From Lifelines to Livelihoods: Non-Timber Forest Products Into the Twenty-First Century

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Abstract

Globally, 1.5 billion people use or trade non-timber forest products (NTFPs) with the majority of NTFP use and trade occurring at local and regional scales, generally invisible to researchers and policy makers. NTFPs cannot be measured by monetary estimations alone, as they have significant subsistence and socio-cultural importance and are commonly one part of multifaceted, adaptive livelihood strategies. In spite of low-cost substitutes, both rural and urban people continue to use select forest resources for medicine, crafts, rituals, and food. And as drought, disease, famine, and conflict escalate globally, growing numbers of displaced and marginalized people depend upon forest resources for survival. In general, forests managed for timber and NTFPs retain more biodiversity and resilience than forest plantations or forests managed for industrial timber. Forests that harbor NTFPs also protect ecosystem services such as hydrological functions and soil retention and act as a buffer against climate variability. Land use change through logging, fire, and agribusiness is contributing to the degradation of forests, resulting in declining access to NTFPs for local communities. Land stewards can mitigate detrimental impacts to NTFPs by employing multiple-use management practices that emphasize ecosystem services and community needs in addition to traditional forestry outputs (timber and non-timber). For multiple-use forestry to be applied broadly, forest policies need to be cross-sectoral and scale sensitive to lessen regulatory obstacles for small holders and for common pool/property systems. In addition, forestry training needs to include a stronger social focus and improved understanding of the ecology, use, and societal and ecosystem service values of NTFPs.

Keywords
Non-timber forest products • Forest management • Forest policy • Economic botany • Rural livelihoods • Subsistence • Forest value

Introduction

For millennia, forests have provided humankind with a wide range of crucial goods and services: as agricultural land, climate regulator, timber, sacred grove, and the primary raw materials used in household economies. Although timber has assumed a dominant position among forest resources over the last century, for most of human history, forest goods other than timber fed, clothed, and sheltered our ancestors. These included aromatic spices, fruits, roots, seeds, nuts, barks, fungi, resins, feathers, bushmeat, fibers, and leaves. Today, even as a vast global trade of industrialized goods, including processed foods, artificial flavors, synthetic pharmaceuticals, and plastic wares, briskly circumnavigates the globe, the trade and value of tropical forest resources remains significant.

In addition to feeding, healing, and providing homes to billions of people in the tropics, forests supply an expanding global market for traditional medicine and health-care products, specialty foods, and ethnic crafts, some of which have no mass-produced alternative. Non-timber forest products (NTFPs) also offer phytonutrients and nutritional diversity lacking in contemporary diets. Consumed and traded by rural and urban people of all classes, forest foods, resins, gums, fuel, fiber, and medicines are available to those most in need: low-income populations, women, children, and increasingly families weakened by famine, disease, or drought; migrants beset by natural disasters; and refugees in conflict-ridden zones (Shackleton and Shackleton 2004; Pierce and Emery 2005).

The traditional knowledge surrounding forests and the multiple-use management systems in which they exist are also vital to ecosystem processes and livelihoods. NTFPs are drawn from diverse habitats and management systems, along a gradient from cultivation on farms to wild harvest in forests. Many NTFPs, particularly those which reach international markets, have become cultivated as farm crops. Others, for local and regional trade, are managed within home gardens, fallows, and forests. Indigenous management systems frequently optimize diversity, embodying an essential adaptation strategy, the significance of which will increase with resource scarcity and climate variability (Shackleton 2014).

During the last century, forests have been managed principally for their timber, with scant recognition of the role that forests and traditional knowledge systems play in supplying crucial goods and ecosystem services to the industrialized world as well as to the world's poorest and most vulnerable communities. Shortsightedness and lack of compliance with basic laws is contributing to an erosion of the forest resources upon which humankind depends. Approaching forests holistically, not reducing them to carbon, lumber, farm, fiber, or fruit, but taking account of their complexity, diversity and the far-reaching consequences of our actions, could lead

Fig. 1 NTFPs comprise a wide range of products including roots, leaves, seeds, resins, and fruit harvested from forests, fallow, and/or home gardens (Photo: P. Shanley)

to more responsible stewardship. Ancestral veneration of forests reveals a profound comprehension that humankind is wholly dependent upon flora and fauna for the necessities of life. Forest leaves, fruits, roots, and resins awaken one's senses, evoking a sense of place, a connection to community, and an affirmation of one's cultural landscape. Forests and their goods may offer a key to recalling this bond and renewing a cognizant and respectful interaction with woodlands.

What Are NTFPs?

The term non-timber forest product is used to describe a wide range of biological resources that originate from forests, but which are neither timber nor industrial wood fibers. NTFPs are drawn from very different ecological, economic, and cultural contexts and include globally traded commodities like wild-harvested rubber, rattan, Brazil nuts, and medicinal plants. NTFPs also encompass thousands of species traded or consumed locally with a wide range of uses that include medicines, foods, building materials, game attractants, household products, baskets, and crafts. Some definitions of NTFPs include bushmeat, while others exclude bushmeat but include insects; other definitions include fuel wood, and some only include products derived from plants (de Beer and McDermott 1989; Falconer 1990; Ruiz-Pérez and Arnold 1996; Neumann and Hirsch 2000; Shackleton et al. 2011) (Fig. 1).

The absence of a fixed definition for NTFPs illustrates its origins as a description of what it is not: industrial roundwood and wood fiber processed as lumber, wood chips, particle board, pulp for paper, cardboard, and other products (Wickens 1991; Neumann and Hirsch 2000). This means that a vast range of products, goods, and services are included in the category of NTFPs and that the term – and related terms like natural products, biological resources, environmental income, non-wood forest products, and secondary forest products – is used and understood in very different ways. To address the scientific, policy, and practical implications of this imprecision and resulting confusion, the FAO promoted use of the term NWFPs – non-wood forest products – in recent decades, defined as "goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests." Despite these efforts to harmonize the language of forest products other than timber, "non-timber forest products" persist as the most widely used term.

Used first by de Beer and McDermott (1989), "non-timber forest products" were intended as a replacement for the term "minor forest products" which implied that the majority of useful species present in forests, and other ecosystem services and benefits, lacked value compared with industrial forms of wood. This was clearly not the case on a cash and commercial basis in areas that produced rattan, Brazil nuts, and other high-value NTFPs in international trade. Moreover, it also failed to account for the substantial subsistence and local trade values of NTFPs in much of the world (Falconer 1990; Scoones et al. 1992; Emery and Pierce 2005; Laird et al. 2011).

After several decades of debate over what products (e.g., crafts, fuel wood, fodder, stones), habitats (e.g., forests, plantations, home gardens, farm trees), nature and scale of management (e.g., wild harvest, domestication, industrial agriculture), and end use (e.g., subsistence, local trade, international trade) define an NTFP, the term remains ambiguous. As Peters (2011) put it, greater understanding has led to greater appreciation of the "differences rather than similarities in the ways that communities collect, manage, and market NTFPs." What is clear is that the category of NTFPs is so large and diverse that umbrella forest management and policy recommendations do not easily attach to this group of products. Research over the last few decades has pointed out that NTFPs must be understood as part of broader and diverse ecological, social, economic, and cultural contexts and practices (e.g., Padoch and Pinedo-Vasquez 1996; Arnold and Ruiz-Pérez 1998; Neumann and Hirsch 2000; Emery and Pierce 2005; Laird et al. 2010). Although the definition of this category will no doubt continue to evolve, a recent effort by Shackleton et al. (2011) develops a working definition of NTFPs that addresses many of the questions identified above (Box 1).

Box 1: A Working Definition of NTFPs

- Biological products (i.e., not abiotic products or ecosystem services).
- Wild species (indigenous, naturalized, or alien) which means that the bulk of the total species population is self-replicating without human agency. A small proportion of the total species population may be only recently cultivated or domesticated at a local level or self-reproducing within human-dominated systems.
- Harvested by humans, and thus fodder consumed by free-ranging animals would be excluded (as it would be accounted for under benefits from agriculture rather than NTFPs), unless it was harvested by humans and transported to the animals to consume.
- Consumptive and nonconsumptive uses.
- Available from any landscape or ecosystem (including human dominated).
- The broad scale management objectives are set, monitored, and regulated by those on whose land the NTFP occurs.
- Most, if not all, of the benefits from the direct or indirect use accrue to local livelihoods and well-being.
- The benefits accruing can act as an incentive to conserve the species or site if the necessary enabling factors and institutions are in place.

Source: Shackleton et al. (2011)

The Reemergence of NTFPs onto the Global Forestry and Conservation Stage

Unlike timber, NTFPs were not understood as a distinct category until relatively recently, when the term was developed to draw the attention of foresters and governments to important but "invisible" values and uses of forests. Integral to rural and forest livelihoods, interwoven with agriculture and wood harvesting, NTFPs were not seen as a separate category of products or area of management and only became understood as such when the scale, beneficiaries, and ecological impact of the international tropical timber trade broke free of traditional forest management and uses.

For centuries, NTFPs were a far more valuable product of tropical forests than timber. Colonial governments moved species like rubber, quinine, oil palm, and cocoa into cultivation around the world and harvested NTFP species such as Brazil nuts and rattan on an industrial scale. However, over the last century, the enormous value of the thousands of wild, semidomesticated, and domesticated forest species to forest-dwelling people was increasingly eclipsed in the global research and policy arena by industrial tropical timber. NTFPs harvested from the forest became a poorly understood and increasingly marginalized part of forest management (Scoones et al. 1992; Belcher et al. 2005; Shackleton et al. 2011).

Fig. 2 The gravesite of Rainforest Crunch, indicative of the promise and challenges associated with the international marketing of forest goods at Ben & Jerry's ice cream factory, Waterbury, Vermont (Photo: A.R. Pierce)

In the 1980s, NTFPs emerged from their relative obscurity due to a convergence of interests, including global concern over tropical forests and the development of new conservation approaches that incorporated sustainable use and social justice. Commercial NTFP harvesting, it was thought, could generate income for local groups, while proving less destructive to the forest than timber harvesting or industrial agriculture, thereby creating incentives for the conservation of tropical forests. Beginning in the 1980s, a surge of research interest led to better understanding of the uses and values of NTFPs, and donors, NGOS, and socially responsible businesses sought to sustainably source and market them (Peters et al. 1989; Nepstad and Schwartzman 1992; Clay and Clement 1993; Plotkin and Famolare 1992; Clay 1996).

The enthusiasm of this approach did not last long because the conservation and development gains from commercializing NTFPs were limited. A process of reevaluation soon ensued (Godoy et al. 1993; Arnold and Ruiz-Pérez 1998; Neumann and Hirsch 2000; Ros-Tonen and Wiersum 2003; Alexiades and Shanley 2005). In a particularly cogent critique, Homma (1992) drew upon historical data from the Amazon and posited that expanded commercialization of NTFPs results in one of the following fates: overexploitation and a decline in the resource population, a shift from wild production to intensive cultivation, or product substitution. Dove (1994) foresaw that as soon as an NTFP became profitable, it would move from the realm of smallholders and become appropriated by central economic and political elites, as has happened in the case of numerous products including sandalwood in east Timor, clove in Indonesia, and açai in Brazil. Other scholars raised additional issues, including the highly perishable nature of some products,

Fig. 3 Children's harvest of wild foods contributes significant vitamins, minerals, and protein to their diets (Photo: P. Shanley)

difficulties in marketing products at both the local and international levels (Pendelton 1992), inappropriate pricing estimations and failures to predict annual yields of products (Godoy et al. 1993), general unfamiliarity with the market economy on the part of many local communities (Shanley 1999), the high-quality-control standards of importing countries, and the whimsical (boom-bust) nature of international markets (de Beer and McDermott 1996) (Fig. 2).

After two decades of experience, experts recognize that non-timber forest products are used on a vast scale for subsistence and traded widely in local and regional markets, and this is where their real and sustained value lies (Shackleton et al. 2007b; Sills et al. 2011). Commercialization for international markets holds promise in some cases, but it also requires a number of critical preconditions, including a favorable law and policy environment, well-developed and accessible markets, secure tenure, and a well-managed resource base (Marshall et al. 2006; Laird et al. 2010; Laird and Wynberg 2013).

A more effective approach has emerged in recent years in which NTFPs and other forest products and services are viewed as part of an integrated approach to livelihoods and forest management, and forest and natural ecosystems are seen as critical elements in sustaining human populations and biological diversity (Shackleton et al. 2007b; Ros-Tonen 2012). Goods from the forest are now routinely folded into new conservation and development strategies as well as environmental accounting schemes such as payment for ecosystem services and valuation of ecosystems and biodiversity (TEEB 2010). The dialogue surrounding "NTFPs" has expanded to view these products as part of larger and diverse management and livelihood systems in which agriculture, wild harvesting, timber production, and other practices are interdependent parts of livelihood systems and biological and cultural diversity are intertwined (e.g., Pretty et al. 2009; Cocks et al. 2011; Laird et al. 2011; Maffi and Woodley 2012).

The Value and Use of NTFPs

NTFPs are difficult to quantify or observe casually, and scientific study of their value is inconsistent and limited in scope, and government record-keeping very limited. What studies have been done demonstrate that throughout tropical forest regions, NTFPs are a central component of local economies and subsistence and for most rural people a far more significant part of livelihoods than timber. Even NTFPs in export trade are difficult to value, and records are patchy. The FAO undertook a study on the value of the forestry sector between 1999-2011 in which it determined all global exports of forest products total around $421 billion, with around 5% of this being NTFPs and roundwood. However, the study acknowledged the likelihood of underestimation resulting from poor availability of any records on NTFPs (FAO 2014).

New sweeteners, botanicals, food, beverages, cosmetic ingredients, and other products continue to emerge onto national and international markets, driven by consumer demand for the novelty and bioactivity found in tropical forests.

Economic Values

The economic significance of non-timber forest products is vast and far reaching, particularly for some of the world's poorest citizens. Globally, 1.4–1.6 billion people are estimated to use, consume, or trade NTFPs (FAO 2001). Estimating the local, regional, and global significance of NTFPs is daunting because they are traded in both formal and informal markets. Below, we indicate their relative economic importance at various scales, based on available statistics and studies.

Subsistence

Tropical forests provide a host of environmental services and goods, including NTFPs, to the poor. Terminology describing such goods and services, such as "the subsidy from nature" (Hecht et al. 1988) or "the GDP of the poor" (TEEB 2010), succinctly encapsulates the critical role forests play as sources of food, fuel wood, and building materials for daily sustenance. NTFPs are accessible to a range of users as they are, generally, readily available, open-access goods found in proximity to rural communities which require low levels of skill and technology to harvest and process. NTFP use crosses, gender, age, occupation, and other boundaries within communities, with different groups relying on NTFPs in distinct ways. For example, children regularly harvest NTFPs and obtain valuable protein and vitamins by gathering and consuming wild forest fruits or animals (Colfer et al. 1997) (Fig. 3).

In a survey of 8,000 households across the developing world, subsistence reliance on forests was highest among households with income levels in the bottom 40 % (Anglesen et al. 2014). In a study of NTFP usage in northern Laos, NTFPs are

Table 1 Estimated income contribution from traded NTFPs as reported in case studies from across the tropics

Species/ products	Country/ region	Income contribution	Reference
NTFPs	Benin	39 % of annual income	Heubach et al. (2011)
NTFPs	Northern Laos PDR	40–50 % of annual income	Foppes and Ketphanh (2004)
Uchi fruits *Endopleura uchi*	Eastern Brazil	20 % of annual income	Shanley and Gaia (2004); Shackleton et al. (2007a)
NTFPs	Orissa State, India	19 % of annual income	Mahapatra et al. (2005)
NTFPs	Central Vietnam	4–22 % of annual income	Polesny et al. (2014)
Mushrooms Var. species	Tanzania	$400-900/yr. (greater than the gross national income of $340/ yr)	Tibuhwa (2013)
Weaver ants *Oecophylla smaragdina*	Northeastern Thailand	30 % of annual income (or 1.5–2.6 times the minimum wage)	Sribandit et al. (2008)

estimated to contribute as much as 50 % of food consumed by poor households, leading Foppes and Ketphanh (2004) to conclude that "NTFPs are therefore the most important safety net or coping strategy for the rural poor in Lao PDR." In his study of a Karen ethnic group in western Thailand, Delang (2006) observed that subsistence farmers gathered wild forest foods because it was a more efficient way of obtaining food than engaging in the formal economy. Around Mt Cameroon, Laird et al. (2011, 2007) found that wild collections of NTFPs contribute around 41% to local livelihoods, and native species contribute 45 %. The study also demonstrated that all households, wealthy and poor, participate in NTFP collections since NTFPs contribute not only nutritionally and for survival, but also provide high quality seasonal wild greens, fruits, mushrooms and spices, a wide variety of effective traditional medicines, and many other products that enhance well-being and quality of life in ways that do not result primarily from financial considerations.

The World Bank (2001) estimated that nearly 60 million indigenous people are "wholly dependent" on forests, while an additional 350 million people, mostly living in the tropics within or adjacent to forests, were highly reliant on forests for "subsistence and income." Recent studies have found that forests provide an average annual income of $440, equivalent to more than a fifth of total income in households surveyed (Anglesen et al. 2014). Considering that the World Bank (www.worldbank.org) estimated that more than 20 % of the developing world's population lived on less than $1.25 per day in 2010, the significance of forest goods and services to the poor is overwhelming.

Recently, new populations are increasingly thrust into subsistence use of wild resources due to environmental and political upheaval (Pierce and Emery 2005). According to the USAID, international water and weather-related disasters doubled

Table 2 Estimated number of people engaged in NTFP harvest and sale from various parts of the tropics

Species/ product(s)	Country/region	Number of people employed	Reference
Rattan Var. species	Southeast Asia/Africa	700 million	Dransfield and Manokaran (1994)
NTFPs	India	100 million	Saxena (2003)
Tendu/kendu leaf *Diospyros melanoxylon*	India	11.9 million	Lal (2012)
Sal seed *Shorea robusta*	India	20–30 million	Patnaik (2008)
Lac	India	3 million	Sharma et al. (2006)
NTFPs	Cameroon and Democratic Republic of Congo	350,000	Awono et al. (2013)
Natural rubber *Hevea brasiliensis*	Brazil	100,000	Shanley et al. (2011)
Brazil nut *Bertholletia excelsa*	Peru and Bolivia	30,000 and 22,000 respectively	Collinson et al. (2000); Bojanic (2001)

in the 1990s resulting in exploding populations of refugees seeking water, food, and shelter. As natural disasters, drought, famine, and conflict escalate, dependence on wild plant and animal resources and the traditional knowledge of how to identify and use them becomes one of the few means of survival for millions of displaced persons worldwide (Pierce and Emery 2005).

Local Livelihoods

The bulk of NTFP trade takes place at the local and regional scale where local people engage with the market on a part-time, seasonal, or full-time basis as their livelihoods require (Shackleton et al. 2007a). With regional variation, income derived from the gathering and sale of NTFPs can be particularly important to women (Awono et al. 2002; Ahenkan and Boon 2011; Tibuhwa 2013; Sunderland et al. 2014). NTFP gathering and sale as a livelihood strategy is not solely restricted to forest dwellers; peri-urban and even urban dwellers in the tropics also take part in NTFP trade (Stoian 2005; Schlesinger et al. 2015).

NTFP trade does not in itself lift most households out of poverty, but it contributes to a portfolio of livelihood strategies employed by rural communities (Neumann and Hirsch 2000; Shackleton et al. 2007a, b). Income from NTFPs can contribute significantly to a households' cash needs (e.g., to pay for school fees, medicines, clothing, and other needs) and acts as a safety net in times of crisis. In the Indian state of Orissa, 95 % of surveyed households obtained some cash from NTFPs annually (Mahapatra et al. 2005). Income from NTFPs can be equivalent to or exceed the minimum wage and provides many tropical households with a fifth or more of their annual income (Table 1). Yet, as in the case of subsistence, reliance on NTFPs for income is highly variable within and across villages due to economic and social contexts, availability of alternative employment, proximity of markets and forests, extent of forest degradation, family traditions, and a host of other factors.

The few published “guesstimates” of numbers of people employed in various NTFP sectors reveal vast numbers (Table 2). While figures in Table 2 estimate the number of harvesters, they do not reflect the broader impact of NTFP employment on families or to the national economy. For example, the BBC, citing Sudan’s Gum Arabic Board, reported that, when accounting for the often large families of tappers, more than five million people rely on gum arabic income (Copnall 2010). In Cameroon, 45 high-value NTFPs, including bushmeat, fuel wood, and various plants, are estimated to generate over $1 billion annually (Awono et al. 2013). Most tellingly, the number of people employed by the NTFP sectors in Cameroon and the Democratic Republic of Congo is double the number employed by the forestry industry (Awono et al. 2013). The ITTO (2007) estimates the contribution from NTFPs to be worth about $27 billion per year to the Indian economy, compared to $17 billion from timber products. In Bolivia, Brazil nuts earn more than double the export revenues of raw and semi-processed timber (Cronkleton and Pacheco 2010).

International Trade

Internationally traded tropical NTFPs include bamboo, rattan, rubber, gum arabic, Brazil nuts, and medicinal plants, with the total number of products likely in the hundreds. FAO (2010) estimated that the global harvest of NTFPs was equivalent to $ 18.5 billion dollars in 2005, with the caveat that this estimate failed to account for the value of subsistence and likely represented “only a fraction of the true total value of harvested non-wood products.” Iqbal (1995) estimated the value of internationally traded NTFPs to be worth $11 billion; what share was comprised of tropical NTFPs is unknown. Few scholars have attempted to update Iqbal’s figures because of poor trade data and aggregated commodity categories (e.g., “plants”) which make it close to impossible to separate by species or origin (i.e., from wild or cultivated stocks). In addition, some NTFPs may be traded in raw form and then re-traded (sometimes after further processing). For example, according to UN Comtrade (comtrade.un.org), Indonesia and Mexico are the world’s largest suppliers of balata, gutta-percha, guayule, chicle, and similar natural gums, yet Singapore is the largest exporter of the exudates. Most medicinal plants in the $85 billion global botanicals market today make the journey from country of harvest, to India or China for processing, and are then exported back to consuming countries for sale by marketing and manufacturing companies (Laird and Wynberg 2013).

Global demand for novel NTFPs has grown in recent decades. Burgeoning travel to tropical regions expanded disposable incomes in developed and developing countries, and popular interest in ethnic crafts, cuisines, and health care, among other factors, has stimulated an increase in the use and trade of non-timber forest products within urban areas around the world. These include baskets from Bali, bamboo flooring from the Philippines, yohimbe from Cameroon, and açai from the Amazon for energy drinks. Although traditional products are often substituted for inexpensive alternatives in rural communities (e.g., baskets for plastic pails), many forest-derived goods such as fruits, fungi, and medicines have no substitutes on a local level, and international markets for select tropical forest goods have increased (Sills et al. 2011; Laird and Wynberg 2013).

Sociocultural and Nutritional Values

NTFPs are part of complex cultural, social, and political relationships with tropical forests. Social and cultural relationships with forests include shared notions of kinship, marriage, prohibitions, cosmology and ritual, as well as traditional ecological knowledge on flora and fauna, edible and inedible foods, medicinal plants, and the functions of the forest ecosystem (Balée 2013). Traditional ecological knowledge guides the seasonality, location, and techniques employed in harvesting NTFPs and processing them for use or trade. Social and political aspects of NTFP use, management, and trade include issues of social justice, social welfare, gender, land tenure, the relationship between statutory and customary law, rural poverty, and political empowerment (Neumann and Hirsch 2000; Pierce 2002b; Laird et al. 2010).

Research conducted over the last three decades has demonstrated that the value of NTFPs and forests is far greater than that captured by monetary valuations (Bennett 1992, Cocks and Dold 2004, Laird et al. 2011; Pierce 2014). In spite of globalization, urbanization, and accessible alternatives, people continue to use NTFPs on a vast scale for a wide range of reasons including the taste, nutrition, health benefits, well-being, and tradition that informs all household use of medicines, foods, building materials, crafts, and other products around the world (Stoian 2005; Padoch et al. 2008; de Beer 2011).

Immigrants to urban areas as far flung as Shanghai, Paris, Nairobi, and New York continue to seek out leafy greens, fruits, fibers, medicinal plants, and ritual products from their home forests, maintaining strong cultural ties to their communities and place of origin (Xu et al. 2005; Padoch et al. 2008; Cocks et al. 2011). NTFPs have been shown to provide nutritional diversity and phytonutrients unavailable in supermarkets (Dounias et al. 2007; Vicenti et al. 2013; Johns and Sthapit 2014). For generations, rural people have selected specific germplasm from forests, fostering nutrient-dense foodstuffs that are not sweet, but composed of starches, oils, and phytonutrients with relatively low concentrations of sugar (Clement et al. 2008) and that enhance family and societal well-being (Johns and Sthapit 2014). An unanticipated consequence of processed foodstuffs has been the proliferation of nutrient deficiencies. These can be ameliorated through dietary diversity and intake of forest species rich in nutrients and compounds such as carotenoids that act as antioxidants and prevent damage to cells (de Beer 2011; Johns and Sthapit 2014). Thus, traditional ecological knowledge may embody physiological knowledge and memory, internally orienting families as to which foods are nutrient rich and which curb illness.

The cultural and social values of NTFPs are difficult to capture in the short-term, questionnaire-, and workshop-based methods common in this field. Longer-term, multidisciplinary research less focused on a decisive quantitative outcome and argument is required to understand the role of NTFPs in local livelihoods and forest management and conservation. These types of studies have led to increasing awareness of the powerful links between culture and place and the profound connections between cultural diversity and biological diversity (Posey 1999; Dounias et al. 2007; Cocks et al. 2011; Laird et al. 2011; Pierce 2014).

Ecological Values

In addition to their economic, sociocultural, and nutritional functions, forests serve to protect ecosystem services, including carbon sequestration, hydrological functions, and soil retention, as well as mitigate climate change. Forests maintain biological integrity through their primary role in renewal processes including the formation of soil, recycling of nutrients, sedimentation and flood control, regulation of microclimate, suppression of undesirable organisms, and detoxification of noxious chemicals (Altieri 1999). When forests are properly managed for timber and NTFPs, taking into account their sociocultural and environmental complexity, less biotic degradation results.

NTFPs are commonly, but not always, part of small holder management systems that include management of a wide range of forest types for multiple uses and which can maintain high species diversity while supporting local livelihoods (Wiersum 2004). The complex and sophisticated forest management systems that small holders practice generate dietary variety and reduce environmental risks and as such represent a key adaptation strategy in the face of climate change (Gómez-Baggethun et al. 2013).

How timber is managed and harvested has a significant impact on non-timber forest products. For local communities, timber and non-timber forest product harvestings are integrated parts of a whole (Pierce 2002a; Padoch and Pinedo-Vasquez 1996). However, NTFPs are often invisible to commercial timber producers, which can lead to destruction and depletion of species with high value for local communities and eradication of valuable germplasm necessary for regeneration of forests and species (Shackleton and Shackleton 2004; Rist et al. 2012). Wild-crop relatives provide advantageous traits for crop improvement such as biotic and abiotic resistances, leading to enhanced stability and yield (Maxted et al. 2012; Vincenta et al. 2013).

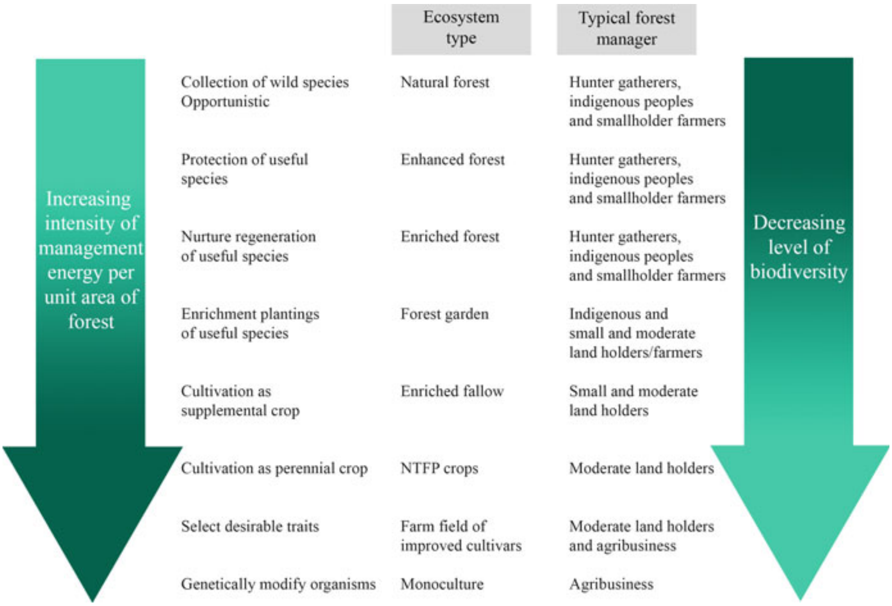

Fig. 4 The gradient of intensity of NTFP management (Adapted from Wiersum 1997; Shackleton et al. 2011)

Sustainable Management of NTFPs

Within tropical forest areas around the world, extremely complex management systems are used by local groups that include a range of ecosystems and management practices, including agriculture, semidomestication and management of fallows, secondary forests, and home gardens (Clement 1999). NTFPs are drawn from diverse management systems and habitats, existing along a gradient from domestication to wild harvest from primary forest (Homma 2012) (Fig. 4).

When commercial demand increases, harvesting rates intensify and resource overexploitation can occur, particularly in open-access conditions. In some instances, intensively managed NTFP production systems displace the natural vegetation and are grown as monocultures, for example, guarana (*Paullinia cupana*) in South America, tea (*Camellia sinensis* and other species), rubber (*Hevea brasiliensis*) in Indonesia (Homma 1992), and bamboo (various spp.) in China (Fu and Yang 2004). In other situations, enrichment planting to promote a given qualitative trait of the NTFP, may provide incentives to conserve forests (Marshall et al. 2006).

Gradient of Management Practices

The sheer variety of NTFPs comprise a continuum from those that are traded internationally and regionally to those traded locally and/or consumed directly by households. Within this wide range of use, there exists a corresponding variety of habitats and management systems in which NTFPs occur (Ticktin and Shackleton 2011). On the extractive end of the spectrum, NTFPs are sourced from extensive areas of forests, wetlands, and mountains. Examples include Brazil nut from the Amazon and bird's nests and honey from the cliffs of Kalimantan and India. Forest resources are also sourced from intermediate management systems such as secondary forests and fallows in which semi-cultivated species and forest resources intermingle in ways that maintain the complexity of the natural ecosystem while enriching the diversity of useful forest resources (Wiersum 2004). Areas of intermediate management may contain hundreds of NTFP species for subsistence use (Michon et al. 2007) with often higher yields than either primary forest or actively managed pasture (Pulido and Caballero 2006). At the intensive end of the spectrum, NTFPs may be sourced from gardens, cultivated fields, and vacant lots in and near towns and cities (Ticktin and Shackleton 2011).

The degree of management depends on numerous factors, including availability and proximity of forest, land use policies, soil conditions, state of forest resources, distance to market, tenure, access, and the cultural and experiential background of collectors. Small holders generally experiment with enrichment plantings, selection of germplasm, and other techniques to enhance the growth of preferred species within their forests, fallows, and farms (Leakey et al. 2012; Menezes et al. 2012; Dawson et al. 2014). Such management systems are based on generations of experimentation and observation and can result in complex indigenous silvicultural practices that are, however, not widely understood or documented within western science and are often invisible to researchers, policy makers, and extensionists (Wiersum 2004; Homma 2012).

Status of NTFPs: Gaps in Knowledge and Loss of Habitat

Over the past two decades, research has demonstrated the critical importance of biodiversity and NTFPs to the livelihoods of people worldwide (Cavendish 1999; Shackleton et al. 2011; Luckert and Campbell 2012). However, the influence of factors such as livelihood dependency, proximity to markets, and local ecological knowledge on the harvest of NTFPs remains poorly understood (Steele et al. 2015, Duchelle et al. 2014). Notably, meager information is also available regarding the phenology, production, distribution, or density of even widely used and traded forest products in most of the tropical lowland forests (Jimoh et al. 2013).

Previous ecological studies have focused on how to sustainably extract NTFPs or analyzed the impact of NTFP harvest on plant and population vigor (Ticktin 2004). Yet, research often overlooks the major cause of the decline in NTFP populations. The vast majority of detrimental impact to NTFP populations has

Fig. 5 Joint planning between timber companies and communities can minimize damage and conserve valuable species (Photo: P. Shanley)

not been direct harvest of the NTFP species by users but rather the destruction of the habitats in which they occur by agribusiness, logging, and development (Dove 1994). Agricultural expansion was the single largest driver of deforestation in the tropics from 2000 to 2010, accounting for 73 % of tropical deforestation, with 40 % driven by commercial agriculture and 33 % by local and subsistence farmers (Hosonuma et al. 2012). Furthermore, over 70 % of forest degradation in tropical forests of Latin America and Asia is driven by commercial timber extraction and logging (Hosonuma et al. 2012). Selective logging, implemented in some regions as a less damaging forestry practice than clear cutting, has instead become an initial step in a trajectory of deforestation leading to forest conversion (Asner et al. 2009).

Methods to Improve Forest Management and Conserve NTFPs

Research and practice are demonstrating that through implementation of improved logging techniques, fire management, control of invasive alien species, regulation of wildlife harvest, and sound agricultural, forestry, and development policies, non-timber forest products can be conserved. In addition to sustaining rural and urban families' nutrition and life ways, such steps can also help to reduce carbon emissions, contributing to the mitigation of climate change, conservation of watersheds, and preservation of ecosystem functions.

Multiple Use

The last two decades have witnessed a trend in logging from a single purpose approach – extraction of timber – to integrated uses, specifically multiple use, with the purpose of enhancing social, economic, and ecological outcomes. Multiple-use forestry entails considering the needs of local communities and managing forests for not only forest products (both timber and non-timber) but also ecosystem and human services: i.e., recreation, carbon storage, climate regulation, and watershed protection (Guariguata et al. 2012).

In the specific case of integrated management of timber and non-timber species, methods cannot be generalized because of the diversity of forest types and NTFPs. In some cases, NTFP harvest may complement timber management. Valuable medicinal or edible, shade-reliant species can grow in conjunction with timber species, providing managers with several economic outputs over time. In other cases, valuable timber trees may also serve as nutritious fruit and/or medicinal oil species. In integrated operations, the costs and benefits of logging particular species are weighed, and the planning, timing, and avoidance of collateral damage to either the NTFP or timber species are of critical importance (Laird 1995; Pierce 2002a; Guillén et al. 2002; Guariguata et al. 2009).

Integrating Timber and Non-timber Resources

To ensure NTFPs are taken into account in long-term timber management plans, one initial step is to include NTFPs in forest inventories. Timber inventories are relatively rapid and straightforward, collecting limited information such as height, DBH, and species. By contrast, for each NTFP, a range of information as to natural history, production/yield, seasonality, interaction with wildlife, market and subsistence value, management, and belief systems is of interest (Laird 1995). Additional time, new methods, identification techniques, and specifically trained personnel are helpful to accomplish this. Community members, familiar with locally useful fruit, fiber, medicinal, and game-attracting species, can serve as highly knowledgeable members of the forest inventory team (Guillén et al. 2002). Harvesters have a wealth of empirical information that can provide practical guidance to timber operations (Fig. 5).

The benefit in collecting information with local communities is that immediate value is given to what is often an “invisible income.” Once this information is collected, communities and timber industries can better negotiate which NTFP species should be protected and how. Community monitoring of logging operations is generally needed to ensure that favored fruit and/or medicinal species are protected from removal and/or collateral damage. In some areas of Amazonia, organized communities have influenced forest management operations, by protecting valuable latex and/or fruit trees to ensure they are conserved (Shanley et al. 2012).

Fig. 6 The top 12, locally prized fruit, medicine, and game attracting trees are extracted for their timber along the Capim River, Pará, Brazil (Photo: P. Shanley)

Reduced Impact Logging (RIL)

Over the past two decades, best practices to harvest timber and minimize damage to the forest and other tree and understory species have been developed (Putz et al. 2008). Good practice and reduced impact logging norms (RIL) may, in some cases, facilitate NTFP management objectives (Guariguata et al. 2010). For example, a given NTFP species may benefit from the occurrence of logging gaps (Salick et al. 1995). Lianas in tree crowns can reduce tree fruiting (Wright et al. 2005); hence, liana cutting while applied to minimize logging damage to residual trees (Putz et al. 2008) could be extended to enhance fruit production in NTFP-bearing trees (Kainer et al. 2014).

The application of RIL norms may also help in sustaining yields of NTFPs as suggested for the Brazil nut tree, which coexists with valuable timber species across the Western Amazon (Duchelle et al. 2012). Silvicultural treatments such as "liberation thinning" of future crop trees (Wadsworth and Zweede 2006) and stand refinement and soil scarification in logging gaps (Peña-Claros et al. 2008) may enhance the regeneration of light-demanding NTFPs. Harvest systems typically applied in Asian dipterocarp forest such as shelterwood cutting which remove or reduce canopy cover are also amenable for concurrent management of timber and light-demanding NTFPs (Ashton et al. 2001).

However, existing silvicultural norms for timber may need refinement in order to minimize tradeoffs. For example, in Indonesia, the current timber cutting regulation requires companies to slash all undergrowth and climbers every year for 5 years in logging concessions after timber harvesting to promote the regeneration of timber species. Yet locally important NTFPs (rattans, food, and medicinal plants) are usually slashed (Sheil et al. 2006), a practice that has been perceived as questionable (Meijaard 2005).

In contrast to the above examples, little is known about how silviculture of NTFPs affects timber values. In Mexico, Trauernicht and Ticktin (2005) showed how planting the understory (xate) palm *Chamaedorea hooperiana* under natural forest cover led to a reduction of the density of saplings of timber species, possibly due to slashing during site preparation. Another example is the planting and tending of saplings of benzoin trees (*Styrax* spp., tapped for trunk resin) in the understory of montane forests in Sumatra which leads to species-poor tree canopies over time (García-Fernández et al. 2003).

Reduce Conflict of Use

An important mode of interaction between selective logging and NTFP sustainability arises when the same tree species provides both timber and NTFP values. In Central Africa and South America, conventional and predatory logging has resulted in harvest of not only valuable timber species but many which are also nutritious fruit and medicinal tree species, often occurring in low densities (Shanley and Luz 2003; Tieguhong and Ndoye 2007; Herrero-Jáuregui et al. 2009). For remaining individuals, decreasing rates of regeneration as well as lower pollinator frequency and reliability can lead to a reduction of genetic diversity through loss of vigor, decreased fruit set, and mortality (Dawson et al. 2014).

In the Brazilian state of Pará, 47 % of the timber species currently traded have non-timber use (Herrero-Jáuregui et al. 2009). For forest-reliant rural communities, the impact of logging on food, game attracting, and medicinally used species can be deleterious; of the 15 most highly valued trees in the Capim region of Pará, all are targeted by the timber industry (Shanley et al. 2002). In the particular cases of *Tabebuia impetiginosa* and *Hymenaea courbaril*, which are collected for their medicinal barks, conflict of use is acute because both species regenerate poorly due to their very high light requirements, low population densities, and low growth rates (Schulze 2008). In this case, silvicultural practice is needed in addition to the effect generated by logging gaps alone. In Cameroon, out of the 23 top timber species being exported, over half also have NTFP value. The three most exploited timber species *Triplochiton scleroxylon*, *Entandrophragma cylindricum,* and *Milicia excelsa* are also sources of medicine and food (Tieguhong and Ndoye 2007) (Fig. 6).

One intervention for minimizing conflict of use is the application of legal protections from logging in cases where an NTFP's economic and social value equals or exceeds its timber value. However, the extent of conflict of use is often culturally and geographically specific, thus complicating potential steps towards legal protection at broad spatial scales or even within a single country (Herrero-Jáuregui et al. 2013). Another option is the spatial separation of management units, or zoning, for either timber or NTFPs. For example, the locally valuable, multipurpose tree *Carapa guianensis* presents higher adult densities in seasonally flooded forests than in *terra firme* forests in the southwestern Brazilian Amazon. Here, gazetting flooded forest for seed collection is proposed as a multiple-use management alternative (Klimas et al. 2012). Implementing multiple-use forest plans that include NTFPs is inherently loaded with social, regulatory, ecological, and economic tradeoffs (Guariguata et al. 2012); thus, management outcomes are contingent on a deep knowledge on how to minimize these (Duchelle et al. 2012).

Sustainable Harvest of NTFPs

Sustainable harvest of NTFPs is a function of the plant part harvested, the plant's degree of habitat specificity, population and individual growth rates and individual longevity, reproductive mode, and extent and relationships with other biodiversity components such as seed dispersers and pollinators (Peters 1994). In addition to the plant's natural history, the seasonal timing, nature, frequency, and intensity of harvest as well as the larger socioeconomic, political, and environmental context in which the products are gathered need to be taken into account (Shackleton and Pandey 2014; Cunningham 2001).

At the individual level, the harvesting of fruits, seeds, and dead wood shows the highest potential for sustainability. Similarly, long-lived species (e.g., Brazil nut, *Bertholletia excelsa*; Zuidema and Boot 2002) and those with fast growth rates and large populations are more amenable to withstand repeated harvest of fruits and/or nuts than those without these attributes. NTFP species with abiotic dispersal modes and/or dependent on a generalist pollinators as well as seed dispersers are also more resilient to repeated harvest. On the contrary, the harvesting of whole individuals, NTFP species with restricted habitats and/or low population and individual growth rates, low adult population densities, and those with specialist biotic relationships generally show low potential for sustainable harvest (Cunningham 2001).

The plant part harvested usually determines the focus of management and monitoring. Restricting harvesting to specific size classes of the population can be an important determinant of sustainability (Ticktin 2004). For reproductive propagules, it is important to take note of the ability of target species to regenerate and the potential impact on wildlife postharvest. For vegetative structures such as root, bark, or stem, short- and long-term observations need to be made regarding plant vigor and the species' response to harvest. For exudates, evaluation needs to be made of the tapping procedures, extent of injuries, physiological impacts of tapping, harvester skill, and techniques (Plowden 2003; Murugesan et al. 2011; Watkinson and Peres 2011). Of plant parts harvested, least is known about the ecological impacts and sustainable harvesting methods for bark, roots, and resins on a commercial scale (Ticktin and Shackleton 2011).

Communities generally harvest NTFPs based on adaptive management techniques in which harvest levels are adjusted by observation and practical experience (Dawson et al. 2014). Matrix and mechanistic modeling may be used to predict changes in population and ecosystem structure (Wong 2000); however, few forestry operations have the technical expertise, time, and resources to do this for NTFPs (Peters 1994). Based on monitoring the yield of the product, and the population demographics of the target species, harvest levels are adjusted (Ticktin 2004). In tropical forests, ecological functions such as any changes in pollinators, seed

Fig. 7 Cultivated and semidomesticated fruits on sale in Belém, Brazil, including pupunha (*Bactris gasipaes)*, cacao (*Theobroma cacao*), and cupuaçu (*Theobroma grandiflorum*) (Photo: P. Shanley)

dispersers, genetic diversity, and wildlife diversity should also be noted (Pierce 2002a, Guillén et al. 2002).

Economic Botany: The Various Classes of NTFPs and Their Uses

Over millennia, humankind has amassed a wealth of knowledge regarding the habits and uses of various plants, fungi, and animals that live within tropical forests. Forests serve as food larder and medicine cabinet for billions of people in the tropics, and are also a source of fodder for livestock. A recent pantropical survey of 8,000 households, found the most dominant use of forests was for fuel wood (35.2 %), followed by food (30.3 %), and fibers/construction material (24.9 %) (Anglesen et al. 2014). Through trial and error, humans have learned that the exudates of various trees yield an astonishing array of useful products, including antiseptics, insecticides, food emulsifiers, electrical insulation, dyes, marine caulking, rubber, incense, and perfumes. A variety of tropical plants and lichens yield natural dyes – some only available after complex fermentation and oxidation processes – that literally colored our world for generations before the advent of synthetic dyes. Tropical plants also beautify our lives, as attested to by the global trade in tropical house plants and cut flowers which is valued in the billions.

Below, we review the various classes of NTFPs and their diverse uses. Some plant parts have multiple uses; for example, turmeric (*Curcuma longa*) roots are used as medicine, as a cooking spice, and as a textile dye. Other species yield a number of useful plant parts. In Africa, the bark of the baobab (*Adansonia digitata*) tree is used for weaving and cordage, while the leaves and fruits are eaten as food and used medicinally. Space constraints prohibit a comprehensive overview of tropical NTFPs. Rather, the purpose of this section is to portray the breadth and scope of NTFPs used, and in cases where data is available, to give an indication of their importance or value.

Food

Tropical forests can sustain human dietary needs with a mix of proteins, vitamins, starch, and minerals. In natural forests, the distribution of food is patchy and seasonally variable. Production of many tropical forest foods has been increased through management, ranging from subtle manipulation of species to domestication and cultivation in plantations. In food-scarce areas, food from tropical forests offers significant benefits to local communities and can act as a buffer against malnutrition.

Fruits and Nuts

Tropical forests are the original seed sources for many fruits in trade, such as bananas, mangos, cocoa, lychees, papayas, coconuts, rambutans, and various species of citrus trees. While these popular species are now cultivated on a wide scale across the tropics, people continue to harvest a variety of fruits from natural as well as managed forests. Some locally important but lesser known African tropical fruits include Mobola plum (*Parinari curatellifolia*), native to West African savannas as well as miombo woodlands in central and southern Africa, and bush mango (*Irvingia gabonensis* and *I. wombolu)* used as a spice and thickener in Central Africa. Amla fruits (*Phyllanthus emblica*) are rich in vitamin C and are widely collected in India for fresh consumption as well as for use in Ayurvedic medicine. Bacuri (*Platonia insignis*), piquiá (*Caryocar villosum*), and uchi (*Endopleura uchi*) are nutritious and popular wild fruits in the Brazilian Amazon (Shanley et al. 2011) (Fig. 7).

One of the most well-known tropical nuts is the Brazil nut (*Bertholletia excelsa*), which is still collected from natural stands in the Amazon Basin. According to UN Comtrade, Bolivia, Brazil, and Peru exported more than 35 million kilos of nuts worth $190 million in 2012. Shea nuts (*Vitellaria paradoxa*) are an import item of commerce in Western Africa. The fruits are eaten by locals, and the oily seeds are also processed into shea butter which is exported for use in the cosmetics industry. In 2003, combined exports of shea nuts from Ghana, Burkina Faso, Togo, Mali, Cote d’ Ivoire, and Benin totaled more than 140 million kilos, with an estimated worth of $24 million (UN Comtrade). Cooking oils are derived from illipe nuts (*Shorea* spp.) in Southeast Asian dipterocarp forests and from sal nuts (*Shorea robusta*) in India. The betel nut (*Areca catechu*) – technically a drupe rather than a true nut – is chewed with betel leaves and lime to produce a mild psychoactive effect and has customarily been used by a number of cultures in southern Asia and Oceania for thousands of years. The okari nut (*Terminalia kaernbachii*), native to

Papua New Guinea and the Solomon Islands, but cultivated elsewhere in the tropics, is esteemed for its flavor and holds potential as a future crop.

Edible Leaves, Roots, and Shoots

Forest vegetables are key ingredients to local diets. In East Kalimantan, the Dayak make use of a variety of wild forest vegetables, including ferns (e.g., *Stenochlaena palustris*, *Ceratopteris thalictroides*, *Cyathea contaminans*) as well as various plants in the Zingiberaceae family (Chotimah et al. 2013). Bamboo shoots (various spp.) have been a staple of temperate and tropical Asian cuisines for centuries. In Central Africa, Gnetum leaves (*Gnetum africanum* and *G. buchholzianum*) are widely consumed as food; Ingram et al. (2012) estimated the annual trade in the liana's leaves in southwestern Cameroon and the Democratic Republic of Congo alone exceeded 4,000 tons with a value of more than $5 million. Palm hearts from various species, including *Bactris gasipaes* and *Euterpe oleracea*, are harvested from natural stands and plantations across the tropical Americas for local consumption as well as for export. In 2011, combined exports of palm hearts from Ecuador, Costa Rica, Bolivia, Brazil, and Peru exceeded 50 million kilos with an estimated value of USD $115 million (UN Comtrade).

Mushrooms

The global trade in wild mushrooms is estimated to be worth more than $2 billion annually (Hall et al. 2003), and much of it is dominated by four genera that are widely consumed in temperate countries, namely, boletes (*Boletus* spp.), chanterelles (*Cantharellus* spp.), matsutakes (*Tricholoma* spp.), and truffles (*Tuber* spp.). Wild mushrooms from tropical forests, although less studied by scholars than temperate fungi, are important sources of food and income. One tropical hot spot of mushroom production is the vast miombo woodlands of central and southern Africa where scores of mushrooms, including species from the genera *Agaricus*, *Amanita*, *Boletus*, *Cantharellus*, *Lactarius*, *Pleurotus*, *Russula*, *Schizophyllum*, and *Termitomyces*, are harvested by local communities (Härkönen et al. 1994; Ngulube 1999; Tibuhwa 2013).

In the Machinga District of Malawi, mushrooms provide income and food before agricultural crops are ready for harvest and account for 73 % of all NTFPs sold at local markets (Ngulube 1999). The poorest mushroom gatherers in Malawi eke out a living by selling mushrooms for money to buy staples such as maize, while more prosperous traders can obtain a good income from buying mushrooms in rural markets and reselling them in cities (Lowore 2006). In a survey asking rural women in Ghana to rank 16 NTFPs from most important to least important as sources of food and income, the majority (76 %) ranked mushrooms as a "most important" resource (Ahenkan and Boon 2011). Foppes and Ketphanh (2004) classify mushrooms as an important NTFP in Lao PDR, reporting that 100 % of households in Sombpoi village collect an average of 100 kg of wild fungi per year.

Indigenous groups including tribes of the Southern Highlands in New Guinea (Sillitoe 1995), the Dayaks of Kalimantan (Chotimah et al. 2013), the Bagyeli (pygmies) in southern Cameroon (van Dijk et al. 2003), the Sanema of the Amazon

(Fidalgo and Prance 1976), and the Jotï of Venezuela (Zent 2008) collect and eat mushrooms. Mushrooms are an integral part of Jotï cosmology, featuring in myths and life cycle rituals, and are used by the tribe as mediums for restoring hunting skills and as protection against sorcery (Zent 2008). Wild mushrooms are good sources of proteins, carbohydrates, and minerals and can be important dietary supplements (Boa 2011). As Zent (2008) points out, mushrooms are therefore likely to be important to indigenous forest dwellers who experience seasonal food scarcity.

Bushmeat

Hundreds of tropical species of ungulates, primates, birds, rodents, reptiles, and amphibians are hunted for their meat, termed "bushmeat." Bushmeat is a crucial source of protein and income for people living in the tropics and is particularly important in the Congo Basin where inexpensive alternative sources of protein are scarce and cultural preferences for bushmeat are strong (Van Vliet et al. 2012). For indigenous groups and remote forest dwellers, bushmeat is a primary source of protein and consumption rates per person, in both the Amazon and Congo Basins, typically ranging from 40 to 70 k per year, sometimes much higher, depending on location (see Nasi et al. 2011).

The scale of the annual harvest of bushmeat is staggering; in 2010, it is estimated that six million tons of animals were taken in the Congo and Amazon Basins alone (Nasi et al. 2011). The value of the bushmeat trade is likely in the billons of US dollars (Brashares et al. 2004). Fargeot (2012: 130) estimates that the total value of bushmeat consumed each year in Bangui, capital of the Central African Republic, is worth $ 16 million, equivalent to more than 1 % of the country's GDP. Market demand for bushmeat in the cities of Equatorial Guinea, Gabon, and Cameroon, where the product is viewed as a luxury good, has spurred demand, increased prices paid to rural hunters, and thus intensified hunting pressure (Nasi et al. 2011). Demand for bushmeat among urbanized Africans is not restricted to the continent. The amount of illegal bushmeat smuggled through Charles de Gaulle airport in France is estimated to be equivalent to 270 tons per year (Chaber et al. 2010). The authors further report that a 4 kg monkey sells for as much as 100 Euros in France, more than 20 times its price in Cameroon (Chaber et al. 2010).

Although some species appear to adapt to hunting pressure, the harvest of bushmeat poses a dire conservation threat, particularly to large primates and large carnivores (Van Vliet et al. 2012). The removal of animals from tropical forests is also likely to broadly impact ecosystem processes and floral composition because animals are integral parts of food webs and serve critical functions as seed dispersers, seed predators, pollinators (in the case of bats), and herbivores (Van Vliet et al. 2012). Many tropical animals are also hunted for their skins, horns, antlers, and feathers, and some, particularly birds in the Americas, are also captured live for sale in the exotic pet trade, or in the case of beetles and other charismatic insects, killed, mounted, and sold to collectors.

Fig. 8 The medicinal bark of *Endopleura uchi* harvested in Amazonia, Brazil (Photo: P. Shanley)

Insects

More than 1,700 species of insects are eaten as food by some two billion people globally, mostly in the tropics (Durst et al. 2010; van Huis et al. 2013). Insects are an excellent source of protein, and their cultivation for food and feed is currently being explored as a strategy to address future food security issues (van Huis et al. 2013). Edible species are taken from many well-known insect orders including Coleoptera (beetles), Lepidoptera (butterfly and moth caterpillars), Hymenoptera (bees, wasps, and ants), Orthoptera (grasshoppers, locusts, and crickets), Hemiptera (cicadas, leafhoppers, scale insects, and true bugs), Isoptera (termites), Odonata (dragonflies), and Diptera (flies) (Durst et al. 2010; van Huis et al. 2013).

In the Americas, 679 insects are consumed as food. Africa ranks second with 524 edible species and Asia is third with 349 species (Johnson 2010). A 2010 national survey in Laos PDR (Barennes 2010) determined that 95 % of Laotians consume insects, the most preferred being ant eggs, crickets, and grasshoppers. Caterpillars are a source of food and income for many in central and southern Africa. Latham (2003) estimates that in the Democratic Republic of Congo, caterpillars account for 40 % of all animal protein eaten. According to van Huis et al. (2013), commercialization of caterpillars, particularly the mopane caterpillar (*Imbrasia belina*), has led to overharvest, a situation which poses a serious conservation and food security issue for the region. One insect harvested across the tropics is the palm weevil (*Rhynchophorus* spp.), a species high in fat that is enjoyed in the Americas, Africa, Asia, and the Pacific islands (Johnson 2010). An important pantropical insect by-product is wild forest honey.

Table 3 Select tropical forest medicinal species in the international botanicals trade

Common name	Scientific name	Origin	Habit	Cultivated/wild harvested	Trade data
Cat's claw	*Uncaria guianensis, U. tomentosa*	Central and South America (most trade from S.A., part. Peru)	Vine	Wild harvested with some cultivation trials underway	Exports from Peru in 2010, FOB value $ 1,376,000 (ITC 2012). Bark powder traded at $ 9.50/kg (BTC 2014).
Pygeum	*Prunus africana*	East, Central, and West Africa, Madagascar	Tree	Majority wild harvested; some efforts to cultivate are coming on line	Cameroon exported 658.6 tons in 2012, valued at more than $3.9 million, and accounting for 72.6% of the global export market (Cunningham et al. 2014)
Rosewood	*Aniba spp.*	South America	Tree	Wild harvested	92.3 MT exported from Brazil, 1985 worth $938,000 (FAO 2002)
Red sandalwood	*Pterocarpus santalinus*	India	Tree	Wild harvested and some cultivation (rare through overexploitation in wild)	287.8 tons exported 2004-2005 (Mulliken and Crofton 2008)
Sangre de drago	*Croton lechleri*	South America	Tree	Wild harvested and cultivated	26 tons of latex exported to US in 1998 (Alexiades 2002)
Yohimbe	*Pausinystalia yohimbe*	West-Central Africa	Tree	Wild harvested	2013 sales of yohimbe products in mainstream outlets in the US totaled $67,393,961 (Lindstrom et al. 2014)

Adapted from: Pierce and Laird 2003.

Fig. 9 Resin tapping in the Nilgiris, India (Photo: J. de Beer)

Medicines

Medicinal plants are one of the most widely studied groups of NTFPs coming from tropical forests. In recent decades, the “medicinal riches” of tropical forests were a popular argument for conservation. The ecological, species, and genetic diversity of these regions has created novel chemical compounds and genes of interest to researchers in the pharmaceutical industry, as well as providing important botanical medicines for local and international markets (Laird and Wynberg 2005). Tropical forests also produce thousands of invaluable medicines used in traditional medical systems around the world. Traditional medicine provides the vast majority of primary health care in many regions, including 80 % in Africa according to the World Health Organization (Fig. 8).

The global botanicals market is growing more than 7 % annually, with annual sales of roughly \$85 billion. Natural personal care and cosmetics generate \$31 billion in sales each year, and the market is expected to reach \$46 billion by 2018 (Laird and Wynberg 2013). Only a small portion of these sales represent species from tropical forest regions, but there are many high-value tropical forest species in the botanical trade, and companies continue to search for novel products (Table 3).

The pharmaceutical industry is magnitudes larger than the botanicals industry, with annual sales of around \$1 trillion. R&D approaches have changed in recent years, natural products research is largely outsourced to smaller companies, and large-scale collections of plant and other materials from tropical forests are reduced in scale and number. However, interest in novel genetic material continues, particularly that of microorganisms, including those found in forests (Laird 2013).

Table 4 The use, origin, and trade of select tropical gums, resins, and latexes

Exudate type	Common name and species name	Use	Origin	Estimated amount produced (source)	Estimated annual value (USD) (source)
Gums	Gum arabic (*Acacia senegal, A. seyal*)	Food emulsifier, stabilizer, and thickener; also used in the art, printing, and pharmaceutical industries	Sub-Saharan Africa from Senegal to Somalia (largest producers are Sudan, Chad, and Nigeria)	2010 global production: 142, 123 tons (UNCTAD – unctad.org)	2010 global trade: $490 million (UNCTAD)
	Gum karaya (*Sterculia* spp.)	Colostomy bag fixings, laxative, dental adhesive, food stabilizer, various other industrial uses	Asia and Africa (India; Senegal, Sudan, and Pakistan also export karaya)	5,500 tons (Vantomme et al. 2002 - although annual supply has reportedly been in decline since)	N/A
	Copaíba (*Copaifera* spp.)	Antiseptic, anti-inflammatory; also used in soaps and cosmetics and as a source of biodiesel	South America; most common in the Brazilian Amazon	2009 production in Brazil: 538 metric tons (Newton et al. 2012)	2009 value: $2.2 million (Newton et al. 2012)
	Almaciga/Manila copal (*Agathis philippinensis*)	Varnishes, paints, floor wax; locally used as lamp fuel or mosquito smudge	Indonesia, Philippines	2011 Philippine production: 678,000 kg (Philippine Forestry Statistics 2012)	2011 Philippine export (123,00 kg) value: $226,000 (Philippine Forestry Statistics 2012)
	Natural rubber (*Hevea brasiliensis*)	Tires, latex, various manufacturing uses	Plantations in Asia, Africa, and Pacific island nations; production from natural forests in Brazil	2012 global production 11.6 million tons (International Rubber Study Group – www.rubberstudy.com)	Thailand, Indonesia, Malaysia, and Vietnam 2012 exports combined: $16.4 billion (UN Comtrade)
	Balata (*Manilkara bidentata*), gutta-percha (*Palaquium gutta*), guayule (*Parthenium argentatum*), chicle (*Manilkara zapota*/*Achras zapota*), and similar gums	Insulation, manufacturing, golf ball covering, dentistry, chewing gum base	Central and South America, Southern Asia	2012 Indonesian and Mexican exports combined: 1.3 million kg (UN Comtrade)	2012 Indonesian and Mexican exports combined: $4 million (UN Comtrade)

Table 5 Tropical plants used as dyes and tannins

Botanical name	Family	Common name	Occurrence	Uses
Acacia catechu	Fabaceae/ Leguminosae	Cutch, catechu, sa-che, seesiat	India, Myanmar, Thailand	Tanning agent, brown dye, and preservative for canvas and fishing nets
Bixa orellana	Dilleniidae	Annatto	Central America and tropical South America	The fruit's red seeds are used as a food colorant/flavoring
Caesalpinia spp.	Fabaceae/ Leguminosae	Brazilwood, Pau de Pernambuco, sappanwood, tara	South America, India, and S.E. Asia	The wood of several species produces a red dye called brazilin; the tannin-rich seed pods of *C. spinosa* produce a light-colored leather
Chlorophora tinctoria/ *Morus tinctoria*	Moraceae	Old fustic, dyer's mulberry	Tropical Americas	The wood produces a yellow or khaki dye
Curcuma longa	Zingiberaceae	Turmeric	Southern India (now widely cultivated)	The rhizomes are used as a cooking spice and as a yellow dye
Indigofera tinctoria	Fabaceae/ Leguminosae	True indigo	Southern Asia	The fermented leaves produce the blue dye indigotin
Haematoxylum campechianum	Fabaceae/ Leguminosae	Logwood	Central America and tropical South America	The heartwood produces a dark pigment used for textiles and in inks
Pterocarpus santalinus	Fabaceae/ Leguminosae	Red sandalwood, red sanders, santalin	Southern India	The powdered heartwood is both a dye and food additive
Relbunium spp.	Rubiaceae	Chamiri, antaco	South America	Roots make an orange or red dye
Roccella spp.	Roccellaceae	Orchil	South America, Angola, Madagascar, the Mediterranean	The fermented lichen makes a red-purple dye; also used in litmus paper

Sources: Green (1995), Ferreira et al. (2004)

Natural products also continue to contribute significantly to industry bottom lines, particularly in areas like anti-infectives and cancer, where 48.6 % of all drugs are natural products or derived therefrom (Newman and Cragg 2012).

Gums, Resins, and Latexes

Several hundred species of tropical trees produce useful gums, resins, and latexes (Coppen 1995a, Coppen 1995b). Internationally, a number of these tree exudates are widely used in the food, pharmaceutical, and fragrance industries, as well as in a variety of manufacturing processes. Once traded in large volumes, many wild-sourced gums, resins, and latexes have lost market share to inexpensively produced synthetic substitutes. Examples of products that have lost markets to substitution effect include chicle (latex from *Manilkara zapota*), once used as a natural base for chewing gum; balata (latex from *Manilkara bidentata*), formerly used to coat submarine and telephone cables, as well as golf balls; and damar (resin principally collected from *Shorea* spp.), an ingredient used in varnishes and lacquers (Fig. 9).

The income generated from the sale of tropical forest exudates supports rural livelihoods – such as those of the rubber tappers living in extractive reserves in Brazil as well as almaciga (*Agathis philippinensis*) resin tappers in the Philippines – but also generates significant hard currency for national economies, hundreds of millions of dollars in the case of gum arabic (*Acacia* spp.), and billions of dollars for plantation-grown natural rubber (*Hevea brasiliensis*) (Table 4). While internationally traded exudates often end up being used in industrial applications, local communities use these substances for pragmatic as well as spiritual purposes. In Brazil, resin from Copaíba (*Copaifera* spp.), known as “the antibiotic of the forest,” is used to treat wounds, but also serves as lamp oil (Shanley et al. 2011). Almaciga resin serves as a torch fuel in the Philippines, but is also used to caulk boats and is burned as incense in religious ceremonies. In similar fashion, benzoin (*Styrax* spp.) resin is ritually burned in Indonesia during rice-harvesting ceremonies, as an offering to the dead, and as protection from bad spirits.

Dyes and Tannins

Humans have dyed textiles for thousands of years, and until the advent of synthetic dyes 150 years ago, dyes were produced from natural sources, including roots, leaves, barks, fruits, and lichens (Ferreira et al. 2004). One of the most famous tropical dyes is indigo, a deep blue obtained from *Indigofera tinctoria*, a plant native to tropical Asia. Indigo was a significant item of commerce between Europe and Asia in the sixteenth century. During the seventeenth century, the plant was introduced to the West Indies and the Americas as a plantation crop to supply the European dye industry (Ferreira et al. 2004). Plant tannins, derived from bark, wood, fruits, and other plant parts, are used for tanning leather as well as for dyes and inks. Examples of tropical plants used as sources of dyes and tannins are given in Table 5. A noteworthy insect-derived dye is lac, the scarlet-colored, resinous secretions of various genera of scale insects including *Kerria, Laccifer*, *Metatachardia*, and others. Lac cultivation occurs across Asia in natural forests. Lac is also processed into shellac, varnishes, and waxes. India is the world’s leading

Fig. 10 Palms and hemi-epiphytes are widely used in basketry and broom construction (Photo: M. Cymerys)

producer of lac. According to UN Comtrade, India, Thailand, and Indonesia exported a total of 13 million kg. of lac in 2006, worth an estimated $50 million.

Construction and Fiber

Since the dawn of civilization, humans have used a variety of forest fibers and construction materials to make their homes, thatch their roofs, fashion their tools, and weave cordage, baskets, and mats. The most important tropical forest fibers in international trade are bamboo and rattan. Woody and herbaceous bamboos (var. spp.) are members of the grass family and are found across the tropics, as well as in temperate forests. Noted for their tensile strength, the woody bamboos have a deep history of use in Asia where they have been used to make dwellings, tools, paper, and musical instruments.

Rattans (various genera including *Calamus*, *Daemonorops*, *Eremospatha,* and *Laccosperma*) are spiny, climbing palms whose strong stems ("canes") can be woven into furniture, baskets, handicrafts, and fish traps. Rattans are almost exclusively harvested from natural forests in Africa, Asia, and parts of the South Pacific. Southeast Asia is the hub of the global rattan trade.

International trade in rattan and bamboo products was worth $2.5 billion in 2012 (Wu 2014). Domestic and subsistence use of bamboo and rattan in the tropics is substantial. For example, the domestic market for bamboo in China was valued at $19.5 billion in 2012 (Wu 2014). The bamboo sectors in China and India alone are estimated to employ more than 16 million people (Wu 2014). In addition to their use in construction, young bamboo shoots are edible and some rattans produce edible fruits and palm hearts as well.

In South America, palm fibers are widely used for home construction, basketry, tools, and ceremonial purposes. Important genera include *Attalea*, *Astrocaryum, Leopoldina*, and *Syagrus*. Kapok fibers from the seed pods of *Ceiba pentandra*, native to Central and South America, have long been used as insulation as well as stuffing for pillows, mattresses, and, due to their buoyancy, life preservers. In Brazil, the roots of the hemi-epiphytic vine titica (*Heteropsis* spp.) are used to bind housing frames and to make a variety of household products such as brooms, bags, and baskets (Fig. 10).

Governance of NTFPs

As we have seen, NTFPs include a broad range of species with extremely different ecological, livelihood, and market niches and equally diverse management and trade practices, end products, and consumers. It is very difficult to regulate such a wide range of related but different products and activities under one body of law, and very few governments have succeeded. Common problems with NTFP regulation around the world include lack of clarity over what is being regulated and why; inconsistent and poorly coordinated bodies of law drafted in reactive and opportunistic, rather than strategic, ways; and an absence of consultations with harvesters, producers, local communities and other stakeholders (Wynberg and Laird 2007; Laird et al. 2010).

NTFP laws are also often poorly implemented because government resources and capacity are rarely allocated for what are still perceived as "minor" products (Shackleton and Pandey 2014; Tomich 1996). In addition, ambiguity in government institutional responsibilities creates conflict and confusion, with local, provincial, and national authorities often competing for jurisdiction over products when they become commercially valuable. In some countries, legal ambiguity creates opportunities for corruption. Bureaucratic and confusing NTFP laws in the Philippines and Cameroon, for example, have been shown to make "unofficial payments" to government officials for paperwork or "informal taxation" along trade routes an expected requirement of participating in the NTFP trade (Arquiza et al. 2010; Ndoye and Awono 2010).

Another central problem with NTFP law and policy around the world is that what could be important and complementary customary laws and institutions are sidelined and even undermined by statutory systems of law (Alexiades and Shanley 2005; Laird et al. 2010, Blackman and Rivera 2011). In many tropical forest countries, including Brazil, Cameroon, Fiji, India, and the Philippines, "less is often more" when it comes to statutory NTFP regulation; existing customary structures can prove far more effective at regulating such locally and culturally specific products (Wynberg and Laird 2007; Arquiza et al. 2010; Lele et al. 2010; Novellino 2010).

Fig. 11 National legislation in Brazil protects the Brazil nut tree from timber extraction (Photo: P. Shanley)

Laws and Policies that Impact NTFPs: Direct and Indirect

Laws and policies impacting NTFPs include those that directly regulate these products and those that indirectly but significantly do so. Direct regulation is usually for species in commercial trade, and regulatory frameworks are part of national or international efforts (generally under CITES) to protect endangered or endemic species or to generate revenues for governments. For example, in India, tendu (*Diospyros melanoxylon*) provided as much as 74 % of Orissa state's total earnings from forests, and as a result, the state established direct regulation of this species through nationalization (Lele et al. 2010). Policies that directly regulate NTFPs include quotas and permitting, as part of forestry and natural resource laws; quality, safety, and efficacy standards and measures; transportation; trade restrictions; and taxation (Laird et al. 2010).

Laws and policies that indirectly impact NTFP management, use, and trade can often have as great, or greater, impact on these species as those drafted to regulate them (Dewees and Scherr 1996). These include agricultural policies that discourage or promote farming practices linked to NTFPs and local livelihoods such as restrictions on swidden agriculture (Novellino 2010), incentives to cultivate NTFPs, or agricultural policies that create changes in land and resource rights with significant impacts on NTFP management and the livelihoods of small-scale producers and harvesters (Cronkleton and Pacheco 2010). Land tenure and resource rights are fundamental to the achievement of equity and sustainability in NTFP management, use, and trade, but their central role is often overlooked. NTFPs are harvested under a wide range of land ownership regimes including communal, private, and various tiers of state control, as well as different access regimes, from strict prohibitions on use through to open access (Laird et al. 2010).

Incorporation of NTFPs into Forestry Laws

In most countries, forestry laws historically focused almost exclusively on timber production and paid little attention to NTFPs. However, in recent decades, efforts have been made to incorporate NTFPs into national forestry laws as part of trends discussed earlier towards a wider and more inclusive view of the values, goods, and services provided by forests. In most countries, this meant tagging NTFPs onto existing timber-centric policy processes or laws in the 1980s and 1990s. The result was lack of clarity on definitions and scope, with many governments uncertain of the products and activities they were regulating. The actions prescribed often focused on permits, quotas, management plans, and royalties or taxes – an approach lifted directly from the timber sector and entirely inappropriate for NTFPs (Laird et al. 2010). In a positive development, however, some of these revised forestry laws included recognition of NTFP values in timber management plans and logging operations in order to minimize negative impacts on these locally valuable species (Fig. 11).

NTFP Certification

Certification has emerged as a voluntary policy tool for promoting sustainability and equity in the use and trade of NTFPs. It can complement statutory and customary laws by using a market-based instrument to further raise awareness of the ways NTFPs are sourced and the interrelationship between timber and non-timber production. NTFP certification is far more limited in scope than timber certification and is made more expensive and difficult due to the complexity and diversity of the products found within this category and the smaller revenues generated by each product. Certification schemes and standards addressing NTFPs vary and include organic, fair trade, and forest/ecological (Shanley et al. 2002; Market Insider 2014).

Training, Education, and Research

Professional forestry careers and training programs are suffering reduced enrollment in many countries, with individuals seeking a degree in forestry down by 30 % since the 1990s (Van Lierop 2003; Temu and Kiwia 2008). One of the reasons identified by potential students for reduced enrollment was a perception that rather than promoting stewardship and looking at the broad social as well as ecological values of forests, forestry was narrowly focused on the extraction of timber (Temu and Kiwia 2008).

Training and Education

Repeated calls for interdisciplinary training in forestry have been made for graduate and undergraduate training (Zarin et al. 2003; Innes 2010). Advances have been made and many promising initiatives and training programs exist, but NTFPs and local perspectives on the value and use of forests continue to be taught separately from timber management (Lawrence 2003). In cases where NTFPs have been integrated into the curriculum, positive results have followed whereby systems thinking, critical analysis, and an interdisciplinary approach help prepare foresters to design and manage multiple-use forest systems. NTFP courses have been integrated into university curriculum at forestry and agricultural training schools in the Brazilian States of Acre, Para, Amazonas, and Amapa (Guedes Pinto et al. 2008; Shanley et al. 2012), into postgraduate natural resources management programs in the Universidad Veracruzana (Guariguata and Evans 2010), and NTFP subjects have been included in the syllabi of two faculties of the National University of Laos (Ingles et al. 2006). However, as Morris and Van (2002) note in Vietnam, no University or college faculty has specialized in NTFP training, and where NTFPs are taught, the focus is often on a few products in trade (Guariguata and Evans 2010).

A large number of NTFP educational programs and curricula development exist outside formal education settings, which are largely developed by communities or NGOs. These tend to be more practical and applied and thus respond more immediately to the socioeconomic and ecologic challenges faced by communities (Shanley et al. 2011). By affirming the local knowledge and management practices forestry students have grown up with, and listening and using case studies from farmers' life contexts (Dove 1992), forestry extension and teaching at the village level can affirm student's cultural and ecological heritage at all school levels (Quave 2014).

A Biocultural Approach: Indigenous Educational Training Initiatives

A trend occurring in the educational sector in various regions is tailored educational and training initiatives for indigenous communities. Such programs range from bilingual education providing literacy, community health, community forestry, and marketing skills (Thomas 2002) to formal education institutions focused on the integration and implementation of intercultural education models (Alexiades et al. 2013). Examples such as the Intercultural University of Veracruz and Iwokrama in Guyana illustrate how intercultural education seeks to understand and enhance the sum of ideas, practices, and values that marginalized societal groups generate from within, creating a path for endogenous development. By including the practices, values, and uses of NTFPs, these educational models establish inclusive and respectful dialogues and contribute to the conservation and defense of indigenous territories and resources (Haverkort and Rist 2007; Pedota 2011). Since the aim of intercultural programs is to create opportunities for intergenerational transmission of knowledge, this could become a promising path for maintaining and conserving forests in various areas of the world. Indigenous NTFP approaches constitute a framework closer to the views, practices, and values of indigenous communities who manage their forest resources for multiple uses and not just wood.

Closing Gaps in Knowledge and Practice

Data Needs

During the past 20 years, gains have been made in recognizing the value of non-timber forest resources at the global and local scales, and NTFPs have taken a firm place in international policy discussions. And yet, basic field research on the ecology, use, and management of NTFPs remains scant, as well as initiatives to generate key information and/or put into practice what is known about NTFPs – joint timber and NTFP inventories and production studies, documentation of complex management systems, policies which support NTFP gatherers, and global initiatives to capture the still invisible trade in and cultural importance of forest products. Below is a partial list of areas in need of attention.

National and International

- Modify national agricultural and labor census to capture trade and employment in NTFPs.
- Generate regional and national statistics documenting trade in a wide range of NTFPs.
- Make trade categories more distinct to capture species-specific trade, regionally and internationally.
- Train data collection agencies that monitor local, regional, and national markets and agricultural trade to augment their list of crops to include forest resources.
- Generate rigorous data on forest resources to feed into Food and Agricultural Organization's (FAO's) annual global forest resources report (Zhu and Waller 2003).
- Use satellite remote-sensing tools for national monitoring of deforestation and forest degradation to discern drivers (Hosunoma et al. 2013).

Regional

- Conduct longitudinal analyses of management, use, trade, and impacts of land use change on forest products and the people who rely upon them.
- Develop and share methods to streamline the monitoring of NTFP harvest.

Fig. 12 Annual Negrito Cultural Revival and Forest Food Festival, Agta Tribal Council, Philippines (Photo: G. Cruz)

- Promote exchanges between small holders to share use, processing, and management techniques.
- Investigate the range of motivations of gatherers and the cultural and personal connection of people to place with attention to the intangible benefits and cultural opportunities and challenges of NTFPs.

Forest Resources: Site and Species Specific

- Initiate ongoing ecological studies: phenology, distribution, density, production/yield, dispersers, pollinators, etc. of locally and regionally important NTFPs.
- Identify NTFPs which are valuable to local populations and vulnerable to land use change and document associated small holder management practices.
- Conduct studies to determine sustainable extraction of understudied but widely utilized classes of NTFPs, including barks, roots, and exudates.
- Integrate local and scientific knowledge to identify best practices and resources monitoring systems.
- Offer technical assistance for improved preserving/processing of NTFPs for market/value addition.
- Undertake studies on the subsistence use of the full range of species in a large number of forest communities so NTFP discussions can move beyond anecdote to real analysis.
- Support communities in intergenerational transfer of traditional ecological knowledge through research, workshops, and technical and cultural exchanges between indigenous communities (de Beer 2011).

Methods

Forest inventories, forest management courses, university curricula, and field research on natural resources are often timber oriented, restricting understanding of the vast range of forest products and services. Interdisciplinary methods are needed that provide practical, low-cost, participatory means for communities to assist in conducting and monitoring sustainable forest management:

- Develop methods for improved integration of timber and NTFP inventories, management, monitoring, and harvest.
- Improve research design and methods by fostering improved communication and understanding between rural communities, extensionists, and scientists (Sunderland et al. 2009).
- Test various monitoring methods for sustainable extraction of NTFPs across regions and NTFP classes.
- Advance RIL techniques and train foresters in RIL and integration of NTFPs and timber.
- Develop participatory methods by which communities monitor phenology, production/yield, and sustainable offtake of NTFPs.

Policy

- Promote cross-sectoral communication (i.e., agriculture, forestry, land and resource rights, education, transportation, culture) to mitigate detrimental impacts of policies on land use, NTFPs, and livelihoods, and enhance the effectiveness of laws.
- Undertake careful and thorough consultations with the wide range of affected stakeholders (communities, traders, harvesters, companies, exporters, etc.) before embarking on legislation.
- Provide adequate resources to develop and implement laws and ensure institutional responsibilities that are clear and well-resourced.
- Respect and incorporate the important role of customary laws and institutions in regulating such a diverse group of products.
- Learn lessons from former NTFP projects and conservation and development initiatives (i.e. community based forest management (CBFM), payment for environmental services (PES), and others) in order to learn from past experiences and avoid repeating mistakes.
- Examine the interface between NTFPs and climate change including adaptation and mitigation, and the potential role of REDD+ in national NTFP strategies and laws.
- Approach policy in a more holistic manner that promotes management of forests for a broad spectrum of products and beneficial services that seek to concurrently mitigate climate change, biodiversity loss, and species extinction.

Communication and Information Access

The majority of data generated about NTFPs is available to scientists with access to international journals rather than foresters, practitioners, national scientists, and people who rely upon NTFPs. Equitable sharing of science through extension and outreach has improved outcomes in the agricultural and health-care sectors but is in vast need of improvement in the forest resources sector:

- Synthesize existing knowledge from long-term and rigorous site-specific studies – specifically ecology, trade, processing, use, nutrition, and management.
- Expand information access through production of radio programs, films, and illustrated, accessible reference works.
- Employ popular media outlets to share relevant and timely forest resource information on nutrition, processing, management, trade, and legends regarding forest resources.
- Promote education about NTFPs by fostering exchange between civil society, policy makers, and gatherers, through forest food and cultural festivals – celebrating the connection between people and forests (de Beer 2011) (Fig. 12).

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