Review

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Is Non-Timber Forest Product Harvest Sustainable in the Less Developed World? A Systematic Review of the Recent Economic and Ecological Literature

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Abstract
Non-timber forest products (NTFPs) provide material subsistence and cash income to millions of rural people, particularly in less developed countries. This paper offers a systematic review of recent trends (2000-2010) in the ecological and economic sustainability of NTFPs. Of 101 NTFP ecological studies, most addressed harvest consequences at the population-individual level (62.4%), and over half (52.5%) were carried out in Latin America. Nearly two-thirds of research (63.3%) reported that extraction was sustainable or likely to be so, compared to less than one-fifth (17.8%) that found it to be unsustainable. Extractive enterprise in Latin America was most often reported as ecologically sustainable (82.6%), and least often in Asia (58.8%). Because little of the economic NTFP literature identifies whether extractive returns meet the financial needs of extractors, at least on a daily basis, we outline economic sustainability criteria in terms of whether returns surpass an absolute poverty line or alternative wage. Of the 71 articles presenting financial data, over two-thirds met or exceeded the threshold of economic sustainability. Roughly 75% of studies demonstrated that gatherers earned more than USD$2 PPP/day (the international absolute poverty line) or more than a local wage. These positive results do not, however, demonstrate that gathering reduces long-term poverty because forest dependence, and likely tenure security, remains low among these populations. Caution must be exercised in terms of extending these results into the future, as changing economic conditions, rates and sources of habitat modification, and climate change all point to increased extractive pressures on tropical forests and savannas.

Keywords: *Non-timber forest product – Non-wood forest product – Extraction – Ethnobotany - Ecological sustainability – Economic sustainability*

Introduction

The extraction of non-timber forest products (NTFPs) from old- and second-growth habitats includes foods, fiber, medicines, latex, and sundry other plant and fungal products (Shackleton et al. 2011; Voeks 2011). Long regarded as economically atavistic and environmentally destructive by government planners, NTFP collection and trade by the 1990s began to be viewed by national and international entities as a potential rural development-resource conservation win-win (Hagen and Fight 1999; Peters et al. 1989; Schwartzman et al. 2000). Whether destined for personal consumptive or commercial ends, NTFPs can open several routes to livelihood improvement among marginalized, rural communities in the developing world (Avocevou-Ayiso et al. 2009). And unlike alternative destructive forms of land use, such as logging, mining and plantation agriculture, the collection of wild nuts and fruits, leaves, bark, resin, and roots affects the structure and function of forests much less than other uses. Under favorable circumstances, NTFP extraction is capable of achieving the overarching goal of sustainable development, that is, “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (UN 1997).

But some have argued that external demand for NTFPs necessarily leads to unsustainable “boom and bust” economic cycles, further marginalization of rural people, and over-exploitation of botanical resources to the point of extinction (Crook and Clapp 1998). The question of when and where NTFP extraction is an appropriate land use is clearly more complex than originally envisioned (Ingram et al. 2012; Neuman and Hirsch 2000). At its foundation, the lofty objective of integrating biodiversity conservation and rural economic development through material exploitation of nature’s botanical bounty can only be realized if the extractive enterprise is both economically and environmentally sustainable.

This article reviews the research on ecological and household livelihood changes from NTFPs in the recent decade (2000-2010). Our underlying premise is that long-term successful NTFP extraction depends on both economic and ecological sustainability, but that few if any studies take both of these variables into consideration. We contribute to the interdisciplinary analysis by offering the first, to our knowledge, systematic review combining financial and ecological data on relevant extractive plant species. We first outline trends during this period in the published literature on the most relevant factors that affect NTFP economic and ecological sustainability. We then outline a methodology to compare economic sustainability across recent studies. This is followed by an overview and quantitative summary of specific non-timber forest goods, with a focus on those gathered in less developed countries (excluding wetlands).

Economic Considerations

Because extraction households are often the poorest in rural communities (cf. Pouliot 2012), incomes generated from NTFPs have the potential of reducing absolute poverty and changing income distribution. Extractors earn cash from the sale of products such as latex and medicinals; they gather free food in the form of fruits and tubers; they acquire energy from fuelwood; they collect free medicines from plant leaves and roots and bark; they acquire free thatch and construction poles from palm fronds and stems; and/or they obtain free ornamental decoration from wild foliage and orchids (Neumann and Hirsch 2000; Senarathne et al. 2003). Not all forest products are sold, but they nonetheless provide alternative use values to households that eliminate the need for market purchases. Unlike market items, however, extractive resources used in personal consumption and use must be priced through shadow prices of a substitute product, the loss of alternative earnings involved with collection time, or contingent valuation.

Many authors have addressed how non-timber forest product collection and trade contributes to support for current consumption, longer-term poverty reduction, and the safety-net of families (Babulo et al. 2009; Fang 2009; Lopez-Feldman et al. 2007; Sunderlin et al. 2008; Vedeld et al. 2004). First, by consuming edible forest products and other subsistence items, households avoid cash outlays, thus lowering the family's poverty line. Further, people involved in the commerce and processing of consumptive NTFPs in rural and peri-urban areas gain employment through the products' secondary links (Stoian 2005). Second, NTFPs mitigate poverty and reduce overall household risk by providing incomes during difficult times of the year, a form of natural insurance against economically-inclement periods (Pattanayak and Sills 2001; Takasaki et al. 2004; McSweeney 2002). Income timing is crucial for NTFPs to serve as "gap fillers" and to offset cash shortfalls during "hunger seasons" (cf. Pouliot 2012; Schreckenberg et al. 2002). For households that have no other financially-worthy uses of time, additional income from NTFPs represents a bonus as well as an incentive for the household to protect the environment.

Non-timber forest resources nevertheless seldom provide sufficient income to fully support a household (Wilkie et al. 2001). Most households exhibit varying degrees of "forest dependence" (the ratio of forest income to total income). Forest dependence varies across livelihoods, as poorer households involved in extraction often choose this option due to relatively limited access to land and other assets compared to more prosperous households. An earlier meta-analyses of 61 CIFOR case study returns to NTFPs (Belecher et al. 2005) suggested forest dependence ranging from 10-65% of total household income, whereas in 1980s case studies in Vedeld et al. (2007) it represented 22-25% of total income net of timber.

Peters' et al. (1989) pioneering study provided early optimism that extraction could be a profitable form of land use in less developed countries. They discovered that potential gross yearly returns per hectare (USD$700) could exceed those of logging. Taking a net present value analysis and deducting labor and transportation costs pointed to over USD$6000/hectare value from a representative forest site. These high returns suggested that poor people had an incentive to protect the forest rather than clear it. But other studies were less optimistic, eliciting wide variation of net returns (USD$1-$420/hectare/year) using different methodologies (Godoy, et al., 1993). And a later study placed the range of Central American rainforest products between only USD$17.79 and $23.72/hectare (Godoy et al. 2000).

These income figures are meant to guide planners who may consider offering incentives for particular crops or forest activities. Sheil and Wunder (2002) call for a greater focus on the returns to labor from gathering. Yet little attempt has been made either to provide a common labor analysis or to generalize the recent economic studies.

Ecological Considerations

The economic benefits of NTFP extraction are viable over time only if collection of the species (or group of species) is ecologically sustainable. A maximum sustainable harvest limit implies that the rate at which these parts are taken from a plant, or individuals are culled from the population, will not exceed the natural rate of regeneration in a given time period. There was a long-standing, general assumption that because rural people had collected nuts, fruits, latex, fiber and the myriad other plant products for generations, the activity must not have a dramatically negative impact on the affected species or ecosystem (Voeks 1996). Certainly this was a defining rationale for the establishment of Brazil's much-publicized rubber extractive reserves (Salisbury and Schmink 2007). But human population growth and especially the increasing commercialization of these plants and plant products—regionally, nationally, and internationally—encourage strategies and intensities of harvest to meet distant markets that these species and ecosystems would seldom have witnessed in the past (Hamilton 2004). Deleterious outcomes are clearly the case for individuals that are regularly killed to retrieve the useful product, such as endangered South African cycads (Cousins et al. 2011), Mexican cacti (Jimenez-Sierra and Eguiarte 2010), Costa Rican palms (Sylvester and Avalos 2009), and many others.

Outside of directly culling individuals, there are a variety of subtle impacts at the individual, population, community and ecosystem level that detract from long-term ecological sustainability. Harvest objectives and techniques can negatively affect the physiology and vital rates of individuals, modify demographic and genetic patterns, and alter community/ecosystem-level processes (Ticktin 2004). For example, excessive tapping of latex or resin from trees can lead to their death, such as in the case of the Brazilian copaíba (*Copaifera* spp.), a traditional antioxidant and antiviral that is used throughout the country and exported to Europe (Plowden 2003). Leaf harvest can be sustainable if kept at low intensities, but increased harvest to meet foreign demands, for example in the case of *Chamaedorea radicalis*, may put individuals and the population at risk (Endress et al. 2006). And although the quantity of seed wastage under natural conditions is formidable, the excessive commercial harvest of fruits and seeds can negatively affect demographic patterns. Two such cases include Indian *Phyllanthus* spp., in which 86%-94% of total fruit yield per tree is harvested by locals (Sinha and Bawa 2002), and Brazil nuts (*Bertholletia excelsa*), in which up to 93% are collected (Zuidma and Boot 2002).

Methodology: An Inclusive Sustainability Framework

We focus on ecological and monetary aspects of sustainability in order to assess recent trends of specific NTFPs in different regions of the (largely) developing world. We offer a product approach by listing studies that have reported harvest rates of NTFPs (parts or whole organism) and/or income earned by household members across different time periods. Our review includes only English language, peer-reviewed journal studies published between the years 2000 and 2010, inclusive. Articles that were published online in 2010 but not in print until 2011 are included. We omit unpublished government and non-governmental agency reports. We started with a Google Scholar search of the terms "non-timber forest product(s)" and "sustainability" and then branched out into other specific ecological and financial terms, as well as reviews in discipline-specific search engines. For the economics analysis, we searched under the terms "non-timber forest products" and/or "non-wood forest products" and any of the following: "economics", "financial", "value", "revenue", "returns" and "profits." For the ecological analysis, we searched "non-timber forest products" and/or "non-wood forest products" combined with the terms "sustainable", "impact", and "harvest."

For this study, we limited the scope of non-timber forest products to include only wild-harvested plants and parts, bryophytes and fungi (hereafter included as plants for convenience) inhabiting (with few exceptions) less-developed countries, especially tropical and sub-tropical Latin America, Sub-Saharan Africa, and Asia. We did not include other harvestable forest biota, such as mammals, fish, birds, and insects (or honey), or the value of ecological services, such as carbon fixation (cf. Belcher 2003; Shackleton et al. 2011). We ignored processed products along the "next stage" of a value-chain from gathering, such as returns from handicrafts, artisanal products, processed medicinal tonics and the like. We included both single species and multiple-species analyses, although it became clear early on that this was a primary feature dividing economic and ecological NTFP research. The former most often focused on forest income from the full range of plant and fungi products, whereas the latter usually concentrated on a single taxon. And we included forest products that were both marketed and non-marketed, that is, used for household consumption or bartered. This is because household total income theoretically includes not only cash income but also the value of own-produced and subsistence goods (Cavendish, 2004). In most cases, proxy values were derived for the non-marketed uses.

Additional caveats were included for the ecological and economic analysis. In the ecological analysis we only included studies that provided quantitative assessment of harvest rates and/or impacts in terms of a maximum rate of harvest threshold. Descriptive or otherwise anecdotal evidence for what was perceived by the author(s) to be either sustainable or destructive harvest was omitted. We concluded that the NTFP harvest was or was not ecologically sustainable or suitable for a sustainable extraction management scheme (at the place and time of the study) following the author's determination, although this feature in some instances required a value judgment on our part.

The economic analysis included only studies that provided a monetary value (cash or use) of the products gathered at the household or individual level. Thus we excluded some important articles that relied upon forest use values per hectare (Gavin and Anderson 2007), input-output analysis of cash flow (Obiri et al., 2007), goods use and consumption quantities (Tabuti et al. 2003), and species ranking (Lykke 2000). The included studies relied primarily on household survey data. We focused on the specific value reported (gross or net returns) for a set number of people, time and currency. Removing the cost of labor would not allow us to see the residual to workers per se. If returns net of labor are positive, then labor has received its alternative wage and by definition the activity is attractive to gatherers. These points are contentious, however, as Godoy, et al. (2000) argue that both the cost of materials and the cost of a gatherer's time should be deducted for a focus on net returns. Shackleton et al. (2002) point out, however, that materials costs are negligible while taking out the time cost is unnecessary, and Cavendish (2004) suggests calculating household returns based on a gross level inclusive of family (free) labor costs.

Economic Sustainability: A Working Framework

Unlike many ecological studies, most peer-reviewed articles in the economics/financial areas do not specifically answer the question of whether the activity is sustainable. To address this, we developed our own thresholds for economic sustainability, and reviewed the published articles from this perspective. We considered economic sustainability along two paths: how the observed household cash incomes or use values in dollars compare to an international poverty line and/or an alternative wage rate. Gathering is often part of a diversified household strategy of labor use and income flows. Thus analyzing a study's reported figure on yearly NTFP income (against a national income benchmark) is not sensible because it is likely the household had other income sources during the year. And whereas a few studies do report the contribution of gathering income to total income (forest dependence), this does not mean that gathering time was spent in equal proportion. For example, while gathering may have represented 20% of yearly income, it might have required more or less than 20% of household time.

What likely matters most to a gatherer is that the returns from a day's work at extraction provide enough to purchase a survival basket or at least match a day's work elsewhere. If a gatherer continues to earn below that local wage for a paid labor opportunity, he/she would abandon non-timber forest products extraction should a wage job arise (Southgate et al. 1996; Ruiz-Perez 2004). Given the paucity of studies regarding NTFP poverty-reduction impacts or alternative work opportunities, we set up two possible *economic sustainability thresholds* regarding the returns from a gather's work for a day:

1) *International comparison*: It should be above an absolute poverty line. The daily returns Y for a single gatherer can be compared to the well-known international absolute poverty line of USD$ 2/ per day/ per capita (purchasing power parity (PPP), per international comparisons) (World Bank 2011).Thus for each study we consider if:

   Y_i per person daily NTFP income \$ PPP > \$2 PPP/day/per capita

2) *National comparison*: It should meet a "time opportunity cost" standard. That is, the daily return Y_j to the household should match a possible alternative wage earned in other paid labor opportunities, converted to dollars at a current rate. We assume that such a labor market payment would represent that earned by the whole household, since the studies did not offer data on the specific members gathering. Although numerous debates exist around whether a "minimum wage" is adequate to support a family, we consider the original intention of such a wage as a price floor to pay workers so that they are willing to sell their labor, in that they find it sufficient to live on.

Thus for each study we consider if:

Y_j household daily NTFP income \$ > \$ daily local (or minimum) wage

Further details of the conversions necessary to make the studies comparable are discussed in Appendix 1.

Because the actual precise time (person-days) harvesting is not reported in many of the studies, we were unable to report the precise average return per harvesting day per person. Instead, we chose to develop a threshold of the number of days (N) that would be reasonably rewarded given the reported income, converted to a \$ per scaled adult or household daily basis. We reframe the question as:

> *"What is the maximum amount of non-poverty days (or days above the going wage) that could be supported with the income reported in the study?"*

Thus for each study we consider if either sustainability threshold is achieved:

1) N_1 maximum days income provides at \$2/day/adult PPP per day > N days reported OR
2) N_2 maximum days income provides at \$ local wage/day > N days reported

A study income in which the \$ PPP returns per person exceeds USD\$730 clearly would have supported 365 days above absolute poverty. Thus, if gatherer income per scaled adult unit is found to be USD\$100 PPP per year, then any time working more than 50 days would have generated less than USD\$2 per day on average to have risen above an absolute poverty line. Or if gatherer income per household is found to be USD \$200 per year per household, and an alternative daily wage would be USD\$4, then having extracted for more than 50 days would have generated less than an alternative return.

Results: Ecological Review

A total of 101 studies on the ecological impacts of NTFP extraction met the necessary criteria for review (Appendix 2). Of these, the majority were carried out in Latin America (53/101, or 52.5%), followed by Sub-Saharan Africa (25/101, or 24.8%), and Asia (23/101, or 22.7%) (Table 1).

We followed Ticktin's (2004) similar 10-year NTFP ecological review by organizing impacts of NTFP extraction in terms of four levels of organization: individuals, populations and individuals, communities, and ecosystems (Table 1). The "Individual" category explored individual rates of growth, survival, and reproduction. Campbell (2003), for example, considered the possible effects of medicinal oleoresin extraction from Brazilian copaíba (*Copaifera* spp.) on individual tree longevity. The "Population and Individuals" category assessed impacts on individuals, with a view towards understanding the greater demographic implications. For instance, Larsen (2002) investigated the effects of extracting the medicinal herb (*Nardostachys grandiflora)* in alpine Nepal on the total root biomass of the population. The "Communities" category included studies on the effects of extraction on community structure and composition. Arjunan et al. (2005), for instance, investigated the impact of fuelwood and other extractive enterprise on overall forest diversity and tree height in India's southwestern Ghats. The "Ecosystem" category examines ecosystem-wide impacts of harvest, such as nutrient cycling changes or soil and habitat degradation. Thus Mutenje et al. (2011) reported that socio-economic and geographical attributes of Zimbabwean extractors were significantly associated with level of habitat degradation.

Table 1. Sustainability and regional assessment of studies that quantitatively assess the ecological impacts of harvesting NTFPs in less developed countries.

Level	Region	Sustainable	Unsustainable	Unknown	Unspecified	Total
Individuals		**3**	**1**	**1**	**2**	**7**
	Latin America	1	1	1	1	4
	Asia	1	0	0	1	2
	Africa	1	0	0	0	1
Populations and individuals		**39**	**8**	**9**	**2**	**58**
	Latin America	26	3	3	4	34
	Asia	4	1	2	0	7
	Africa	9	4	4	0	17
Communities		**15**	**9**	**0**	**1**	**25**
	Latin America	10	4	0	0	14
	Asia	2	5	0	0	7
	Africa	3	0	0	1	4
Ecosystems		**7**	**1**	**3**	**0**	**11**
	Latin America	1	0	0	0	1
	Asia	3	1	3	0	7
	Africa	3	0	0	0	3
	Total	**64**	**18**	**13**	**5**	**101**

The proportion of ecological studies between 2000 and 2010 that fell into these four categories was quite similar to that reported by Ticktin (2004). A majority of ecological studies in this review (63/101, or 62.4%) focused on the impacts of harvest on "populations and individuals", similar to the figure (60%) identified by Ticktin (2004) for the decade 1990-2000. This was followed in our review by the "community" category (23/101, or 22.8%), which differed considerably from Ticktin's (2004) figure (13%). Much less research (9/101, or 8.9%) was carried out at the "individual level" in our study compared to Ticktin's (2004) review (23%), and even fewer (6/101, or 5.9%) of studies in our review explored "ecosystem" impacts, similar to the figure (4.0%) reported by Ticktin (2004).

A majority of authors self-reported that the extractive enterprise was ecologically sustainable or likely sustainable, in spite of the fact that they often recorded negative impacts associated with NTFP extraction in their studies. A total of 63.3% (64/101) reported that extraction was sustainable or likely to be so, compared to only 17.8% (18/101) who reported unsustainable levels and/or intensity of harvest, or a 3.6:1 ratio of sustainable to unsustainable (Table 1). The remainder of researchers were either unsure, did not have sufficient data to make a reasoned judgment, or did not address the sustainability question directly. NTFP harvest was most often reported to be ecologically sustainable in Latin America (38/46, or 82.6%) and least likely in Asia (10/17, or 58.8%). Among the four levels of classification, each exhibited a very similar ratio of reportedly sustainable to unsustainable extraction—individuals (5:1), ecosystems (5:1), and individuals and populations (5.1:1). Only studies at the community level reported a disproportionately lower ratio of sustainable versus unsustainable harvest results (2.5:1).

The ecological results are also organized by life form and plant part harvested (Table 2). Palms represent the most numerous extractive life form (24/59, or 40.7%) among studies that focused on one species, followed by trees (19/59, or 32.2%) and herbs (9/59, or 15.2%). Of the studies focusing solely on a single life history, none included mushrooms and only one each for lianas and epiphytes, although more studies include these life histories in combination with others. These results are very similar to those identified by Ticktin (2004), who found that 40% of studies were of palms. In terms of plant part harvested, leaves, fronds, and foliage were the most common plant parts investigated (23/59, or 39%) followed by fruit, seeds and nuts (16/59, or 27.1%). Only three single-species studies explored the impacts of branch harvest, all in combination with the harvest of other parts. Only three studies examined flower and inflorescence harvest; each of these were single-species studies examining the extraction of multiple plant parts.

Numerous studies explored ecological impacts from the perspective of a single life form and two to several plant parts being harvested, such as fruit, leaf and bark harvested from a single tree species (Table 3). Trees were far and away the most versatile in this respect, as 71% (32/45) were exploited for more than one product. Outside of herbs (5/45, or 11.1%) and palms (4/45, or 8.8%), no other studies investigated the exploitation of more than one plant part. Although most studies concentrated on a single or few species or life histories, a minority of research (16/101, or 15.8%) explored the question of ecological sustainability at the household level, that is, including many or all of the principal plant species that are extracted for personal and/or commercial use and the associated plant parts collected (Table 4). Among these, trees, palms and shrubs are the most common constituents of these group collection efforts.

Table 2. Number of articles that quantitatively assess impact of NTFP harvest according to a single life form and plant part extracted*.

Life Form	Plant part extracted								**Total**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Tree	0	13	1	0	0	3	0	3	20
Shrub	0	0	2	0	0	0	0	0	2
Palm	0	3	16	5	0	0	NA	0	24
Herb	1	0	2	4	2	0	NA	0	9
Liana/Vine	0	0	0	0	1	0	0	0	1
Epiphyte	0	0	0	1	0	NA	NA	NA	1
Fern	NA	NA	2	0	0	NA	NA	NA	2
Bryophyte/Mushroom	NA	0	NA	0	NA	NA	NA	NA	0
Total	1	16	23	10	3	3	0	3	59

Legend: A: Flower, inflorescence; B: Fruit, seed, nut; C: Leaf, frond, foliage; D: Whole plant, stem, meristem; E: Root, tuber, bulb, corm; F: Bark; G:Branch; H: Resin, pulp, woody parts**; *Articles are counted in each of the multiple classes to which they apply (the total is not a sum of articles); NA: not applicable; **Woody refers to NTFPs derived from modified, decomposed, or pulpy woody parts, such as gaharu.

Table 3. Number of articles that quantitatively assess impact of NTFP harvest according to a single life form and multiple plant parts extracted*

	Plant part extracted									
Life Form	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Total**
Tree	1	5	7	1	2	7	3	0	6	32
Shrub	0	0	0	0	0	0	0	0	0	0
Palm	0	1	1	1	1	NA	0	0	0	4
Herb	1	1	1	2	0	NA	0	0	0	5
Liana/Vine	0	0	0	0	0	0	0	0	0	0
Epiphyte	0	0	0	0	0	NA	NA	NA	0	0
Fern	NA	NA	0	0	0	NA	NA	NA	0	0
Bryophyte/Mushroom	NA	0	NA	0	NA	NA	NA	NA	0	0
Generic or Unspecified***	0	0	0	0	0	0	0	0	4	4
Total	2	7	9	4	3	7	3	0	10	45

Legend: A: Flower, inflorescence; B: Fruit, seed, nut; C: Leaf, frond, foliage; D: Whole plant, stem, meristem; E: Root, tuber, bulb, corm; F: Bark; G: Branch; H: Resin, pulp, decomposed wood parts**; I: Generic or unspecified***; *Articles are counted in each of the multiple classes to which they apply (the total is not a sum of articles); **Woody refers to NTFPs derived from modified, decomposed, or pulpy wood parts, such as gaharu; ***Generic or unspecified class may be one or more forms or parts.

Table 4. Articles that quantitatively assess impact of NTFP harvest according to multiple life forms and multiple parts extracted classes*

Life form combination	**Parts extracted combination**
Tree, Palm	Fruit, seed, nut; Leaf, frond, foliage; & Resin, pulp, woody**
Tree, Shrub, Liana	Whole plant, stem, meristem; & Branch
Tree, Shrub, Herb, Bryophyte/Mushroom	Fruit, seed, nut; Leaf, frond, foliage; Whole plant, stem, meristem; & Root, tuber, bulb, corm
Tree, Shrub, Palm, Herb, Liana, Epiphyte	Fruit, seed, nut; Leaf, frond, foliage; Bark; & Resin, pulp, woody*

Legend: *One article in each of the life form combination groups; **Woody refers to NTFPs derived from modified, decomposed, or pulpy woody parts, such as gaharu.

Results: Economic Review

Our assessment of economic sustainability in non-timber forest product harvest yielded a total of 71 studies (Appendix 3).The largest number of studies were carried out in Asia (38/71, or 53.5%), followed by Latin America (19/71, or 26.7%), and Africa (14/71, or 19.7%) (Table 5).The methodologies employed by researchers varied considerably across the articles (Table 6).Studies reported household values across different time periods (day, month or year) and human units (household or individual). Most of the studies (47/72, or

69.1%) considered the household unit of analysis, with little input provided on how all household members put time into the extraction effort. And a large majority (62/72, or 86%) of the studies considered the extraction process across a whole year, rather than a discrete daily basis. Most studies either surveyed households at different seasons or relied upon recall at year-end.

Table 5. Regional assessment of studies that quantitatively assess the economic implications of harvesting non-timber forest products

Region	Number of studies
Latin America	19
Asia	38
Africa (Sub-Saharan and North)	14
Total	71

Across all the regions studied, 68.1% (48/72) provided data to suggest that household earnings per year from NTFP collection averaged USD$791 (at current rates) (Appendix 3). Alternatively, the returns per person (scaled) came out to USD$151 ($408 PPP) per year. These amounts are well-above the trends reported in earlier meta-analyses (Vedeld et al. 2007; Ruiz-Perez et al. 2004). Of the studies that focused on a daily analysis, the returns appeared to be USD$11.20/person/day on average; this level includes the omission of the extremely-high outlier returns to tila (*Ternstroemia lineata*) and blackberry (*Rubus* spp.) picking in Mexico (Marshall and Newton 2003).

Table 6. Focus of studies that quantitatively assess the economic implications of harvesting non-timber forest products

Level	Type of assessment	Number studies
Individual	Daily/weekly gross cash income	9
	Yearly gross or net cash income	15
Household (or family)	Daily gross cash income	0
	Yearly gross cash income	23
	Yearly net cash income	4
	Yearly total value (cash + use)	20

Employing the benchmarks outlined above, economic sustainability assessment was possible in just over half of the studies (47/71, or 66.2%) (Table 7). Of these, a large majority (36/47, or 76.6%) of extractive enterprises were determined by the criteria employed in this review to be economically sustainable. Among economic studies for which sustainability could be assessed, a greater percentage were sustainable at the individual level (15/18, or 83.3%) compared to the household level (21/29, or 72.4%). There were regional trends as well. For Africa, 71% of the studies could be assessed, with 70% suggesting that gathering household incomes associated with days remunerated were above an international poverty line or a going wage rate. Asian studies were less clear, with only 54% providing sufficient data. Of these, 80% of households appear to get returns adequate to justify continued participation, according to our thresholds. For Latin America, 89.5% of cases demonstrated similar extraction success, and 76% of households earned incomes associated with the days' returns above absolute poverty or above alternate wage rates. Some products were shown to be economically sustainable in one study, but not in another, such as wild asparagus (*Asparagus racemosus)* gathering in Nepal. Numerous other products, such as thatch grass in Malawi, betel leaf (*Piper betel*) in Bangladesh, bark and uppage fruit (*Garcinia gummi-gutta)* in India, and mushrooms in Mexico, to name a few, could not be assessed given study limitations.

Table 7. Results of studies that quantitatively assess the economic implications of harvesting non-timber forest products

Level	Sustainable	Unsustainable	Could not be assessed	Total
Individual	15	3	6	24
Household	21	8	18	47
Total	36	11	24	71

Discussion and Conclusions

Assessment of recent studies of non-timber forest products (2000-2010) in the tropical and subtropical world suggests that these extractive activities are overall ecologically and economically sustainable under current or practical conditions. This is the case in Latin America, Africa, and Asia. A considerable majority of studies report that current levels and intensities of harvest do not threaten the ability of individuals and populations to replace themselves, nor is the ecological integrity of the relevant ecosystems threatened. Researchers were less sanguine regarding the impacts of extractive activities on associated community members, such as removal of food sources for frugivorous birds and mammals. They also report complementary negative community effects, such as the local extinction of large mammals due to overhunting by palm heart extractors (Matos and Bovi 2002) or unsustainable agricultural practices and timber removal during non-gathering periods of Brazil nuts (Escobar and Aldana 2003). Most researchers acknowledge the challenges associated with assessing ecological sustainability in a fixed temporal setting while conditions and feedbacks, such as ecological dynamics and supply and demand, are ever-evolving. Such acknowledgement requires nuanced assessments weighing the potential ecological threats to and associated with NTFP extraction. In this vein, positive sustainable impact assessments most typically propose management strategies or practices that, if implemented, could maximize the benefits of NTFP extraction while providing or maximizing ecological conservation and associated benefits.

What researchers know about the relative sustainability of NTFP harvest for this review period is geographically contingent. Much more is known about the ecological consequences of extractivism in Latin America than in Asia or Africa. And within these regions, a few countries have received abundant research attention, such as Brazil, Bolivia, Benin, South Africa, India and Nepal. But because so many less developed countries are not represented by a single study, our conclusions regarding ecological sustainability of NTFP harvest must be taken with caution. Nevertheless, the fact that many of the features associated with NTFP extraction identified in this review were quite similar to those reported by Ticktin (2004) in her review of the 1990s literature suggests both that these studies represent a reasonably good barometer of current extractive patterns and that there is considerable continuity of harvest characteristics over time. Thus, most studies continue to be carried out on the ecological consequences of NTFP harvest on plant populations and individuals. Research at the community and ecosystem level continues to receive much less attention. Trees and palms are investigated far more frequently than other life forms, and they both supply multiple harvestable products. Nearly all research is directed at the extraction of seeds/fruit/nuts, leaves, and meristem (especially palm heart) harvest. The ecological effects of lianas, epiphytes and mushroom harvest are almost never investigated in the tropics and subtropics.

In regards to financial returns, our review suggests that NTFP collection represents an attractive option for keeping gatherers out of poverty. Earnings represent an economically justifiable use of gatherer time, except in the very poorest countries of East Asia. This could be due to the overall degree of poverty there (mean household annual incomes are usually less than USD$1000 per capita/year). In wealthier less-developed countries, such as several in Latin America, overall yearly mean incomes are higher, so it is more likely that NTFP gathering will elevate people above the international poverty line standard. These regional differences are important since going rural wage rates have long been higher in Latin America. Vedeld et al. (2004) found the highest overall NTFP incomes (across meta-analysis case studies) in Latin America (USD$5,676 PPP) with the lowest in East Africa (USD$1697 PPP). And Ruiz-Perez et al. (2004) report USD$10.25/day in Latin America against USD$5.62 per day in Africa.

These economic findings must, however, be kept in perspective. A few successful days of extraction may be an attractive, short-term option, but they are unlikely to remove families from long-term poverty, or to change national poverty rate statistics if families have limited resource access or limited tenure security. Some products require extensive areas from which to gather in order to acquire sufficient material, but few of the studies reviewed here provided details on the geographical range within which gatherers extracted or whether these spatial features had changed over time (but see Jensen and Melby 2010). The reality of limited and uncertain resource access is revealed by the fact that most households continue to rely upon other activities for most of their income. In the African studies, for example, the mean across all studies was 25.0% of the total household income derived from NTFPs, which was close to that in Asia (24.3%) and Latin America (24.8%). But the variation was considerable. NTFP values can account for only 2-7% of total income, even among “forest dependent” households such as those in Sri Lanka (Illukpitya and Yanagida 2010). Elsewhere this dependence is greater, such as gathering of Brazil nuts (51%) in Peru, wild asparagus (67%) in Nepal, and gaharu resin (71%) in Indonesia (Escobal and Aldana 2003; Maraseni et al. 2008; Wollenberg 2001). Finally, we know much more about the economic sustainability of NTFP harvest in Asia, which was the subject of more research during this review period, than Africa and Latin America combined.

If the 150 plus studies examined in this systematic review are representative, then researchers are guardedly optimistic in regards to the ecological and economic sustainability of NTFP extraction. However, our survey is not representative of every recent finding regarding sustainability, as we specifically included only articles with household financial values and omitted many trends observed in book chapters and technical reports. And caution must be exercised in terms of extending these results into future decades. Changing economic conditions, rates and sources of deforestation, and climate change all point to increased pressures upon forests. In Tibet's "Medicine Mountains", overharvest of medicinal species combined with temperature increases (5-6^{o} C by the end of the century) threatens the ethnobotanical foundation of Tibetan culture and religion (Salick et al. 2009). And in the Brazilian Amazon, rubber tappers once famously fought to forestall deforestation for cattle expansion. Today, as income from rubber fails to fill financial needs, tappers have diversified into cattle ranching, representing a newfound source of Amazonia's "cattle-ization" problem (Gomes et al. 2012).

Our analysis also points out persistent methodological problems in studies of the returns of non-timber forest products. First, many economic analyses bundle products together and fail to delineate specific outcomes by single products and species. The absence in so many economic reports of scientific names limits the scope of analysis as well as the opportunity for interdisciplinary comparison. And as stated earlier, sustainability must be measured (at the least) in ecological and economic terms, yet there is very little chance to consider both of these factors in a single extractive enterprise. With very few exceptions, economists assess financial dimensions of NTFP collection, and biologists assess ecological issues, with limited overlap. Collaboration between these researchers during the study design process seems the obvious solution.

Second, many analyses fail to account for household labor time by period or by person across a full year. A broad aggregation is presented in most published research. Only a few investigators consider the number of collecting trips per year (to compare to the value of the gathered product per year). These research practices prevent a thorough analysis of daily returns which is crucial for clear comparison of alternative uses of rural residents' labor. Additionally, studies fail to specify the number of household members working in gathering compared to the members consuming from the income streams generated. Future survey instruments should include time use patterns and collection rates and returns across all seasons.

Third, the question of ecological sustainability is clearly fundamental to long-term success of extractivist activities. Each of the ecological studies cited here discusses this feature either in their introduction or conclusion, and most employ field methods and quantitative analyses to explore the question. Yet a surprising number of studies fail to make explicit statements regarding the relative sustainability of the harvest activity. In the interests of the myriad stakeholders involved, we encourage authors to articulate, to the degree possible, whether harvest of the NTFP under current conditions is sustainable, and to make recommendations that would foster future sustainability.

Finally, we note that most studies in the ecological analysis report physical extraction rates over a short study period, usually two years or less. Ultimately a longer term analysis is needed, particularly since extraction quantities and prices can affect household incomes. The Homma model of extractive production suggests a rapid expansion, followed by stabilization and then decline in the ratio of production/extraction

(Homma, 1996). If extraction and cultivation eventually occur at the same time, prices will fall. While standard economic theory suggests that higher prices create a greater quantity supplied, what often matters to poor people is meeting a subsistence income threshold. In other words, falling prices could also create pressure for over-extraction as gatherers seek to get a minimum cash flow. Crook and Clapp (1998) suggest low returns would cause overexploitation of a target species, and others (Belcher and Schreckenberg 2007) suggest commercialization and specialization brought by high prices would do so in “boom and bust” fashion. Future research is needed on the dynamic interaction between economic and ecological sustainability across studies or within a single study.

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Appendix 1: Creation of Economic Sustainability Thresholds

We use the following steps to assess economic sustainability:

a) take the study-reported (usually household and/or yearly) reported values from NTFP gathering (both cash income and use), usually presented in local currency;
b) convert those values to a $ figure using a current exchange rate and a PPP conversion factor;
c) use information regarding household size to convert to the "adjusted scale size" of household members;
d) define an appropriate alternative wage to gathering;
e) calculate the total, scale-adjusted, per-person PPP$ value from NTFPs at a period-level (usually yearly); calculation of the number of "non-poverty days" this value would cover, if each day requires $2 PPP/day;
f) calculate the total household current $ value from NTFPs at a period-level; calculation of the number of "attractive days" this value would cover, if each day requires meeting the alternative local wage;
g) compare the reported days (if available) to the criteria in e) and f).

Each included study reports some form of value from extraction at the household (or individual) yearly (or daily, monthly) level. Our goal is to compare all studies on a daily basis of $ PPP per person (scaled) and on a daily basis of returns ($ current rate) against a local wage. If the study authors report the values from gathering across sub-samples of a population (i.e. for each of 3 villages), we reported the sample-weighted mean of returns in Table 2. Steps are still needed to convert dollars, on a per-person basis, and against a threshold.

Currency conversion issues (step 2) have been dealt with in many of the included studies. Over 50% report an accepted current exchange rate accepted at the time and place of the study. However, for consistency, we choose to work with a common source PPP-adjusted exchange rates. The World Bank's World Development Indicators database allows us to find what was the current level GDP in local and $ values for that year, as well as a PPP-adjusted GDP total for a PPP-adjustment factor to convert local currency to a level consistent with consumption standards. [Most developing countries in the sample required a 1.2-4 PPP adjustment on GDP.]

For (c) we should convert the total reported income to values in adult equivalents, which offers a more realistic measure of household consumption instead of per capita levels (Cavendish, 2004). However, while most studies report total household size they offer few details on demographic composition of the sample. So we work with Deaton's economies of scale measure (reported in Cavendish, 2004) to better compare consumption needs across households. [That is, a household of 10 people really has the consumption needs of 7.3 adults while those of 5 people require about 4.5.][1]

Few studies give "time opportunity cost" data regarding the local wage rates for paid labor around the study site during the study year for step (d). So we also rely upon data from the ILO's Laborstat database (ILO, 2011). Here 42 developing countries provide

[1] In studies in which absolutely no information was available on household size we extrapolate using the regional mean derived from the other studies.

information on wage income by sector, usually on a monthly basis for all men and women in a labor survey. Over half of these countries provided the income for both workers in the manufacturing and the agricultural sectors. We are most interested in finding a daily agricultural wage rate for the NTFP study countries in the early part of the decade, around 2000. For this we convert all monthly individual wage incomes to a daily $ wage rate and run an OLS regression to impute the probable agricultural wage rate for those countries with no data.[2]

[2] We find the current $1 US exchange rate using the OANDA converter. We use this same converter for the conversion of the study findings and a within-country comparison. We convert the threshold survey monthly income to a daily rate by assuming 4.33 work weeks at 5 days each. Agricultural incomes are usually less than manufacturing incomes, with an OLS estimation as:

$$W_{agric} = \underset{(0.93)}{1.46} + \underset{(0.04)}{0.486}\, W_{manufacture} \qquad \text{R-squared} = 0.94 \quad F_{(1,21)} = 166.86$$

Generally this provides levels of a "going daily wage" in the agricultural sector between $2.04 per person (Honduras) to $12.86 (Jamaica). Overall, however, these imputed daily agricultural wage rates appeared the lowest in the Asian developing countries compared to the Latin American region. This follows the general pattern of the earlier studies in Ruiz Perez, et al. (2004) in which the local labor rate varied from $5.62 per day in Africa to $10.25 per day in Latin America across the 1990s.

Appendix 2: Recent trends in the assessment of sustainability of non-timber forest products assessed by studies focusing on 1-2 species

Identifier		Ecological Concerns		# of studies							
				Level of focus				Sustainability assessment			
Species, Genera, or Life Form	Region/Country	Environment	Part harvested	Individual	Population & Individual	Community	Ecosystem	Sustainable[1]	Unsustainable[2]	Unknown[3]	Unspecified
Adansonia digitata L.	AFR (Mali, Burkina Faso)	S	Fruit, seed, nut Leaves, fronds, foliage Bark		2			2			
Aechmea magdalenae André ex Baker	LA (Mexico)	TE	Leaves, fronds, foliage		2					2	
Agave marmorata Roezl	LA (Mexico)	TSE, H	Flower, inflorescence Leaves, fronds, foliage Whole plant, heart, stem, meristem		1			1			
Aloe peglerae Schönland	AFR (South Africa)	S	Fruit, seed, nut Whole plant, heart, stem, meristem		1				1		
Aquilaria malaccensis Lam.	AS (Indonesia)	TE	Resin, pulp, woody portion**		1			1			
Astrocaryum tucuma Mart.	LA (Brazil)	TE	Fruit, seed, nut		1			1			
Bertholletia excels Bonpl.	LA (Bolivia, Brazil, Peru)	TE	Fruit, seed, nut Whole plant, heart, stem, meristem		4	2		5	1		
Calamus zollingeri Becc.	AS (Indonesia)	TE	Leaves, fronds, foliage		1		1	1		1	
Carapa procera DC.	LA (Fr. Guiana & Suriname)	TE	Fruit, seed, nut			1		1			
Carapa surinamensis Miq.	LA (French Guiana)	TE	Generic or unspecified Whole plant, heart, stem, meristem			1		1			
Chamaedorea elegans Mart.	LA (Mexico, lab in USA)	TE	Leaves, fronds, foliage	1	1			1			1
Chamaedorea radicalis Mart.	LA (Mexioo)	TE, ME	Leaves, fronds, foliage	1	2	1		3		1	
Copaifera spp.	LA (Brazil)	TE	Resin, pulp, woody portion**	1					1		
Copaifera multijuga Hayne	LA (Brazil)	TE	Resin, pulp, woody portion**			1		1			
Cyperus scariosus R. Br.	AS (India)	TSE	Whole plant, heart, stem, meristem	1				1			
Desmoncus orthacanthos Mart.	LA (Belize, Mexico)	TE	Leaves, fronds, foliage		2			2			
Dioon merolae De Luca, Sabato & Vázq.Torres	LA (Mexico)	TSE, TD*	Leaves, fronds, foliage		1			1			
Dioscorea spp.	AFR (Madagascar)	TSE, TD*	Root ,tuber, bulb, corm		1			1			
Eremospatha macrocarpa H. Wendl	AFR (Côte d'Ivoire)	TE	Leaves, fronds, foliage		1			1			
Euterpe edulis Mart.	LA (Brazil)	TE	Whole plant, heart, stem, meristem		1	2		2	1		
Euterpe oleracea Mart.	LA (Brazil)	TE	Fruit, seed, nut			2		2			

			Whole plant, heart, stem, meristem								
Euterpe precatoria Mart.	AS (Bolivia)	TE	Whole plant, heart, stem, meristem		1				1		
Garcinia gummi-gutta (L). Roxb.	AS (India)	TE	Fruit, seed, nut	1				1			
Garcinia lucida Vesque	AFR (Cameroon)	TE	Fruit, seed, nut Bark Branch		2			2			
Geonoma deversa (Poit.) Kunth	LA (Bolivia)	TE	Leaves, fronds, foliage		1			1			
Geonoma edulis H. Wendl. Ex Spruce	LA (Costa Rica)	ME	Whole plant, heart, stem, meristem		1				1		
Geonoma macrostachys Mart.	LA (Ecuador)	TE	Leaves, fronds, foliage		1			1			
Geonoma orbignyana Mart.	LA (Colombia)	TE	Leaves, fronds, foliage		1			1			
Heteropsis flexuosa (Kunth) G.S. Bunting	LA (Brazil)	TE	Root ,tuber, bulb, corm		1			1			
Iriartea deltoidea Ruiz & Pav.	LA (Ecuador)	TE	Leaves, fronds, foliage		1			1			
Ischnosiphon polyphyllus (Poepp.& Endl.) Körn	LA (Brazil)	TE	Whole plant, heart, stem, meristem		1				1		
Ischyrolepis eleocharis (Nees ex Mast.) H.P.Linde	AFR (South Africa)	CD	Whole plant, heart, stem, meristem		1			1			
Khaya senegalensis (Desv.) A.Juss.	AFR (Benin)	S	Leaves, fronds, foliage Bark Branch		3	1		2		2	
Laccosperma secundiflorum (P.Beauv.) Kuntze	AFR (Côte d'Ivoire)	TE	Leaves, fronds, foliage Leaves, fronds, foliage		1		1	2			
Lychnophora ericoides Mart.	LA (Brazil)	S	Leaves, fronds, foliage				1	1			
Mauritia flexuosa L.f.	LA (Brazil, Ecuador)	TE	Fruit, seed, nut Leaves, fronds, foliage		2			2			
Microlepia strigosa (Thunb.) C. Presl	AS (U.S.A.-Hawaii)	TE	Leaves, fronds, foliage		1			1			
Nardostachys grandiflora DC.	AS (Nepal)	AM	Root ,tuber, bulb, corm Leaves, fronds, foliage Whole plant, heart, stem, meristem		1					1	
Otatea spp.	LA (Mexico)	TE	Whole plant, heart, stem, meristem		1			1			
Pentadesma butyracea Sabine	AFR (Benin)	TE	Fruit, seed, nut		1					1	
Phyllanthus emblica L.	AS (India)	TD, H	Fruit, seed, nut			1			1		
Phyllanthus indofischeri Bennet	AS (India)	TD, H	Fruit, seed, nut			1			1		
Prunus Africana (Hook f.) Kalkman	AFR (Cameroon)	ME	Bark		1			1			
Rumohra adiantiformis (G. Forst.) Ching	LA (Brazil)	TE	Leaves, fronds, foliage		1					1	
Sclerocaryabirrea subsp. *caffra* (Sond.) Kokwaro	AFR (South Africa)	TD	Fruit, seed, nut		1			1			
Sphenomeris chinensis (L.) Maxon	AS (U.S.A.-Hawaii)	TE	Leaves, fronds, foliage		1			1			
Syngonanthus nitens (Bong.) Ruhland	LA (Brazil)	S	Flower, inflorescence Leaves, fronds, foliage		1			1			

			Whole plant, heart, stem, meristem								
Ternstroemia lineate DC.	LA (Mexico)	ME	Flower, inflorescence Fruit, seed, nut		1			1			
Thrinax radiate Lodd. ex Schult. & Schult.f.	LA (Mexico)	TSE, TD*	Leaves, fronds, foliage Root ,tuber, bulb, corm	1				1			
Epiphyte	LA (Mexico)	TSE, TD*	Whole plant, heart, stem, meristem			1		1			
Palm	LA (Brazil, Ecuador, Peru)	TE	Leaves, fronds, foliage Generic		2	1		1	1		1
Tree	AFR (Benin, Kenya, Nigeria, South Africa, Tanzania, Uganda, Zimbabwe) AS (India, Nepal)	TE, TSE, TD, ME, H	Fruit, seed, nut Leaves, fronds, foliage Root ,tuber, bulb, corm Bark Resin, pulp, woody portion** Branch Whole plant, heart, stem, meristem Generic	2	4	3	3	5	3	2	2
Palm and Fern	AS (U.S.A.-Hawaii)	TE	Leaves, fronds, foliage			1		1			
Shrub and Herb	AS (Nepal)	AM	Generic		1			1			
Tree and Herb	AS (India)	TE	Generic				1			1	
Tree and Palm	LA (Panama)	TE	Fruit, seed, nut Leaves, fronds, foliage Resin, pulp, woody portion**		1			1			
Tree, Shrub, and Liana	AS (India)	TSE, TD*	Branch Whole plant, heart, stem, meristem			1			1		
Tree, Shrub, and Herb	AS (India)	TE	Whole plant, heart, stem, meristem				1		1		
Tree, Palm, Herb, and Bryophyte	AS (India)	TD	Generic				1	1			
Tree, Shrub, Liana, and Herb	AS (Sri Lanka)	TE, TSE, H, S	Generic				1			1	
Tree, Shrub, Herb, and Bryophyte	AS (Nepal)	TSE	Fruit, seed, nut Leaves, fronds, foliage Root ,tuber, bulb, corm Whole plant, heart, stem, meristem			1			1		
Tree, Shrub, Herb, Liana, and Bryophyte	AS (India)	ME	Generic			1		1			
Tree, Shrub, Palm, Liana, Fern, and Herb	AFR (Uganda)	TE, ME	Generic			1		1			
Tree, Shrub, Palm, Herb, Liana, and Epiphyte	LA (Panama)	TE	Fruit, seed, nut Leaves, fronds, foliage Bark Resin, pulp, woody portion**		1						1
Generic, unspecified						2	2	3	1		

Legend: Sustainability assessment - [1]Sustainable or suitable for sustainable extraction or management; [2]Unsustainable or predicts unsustainable at high level; [3]Unknown or both sustainable and unsustainable, depending on future actions. Regions - LA: Latin America; AS: Asia; AFR: Africa; (country of ecological studies). Environments of ecological studies – TE: tropical evergreen; TSE: tropical semi-evergreen; TD: tropical deciduous; ME: montane evergreen; H: healthland, shrubland, cactus or Joshua tree forest; S: savanna, cerrado; CD: coastal dune; AM: alpine meadow. *Those stated as tropical dry forests are cross-classified as "TSE, TD"; **Woody refers to NTFPs derived from modified, decomposed, or pulpy woody parts such as gaharu.
Note: Bryophyte category also includes mosses and lichens and other non-vascular plants, and mushrooms

Sources: Ackermann 2004; Amusa et al. 2010; Anderson and Putz 2002; Anten et al. 2003; Arjunan et al. 2005, Avocèvou-Ayisso et al. 2009; Baldauf and Dos Reis 2010; Bhat et al. 2003; Calvo-Irabién et al. 2009; Chhetri and Gupta 2006; Dalle and Potvin 2004; Datta et al. 2010; Andrade and Hay 2007; Delvaux et al. 2009, 2010; Dhillon and Gustad 2004; Reis et al. 2000; Emanuel et al. 2005; Endress 2004; Endress et al. 2004, 2004, 2006; Escalante et al. 2004; Escobal 2003; Fantini and Guries 2007; Forget and Jansen 2007; Gaoue and Ticktin 2007, 2008, 2009, 2010; Guariguata et al. 2009; Guedje et al. 2003, 2007; Holm et al. 2008; Jiménez-Valdés et al. 2010; Jones and Gorchov 2000; Karanth et al. 2006; Kouassi et al. 2008; Laresen 2002; Lázaro-Zermeño et al. 2010; Lermyte and Forget 2009; Marshall and Newton 2003; Martínez-Ramos et al. 2009; Matos and Bovi 2002; Medeiros and Vieira 2008; Menton 2003; Mishra et al. 2010; Misra and Dash 2000; Moegenburg and Levey 2002; Mukwada 2009; Mutenje et al. 2010; Meyers et al. 2000; Nakazono et al. 2004; Ndangalasi et al. 2007; Olupot et al. 2009; Omeja et al. 2004; Pandit and Thapa 2003; Paoli et al. 2001; Pedersen and Skov 2001; Peres et al. 2003; Pfab and Scholes 2004; Plowden 2003; Plowden et al. 2003; Portela et al. 2010; Rai and Uhl 2004; Rani et al. 2009; Robinson and Lokina 2010; Rodríguez-Buriticá et al. 2005; Runk et al. 2004; Russell-Smith et al. 2006; Sampaio et al. 2008; Schmidt et al. 2007; Schroth et al. 2004; Schumann et al. 2010; Shaanker et al. 2004, 2004; Shackleton et al. 2005, 2009; Siebert 2000, 2001, 2004; Sinha and Bawa 2002; Stave and Stenseth 2001; Stewart 2009; Straede et al. 2002; Svenning and Macía 2002; Sylvester and Avalos 2009; Thapa and Chapman 2010; Ticktin 2004, 2005; Ticktin and Nantel 2004; Ticktin et al. 2006, 2007; Trivedi et al. 2004; Vazquez-Lopez et al. 2004; Vormisto 2002; Wadt et al. 2008; Weinstein and Moegenburg 2004; Wolf and Flamenco-S 2006; Zimmerman et al. 2001; Zuidema and Boot 2000, 2002; Zuidema et al. 2007

Appendix 3: Recent trends in the economic assessment of non-timber forest product sustainability.

Identifier		Economic Concerns					
Main Species, Genus, or Life Form (if in a bundle)	Country	Part harvested*	Measurement	Value given bundle (local currency or $)	Days for> $2 PPP	for> local wage	Given Days
Acacia rehmanniana Schinz	South Africa	3	HH gross direct use value/yr.	4559 Rand user households	<139		
Agathis philippinensis Warb.	Philippines	5	Daily income in collecting season 4days/mo.	170 PhP $3.12 per day	any		January-March season, about 15 days
Aquilaria malaccensis Lam.	Borneo	5	revenue and Net income/hh/yr.; also per person day	1014000 rps. gross; 26,000 returns/person/day	<465	81	29 days gathering/HH
Aquilaria malaccensis Lam.	Indonesia	5	Annual gross financial return/gatherer/day	$8.80	<10		up to 140 days/yr. as 14-day trip 10 times
Aquilaria crassna Pierre ex Lecomte	Laos	5	Average net revenue/day	73,735 kip $7; varies $4-$13/day by locality			average 92.25 collection days, 8.77 trips
Asparagus racemosus Willd.	Nepal	8	Income/hh/yr.	8820 NRs	<45	50	
Attalea phalerata Mart. ex Spreng.	Bolivia	2	Mean value HH consumption; mean cash earnings	$199-$337; $28-$108	<109		sampled days to extrapolate year
Bambusa tulda Roxb.	Thailand	8	Time value/hh/yr. of consumption products	$30.86; $302. substitute value	<89	66	14.63 days/ yr./HH
Bertholletia excelsa Bonpl.	Peru	2	Income/hh/yr.	$3778-$3918	<853		3 months time, so 65 days
Boletus pinophilus Pilát & Dermek	Mexico	8	Value of cash income/ household/day for 3 months/yr.	62.5 MX pesos	<11		
Calamus spp.	Philippines	5	Daily income in collecting season 4days/mo.	170 PhP $3.12 per day	any		January-March season, about 15 days
Centella asiatica (L.) Urb.	Bangladesh	7	Consumption value/hh/month	I TK 594	<30		

Chamaedorea spp.	Mexico	3	Net income (cash & use-purchased inputs) per capita/yr.	820 pesos	<63		
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	Nepal	4	Revenue/hh/yr	3148 NRs	<15	35	
Dalichini [common name]	Nepal	3	Revenue/hh/yr	17767 NRs	<94	104	
Dipterocarpus alatus Roxb. Ex G.Don	Cambodia	5	gross income/collector/year	$58.5 all plant-based NTFPs	<88	20.3	
Euterpe oleracea Mart.	Brazil	2	est. gross income/hh/yr	$70-$8100	< 740	520	most in summer season June-Dec. for 152 days
Euterpe precatoria Mart.	Bolivia	2	Gross income/person/yr.	3634 Bolivians Brazil nut; 3948 all products	<900		few months gathering (3 men, 1 women); so 65 days men
Euterpe precatoria Mart.	Peru	2	Income/hh/yr. as 14 months	$1224/hh; about $552/participant	<457		6 months total, so 130 days
Garcinia gummi-gutta (L.) Roxb.	India	2	Annual per household cash income	10792 Rps.	<91	115	up to 66 days season
Gevuina avellana Molina	Chile	7	Gross financial returns/collector/3-5 hrs. in yr.	Romerillo $5.6, Avellana $8.1	<11	Any	
Gnetum africanum Welw.	Nigeria	2	Individual mean annual income	19,977 NGN	<131		seasonal 3-5 months; 108 days
Lacosperma sp.	Cameroon	6, 8	Net income per AEU	10,500 CFA	102 days	OC labor already included	
Lomatia ferruginea R. Br.	Chile	7	Gross financial returns/collector/3-5 hrs. in yr.	Romerillo $5.6, Avellana $8.1	<11	Any	
Mauritia flexuosa L. f.	Peru	2, 3	Revenue (use+sale)/hh/year Total income (use, sale)/hh/yr.;mean daily income	$1658, $376 no game $1374/hh total	<879 <4.5		

			extraction Income/hh/yr. as 14 months	 $1224/hh; about $552/participant	 <457		 6 months total, so 130 days
Ophiocordyceps sinensis (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora	China	8	Household sales income per year	2200 CNY mushrooms; 350 CNY medicinal plants	<83	78	44 days in season
Phyllanthus emblica L.	India	2	gross income sales + consumption/hh/yr	3583 Rps./HH	<26	38.5	
Pinus halepensis Mill.	Israel (Negev)	8	Daily income collecting season	$23-$64/day	<27	Month here less	harvest 3 weeks, so 15 days
Pinus oocarpa Schiede	Honduras	5	Daily income in collecting season 4days/mo.	90 lps. ($5)	any		year-round, less in July-February; so 173 days
Piper betel Blanco	Bangladesh	3	HH yearly income sales/yr. (8 HH in village)	33652 TK betel leaf, 2358 TK Betel nut	<127		
Tamarindus indica L.	Benin	2	6 months per capita income use value (woman)	5021 XOH	<10		dry season 6 months; 132 days
Tricholoma matsutake Sing.	China	8	Household sales income per year Revenue/hh/year	2200 CNY mushrooms; 350 CNY medicinal plants 19583-22166 Y; $2448-$2760	<83 <69	78 757	44 days in season 40 days
Bryophyte	China	8	Revenue/hh/ year income/per capita/yr	350 CNY medicinals 1569 Yuan	<10 <208	12.5	 40 days
Herb	India Philippines Vietnam	8 8 2, 7	Projected yearly income per capita HH consumption/use value/year Cash income/ per capita/yr.	134-4955 Rps. $4-$147 37,648 pesos 52,000 VND	<133 <223 <6.5	Sep-36	

Liana	Bangladesh	3	Gross income/hh/month	TK 4,900 $74.20	<278		
Palm	Peru	2, 3, 8	Projected gross weekly income/harvester	$12.50	<2.5		
			Earnings per HH/yr.	$119/hh/yr.	< 41		more than 2 months, 43 days
Tree fruits, resins	Brazil	2	HH income/ yr.	828 R 1996, 735 R 2000	<69	105	
	China	4	Net income/hh/yr	306.54	<70	89	
	Ethiopia	5, 7	cash income/hh/yr.	$80	<23		
				283 ETB $30.63	<9		
			Forest income per HH/yr. in PPP	$650; of which fuelwood $360	<68		
	Honduras	6, 7	Mean value HH consumption; mean cash earnings	$249-$320; $19.70-$402	<149	241	sampled days to extrapolate year
			Yearly HH income (extrapolated from Jan-April)	2401 lps.	<38	89	
	India	3, 7	HH yearly cash income raw materials	tendu leaf 53640 Rps.	< 638	614	
			HH yearly total value (use+sales)	3678-5965 Rp.; mean 4680 Rps. $90-146	<32	55	
Tendu leaves, bryophyte			HH yearly cash income	478-2765 Rps. $11.7-$68;	<9	19	78 days
			Gross sales+use income/per AEU/hh	543 Rs all resources	<20	5.6	
	Indonesia	5	Net annual household income (costs hired labor, fertiliser out)	2,904,000, of which 2,694,000 resin	<81	113	4.35 harvest weeks 1995; 2.98 harvest weeks 2004; so 15-22 days
	South	7	HH gross direct use value/yr.	13550 Rand users	<381		

	Africa						
	Zimbabwe	7	Fuelwood, woodland products value/hh/yr substitute value	$45-$74 net; $180-$296 gross	< 22	53	seasonal 3 months, 65 days
Resin							
Palm, Herb	Bolivia	3	Consumption value/HH/yr.	$268 plants		80	
Tree, Bryophyte Rubber	China	5, 8	Revenue/hh/year	$150-$649; of which rubber $408; NTFP $46.50	<118	119 rubber; 13.5 NTFP	12 hrs./person/wk. March; 6.3 hrs./person/wk April-June; about 16.5 days
Tree, Herb Resin	India	2, 3, 5, 6	Income/day/collector	$3.15/day all households; $21.26 damar	<4.5		work 1528 hrs/yr. gathering, about 191 days
			Annual per capita income (commercial and subsistence values)	1001 Rps. $28	<43	13.5	
			HH revenue/yr.	1233-2445 Rs. Dry vs. evergreen species	<6	28	
	Malawi	3	Total value (income+use)/hh/year	8256 MK	<26		
	South Africa	2, 7	HH gross direct use value/yr.	3941 Rand users total;; sherbs 111 R users	<131	336	90-100 days
			HH gross direct use value/year	$707 users	<138	707	
			HH gross direct use value/yr.	3959 Rand; $559	<745		
	Sri Lanka	2	HH value/yr. for cash sales, OC time, substitutes	2363 Rps. NTFP $22	<6.5	8	
	Vietnam	2	Consumption value/hh/year	58,000,000 VND $3,867	<1530		
Tree, Herb, Bryophyte	Sri Lanka	2	HH gross direct/income value/yr. cash sales, OC time, subs	2402 Rps. NTFPs; 4252.5 Rps. Fuelwood	<8.5	9	
	Vietnam	3, 7,	Total cash and environmental	660,125 VND	<40		

		8	subsistence income/hh/yr. Income/hh/year	 7,715,000 VND	 <196		
Tree, Palm	Peru	2, 3, 8	net Value (use, sale) gathering/hh/yr. after materials	$668	<127		18-69 days
Tree, Palm, Herb	Malaysia	2, 8	Median monthly income (cash and use)/hh Value of extraction/hh/year (indirect opportunity cost method)	65-72 RM (less without animals) $1,049/hh/year PPPUS $2,455	<44 <277	 101	 60 days/yr as 20% of 300 days/yr. work
Tree, Shrub Blackberry Tila	Mexico	2	Value of cash income/person/year @ 2-8 days/yr.	N$702 P blackberry, N$357 Tila		8	

Legend: *Parts Harvested summarized by Identifier and Country – 1: Flower, inflorescence; 2: Fruit, seed, nut; 3: Leaves, fronds, foliage; 4: Root, tuber, bulb, corms; 5: Resin, pulp, woody portion**; 6: Bark; 7: Branch; 8: Whole plant, heart, stem, meristem. **Woody refers to NTFPs derived from modified, decomposed, or pulpy woody parts such as Gaharu. (p) part of same study.
Note: Bryophyte category also includes mushrooms, lichens, and all other forms

Sources: Ambrose-Oji 2003; Arora 2008; Arun 2004; Bista and Webb 2006; Campbell et al. 1997; Chaudry et al. 2008; Chaudry et al, 2008; Coomes et al.2004; Delang 2006; Dovie et al. 2002; Escobar and Aldana 2003; Ezebilo and Mattson 2010; Fandohan et al. 2010; Fu et al.2009; Fu et al.2009b; Godoy et al.2002; Gram 2001; Gram et al.2001; Gubbi and MacMillan 2008; He et al. 2009; Hedge and Enters 2000; Howell et al. 2010; Huber et al. 2010; Illukpitiya and Yanagida 2008; Illukpitiya and Yanagida 2010; Jensen and Melby 2010; Kamanga et al., 2008; Kim et al. 2008; Kronborg et al. 2008; Kusters et al. 2008; Kvist et al., 2001; Lemenih 2003; Lopez-Feldman et al. 2007; Mahapatra et al.2005; Mamo et al. 2007; Maraseni et al. 2008; Marshall and Newton 2003; Mcelwee 2008; McSweeney 2002; Montoya et al. 2008; Murthy et al. 2005; Nahuelhaul et al. 2008; Narain et al. 2007; Narendran et al. 2001; Ngueyn 2006; Nygren et al. 2006; Pabuayon 2004; Paoli et al. 2001; Pyhala et al. 2006; Quang and Anh 2006; Quang and Norik 2008; Rahman et al.,2009; Rai and Uhl 2004; Reyes-Garcia et al. 2006; Riadh 2007; Rueff et al.2008; Shackleton et al. 2002a; Shackleton et al. 2002b; Shackleton et al. 2007b; Shone and Caviglia-Harris 2006; Shylajan and Mythili 2003; Stoian 2005; Svarrer and Olsen 2005; Twine et al. 2003; Weinstein and Moegenburg 2004; Weinstein and Moegenburg 2004; Wollenberg 2001; Yang et al. 2009.