5.

ESCOBAR, A. 1995. *Encountering development: The making and unmaking of the third world*, *Princeton studies in culture/power/history*. Princeton University Press, Princeton, N.J. 290 p.

ESPINOSA, F.M., ALECRIM, W.D. and DANIEL-RIBEIRO, C.T. 2000. Attraction of mosquitoes to pregnant women. *Lancet* 356: 685.

EYZAGUIRRE, P.B. 2006. Agricultural biodiversity and how human culture is shaping it. In: CERNEA, M.M. and KASSAM, A.H. (eds.) *Researching the culture in agriculture: Social research for international development.* CABI, Oxford. 264–284.

FARKOUH, N. 2009. Reframing maternal health in Nepal. *Policy Matters Journal* Spring: 33–38.

FOSTER, G.M. and ANDERSON, B.G. 1978. *Medical anthropology.* John Wiley and Sons, New York.

FRETTS, R. 2010. Stillbirth epidemiology, risk factors, and opportunities for stillbirth prevention. *Clinical Obstetrics Gynecology* **53**: 588–596.

FREUDENBERGER, K. 2010. Paradise lost? Lessons from 25 years of USAID Environment Programs in Madagascar. International Resources Group, Washington D.C.

GAIN, P. 2010. The Garo women in Bangladesh: Life of a forest people without forest. *WRM Bulletin* **152**: 23–25.

GARDNER-OUTLAW, T. and ENGELMAN, R. 1999. Forest futures – Population, consumption, and wood resources. Population Action International, Washington DC. 68 p.

GAUTAM, A.P. 2009. Equity and livelihoods in Nepal's community forestry. *International Journal of Social Forestry* **2**: 101–122.

GBADEGESIN, A. 1996. Management of forest resources by women: a case study from the Olokemeji Forest Reserve area, southwestern Nigeria. *Environmental Conservation* **23**: 115–119.

GBETNKOM, D. 2007. Forest management, gender: and food security of the rural poor in Africa. UNU- World Institute for Development Economics Research (UNU-WIDER), Helsinki, Finland. 20 p.

GEIST, H.J. and LAMBIN, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. *BioScience* **52**: 143.

GITTELSOHN, J. and VASTINE, A.E. 2003. Sociocultural and household factors impacting on the selection, allocation and consumption of animal source foods: Current knowledge and application. *Journal of Nutrition* **133**: 4036S-4041S

GITTELSOHN, J., THAPA, M. and LANDMAN, L.T. 1997. Cultural factors, caloric intake and micronutrient sufficiency in rural Nepali households. *Social Science & Medicine* **44**: 1739–49.

GIRI, K. and DARNHOFER, I. 2010. Nepali women using community forestry as a platform for social change. *Society and Natural Resources* **23**: 1216–1229.

GODFREY, A.J., DENIS, K., DANIEL, W. and AKAIS, O.C. 2010. Household firewood consumption and its dynamics in Kalisizo Sub-County, Central Uganda. *Ethnobotanical Leaflets* **14**: 841–855.

GOICOLEA, I. 2001. Exploring women's needs in an Amazon region of Ecuador. *Reproductive Health Matters* **9**: 193–202.

GUPTA, P.H. 2008. From *Chipko* to climate change: Remote rural communities grapple with global environmental agendas. *Mountain Research and Development* **28**: 4–7.

HAILE, F. 1991. *Women fuelwood carriers in Addis Ababa and the peri-urban forest.* International Labour Office, Geneva.

HELMAN, C. 1984. *Culture, health and illness.* John Wright and Sons, Bristol, England.

HOWARD, N., KOLLIE, S., SOUARE, Y., ROENNE, A.V., BLANKHART, D., NEWEY, C., CHEN, M.I. and BORCHERT, M. 2008. Reproductive health services for refugees by refugees in Guinea: family planning. *Conflict and Health* **2**: 12.

HUNT, C.W. 1993. The social epidemiology of AIDS in Africa: Migrant labor and sexually transmitted disease. In: CONRAD, P. and GALLAGHER, E.B. (eds.) *Health and health care in developing countries: Sociological perspectives.* Temple University Press, Philadelphia. 1–37.

IBARRA, J.T., BARREAU, A., DEL CAMPO, C., CAMACHO, C.I., MARTIN, G.J. and MCCANDLESS, S.R. 2011. Community conservation, payments for environmental services and food sovereignty in an indigenous community of the Chinantla, Oaxaca, Mexico. *International Forestry Review*, this issue.

ISHAYA, S., MAISAMARI, G.J. and MOHAMMED, A.M. 2009. Fuelwood scarcity: women's perception, experience and adaptation strategies in Gwagwalada Area Council, Nigeria. *The Free Library* http://www.thefreelibrary.com/Fuelwood scarcity: women's perception, experience and adaptation. . .-a0235407194 [accessed May 25 2011].

JEWITT, S. 2000. Mothering earth? Gender and environmental protection in the Jharkhand, India. *Journal of Peasant Studies* **27**: 94–131.

JOHNSON, N. and GRIVETTI, L. 2002. Environmental Change in Northern Thailand: Impact on Wild Edible Plant Availability. *Ecology of Food and Nutrition* **41**: 373–399.

JORDAN, B. and DAVIS-FLOYD, R. 1993. *Birth in four cultures: A cross-cultural investigation of childbirth in Yucatan, Holland, Sweden, and the United States.* Waveland Press, Prospect Heights, Illinois.

KIDANU, A., ROVIN, K. and HARDEE, K. 2009. Linking population, fertility and family planning with adaptation to climate change: views from Ethiopia. Population Action International, Washington, D.C. 36 p.

KITTS, J. and ROBERTS, J.H. 1996. *The health gap: Beyond pregnancy and reproduction.* International Development Research Centre (IDRC), Ottawa.

KLETER, G.A. 2004. Control and prevention of contamination and spoilage in the traditional production of smoked fish in Ghana. RIKILT – Institute of Food Safety, Wageningen, The Netherlands. 23 p.

KUMARI, B. 2009. Fallen wombs, broken lives: Responding to uterine prolapse in Nepal. United Nations Family Planning Association. http://www.unfpa.org/public/News/pid/3282.

LAIRD, S.A., AWUNG, G.L., LYSINGE, R.J. and NDIVE, L.E. 2011. The Interweave of People and Place: Biological and cultural diversity in the lives of indigenous Bakweri and migrants to the Mount Cameroon region. *International forestry Review*, this issue.

LANDY, D. (ed.) 1977. *Culture, disease, and healing: Studies in medical anthropology.* Macmillan Publishing Co., New York. 559 p.

LAWN, J.E., GRAVETT, M.G., NUNES, T.M., RUBENS, C.E., STANTON, C. and the GAPPS REVIEW GROUP. 2010. Global report on preterm birth and stillbirth (1 of 7): definitions, description of the burden and opportunities to improve data. *BioMed Central Pregnancy and Childbirth* 10 (Supplement 1): 1–22.

LEACH, M. 2007. Earth mother myths and other ecofeminist fables: How a strategic notion rose and fell. *Development & Change* **38**: 67–85.

LEAMAN, D.J. 1996. *The medicinal ethnobotany of the Kenyah of East Kalimantan (Indonesian Borneo).* Doctoral, University of Ottawa, Canada.

LEMENIH, M. and KASSA, H. 2007. Summary report of the workshop proceedings on bridging the gap between the forestry and health sectors in Ethiopia. CIFOR, Addis Ababa, Ethiopia.

MANOR, J. 2005. User Committees: A potentially damaging second wave of decentralisation? In: RIBOT, J.C. and LARSON, A.M. (eds.) *Democratic Decentralisation through a Natural Resource Lens*. Routledge, London. 192–213.

MAVANZA, M. and GROSSMAN, A.A. 2007. Conservation and family planning in Tanzania: the TACARE experience. *Population and Environment* **28**: 267–273.

MCCLAIN, C.S. (ed.) 1989. *Women as healers: Cross cultural perspectives.* Rutgers University Press, Rutgers, NJ. 274 p.

MCELROY, A. and TOWNSEND, P.K. (eds.) 2004. *Medical anthropology in ecological perspective.* Westview Press, Boulder, CO. 466 p.

MESSER, E. 1997. Intra-household allocation of food and health care: Current findings and understandings – Introduction. Social Science & Medicine **44**: 1675–84.

MESSING, K. and ÖSTLIN, P. 2006. Gender equality, work and health: A review of the evidence. World Health Organization, Geneva. 46 p.

MISHRA, V., RETHERFORD, R.D. and SMITH, K.R. 2005. Cooking smoke and tobacco smoke as risk factors for stillbirth. *International Journal of Environmental Health Research* **15**: 397–410.

MURPHY, S.C. and BREMAN, J.G. 2001. Gaps in the childhood malaria burden in Africa: cerebral malaria, neurological sequelae, anemia, respiratory distress, hypoglycemia, and complications of pregnancy. *The American Journal of Tropical Medicine and Hygiene* **64**: 57–67.

MUTIMUKURU-MARAVANYIKA, T. 2010. Can we learn our way to sustainable management? Adaptive Collaborative Management in Mafungautsi State Forest, Zimbabwe, CERES Research School for Resource Studies for Development, Wageningen University, Wageningen, The Netherlands.

NAEHER, L.P., BRAUER, M., LIPSETT, M., ZELIKOFF, J.T., SIMPSON, C.D., KOENING, J.Q. and SMITH, K.R. 2007. Woodsmoke health effects: a review. *Inhalation Toxicology* **19**: 67–106.

NAKRO, V. and KIKHI, C. 2006. Strengthening market linkages for women vegetable vendors – experiences from Kohima, Nagaland, India. In: VERNOOY, R. (ed) *Social and gender analysis in natural resource management – learning studies and lessons from Asia.* Sage, India. 65–98.

NILSSON, A.K. 2006. Gender work in Lao PDR: Women and the fuelwood collection.

OGLE, B., DUNG, N.N.X., DO, T.T. and HAMBRAEUS, R. 2001. The contribution of wild vegetables to micronutrient intakes among women: An example from the Mekong delta, Vietnam. *Ecology of Food and Nutrition* **40**: 159–184.

OKOKO, B.J., ENWERE, G. and OTA, M.O.C. 2003. The epidemiology and consequences of maternal malaria: a review of immunological basis. *Acta Tropica* **87**: 193–205.

OLIVEIRA, M. 2005. Women of the Amazon forest and citizenship. *Health Care for Women International* **26**: 484–489.

OLSON, S.H., GANGNON, R., SILVEIRA, G.A. and PATZ, J.A. 2010. Deforestation and malaria in Mâncio Lima county, Brazil. *Emerging Infectious Diseases* **16**: 1108–1115.

ORUBULOYE, I.O., CALDWELL, P. and CALDWELL, J.C. 1993. The role of high-risk occupation in the spread of AIDS: Truck drivers and itinerant market women in Nigeria. *International Family Planning Perspectives* **19**: 43–48+71.

PATRICK, E. 2010. Voices from Dadaab: the daily struggle to cook a meal. http://www.womenscommission.org/blog/1069-from-dadaab-refugee-camp [Accessed 28 July 2011].

PATTANAYAK, S., DICKINSON, K., COREY, C., MURRAY, B., SILLS, E. and KRAMER, R. 2006. Deforestation, malaria, and poverty: a call for transdisciplinary research to support the design of cross-sectoral policies. *Sustainability: Science, Practice, and Policy* **2**: 45–56.

PATZ, J.A., OLSON, S.H., UEJIO, C.K. and GIBBS, H.K. 2008. Disease emergence from global climate and land use change. *Medical Clinics of North America* **92**: 1473–1491.

PAULA. 2009. Ngong Forest: Slum women start energy project in Ngong Road Forest. Wildlife Direct. Available: http://ngongforest.wildlifedirect.org/tag/fuel-wood/ [Accessed 8 July 2010].

PÉREZ, M., NDOYE, O., EYEBE, A. and NGONO, D. 2002. A gender analysis of forest product markets in Cameroon. *Africa Today* **49**: 97–126.

PERSOON, G.A. 2008. Hidden suffering on the Island of Siberut, West Sumatra. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 333–345.

POKHREL, A.K., SMITH, K.R., KHALAKDINA, A., DEUJA, A. and BATES, M.N. 2005. Case–control study of indoor cooking smoke exposure and cataract in Nepal and India. *International Journal of Epidemiology* **34**: 702–708.

POPE, D.P., MISHRA, V., THOMPSON, L., SIDDIQUI, A.R., REHFUESS, E.A., WEBER, M. and BRUCE, N.G. 2010. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic Reviews* **32**: 70–81.

POPULATION ACTION INTERNATIONAL. 2000. Why population growth matters to the future of forests. *Fact Sheet*. Available at http://www.populationaction.org/Publications/Fact_Sheets/FS10/Summary.shtml [Accessed 20 January 2011].

POPULATION ACTION INTERNATIONAL. 2004. Finding balance: Forests and Family Planning in Madagascar. http://www.populationaction.org/Publications/Documentaries/Finding_Balance_-_Forests_and_Family_Planning_in_Madagascar.shtml [Accessed 4 August 2011].

PORRO, N.M. and STONE, S. 2005. Diversity in living gender: Two cases from the Brazilian Amazon. In: COLFER, C.J.P. (ed.) *The equitable forest: Diversity, community and resource management.* Resources for the Future, Washington, DC. 242–255.

POSCHEN, P. 1993. Forestry, a safe and healthy profession? *Unasylva* 44. http://www.fao.org/docrep/u8520e/u8520e03.htm#forestry,%20a%20safe%20and%20healthy%20profession.

POWELL, B., HALL, J. and JOHNS, T. 2011. Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania. *International Forestry Review*, this issue.

POWELL, B., WATTS, J.D., ASAHA, S., BOUCARD, A., FEINTRENIE, L., LYIMO, E., SUNDERLAND-GROVES, J. and URECH, Z.L. 2010. The role of wild species in the governance of tropical forested landscapes. In: COLFER, C.J.P. and PFUND, J.-L. (eds.) *Collaborative governance of tropical landscapes.* Earthscan, London. 157–182.

PRADHAN, S. 2007. Unheeded agonies – A study on uterine prolapse prevalence and it's causes in Siraha and Saptari districts. Women's Reproductive Rights Program (WRRP), Centre for Agro-Ecology and Development (CAED), Kathmandu, Nepal. 90 p.

PRICE, L.L. 1997. Wild plant food in agricultural environments: A study of occurrence, management, and gathering rights in northeast Thailand. *Human Organization* **56**: 209–221.

RAO, V.S. 2008. Health and conservation in the cardamoms in Cambodia: Lessons learned from the CI-CARE partnership. Conservation International, Phnom Penh, Cambodia.

RAVINDRAN, T.K.S., SAVITRI, R. and BHAVANI, A. 2000. Women's experiences of utero-vaginal prolapse: a qualitative study from Tamil Nadu, India. In: BERER, M. and RAVINDRAN, T.K.S. (eds.) Safe motherhood initiatives: Critical issues. Reproductive Health Matters, London. 166–72.

REHFUESS, E. 2006. Fuel for life: household energy and health. Geneva: World Health Organization. 42 p.

REUBEN, R. 1993. Women and malaria--special risks and appropriate control strategy. Social Science & Medicine **37**: 473–480.

ROBINSON, E.J.Z. and KAJEMBE, G.C. 2009. Changing access to forest resources in Tanzania. EfD. Discussion Paper 09–10.

ROY, B.C.S. 2008. Fuelwood, alternative energy and forest user groups in Chunati Wildlife Sanctuary. In: FOX, J., BUSHLEY, B.R., MILES, W.B. and QUAZI, S.A. (eds.) *Connecting communities and conservation: collaborative management of protected areas in Bangladesh.* East-West Center, Honolulu. 209–226.

RUDEL, T.K. 2005. *Tropical forests: Regional paths of destruction and regeneration in the late twentieth century*. Columbia University Press, New York. 231 p.

SACHS, J. and MALANEY, P. 2002. The economic and social burden of malaria. *Nature* **415**: 680–685.

SARIN, M. 2000. 'Should I use my hands as fuel?'. In: KABEER, N. and SUBRAHMANIAN, R. (eds.) *Institutions, relations and outcomes: A framework and case studies for gender-aware planning.* Zed Books, London. 231–265.

SARIN, M., RAY, L., MANJU, S., CHATTERJEE, M., BANERJEE, N. and HIREMATH, S. 1997. Gender and equity concerns in joint forest management In: RAO, N. and RURUP, L. (eds.) *A just right: Women's ownership of natural resources and livelihood security.* Friedrich Ebert Stiftung, New Delhi. 267–336.

SCHERF, C., MORISONB, L., FIANDERA, A., EKPOC, G. and WALRAVEN, G. 2002. Epidemiology of pelvic organ prolapse in rural Gambia, West Africa. *International Journal of Obstetrics and Gynaecology* **109**: 431–436.

SEMBA, R.D. and BLOEM, M.W. (eds). 2008. Nutrition and Health in Developing Countries, 2nd ed. Humana Press, New York.

SHANDRA, J.M., SHANDRA, C.L. And LONDON, B. 2008. Women, non-governmental organizations, and deforestation: a cross-national study. *Population and Environment* **30**: 48–72.

SHIVA, V. 1989. *Staying alive: Women, ecology and development.* Zed Books, London. 224 p.

SIMONSEN, P.E., MEYROWITSCH, D.W., MAKUNDE, W.H. and MAGNUSSEN, P. 1995. Bancroftian filariasis – the pattern of microfilaraemia and clinical manifestation in three endemic communities of northeastern Tanzania. *Acta Tropica* **60**: 179–187.

SINGH, S., DARROCH, J.E., ASHFORD, L.S. and VLASSOFF, M. 2009. Adding it up: The costs and benefits of investing in family planning and maternal and newborn health. Guttmacher Institute, New York. 40 p.

SITHOLE, B. 2005. Becoming men in our dresses! Women's involvement in a joint forestry management project in Mafungautsi, Zimbabwe. In: COLFER, C.J.P. (ed.) *The equitable forest: Diversity, community and resource management.* Resources for the Future, Washington, DC. 171–185.

SMAIL, J.K. 2002. Remembering Malthus: A preliminary argument for a significant reduction in global human numbers. *American Journal of Physical Anthropology* **118**: 292–297.

SMITH, K.R. 2008. Wood: The fuel that warms you thrice. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 97–112.

SMITH, K.R. and MEHTA, S. 2003. The burden of disease from indoor air pollution in developing countries: comparison of estimates. *International Journal of Hygiene and Environmental Health* **206**: 279–289.

SMITH, K.R., MEHTA, S. and FEUZ, M. 2004. Indoor air pollution from household use of solid fuels. In: EZZATI, M., LOPEZ, A.D., RODGERS, A. and MURRAY, C.J.L. (eds.) *Comparative quantification of health risks: Global and regional burden of disease attributable to selected major risk factors.* World Health Organization, Geneva. 1435–1493.

SUBBA, S. 1999. Women, woodfuel, and health in Adamtar village, Nepal. *Gender Technology and Development* **3**: 361–377.

SUBEDI, M. 2010. Uterine prolapse, mobile camp approach and body politics in Nepal. *Dhaulagiri Journal of Sociology and Anthropology* **4**: 21–10.

TABUTI, J.R.S., DHILLION, S.S. and LYE, K.A. 2003. Firewood use in Bulamogi County, Uganda: species selection, harvesting and consumption patterns. *Biomass and Bionenergy* **25**: 581–596.

THE ADVOCACY PROJECT. n.d. Uterine prolapse in Nepal: Profile. http://www.advocacynet.org/page/upaprofiles. [Accessed: 25 July 2011].

TSING, A.L. 1993. *In the realm of the diamond queen.* Princeton University Press, Princeton, New Jersey. 350 p.

UN (UNITED NATIONS). 2010. UN chief kicks off drive to save more than 16 million women and children worldwide. *UN Daily News*. Available at http://www.un.org/news/dh/pdf/english/2010/22092010.pdf.

UNDP (UNITED NATIONS DEVELOPMENT PROGRAMME). 2001. Improved fish smoking: Ghana. In: *Examples of successful initiatives in agriculture and rural development in the south, sharing innovative experiences.* Special Unit for Technical Cooperation among Developing Countries, United Nations Development Programme, New York. 240–254.

UN-SCN. 2004. *Fifth report on the world nutrition situation.* Geneva, Switzerland: United Nations, Standing Committee on Nutrition and International Food Policy Research Institute.

VINCETI, B., EYZAGUIRRE, P.B. and JOHNS, T. 2008. The nutritional role of forest plant foods for rural communities. In: COLFER, C.J.P. (ed.) *Human health and forests: A global overview of issues, practice and policy.* Earthscan, London. 63–96.

VITTOR, A.Y., GILMAN, R.H., TIELSCH, J., GLASS, G., SHIELDS, T., LOZANO, W.S., PINEDO-CANCINO, V. and PATZ, J.A. 2006. The effect of deforestation on the human-biting rate of *Anopheles darlingi*, the primary vector of falciparum malaria in the Peruvian Amazon. *The American Society of Tropical Medicine and Hygiene* **74**: 3–11.

WHITAKER, E.D. (ed.) 2006. *Health and healing in comparative perspective.* Pearson/Prentice-Hall, Upper Saddle River, NJ. 589 p.

WHO Data. 2010. Adult mortality rate (probability of dying between 15 and 60 years per 1000 population). http://data.un.org/Data.aspx?q=adult+mortality+rate&d=WHO&f=MEASURE_CODE%3aWHOSIS_000004 [Accessed 7 September 2011].

WHO (WORLD HEALTH ORGANIZATION). 2003. Lives at risk: malaria in pregnancy. Available: http://www.who.int/features/2003/04b/en/ [Accessed 20 January 2011].

WHO (WORLD HEALTH ORGANIZATION). 2005a. Indoor air pollution and health. *Fact sheets*, 292. Available at http://www.who.int/mediacentre/factsheets/fs292/en/ [Accessed 20 January 2011].

WHO (WORLD HEALTH ORGANIZATION). 2005b. The world health report 2005: Make every mother and child count. World Health Organization, Geneva. 219 p.

WHO (WORLD HEALTH ORGANIZATION). 2009. 10 facts of malaria. Available: http://www.who.int/features/factfiles/malaria/en/ [Accessed 18 January 2011].

WHO, UNICEF, UNFPA and THE WORLD BANK. 2010. Trends in maternal mortality: 1990 to 2008. Estimates developed by WHO, UNICEF, UNFPA and The World Bank. World Health Organization, Geneva. 45 p.

WOLLENBERG, E., ANDERSON, J. and EDMUNDS, D. 2001. Pluralism and the less powerful: Accommodating multiple interests in local forest management. *International Journal of Agricultural Resources, Governance and Ecology* **1**: 199–222.

WWF (WORLDWIDE FUND FOR NATURE). 2002. Conservation on a crowded planet: A population sourcebook for conservation practitioners. Conservation Strategies Unit, WWF, Washington, DC.

YAKOOB, M.Y., MENEZES, E.V., SOOMRO, T., HAWS, R.A. DARMSTADT, G.L. and BHUTTA, Z.A. 2009. Reducing stillbirths: behavioural and nutritional interventions before and during pregnancy. *BioMed Central Pregnancy and Childbirth* **9**(Suppl 1): S3.

ZUK, M. and MCKEAN, K.A. 1996. Sex differences in parasite infections: Patterns and processes. *International Journal for Parasitology* **26**: 1009–1024.