CHAPTER 2

Nontimber Forest Products and Production

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2.1 Nontimber Forest Products and their Production

Many products are harvested from U.S. forests that are not derived from timber. These nontimber forest products (NTFPs) are called by many names; regardless of the term, they are products made from plant materials and fungi that are found in the forest soils and throughout the aboveground vegetation, from the duff to the topmost tree canopy. The products are collected for many reasons, including personal enjoyment, cultural and spiritual importance, and commercial gain.

This chapter explores fundamental aspects of the products and their production, in natural and in managed forests. The first section (2.1) explores the terminology, the scale of harvesting, and the product markets. Nontimber forest products contribute to markets that expand the definition of forest products beyond traditional timber industry. Silvicultural practices for timber production are well developed and as discussed in section 2.2 are applicable and appropriate for nontimber products, as well. Forest farming (section 2.3), an agroforestry practice, is viewed as an approach to generate additional income and to conserve natural populations of NTFP species. A brief assessment of the markets and economics is provided in section 2.4, and the reader is directed to chapter 6 for a more comprehensive assessment of the economics. NTFPs occur throughout contiguous United States, Alaska, Hawai'i (section 2.5), and the Caribbean and insular areas of the United States (section 2.6). In the United States there are well-developed systems to inventory trees in forests, yet as discussed in section 2.7 the inventory and analysis of nontimber forest resources is lacking. Methods and strategies for tracking and monitoring NTFPs are explored in section 2.8. Gaps in knowledge are identified in section 2.9, while possible impacts of climate variability are explored in section 2.10. Key findings (section 2.11) and key information needs (section 2.12) are highlighted. A brief set of conclusions (section 2.13) summarizes the chapter.

2.1.1 What Are Nontimber Forest Products?

Nontimber forest products are referred to by many names, including nontraditional, special, specialty, minor, as well as secondary products. We use the definition that NTFPs originate from plants and fungi that are harvested from forests. The products come from forest herbs, fungi, lichens, mosses, shrubs, vines, as well as trees.

The U.S. Department of Agriculture, Forest Service (2001) refers to these products as special forest products (SFPs) and defines them as:

"products collected from National Forest System land that include, but are not limited to, bark, berries, boughs, bryophytes, bulbs, burls, Christmas trees, cones, epiphytes, fence material, ferns, firewood, forbs, fungi (including mushrooms), grasses, mine props, mosses, nuts, pine straw, posts and poles, roots, sedge, seeds, shingles and shake bolts, transplants, tree sap, rails, and wildflowers. Special forest products do not include animals, animal parts, cull logs, derrick poles, house logs, insects, minerals, non-saw log material removed in log form, pulpwood, rocks, sawtimber, small roundwood, soil, telephone poles, water and worms."

Although the preceding definition is specific to national forests, it can be applied to all nontimber forest products. In 2000, the U.S. Congress directed the Secretary of Agriculture to implement a program to collect fees for the harvest and sale of "forest botanical products" (DOI appropriations 2000, 2004, 2008, 2010, 2014; see chapter 7, section 7.2.3). The U.S. Department of the Interior, Bureau of Land Management (BLM) uses the term special forest products and describes the products as "vegetative material found on public lands that can be harvested for recreation, personal use, or as a source of income" (BLM 2014).

For this assessment, NTFPs, SFPs, and FBPs (forest botanical products) are synonymous. Appendix 4 identifies forest plant and fungi species that are presented in the chapters of this national NTFP assessment. The list is neither exhaustive nor comprehensive but illustrative of the diversity of species, organs, uses, and geographic distribution. More than one-half of the 350 plus plant and fungi species identified are found in tropical areas, yet NTFPs from temperate forests are diverse and plentiful as well. Across all forest ecosystem landscapes, a vast number of plants and fungi are being harvested for their nontimber values. The great variety of products amplifies the complexities of social and cultural dimensions that affect economic and ecological dynamics. To fully comprehend these requires an initial understanding of the products and their production.

2.1.2 Plant and Fungi Organs Used

Many different parts (organs) of plants and fungi are harvested for nontimber products that are valued for monetary gain or personal enjoyment. These include the roots, tubers, leaves, bark, twigs and branches, fruit, and sap, as well as small-diameter wood for firewood and arts and crafts. The fruiting body of mushrooms and other fungi are used for food and medicine. In some cases, such as ramps (*Allium tricoccum* Aiton) the entire plant is removed and consumed. Likewise the entire plant of goldenseal (*Hydrastis canadensis* L.) is harvested and separated into aboveground (leaves and stems) and belowground (roots and rhizomes) parts, which are used differently for medicinal purposes.

The roots and/or rhizomes of many plants are harvested to make medicinal products. Roots of American ginseng (*Panax quinquefolius* L.) have been harvested commercially for more than 250 years from eastern hardwood forests for their value as an herbal medicine. Of the 22 medicinal plant species that the American Herbal Products Association (AHPA) tracks, 10 are harvested exclusively for the roots and rhizomes (AHPA 2012). Another four medicinal plant species are harvested for their roots/rhizomes, as well as their aboveground parts.

The fruiting bodies of many different mushrooms and fungi are harvested for personal consumption and for generating income. Dozens of species are enjoyed as edible forest products. More than 20 species are harvested from forests of the Pacific Northwest (Pilz and Molina 2002). In the late 1990s and early 2000s research was undertaken on various aspects of these nontimber products, including viability, economics, sustainability, and management. Schlosser and Blatner (1995) estimated that in 1992 approximately 65 percent of mushroom harvesters in the Pacific Northwest collected for supplemental income, while the remaining portion used the sale of these products for their primary source of income. Pilz and Molina (2002) discussed management and monitoring issues that affect sustainability of mushrooms. Alexander et al. (2002) examined economic nuances of managing for mushrooms and timber. Further, the ecology and management of chanterelle mushrooms were examined as the harvest of this NTFP was reportedly a multimillion-dollar industry (Pilz et al. 2003). The productivity of morel mushrooms in northeast Oregon relative to healthy, burned, and insect-damaged forests has been examined, as well (Pilz et al. 2004). Although these studies provided important insights about various aspects of the products, there has been little reoccurring studies or long-term monitoring or assessments undertaken. Much of the knowledge about the products is based on dated studies, research done in the late 1990s or early 2000s.

2.1.3 Scale of Harvest

The scale of harvest often reflects harvesters' motives. An often-used classification for harvesting is personal versus commercial. People collect NTFPs for their own use, whether for spiritual benefit, consumption of luxury goods, subsistence, or recreational purposes (Emery and Pierce 2005). Luxury goods are nonessential items and harvest typically fluctuates with income. Subsistence, like most noncommercial uses of NTFPs, includes resource use to meet material and cultural objectives separate from commerce (Emery and Pierce 2005). NTFPs are collected on family forest lands, for personal use, and categorized as edible or decorative (Butler 2008, Butler et al. 2014). Cordell and Tarrant (2002) estimated that nearly one-quarter of the U.S. population may gather NTFPs for personal use. Estimating the sheer number of people who collect NTFPs is impractical with any degree of certainty and unnecessary as anyone who harvests NTFPs for any reason may be considered a harvester. Determining the number and volume of products collected for personal uses is challenging, as well. The number of products is limited only by the collectors' personal needs, and the amounts of products harvested are rarely recorded. The 138 products from 80 forest species used by people in Michigan's Upper Peninsula, identified by Emery (1998), illustrate the diversity of plants and their uses. In general, the volumes harvested for personal use are less than those harvested for commercial gain.

The best available data, albeit with challenges to quality and quantity, are from permits for harvesting on Federal lands and industry association surveys. Data from these sources may not fully represent the total harvest, but they provide the best assessment of harvest volumes. The scale of commercial harvesting is influenced by market demand, product value, and availability of the desired NTFP. The Forest Service (national forests) and BLM record volumes and values of permitted harvests that provides some of the best data on NTFPs from public lands. Table 2.1 summarizes the volumes of

Table 2.1—2013 permitted harvest volumes of NTFPs from Forest Service and Bureau of Land Management land by product category, unit of measure, and region. Sources: Cut and sold reports of national forests (USDA Forest Service 2015a) and Bureau of Land Management records.

Product category	Unit	Alaska	North	Rocky	South	West	All United States
Arts, crafts, and floral	Bunches	0	0	100	0	0	100
	Bushel	0	40	590	100	71,093	71,823
	Cords	0	0	5	0	93	98
	Cubic feet	0	0	295	348	22	665
	Number	0	0	1,000	0	0	1,000
	Pounds	150	5,630	116,743	201,506	5,321,503	5,645,532
	Ton	0	651	293	65	6,716	7,725
Christmas trees	Each/number	0	2,678	133,577	249	76,240	212,744
	Linear feet	0	0	1,566	0	175	1,741
Edible fruits, nuts, berries, and sap	Gallon	0	0	890	0	302,858	303,748
	Pounds	200	400	226,868	30	443,228	670,726
	Taps	0	18,430	0	0	0	18,430
Grass and forage	Pounds	0	104	10	0	4,120,869	4,120,983
	Ton	0	295	3	8	830	1,136
Fuelwood	CCF	244	21,431	351,664	18,397	219,759	611,496
Medicinal	Pounds	0	856	12,148	14,936	14,710	42,650
Nonconvertible	Acre	0	0	0	28	0	28
	Bushel	0	0	6	100	0	106
	Cubic feet	0	0	500	750	450	1,700
	Each/piece	0	3,604	250	2,469	6,129	12,452
	Pounds	3,000	0	0	4,320	56,776	64,096
	Ton	0	0	43	0	1	44
Nursery and landscape	Each/number	600	204	9,827	24,942	10,926	46,499
	Ton	0	0	1	0	0	1
Posts and poles	CCF	0	7,538	11,399	97	16,369	35,403
	Linear feet	0	0	0	0	2,140	2,140
	Number	0	100	22,253	0	6,547	28,900
Regeneration and silviculture	Bushel	0	10	2,193	0	3,513	5,706
	Pounds	0	0	316,744	0	17,037	333,781

Note: units were maintained for all categories except for fuelwood and for posts and poles; these two categories were converted to CCF (100 cubic feet) wherever possible.

permitted harvest from national forest and BLM lands in 2013. AHPA is a leader in tracking medicinal plants used by the herbal industry (AHPA 2012) and regularly reports on estimated harvest volumes of 22 medicinal forest products used by its members (table 2.2).

2.1.4 Market Segments

In general, there are five broad market segments (table 2.3) of commercially traded NTFPs: (1) culinary products, (2) medicinal and dietary supplements, (3) decorative products, (4) nursery stock and landscaping, and (5) fine arts and crafts (Chamberlain et al. 1998, Molina et al. 1997). There is no known regular monitoring or tracking of these market segments. The few studies that have been done regarding market aspects provide invaluable though limited insights. Like all markets, NTFP market segments are dynamic. Additional categories may evolve as knowledge about the markets and industry develops. As well, the volumes and values of product harvests change with supply and demand. NTFP markets are commonly described as volatile, informal, secretive, and amorphous, so a clear description of them may remain elusive. The following synopses of each segment provide insight into the breadth and depth of these markets.

Culinary products—Forest products used for edible purposes include the fruit, sap, leaves, tubers, and bulbs. The fruiting bodies of edible fungi, particularly mushrooms, are perhaps the most well-known and documented edible forest product. The geographic distribution of edible forest products is dependent on ecological conditions of suitable habitats. For example, much of the commercial mushroom harvest is centered in the Pacific Northwest. Schlosser and Blatner (1995) identified more than 25 species of fungi commercially harvested in Idaho, Oregon, and Washington. They estimated that in 1992 approximately 3.9 million pounds (lbs) of mushrooms were harvested for commercial markets. From 2009 through 2013, the Forest Service and BLM issued permits for the harvest of more than 2 million lbs of edible fruits, nuts, berries, and

Table 2.2—Average annual harvest of plant species wild-harvested for herbal or medicinal purposes by plant part used. Source: AHPA (2012).

Latin name	Common name	Plant part	Average annual harvest 2001–2005	Average annual harvest 2006–2010	Percent change
Actaea racemosa	Black cohosh	Root	224,072	284,162	26.8
Aletris farinosa	White colicroot	Root	1,012	690	-31.9
Aristolochia serpentaria	Virginia snakeroot	Root	121	43	-64.2
Arnica spp.	Arnica	Whole plant	63	715	1,044.0
Caulophyllum thalictroides	Blue cohosh	Root	6,651	5,169	-22.3
Chamaelirium luteum	Fairywand	Root	4,688	4,541	-3.1
Cypripedium spp.	Lady's slipper	Whole plant	51	48	-4.3
Dioscorea villosa	Wild yam	Tuber	33,422	37,692	12.8
Echinacea angustifolia	Blacksamson echinacea	Root and herb	35,446	36,394	2.7
Echinacea pallida	Pale purple coneflower	Root and herb	12,916	812	-93.7
Echinacea purpurea	Eastern purple coneflower	Root and herb	22,411	3,994	-82.2
Echinacea spp.	Purple coneflower	Root and herb	70,772	41,200	-41.8
Frangula purshiana	Cascara buckthorn	Bark	166,034	366,272	120.6
Hydrastis canadensis	Goldenseal	Root and leaf	73,619	74,708	1.5
Ligusticum porteri	Porter's licorice-root	Root	828	2,095	153.1
Lomatium dissectum	Fernleaf biscuitroot	Root	584	809	38.4
Sanguinaria canadensis	Bloodroot	Root	24,823	5,056	-79.6
Serenoa repens	Saw palmetto	Fruit	3,293,377	2,432,841	-26.1
Trillium erectum	Red trillium	Whole plant	1,099	1,445	31.5
Ulmus rubra	Slippery elm	Bark	182,435	304,207	66.7
Usnea spp.	Beard lichen	Whole plant	1,165	1,300	11.6

Table 2.3—Major nontimber forest product market segments with examples of prominent species, the regions where they are most prominent, and the plant organ used. Some species may have multiple uses for multiple markets. For a more extensive the list, see appendix 4.

Market segment	Species	Common name	Region	Organ
Culinary	*Acer saccharum*	Sugar maple	Northeast, Southeast	Sap
	Allium tricoccum	Ramps, leeks	Northeast, Southeast	Whole plant
	Boletus spp.	Bolete mushroom	Northwest	Fruiting body
	Pinus edulis, P. monophylla	Pinyon pine	Southwest	Seeds
Medicinal and dietary supplement	*Arnica cordifolia*	Arnica	Northwest	Whole plant
	Oplopanax horridus	Devil's club	Alaska	Roots
	Panax quinquefolius	American ginseng	Northeast, Southeast, Midwest	Roots
	Serenoa repens	Saw palmetto	Southeast	Fruit
Decorative	*Abies balsamea*	Balsam fir	Midwest, Northeast, Southeast	Boughs
	Galax urceolata	Galax	Southeast	Leaves
	Gaultheria shallon	Salal	Northwest	Leaves
	Xerophyllum tenax	Beargrass	Northwest	Leaves
Nursery stock and landscaping	*Abies fraseri*	Fraser fir	Southeast	tree
	Arctostaphylos columbiana	Hairy manzanita	Northwest	Shrub
	Cypripedium spp.	Lady's slipper	Southeast	Orchid
	Echinacea purpurea	Purple coneflower	Great Plains	Herb
Fine arts and crafts	*Betula papyrifera*	Paper birch	Midwest, Northeast	Bark
	Callitropsis nootkatensis	Yellow cedar	Alaska	Wood
	Hierochloe odorata	Alpine sweet grass	Northeast	Stem

mushrooms (Alexander et al. 2011; Chamberlain et. al. 2018). In 1998, approximately 25 million lbs of black walnut (*Juglans nigra* L.) nuts were harvested from natural populations (Chamberlain et al. 1998). In 2007, the United States exported pine nuts harvested from southwestern forests worth more than $20,000 (Alexander et al. 2011). "Maine was the leading producer of lowbush, or 'wild' blueberries, harvesting 91.1 million pounds in 2012" (NASS 2013). Maple syrup is primarily produced in Northeastern United States, from Ohio to Maine, with production extending south into Virginia. Vermont is the main producer, followed by Maine and New York. The harvesting of wild onions (ramps or leeks) from eastern hardwood forests has increased over the last 25 years, from personal and community uses (festivals) to large-scale harvesting for corporate and global markets.

Medicinal and dietary supplements—The use and trade of herbal medicines derived from forest plants has a long history and may constitute the highest economically valued segment of the NTFP industry. The roots of American ginseng have been commercially harvested from eastern hardwood forests for over 250 years (Taylor 2006). Farnsworth and Morris (1976) estimated that more than 25 percent of all prescriptions dispensed in the United States contained active ingredients extracted from higher ordered vascular plants. Foster and Duke (1990) cataloged more than 500 medicinal plants in the United States. AHPA (2012) tracks 21 medicinal plant species that are in commerce (table 2.2). The average annual usage (2006–2010) ranged from 43 dry lbs of Virginia snakeroot (*Aristolochia serpentaria* L.) to 2.4 million lbs of saw palmetto (*Serenoa repens* (W. Bartram) Small) berries. The average annual harvest for about half of the products increased from 2001 to 2005, compared to 2006 to 2010. Some products, such as arnica (*Arnica cordifolia* Hook.), saw tremendous growth (i.e., more than 1,000 percent), while others such as echinacea (*Echinacea pallida* Nutt.) declined drastically. Market segments of the NTFPs industry discussed in the following sections have similar dynamics.

In 1995, the U.S. Pharmacopoeia listed more than 25 tree species, 65 herbaceous plants, and 29 shrubs for their medicinal properties (Foster 1995). In the early 1990s extract from the bark of the Pacific yew (*Taxus brevifolia* Nutt.) was found effective in treating ovarian cancer, which resulted in substantial harvesting of the tree from public forest lands in the Pacific Northwest. Saw palmetto, which is used to treat benign prostatic hyperplasia, is sourced primarily from pine forests of Florida (Mitchell 2014).

Decorative products—Many forest plants and their parts are used in decorative arrangements, to complement and furnish the backdrop for flowers, as well as for the main component of fresh and dried arrangements or ornaments. The end uses for many forest-harvested decoratives include fresh/dried flowers, greenery, basket filler, wreaths, swags, and roping. In the Pacific Northwest, forest plants harvested for their decorative values include salal (*Gaultheria shallon* Pursh), evergreen huckleberry (*Vaccinium ovatum* Pursh), Oregon-grape (*Mahonia nervosa* Pursh), and beargrass (*Xerophyllum tenax* (Pursh) Nutt.) (Vance et al. 2001). Spanish moss (*Tillandsia usneoides* (L.) L.) is collected from forests of Florida, Georgia, and Mississippi and exported for use as packaging material for flower bulbs, which may be imported, later, from Europe. In southern Appalachia, grape vine (*Vitis* spp. L.) and Dutchman's pipe (*Aristolochia tomentosa* Sims) are harvested for making wreaths. Western North Carolina is the major source of galax (*Galax urceolata* (Poir) Brummitt) leaves (figure 2.1) for the international floral industry (Predny and Chamberlain 2005).

There are markets for seasonal cuttings of some woody understory shrubs, as well. In New England, collectors of mountain laurel (*Kalmia latifolia* L.) may sign harvest contracts with landowners, while some private landowners collect and sell winterberry holly (*Ilex verticillata* (L.) A. Gray) from their lands (Monthey 2011). Some species, such as pitcherplants (*Sarracenia* spp.) in the Southeast, have strong markets and are vulnerable to over-harvesting, which has led to concern for their conservation (Robbins 1998). Conifer boughs may be the most widely sold decorative forest product in the United States (Chamberlain 2000). In the Pacific Northwest, the harvest and sales of boughs was estimated to employ more than 10,000 seasonal and permanent positions (Schlosser et al. 1991). In 1995, the United States exported more than $14 million in forest-harvested mosses and lichens, most of which originated from Appalachia and the Pacific Northwest (Goldberg 1996).

Nursery stock and landscaping—Live forest plants are collected for the nursery and landscaping industry. These may be marketed as bareroot stock or balled live plants for direct planting. In North Carolina, Fraser fir (*Abies fraseri* (Pursh) Poir.) seedlings are pulled from natural populations to be transplanted to nurseries for Christmas tree production. Rhododendron (*Rhododendron* spp. L.), azaleas (*Rhododendron* spp. L.), and mountain laurel, as well as cacti from Southwestern United States are dug from forests and sold for landscaping. In 2013, the largest volume of forest plants harvested as transplants, for nurseries and landscaping, came from the national forests of North Carolina (USDA Forest Service 2015b).

Collection of forest understory wildflowers for horticultural sales is a cottage industry in the southern Appalachian region and, to a limited extent, throughout New England. Bareroot lady's slipper orchids (*Cypripedium* spp. L.), trillium (*Trillium* spp. L.), and other wildflowers are available through Internet sales and box stores (Botanical Wonders 2015, Cullina 2000, Mainely Crafts 2015). Five states

Figure 2.1—Galax (*Galax urceolata*) leaves are harvested from western North Carolina and shipped worldwide for use in the floral industry. (Photo credit: Gary Kauffman, U.S. Department of Agriculture, Forest Service.)

(California, Colorado, Idaho, Nevada, and Utah) reported more than 99 percent of the national harvest of nuts, seed, and seed cones for forest regeneration plantings (USDA Forest Service 2015a). Government programs that promote the use and salvage of native plants are found at local and Federal levels (U.S. Environmental Protection Agency 2015; Water and Lands Resource Division of King County 2015).

Fine arts and crafts—Artisans that use NTFPs to craft items find the ingredients for their creations in forest plants and fungi. The number of NTFPs used to make fine art and crafts is limited only by the crafters imagination. Wood collected from forests may be used for carvings, turnings, walking sticks, utensils, and containers. Mosses, lichens, and seeds may be formed into jewelry. Vines are crafted into wreaths, sculptures, and statues. Baskets are crafted from the bark of paper birch (*Betula papyrifera* Marshall) that is stripped from trees in northern Minnesota, splints of wood from oak (*Quercus* sp.) and ash (*Fraxinus* spp.) trees, and stems of sweetgrass (*Muhlenbergia filipes* M.A. Curtis, or *M. capillaris*)[1] harvested from wetlands of South Carolina (Hurley et al. 2008, Moser et al. 2015).

NTFPs used for arts and crafts contribute to a multimillion-dollar handicraft industry. Determining the proportional value of NTFPs to this industry is problematic because differentiating the contribution of crafts' ingredients is not possible. The outlets for these fine arts are varied as well. Some artisans prefer local and regional craft fairs, while others may market their products through specialty retail stores or Internet-based outlets.

2.1.5 Iconic Nontimber Forest Products

The total number of NTFPs remains an enigma; by some reports there are hundreds, perhaps thousands of products (Chamberlain et al. 1998, Emery 1998) and listing all of them is not possible. Appendix 4 provides a list of NTFP species discussed in this report. We present in this section brief summaries of iconic NTFPs—products that are familiar to all and may be so important to the culture of the people who use them that the loss of the product due to climate change or other stressors (e.g., over-harvesting, lack of management) would have significant negative impacts on the people and places associated with them.

American ginseng—The extent of this plant's range is in eastern United States, though it occurs in southern Quebec and Ontario. A medicinal forest product, American ginseng grows throughout mixed hardwood forests from Maine to Minnesota, south to Alabama, Arkansas, Georgia, Louisiana, and Oklahoma (Goldstein 1975, Nantel et al. 1996, Stockberger 1928). These forests are some of the most biologically diverse temperate forests in the world. American ginseng shares them with many forest herbs that are harvested for their commercial value. More than 60 percent of the 20 or so medicinal plants tracked by AHPA (2012) grow in the same forest habitat.

Harvesting of American ginseng has impacted the ecology of the forests as well as the economic livelihood of the harvesters. The plant's roots have been commercially harvested for more than 250 years (Chamberlain et al. 2013b). From the mid-18th century to the turn of 20th century, the United States exported an estimated 20 million lbs of American ginseng root. Table 6.3 (Chapter 6: Economics) summarizes harvest volumes by state for the period 2000 to 2007. Chamberlain et al. (2013b) estimate that, between 2000 and 2007, harvesters received on average about $27 million each year (table 6.3). They also demonstrate that ginseng harvests are greater in forests with more growing stock volume. Chandler and McGraw (2015) argue that harvesting of eastern forests for timber has impacted the survival, growth, and reproduction of American ginseng. Removal of underaged or undersized plants reduces population growth below replacement levels (Van der Voort and McGraw 2006). Analysis of herbaria specimen suggests that the plant was more abundant (Case et al. 2007), and patterns of genetic variation show greater diversity in populations that have been protected from harvest (Cruse-Sanders and Hamrick 2004). By the first decade of the 20th century, concerns had been voiced about the declining supply of this medicinal forest product (Taylor 2006).

In 1975, American ginseng was listed in appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES, n.d.), an agreement to which the United States is party. The U.S. Fish and Wildlife Service (FWS) is

[1] Note: The common name "sweetgrass" refers to *Muhlenbergia filipes*, not to be confused with *Hierochloe odorata* (alpine sweetgrass).

the implementing agency for the United States and is charged with determining if the export of ginseng root would be detrimental to the survival of the species and certifying that states that want to export ginseng have an acceptable management and monitoring program. The FWS has approved 19 states to export wild roots: Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Minnesota, Missouri, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin. There are nearly 40 years of harvest data by state and county for ginseng because of its listing in CITES. More is known about the harvest of American ginseng than any other medicinal forest product.

Every year, large quantities of American ginseng root are harvested across its native range, yet the majority is limited to a few states within the core of the range. From 2000 to 2007 more than 500,000 pounds of American ginseng root were harvested from natural forests (figure 2.2; see also table 6.3). Seven states accounted for approximately 70 percent of the total American ginseng harvest for the period. Kentucky's harvest was more than 25 percent of the total, followed by Tennessee (14 percent), North Carolina (12 percent), West Virginia (9 percent), and Indiana (8 percent). The average annual harvest across all States during these years was 63,200 lbs (Chamberlain et al. 2013b), though there has been a general decline in harvest volumes.

Harvesting of wild American ginseng and hardwood timber has been occurring in the same forests throughout this country's history. There is a positive correlation between ginseng harvest and hardwood growing-stock volume, and hardwood growing-stock volume on public lands (Chamberlain et al. 2013b). More ginseng harvest occurs in hardwood forests with greater growing-stock volume and, as the proportion of public forest land base increases, there is an associated increase in reported ginseng harvest. However, to reiterate, harvesting of eastern forests for timber has impacted the survival, growth, and reproduction of American ginseng (Chandler and McGraw 2015). These findings imply that forest management (see section 2.2) of this NTFP and timber is possible and warranted.

Beargrass—This decorative forest product grows in the Western United States and Canada. In its U.S. range there are two distinct distributions (Hummel et al. 2012)—one in west-central California, north through Oregon to the Cascade Mountains in northwest Washington, and the other ranging from western Wyoming through Idaho and Montana, along the Rocky Mountains. The species is an early- to late-successional pioneer that grows in a variety of forest types. It is found in the understory of dry, mixed-coniferous forests to subalpine meadows. The greatest densities of beargrass are in forests with sparse canopies (figure 2.3).

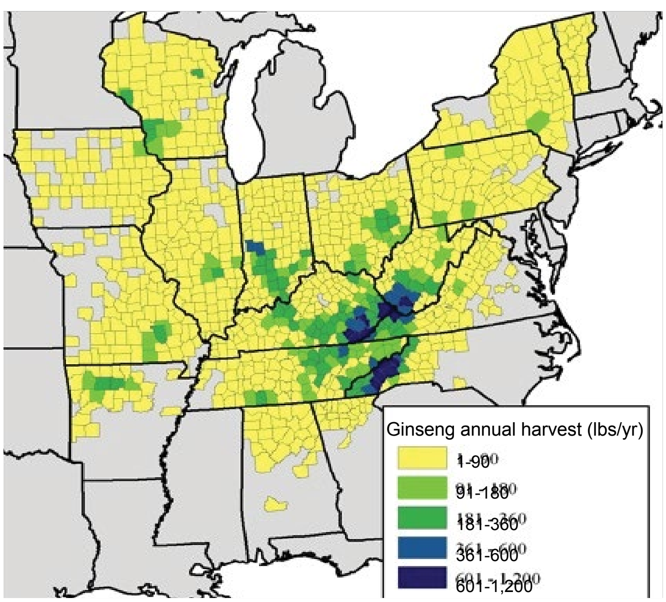

Figure 2.2—Average annual reported American ginseng harvest by county across 19 states certified by the U.S. Fish and Wildlife Service for the years 2000-2007. (Source: Chamberlain et al. 2013.)

Figure 2.3—Many nontimber forest species, such as this patch of beargrass (*Xerophyllum tenax*), live below the trees. Integrating these understory species into forest management increases the complexity, yet critical to forest health. (Photo credit: Frank K. Lake, U.S. Department of Agriculture, Forest Service.)

Beargrass is harvested for making traditional baskets and for the commercial floral industry (Hummel et al. 2012). The plant did not enter the floral greens industry in commercial volumes until the late 1980s, although American Indians have been harvesting beargrass for spiritual and cultural purposes for generations (Lynch and McLain 2003, Weigand 2002). Beargrass was reportedly the most harvested NTFP for the floral industry in the Pacific Northwest (, Schlosser and Blatner 1997, Schlosser et al. 1992). They estimated the commercial value of beargrass to be over $1 million in 1997. Draffan (2006) estimated 10 years later the value of beargrass and salal (another wild-harvested Pacific Northwest floral green) at $54 million. These analyses illustrate the tremendous value of NTFPs and inconsistencies between studies that need reconciliation for a better understanding of the overall market values.

Different groups have preferences for harvest timing and locations as well as plant characteristics. American Indians have traditional ecological knowledge that influences decision making of preferred harvest sites and practices (Hummel and Lake 2015). American Indians harvest after the snow has melted, primarily during the spring and summer. Sites that have experienced low-intensity and frequent fire incidents are preferred by American Indians (Charnley and Hummel 2011, Hummel et al. 2012, Shebitz et al. 2009). Accordingly, American Indian harvesters prefer long, strong, and pliable leaves for basket making. For ceremonial purposes, they want plants with flowers, along with the preferred leaf structure.

Commercial harvesters have different preferences for harvest sites and practices. They bring personal experience that may have been handed down through generations of harvesting NTFPs from their native lands, or that personal experience is new and lacking a full appreciation and understanding of plant. Generally, they look for large populations with plants that have the desired leaf qualities. Commercial harvesters use various techniques to remove leaves, which may result in overharvesting and threaten plant populations (Charnley and Hummel 2011). The preferred leaf characteristics for commercial markets are deep green color, with long, wide, and firm leaves from the center of the plant. These are best found in conifer forests with 60 to 90 percent canopy cover, at higher elevations (Charnley and Hummel 2011, Hummel et al. 2012) According to Schlosser and Blatner (1997), beargrass leaf quality is maximized during the later stages of mid-successional forest development.

Managing beargrass for tribal weaving requires blending traditional and scientific ecological knowledge to craft and implement adaptive management strategies (Hummel and Lake 2015). This will be accomplished by embracing the social and cultural dynamics and working with the community of interested people who want to benefit from the harvest of beargrass. The scale of harvest volumes (commercial versus noncommercial) affects management decisions and potential silvicultural treatments (Hummel and Lake 2015, Hummel et al. 2012). Management strategies for beargrass need to be adapted to different market demands, cultures and ethnicities, as well as climate variations.

Fiddlehead ferns—An edible forest product, fiddleheads, are the tightly coiled, vegetative fronds of the ostrich fern (*Matteuccia struthiopteris* (L.) Todaro). Ostrich ferns have a wide distribution in the United States, from Maine, south to Virginia, west to Nebraska, and north to Minnesota and in warmer areas of Alaska. Ostrich ferns are adapted to USDA plant hardiness zones 3 to 7 (USDA 2012). Their preferred growth habitat is along stream and river floodplains in sandy loam soils under the high canopy of maple, ash, and other hardwoods.

Fiddleheads are culturally important as a harbinger of spring and as a healthy, welcome addition to local diets. Fiddleheads also are an important part of rural economies and sold in neighborhood markets, roadside stands, and large grocery store chains (Fuller 2012). Accurate figures are lacking for total yields but are estimated to be about 100,000 lbs, annually.

Fiddleheads are harvested in the spring as they emerge from the plant's crown with a short piece of the stem. Harvesting is done primarily from wild, unmanaged populations, though some forest farming of this product is known to occur. Proper identification of the fern, sustainable harvesting practices, and proper preparation of ostrich fern is important. For example, misidentifying brackenferns (*Pteridium aquilinum* (L.) Kuhn), which may be carcinogenic, for ostrich fern and improper cooking of ostrich fern has been related to cases of foodborne-related illness (Bolton and Fuller 2013).

Maple syrup—Maple syrup (figure 2.4) is one of the most prominent edible NTFPs in eastern United States (Farrell and Chabot 2012). It is produced primarily from

Figure 2.4—Maple syrup from Vermont, the major producer of this delicacy, and other New England states is an iconic nontimber forest product from trees. In 2013, the United States produced approximately 3.25 million gallons, and annually the sale of syrup adds over $100 million to the Nation's economy. (Photo credit: Cornell University, Uihlein Maple Research Forest.)

the sap of sugar maple (*Acer saccharum* Marshall), but black maple (*A. nigrum* Michx. f.) and red maple (*A. rubrum* L.) also can be tapped. In the United States, sugar maple grows in several eastern States, although commercial production of maple syrup occurs primarily in the Northeastern States. Trees must be at least 10 inches in diameter before they can be tapped without damage to the tree and should occur in fairly dense forest stands to make sap collection economically efficient.

Maple syrup is produced in late winter and early spring when weather conditions fluctuate above and below freezing, stimulating sap movement within the trees. The annual value of U.S. maple syrup production is well over $100 million, distributed across 10 states (Farrell and Chabot 2012). Vermont leads production whereas New York, Michigan, and Pennsylvania have the greatest potential to increase production. Overall, there is tremendous potential to increase maple syrup production as less than 1 percent of more than 2 billion tappable-size maple trees are utilized (Farrell and Chabot 2012).

Pine nuts—In the United States, pine nut production is from primarily natural stands of pinyon trees on public forest lands in western United States, which are not managed specifically for nut production. Pine nuts are harvested from singleleaf pinyon pine (*Pinus monophylla* Torr. & Frém.), found primarily in the Great Basin, and two-needle pinyon pine (*P. edulis* Engelm) on the Colorado Plateau. Both species produce large, highly prized nutritious nuts.

Pine nuts were a staple food of many American Indian tribes in western United States. Today, they are collected and sold in local markets. In 2007, the United States exported pine nuts valued at about $20,000, and imported about $54 million worth of pine nuts (Alexander et al. 2011). This indicates that the United States pine nut market has potential for development with concomitant management considerations.

In the United States, pinyon pine grows with a number of juniper species (*Juniperus* spp. L.) in a forest type known as pinyon-juniper (Eyre 1980). This forest type is the most extensive in Southwest States and dominates 47 million acres (ac) in five states (Intermountain Society of American Foresters 2013). The pinyon-juniper forests are typically unmanaged and are commonly eradicated in favor of rangeland species deemed more favorable to livestock and some wildlife species. Healthy stands of pinyon-juniper can be maintained by thinning and uneven-aged silviculture management. It is possible to comanage pinyon stands for food, livestock, and wildlife.

Management prescriptions (some of which were used by American Indian tribes) may include identifying mixed-aged stands of pinyon pines located on gentle slopes with deep soils, which are more productive sites (Mclain and Frazier 2008). Thinning stands to reduce the non-pinyon tree component will release good nut trees. Pinyon trees with large spreading crowns are typically the most prolific nut bearers and can be retained through selective thinning. Pruning lower branches decreases the risk of crown fires and makes trees less susceptible to infections and pests. Pruning and light thinning results in increased cone production on residual trees. Integrating this NTFP into forest management requires balancing multiple land use objectives that may conflict.

Ramps—A spring ephemeral, ramps (wild leeks) are native to rich, moist hardwood forests of eastern North America (figure 2.5). Leaves of this forest herb begin to emerge when the soil temperatures increase, which usually occurs in late March and early April, depending on geographic location. Young plants produce smooth, broad leaves that die back as the overstory canopy closes and reduces the amount of sunlight that reaches the forest floor. Patches of ramps often can be located by their distinctive odor (Calvey et al. 1997). Before the plants lose their leaves, people forage the forests for this odiferous spring edible.

American Indians and early settlers ate ramps as the first green of the year. In the mid-20th century community groups began organizing ramp festivals to celebrate the arrival of spring and to raise money for local causes (Lohmann 2005, Simmons 2006). An early study documented harvest levels for 10 ramp festivals in western North Carolina to be in excess of 3,000 lbs, annually (Greenfield and Davis 2003), yet total annual harvest volumes have not been documented. More than 50 festivals have been identified from North Carolina to New York. Harvesting intensity increased with development of markets at roadside vegetable stands, farmers' markets, and even to local restaurants. In the late 1990s, the plant's popularity increased tremendously when culinary aficionados started promoting it as a luxury product (e.g., Geraghty 2005, Roach 2005, Sheffield 2005). Large-scale harvesting is supplying farmer's markets and other local food vendors (Levin 2006, Raisfeld and Patronite 2007, Wolcott 2006). Now, ramps are served at upscale restaurants and sold at natural food stores across the Nation and over the Internet (Ellison 2001, Feiring 2006). Expansion of market demand has generated concern for the plant's conservation (Associated Press 2005, Clabby 2005, Ostendorff 2005, Sheffield 2005).

The impact of harvesting and other disturbances on natural populations of ramps is not well understood. Understory herbaceous plant communities may take

Figure 2.5—Ramps (*Allium tricoccum*), a spring ephemeral forest species, are only available for about 10 weeks each year. During that time, people harvest large volumes of this odiferous onion for personal consumption and for sale in a burgeoning market. The increased interest in foods foraged from forests is putting tremendous pressures on natural populations of this and other edible forest products. (Photo credit: Michelle J. Baumflek, U.S. Department of Agriculture, Forest Service.)

longer to recover from harvest disturbance than overstory trees (McLachlan and Bazely 2001). Rock et al. (2004) estimated that a 10-percent harvest once every 10 years from a patch may be sustainable, but a 25-percent harvest was clearly detrimental to natural populations. On the other hand, Walker and Knapp (2010)[2] monitored 22 populations of ramps, with varying degrees of disturbance, and found them to be "remarkably stable" through a decade of analysis. Recolonization may be prohibited by dense vegetation cover of more aggressive plants. Nantel et al. (1996) concluded that the only measure to conserve ramp populations would be to delay bulb harvest until the end of the photosynthetic season when the bulbs are fully developed.

Forest herbs, such as ramps, are recognized as indicators of forest health (McLachlan and Bazely 2001). Slow annual growth and small-sized plants lead to a long preproductive stage (Nantel et al. 1996). Population growth and maintenance is due to vegetative propagation more than seed production. Changes in soil moisture and temperature due to climate variations could impact growth and maintenance of natural populations of spring ephemerals, such as ramps.

2.2 Silviculture for Temperate U.S. Nontimber Forest Products

Most NTFPs are harvested from natural populations in forests. In general there is little professional management of nontimber forest resources, yet as discussed in this section silvicultural practices could be used to integrate NTFPs into forest management to promote sustainable harvesting of natural populations. Opportunities abound for silviculture to address the complexities presented when forest management integrates nontimber plant and fungi species into strategies and prescriptions.

Silvicultural practices for naturally regenerated forest stands provide multiple goods and services for society while protecting and maintaining ecosystem function (Coates and Burton 1997, Curtis et al. 2007, Smith et al. 1997). The integration of NTFPs into timber-focused forest management regimes provides a means for attaining both objectives. The diversity of species and functional groups in forests necessitates the need for management plans that consider a broad range of biotic, abiotic, and social factors for successful outcomes. Balance between spatial, temporal, and economic scales must be maintained with the inclusion of NTFPs, and an increase in management complexity should be expected (Filotas et al. 2014, Hummel 2003, Schmidt and Lotan 1980). The added complexity should be considered not as a deterrent, but as an impetus for better understanding how to increase the utility and health of forest ecosystems. Managing for complexity increases resiliency and adaptive capacity of forests, which is particularly important under increasingly variable climate scenarios (Puettmann et al. 2009).

Plants and fungi that produce NTFPs help facilitate the maintenance of ecosystem processes, contributing to the structural, compositional, and functional diversity of forest systems. The inclusion of these plants in management can lead to economically and ecologically healthy forests. For example, spring ephemeral herbs contribute to nitrogen cycling pathways in eastern deciduous forests, meaning NTFP species with similar life history traits have the potential for ecological as well as economic value (Muller 2003). Similarly, economically valuable fungi are well known for their importance in nutrient cycling (oyster mushrooms, *Pleurotus* spp. (Fr.) P. Kumm.) and mycorrhizal associations (chanterelles, *Cantharellus* spp. Adans. ex Fr.).

Many hard mast (e.g., American hazelnut, *Corylus americana* Walt.; oak, *Quercus*, spp.) and soft mast (e.g., elderberry, *Sambucus canadensis* L., eastern redcedar, *Juniperus virginiana* L.) producing NTFP species provide valuable food and cover for wildlife. Some NTFP species may provide critical resources for invertebrate species (stone root, *Collinsonia canadensis* L.) and may serve as important pollination vectors (mountainmint, *Pycnanthemum* spp.). Similarly, understory species act as filters for guiding regeneration pathways of forest canopy trees, and the same may be true for important NTFP species (George and Bazzaz 1999, Maguire and Foreman 1983).

2.2.1 Treatments and Site Conditions

The compatibility of silvicultural treatments with NTFP production depends on a number of things, most

[2] Walker, J.; Knapp, B. 2010. Wild leek (*Allium tricoccum*) populations in Southern Appalachians: 1999–2009. Presentation at the 2010 Ecological Society of America Annual Meeting. 1–6 August. Pittsburg, PA.

noticeably resource availability. Light is the principal resource manipulated by silvicultural treatments, and will vary based on the type and intensity of treatment, site conditions, and species composition. Many NTFP species are understory herbs that are shade tolerant and associated with later successional stages (e.g., American ginseng, black and blue cohosh). Shade-intolerant NTFP species are associated with open areas or early successional stages and can be herbs (e.g., beargrass), shrubs (e.g., red raspberry, *Rubus ideaus* L.), and trees (e.g., paper birch). Silvicultural treatments fall into two core groups—intermediate treatments promote development of the existing stand, while regeneration treatments create favorable conditions for establishment of a new tree cohort (Curtis et al. 2007, Nyland 2002, Smith et al. 1997).

Intermediate treatments focus on increasing the timber value of canopy trees and can be used to maintain or promote NTFP production. The effects of an intermediate treatment can be manipulated through the amount of basal area removed, types of residual trees retained, and canopy strata targeted. By targeting the lowest canopy class and simulating the mortality of suppressed trees that would be removed naturally through self-thinning processes, low thinnings may be used to manipulate light and soil moisture within the stand to the benefit of NTFP species. Removal of the subordinate strata also may increase the soil moisture available to ground-story vegetation, although the amount of leaf area removed may have more influence on moisture than the thinning method (Smith et al. 1997). In mixed hardwood-conifer stands, low thinnings can maintain shade conditions that are conducive to mushroom production such as shiitake (*Lentinula edodes* (Berk) Pegler), while creating the physical space in the understory for cultivation.

Crown thinning improves incremental growth of target trees by increasing light levels to codominant and sometimes dominant trees. In the case of sugar maple, this increases tree vigor, size, and sap production of residual trees (Lancaster et al. 1974). Crown thinning has the potential to increase trees' surface areas and therefore the value of bark harvested from species such as tulip poplar (*Liriodendron tulipifera* L.). When thinned hardwood stems are of precommercial diameter, they may be used for mushroom production. In the case of species such as oaks, the value of the stems as a mushroom substrate should be weighed against the potential future timber value of the tree.

Selection thinning in conifer stands may create favorable conditions for very shade-tolerant understory species that rely on single tree gaps, but the need for multiple entries into a forest stand may create disturbance regimes that negate these benefits. Geometric thinnings, which remove trees at intervals, usually in rows or strips, may have potential in forest farming systems where the intercropping of canopy trees and NTFPs is a goal. Variable density thinning treatments early in stand development can increase structural complexity within stands (Hummel, 2003), which may increase opportunities for NTFP production.

Regeneration treatments are designed to initiate new forest stands by removing mature forest canopies and can complement certain NTFP resources in naturally regenerated forests. The size of gaps in the canopy, their orientation, and the length of time over which the canopy is removed as well as retention of previous stand structure by retaining group reserves all can influence site conditions and NTFP growth. Clearcut systems release tremendous amounts of growing space, creating open site conditions that benefit a broad suite of shade-intolerant species. Removal of the entire mature canopy strata over a relatively short period of time can result in full-sun conditions (Smith et al. 1997). This light environment can benefit shade-intolerant berry producing shrub species, however these benefits often are ephemeral without continued management as canopy species reestablish and shade the site (Reynolds-Hogland et al. 2006). Similarly, these conditions can promote establishment and growth of nonnative invasive plant species and/or aggressive native species that have potential to outcompete target NTFPs.

Clearcut openings can increase soil temperatures, change moisture regimes, and cause physiological stress and mortality to shade-tolerant NTFP species (Bazzaz 1979, Hicks and Chabot 1985, Meier et al. 1995). Populations of some species are restricted in their ability to reestablish once favorable conditions return (Meier et al. 1995) due to limited dispersal capabilities. Enrichment planting may be necessary to reestablish viable populations of economically important plants. In forest systems where artificial regeneration is practiced, planting density and competition control methods can influence understory structure and composition (Curtis et al. 2007, Hummel 2003, Jeffries et al. 2010, Knapp et al. 2014). Retaining elements of the previous stand (living and dead material) has implications for wildlife habitat and NTFPs (Hummel 2003, Nyland 2002, Smith et al. 1997). Specifically, group reserves or aggregated green-tree retention may provide refugia for certain dispersal-limited understory herb species to maintain populations. In addition, retaining or creating residual snags for wildlife may provide habitat to saprophytic fungi. Therefore, managing stands for complexity may provide nontarget benefits to NTFPs (Puettmann et al. 2009).

Group selection treatments also create open site conditions by removing the mature forest canopy, however gap size is typically smaller than clearcuts. Smaller gaps and associated smaller area-to-perimeter ratio create more diverse range of understory light conditions (Canham et al. 1990, Marquis 1965). By orienting selection gaps accordingly, timber value can be realized while protecting established populations of shade-tolerant understory NTFP species (Aikens et al. 2007). Multiple group selections create an uneven-age forest structure that closely resembles the natural gap phase dynamic and habitat heterogeneity that may support the life history traits of shade-tolerant NTFP species (Beatty 2003, Roberts and Gilliam 1995). Open conditions at the gap center, however, that would support shade-intolerant NTFP species may be more ephemeral than in clearcuts and thus less suitable for long-term production of NTFPs.

Shelterwood treatments are designed to produce single-age stands through a succession of canopy removals that promote establishment of more shade-tolerant canopy species. Evenly spaced mature canopy trees that are left as residual stand structure after the establishment cut mediate light and temperature environment that promote advance regeneration of more shade-tolerant timber species before overstory removal (Nyland 2002, Smith et al. 1997). The mediated environment of shelterwoods could be used to maintain existing populations of shade-tolerant NTFP species by reducing physiological stress and facilitating natural dispersal mechanisms. Care would have to be taken to protect populations of NTFP species, as shelterwood treatments often include a preparatory cut to remove competing vegetation and site preparation.

As with clearcuts, seed-tree treatments generally retain canopy tree densities at low levels, resulting in open site conditions, and NTFP considerations would be similar (Nyland 2002). There may be potential to focus seed-tree treatments on hard mast producing species such as oak to increase acorn production. This approach, however, may be more appropriate for a silvopasture system than a closed canopy timber production system. Single tree selection treatments would have challenges and benefits similar to selection thinning treatments.

2.2.2 Integrating Understory Nontimber Forest Products and Forest Management

Forest understories are complex ecological communities consisting of transient members (i.e., regenerating tree species) and permanent members (e.g., herbs, mosses, mushrooms, and shrubs; Gilliam and Roberts 2003a). Many important NTFPs are permanent members of understory forest communities and have different ecological requirements than associated tree canopy species. The forest understory is a stressful environment where light and moisture are limited. To deal with this, understory NTFP species employ an array of adaptations and life-history characteristics. Abiotic conditions are spatially and temporally variable, and stand-level measurements used to monitor canopy species may not be sufficiently informative or accurate when managing for understory NTFP species (Canham et al. 1990, Muller 2003, Neufeld and Young 2003, Reifsnyder et al. 1971).

Understanding the autecology of understory nontimber forest species is important for successful management. For example, the understory forest species ramps (leeks) and American ginseng have different phenological strategies for dealing with low light levels inherent on the forest floor. Ramps are spring ephemerals and do most of their photosynthesis, growth, and carbohydrate storage before canopy leaf out (Givnish 1987). In contrast, American ginseng is a summer green species (as defined by Uemura 1994) and associated with high leaf area index[3] canopies. Ginseng plants leaf out in spring and photosynthesize throughout the summer, and they produce flowers and fruit under high shade (Proctor 1981). While both species are "woodland herbs," these phenological traits reveal a great deal about their abiotic preferences, and therefore management. Ramps are not shade tolerant, but shade avoiders, while ginseng may be damaged under full-sun conditions (Nadeau et al. 1998, Proctor 1981). Management

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[3] Leaf area index (LAI) is a dimensionless quantity that describes plant canopies and is estimated by the one-sided green leaf area per unit of ground surface area (LAI = leaf area / ground area).

decisions therefore need to consider canopy species composition and interactions with understory plants.

The forest understory is a dynamic community, with each species constantly interacting with biotic and abiotic components of the environment. While abiotic factors have been used to explain vegetation patterns, physiological tolerances are a small part of the story (Tilman 1988, Whittaker and Klomp 1975). Emerging soil biology and community ecology research suggests that biotic interactions may be just as influential in shaping plant community composition (Reynolds et al. 2003, Warren and Bradford 2011). These biotic interactions shape spatial patterns and demographics of plant species and may be even more important for fungal communities (Crowther et al. 2014). In addition, some understory herb species may be more limited by the abundance of mutualist partners (e.g., mycorrhizal fungi, ants for myrmecochorous plant species) than physiological tolerances (McCormick et al. 2012, Warren et al. 2011).

Understory NTFP species are influenced by disturbance as well as resource availability and biotic interaction (Neufeld and Young 2003, Roberts and Gilliam 2003). Forests that are managed for timber inherently deviate from natural disturbance regimes. Timber harvesting should be considered as two separate, interacting types of disturbance in respect to understory plant species. The first is the intensity of canopy removal, which alters edaphic and microclimate conditions (Bhatti et al. 2002, Gilliam 2002, Gilliam and Roberts 2003b). Second is the severity of ground disturbance, which can destroy propagules and expose bare mineral soil, giving competitive advantage to early successional colonizers from outside the stand (Ramovs and Roberts 2003, Roberts and Gilliam 2003).

Interaction effects between canopy and ground disturbance also may be present and are dependent on site conditions (Duguid et al. 2013). Furthermore, the long-term effects on the understory resulting from successional changes and competitive interactions also should be considered (Halpern and Spies 1995). The NTFP species life-history traits, especially the organ harvested, life cycle, and reproductive strategy, define how they respond to disturbances. Ground disturbance and site preparation treatments can be tailored to the NTFP species. For example, forest management with high levels of ground disturbance would not be conducive with perennial herbs whose roots are the desired product, while annual and biennial herbs thrive on high levels of ground disturbance.

Plant and fungi communities or the relative success of an individual understory NTFP species is driven by life-history traits responding to resources availability, disturbance, and biotic interactions. While information on some high-value NTFP species is available, we know very little about the demographics and life-history traits of most understory plants (Bierzychudek 1982, Whigham 2004). The processes driving demographic patterns of fungal communities, and the effects of forest harvesting on those communities, is even less well understood (Crowther et al. 2014, Dahlberg 2001). Additionally, fungal NTFPs belong to distinct functional groups—saprotrophic fungi (e.g., oyster mushrooms, *Pleurotus ostreatus* (Jacq. ex Fr.) P.Kumm.) and ectomycorrhizal fungi (e.g., matsutake, *Tricholoma magnivelare* (Peck) Redhead)—with differing environmental preferences, further making broad generalizations about management difficult.

2.2.3 Integrating Production of Timber and Nontimber Products

The timing of timber harvesting is an important consideration for successful integrated management that occurs when forest stands are managed with multiple objectives that include timber and nontimber products. For example, managing a stand of maple trees for timber and syrup requires integrating these objectives into silviculture prescriptions. Management decisions consider interactions between the timber and nontimber resources. Timber harvesting in mid-summer may stress and damage foliage of understory NTFP species that are challenged in adapting to abrupt changes in solar radiation. Winter timber harvesting, conversely, allows plants to develop under full-sun conditions and acclimate to the new light regime (Ellum 2007).

Rotation length is another consideration when comanaging for NTFPs and timber. Some NTFPs, such as many ectomycorrhizal mushrooms, are only associated with later successional stages. Since commercial rotation cycles are generally shorter than natural disturbance regimes, populations of some valuable NTFPs (e.g., matsutake) may be reduced or even eliminated under short rotation times (Kranabetter et al. 2005).

Three basic classes describe management of forests for timber and nontimber products. Passive management includes timber or other objectives, such as wildlife, water, or recreation that are the primary stand objective. In these cases, NTFPs may provide inconsequential revenue and do not justify large management investments, or the product is ubiquitous and does not warrant management. Floral greens, such as salal, Oregon grape (*Mahonia* spp. Nutt.), and sword fern (*Polystichum munitum* (Kaulf.) C. Presl) harvested from Pacific Northwest forests, provide an example of passive NTFP management. Cuttings of these native plants may be harvested for personal use with a free permit (USDA Forest Service 2013), and these provide no additional revenues to the Government agencies. While permits for commercial harvest are available, salal is an aggressive groundcover, and management objectives are usually associated with reducing salal populations to aid in regeneration of more favorable species (Tirmenstein 1990). Most wild-collected mushroom permits on public lands are considered passive management, since little is known about cultivation and management for most species (Yun and Hall 2004). Other examples of passive management include burls and twigs for floral crafts (e.g., winterberry, *Ilex verticillata* (L.) A. Gray; willow, *Salix* spp. L.; paper birch, *Betula papyrifera* Marshall).

Active management is more common where there is potential for enough additional revenue to invest in research and management operations. One example is Canada yew (*Taxus canadensis* Marshall); after widespread overharvesting in the 1990s the Canadian Forest Service invested time and resources in establishing sustainable management practices to ensure long-term harvest and profits from this resource (Smith et al. 2003). Some provinces even implemented education and training programs along with the issuing permits to collectors and landowners (Prince Edward Island 2013).

Successful and rewarding integrated management of forests includes production of culinary mushrooms (Weigand 1998), balsam boughs (Krantz 2001, Titus et al. 2004), and pine straw (Demchik et al. 2005, Feldhake et al. 2010, Garrett et al. 2004). Foresters working with private landowners on high-value forest lands actively comanage for timber and shiitakes to maintain the property's agricultural status. The balsam fir boughs partnership in Minnesota is centered on sustainable harvesting practices and training (Krantz 2001, Titus et al. 2004). Silvopasture systems in pine forests are integrated approaches where objectives include forage, pine straw, and timber. These examples demonstrate that managing for the NTFP is feasible, though the exception in forest management.

Integrated management practices can be intensive for NTFP resources with extremely high values. Micropropagation, inoculation, and even bioengineering are being applied for management of truffles (*Tuber* spp. P. Micheli ex F.H. Wigg.) and timber (Mycorrhiza Biotech 2013, Symbios 2014, Titus et al. 2004). For instance in sugarbushes, silviculture is targeted at growth and regeneration of sugar maple trees for long-term sustainable yield (Cope 1946, Lancaster et al. 1974), timber harvesting is tailored to support these goals and additional revenue is secondary.

The third class of integrated management is applying silvicultural prescriptions to NTFP resources. In these cases foresters serve as NTFP harvesters or work closely with harvesters to integrate silvicultural treatments to improve NTFP resources. Extracting small-diameter trees for rustic furniture or shiitake logs in low thinnings (Titus et al. 2004) is an example of this type of management. While sections of birch bark can be harvested without harming the standing trees, harvesting large sections of bark for canoes and other crafts might be more efficient from felled trees following crown thinnings (Zasada 2002). Site preparations for stand regeneration can be paired with NTFP collection, such as targeted cutting of aggressive understory shrubs that have value during the preparatory or establishment cuts of a shelterwood, or as timber stand improvement. Witch hazel (*Hamamelis virginiana* L.) harvesting is permitted from Connecticut's state forests to enhance oak regeneration and growth (Associated Press 2009). Whole plants of shade-tolerant evergreen shrubs (e.g., Rosebay, *Rhododendron maximum* L. and mountain laurel) are dug and sold as nursery stock from forest lands in the Southeast. Targeted pruning or thinning of crop trees could be done on species that have potential for essential oil extraction such as eastern and western redcedar (*Thuja plicata* Donn ex D. Don Ciesla 1998; Titus et al. 2004), or for pine oil in the Southeast (Alexander 2003).

Finally, invasive species management has the potential to be paired with NTFPs collection. Blue gum (*Eucalyptus globulus* Labill.) is a problem invasive in California but can be used to produce valued essential oils (Ciesla 1998). While the planting of invasive plant species (e.g., Japanese knotweed, *Polygonum cuspidatum* Siebold & Zucc.; garlic mustard, *Alliaria petiolata*

(M. Bieb.) Cavara & Grande) is not advocated, these have emerged as potential food crops through the permaculture and wild foods movements. To help control invasive species, land managers can provide incentives for their harvest (Pasko et al. 2014).

2.2.4 Considerations and Concerns for Integrating Timber and Nontimber Products

To assure forest health, sustainable harvest, and resilience in a changing climate, there are a number of considerations regarding the integration of NTFP production into forest management. A primary consideration is the phenology of harvest opportunity, which addresses the fact that the majority of NTFPs only can be harvested at a specific time during the species growth cycle. For example, the quality of the outer bark of paper birch trees varies with the season. At the very beginning of the harvest period, the cork cambium is still dormant and more difficult to remove, rougher in texture, and darker color than "summer bark" harvested later in the season, during the active cambial growth of the tree (North House Folk School 2009, Stewart 1995). In addition, many plant species have more than one product, such as paper birch that is valued for sap, outer bark, whole bark layer, small-diameter saplings, roots, leaves, and character wood (Emery and Zasada 2001). There may be distinct harvest times for different products within a single species.

Coordination of harvest activities is another consideration. While harvesting NTFPs prior to cutting timber often produces higher quality products and more efficient harvesting, modern logging equipment has made it possible to reduce soil and understory damage. For some products (specifically from tree species) intensity and sensitivity of the harvest operation may differ based on timber harvesting. NTFP harvests in areas slated for logging may be able to remove entire plants or larger quantities of bark or sap. In contrast, if the goal is long-term sustainable harvest, care must be taken to leave the individual plant or population in a condition from which it can recover to supply future harvest. Of primary concern is protecting individual plants and plant populations, which includes protection of the cambium for healing wounds and adding new bark, protection of aerial and soil bud banks, and maintaining the potential for sexual reproduction.

While there are many opportunities to increase management of timber and NTFPs, there also are challenges to consider. Foremost are logistics, including permitting, enforcement, access, and jurisdiction on public and private lands. NTFP harvesting has the potential to increase ground disturbance and the risk of fire, depending on the number of additional stand entries, season of collection, type of crop, and mode of transportation by harvesters. Decisions must be made whether to allow harvesters access to the resource. These decisions might be based on profit, as some products may give higher returns from multiple small collector permits than one large commercial collector. They may, however, be based on other considerations; for instance, multiple local collectors may increase investment and stewardship of the forest by the community (Emery and Zasada 2001, Titus et al. 2004). Interactions between multiple and different types (e.g., loggers and NTFP gatherers) of harvesters as well as open access scenarios increase the potential for conflicts.

Communication about active logging jobs or other concerns may be easier to maintain between a single commercial harvester and landowner than with multiple parties. In addition, there may be liability concerns for private landowners if they allow harvesters access. Clear communication and easy passage to acceptable harvest areas is necessary; trampling alone has potential to damage sensitive communities. There also is the potential harvesting of additional nontarget species when lands are open to foragers. Most of these concerns can be mitigated with open and frequent communication between landowners, foresters, and collectors. Embarking on the decision to manage for NTFPs should be approached with careful planning and written guidelines.

2.2.5 Challenges to Managing for Nontimber Forest Products

There are inherent ecological and environmental challenges to managing for NTFPs. Forest cover change, invasive species, and a changing climate all contribute to an environment of uncertainty. While most forest management is based on historical conditions, we cannot be sure that the past is an appropriate analog to future forest conditions. Managing for resiliency is one way that ecologists and forest managers seek to mitigate the risks associated with uncertainty (Drever et al. 2006). Resiliency buffers forest ecosystems from large changes in composition and function, and it protects markets and ecosystem services (Millar et al. 2007). High species diversity increases ecological resiliency (Tilman and Downing 1996) and may contribute functional redundancy (Peterson et al. 1998). Intensely managing for one or a few high value NTFPs, especially in forest understories, may decrease diversity and resiliency and increase forest vulnerability.

Invasive species have ecological and economic consequences in managed forests (Pimentel et al. 2005) and can affect NTFP management. For example, invasive feral hogs in many parts of the United States destroy the understory and significantly change plant communities (Aplet et al. 1991, Bratton 1975), which is specifically relevant for many medicinal herbs. Some invasive plant species directly compete with understory NTFP species or employ novel phytochemicals with allelopathic effects (Wixted and McGraw 2010). Garlic mustard, for example, disrupts arbuscular mycorrhizal networks, which is critical for most understory herbs (Barto et al. 2010, Roberts and Anderson 2001, Whigham 2004). Non-native invasive earthworms can impact regeneration and establishment of forest herbs through predation or changing the physical properties of the forest floor (Frelich et al. 2006, Gundale 2002, McCormick et al. 2013). Furthermore, earthworms can have indirect effects on understory plant communities by altering mycorrhizal fungal communities (Lawrence et al. 2003, McLean and Parkinson 1997). Invasive insects and pathogens have reshaped American forests for more than a century (e.g., hemlock woolly adelgid [*Adelges tsugae* Annand], chestnut blight [*Cryphonectria parasitica* (Murrill) Barr]) and interactions between them have unintended consequences for forest understories. For example, gypsy moth (*Lymantria dispar* L.) outbreaks may be responsible for increased garlic mustard and Japanese stiltgrass (*Microstegium vimineum* (Trin.) A. Camus) abundance in eastern forests stands (Eschtruth and Battles 2014).

Unsustainable populations of animals and native plants, such as white-tailed deer (*Odocoileus virginianus* Zimmermann) and eastern hayscented fern (*Dennstaedtia punctilobula* (Michx.) T. Moore) in the eastern deciduous forest, can severely impact management of many understory NTFP species (Avril and Kelty 1999, Horsley et al. 2003, Webster et al. 2005). Diverse forest systems generally are more resilient to invasion of pests or disease outbreaks than more intensive management systems. Moving toward more intense NTFP production, such as forest farming, may increase impacts of pathogens.

2.3 Forest Farming in Temperate United States

Some NTFPs are cultivated under forest trees in a farm setting. Forest farming involves the cultivation or management of understory plants within an established or developing forest (Chamberlain et al. 2009). NTFPs produced in a forest where soils and competing vegetation are manipulated are considered woods grown, while wild-simulated NTFPs are grown in forests with little site disturbance and few inputs. Some NTFP species, particularly American ginseng, have been cultivated under shade-cloth in north-central United States for many years. This section details forest farming practices, challenges, and opportunities.

Forest farming, the cultivation of crops (e.g., decorative ferns, medicinal herbs, and mushrooms) within a forest, is one of five categories of agroforestry recognized in the United States (Chamberlain et al. 2009, Gold and Garrett 2009). Simply harvesting plants or fungi from natural populations without any management is not forest farming. The fundamental criteria that define forest farming are that the crop-forest system is intentionally established, intensively managed, integrated, and interactive, which provides mutual benefits to the understory crops and trees (Gold and Garrett 2009). A naturally occurring population of a plant or fungus, however, can be brought into a forest farming system through propagation and management. Forest farming is designed to provide multiple income streams from the forest and create a more ecologically stable forest ecosystem. Forest farming may be done in a natural forest or in a deliberate planting of trees (Chamberlain et al. 2009). The overstory trees may be managed for timber production, which can allow for several rotations of understory crops to be grown and harvested before the timber is harvested. Forest farming of NTFPs has potential to increase conservation of NTFPs while providing innovative economic opportunities for rural America.

2.3.1 Approaches to Forest Farming

Forest farming ranges from intensive cultivation where seeds are planted in the forest understory to extensive approaches that modify forest stands to enhance production of existing plants. There are three widely recognized methods of forest farming: woods-grown, wild-simulated, and managed populations (Munsell et al. 2013).

In a woods-grown production system, the objective is the highest yields of the products in the shortest period of time (Davis and Persons 2014). It is an intensive system with generally high inputs, including the clearing of understory plants, tilling, and possibly establishment of raised beds. Planting may be done mechanically, resulting in high plant populations in closely spaced rows. Fertilizers, pesticides, and herbicides are used to enhance growth and protect the plants. Pests such as deer, rodents, and other wildlife may be controlled with fences, baits, or traps. Woods-grown production also can refer to the intentional planting of trees for production of a NTFP from the trees such as nuts, berries, or syrup.

In a wild-simulated production system, the objective is to grow the NTFP resource as naturally as possible with few inputs (Davis and Persons 2014). Wild-simulated production is less intensive and less expensive than woods-grown. The plants usually take longer to reach harvestable size and yields often are lower. The site is minimally disturbed and if soil amendments are used, they are done so sparingly. In general, no fertilizers or pesticides are employed after planting, although efforts are often made to protect the planting from thieves and herbivores. In wild-simulated production little if any maintenance may be needed after planting.

Wild-managed natural populations of NTFP species can lead to sustainable production of wild-managed NTFPs. Typically, the wild-managed method is based on the local ecological knowledge (LEK) of harvesters. Activities may involve removing competing vegetation from within and around the population and includes propagation by seed collected from that population or vegetative propagation by cuttings or division of roots and rhizomes. Managed populations can be treated as wild-simulated production systems, with little disturbance and few inputs. Silvicultural treatments, discussed in section 2.2, can facilitate wild-managed NTFPs and improve upon local practices. Nurturing of an existing population of an understory plant, fungus, or trees for NTFP collection, such as maple trees for syrup, is a time-honored method that harvesters have used to ensure the future availability of the product (Chamberlain et al. 2009).

2.3.2 Common Forest Farmed Products

Common NTFPs grown in forest farming systems include medicinal herbs, food (e.g., mushrooms, fruit, honey, nuts, and vegetables), decorative products, and native ornamentals (USDA Forest Service 2012). Shiitake mushrooms are perhaps the most popular edible forest product that is forest farmed, though forest farming of other edible forests products, such as ramps, is becoming common. American ginseng and goldenseal are prominent forest farmed NTFPs that provide insight into opportunities to expand this approach to production and conservation.

The most popular and valuable forest farmed NTFP is the native plant, American ginseng. Nearly 95 percent of the American ginseng produced in the United States is exported to China and other Asian countries (Davis and Persons 2014). In the early 1700s, ginseng was extensively wild-harvested from the forests in North America and exported to China. Cultivation of ginseng started in the 1800s after native populations had diminished (Davis and Persons 2014). Early on, most ginseng was grown under artificial shade, and there was little distinction in price between wild and cultivated ginseng. Ginseng grown in tilled, fertilized soil produces a big smooth root, while ginseng grown in undisturbed soil produces a more wrinkled root with a long “neck” composed of bud scars each representing a year’s growth. Today, the latter is preferred and fetches a higher price.

Field grown under artificial shade structures is the most intensive production system, which results in high yields of smooth ginseng roots in a few years (Davis and Persons 2014). Woods-grown ginseng may take 5 to 7 years to produce marketable roots, while wild-simulated ginseng takes 9 years or more to reach marketable sized roots. Wild ginseng roots, or roots that look wild, are much more valuable than cultivated roots. In 2012 and 2013, the price of wild ginseng ranged from $400 to $1,250 per dried pound, while ginseng grown under artificial shade was valued at $12 to $42 per dried pound (Davis and Persons 2014). Since the mid-1990s, buyer interest in woods-grown and wild-simulated ginseng has increased dramatically. Because of the high value, loss due to theft is a major threat to forest farmed ginseng in areas where ginseng is also wild-harvested.

Goldenseal, another native medicinal herb in high demand, is destined for markets in North America and Europe (Davis and Persons 2014). Goldenseal was wild-harvested throughout its native range in the 1700s and by the 1880s there was concern about the impact harvesting was having on wild populations (Lloyd 1912). Forest farming of goldenseal was practiced across the country throughout the first half of the 20th century, but disease and falling prices reduced production to about 100 acres nationwide by the mid-1970s (Veninga and Zaricor 1976). In the mid-1990s, demand increased once again and due to concern about the pressure on wild populations, there were renewed efforts to encourage forest landowners to grow goldenseal (Davis and Persons 2014).

In contrast to ginseng, there is no difference in prices paid for goldenseal root grown under artificial shade or on the forest. Goldenseal certified as organic or grown sustainably, however, can provide a premium price for producers. In 2013, goldenseal root sold for between $16 and $35 per dried pound, while certified organic root was valued at $67 to $70 per dried pound (Davis and Persons 2014). This pricing structure is typical of other medicinal forest products.

Several other popular NTFPs grown in a forest-farming system include ramps, bloodroot (*Sanguinaria canadensis* L.), and black cohosh. Shiitake mushroom forest farming is increasing across the country. In southern United States, pine straw production through silvopasture also provides forest-based income. Other NTFPs are forest farmed on a very small scale. Growers often cultivate 0.25 acres or less of many native herbs to supply local herbalists, raw material buyers, and crafters. There are plants native to every region of the United States that may be forest farmed. Forest farming of NTFPs is attracting widespread interest among landowners wanting to diversify their income sources.

2.4 Market and Economic Considerations

Many private landowners adopt forest farming as a way to generate income from their forests without having to cut timber (Chamberlain et al. 2009). For others, production of NTFPs is a very deliberate method of generating income while timber matures before harvest. For whatever reason landowners decide to forest farm NTFPs, there are market and economic factors that must be considered in management decisions.

A few enterprise budgets for common forest farmed nontimber forest products have been developed (Burkhart and Jacobson 2009, Kays and Drohan 2003). Ginseng appears profitable on most budgets, while the profitability of other NTFPs is less attractive. Davis and Persons (2014) estimated that a forest landowner could net a profit of about $43,000 from 0.5 acres of wild-simulated ginseng after 9 years, at a per-pound price of $675 for dried roots. Jacobson and Burkhart (2005) estimated that 0.5 acres of wild-simulated ginseng would yield a profit after 10 years of $22,000 with the ginseng valued at $349 per dried pound. Accounting for the difference in price per pound, the estimated net profits on these two budgets would be nearly identical.

Using these studies to compare estimated profits for goldenseal, however, reveal substantial differences. Davis and Persons (2014) estimated that 0.5 acres of woods-grown goldenseal would yield a profit ranging from $300 (low root yields) to $41,000 (high root yields) with the goldenseal priced at $70 per dried pound, after 4 years. In contrast, Jacobson and Burkhart (2005) estimated that profits for a similar scenario with goldenseal would be about $15,000 at $17.69 per dried pound. Inconsistencies between analyses could be addressed through additional research to develop standard production budgets and cost-benefit and profit analysis.

Commercial markets for many raw materials of NTFPs (e.g., medicinal herbs, mosses) are well-established (Greenfield and Davis 2003), yet finding them can be difficult because many of the markets are not highly visible and not easily found through regular channels (Davis and Persons 2014). To enter the market often requires personal contact with buyers. Raw materials are sold to wholesale buyers who consolidate products and may do some processing. In some communities, there are small manufacturers (e.g., herbalists, florists) that buy limited quantities direct from the producer. These markets often pay a higher price per unit compared to larger wholesale markets, but volumes are much less. Forest farmed products also are often in direct competition with wild-harvested products, meaning profit margins for forest farmed products may be small or nonexistent (Chamberlain et al. 2009).

Product branding or certification are ways to add value to the forest farmed products, and efforts are underway to accomplish this using third party verification programs that guarantee product quality or regional identification (Blue Ridge Naturally Program 2015). The USDA National Organic Program (2015) will certify wild crop harvested products for a number of forest farmed NTFPs, and some farmers are using this to distinguish their products. These programs are not for everyone, and the interested landowner should weigh costs and benefits of such.

2.5 Production in Alaska and Hawai'i

The previous sections addressed production of NTFPs in temperate continental United States. There are many NTFPs produced in boreal and tropical forest ecosystems of this country and its insular territories. The contiguous states have different NTFPs than Alaska, Hawai'i, and the island territories. Many people in Alaska rely on wild-harvested foods for subsistence and household nutritional needs. Hawai'i and the island territories have hundreds of plants and fungi that provide NTFPs, and the products are embedded deep in traditional cultures of these tropical environments. Both states have strong cultural ties to NTFPs, as the products have been used by native people since they inhabited the places. Continued use and enjoyment of NTFPs is essential to the well-being of the people throughout the country. This section focuses on important NTFPs and their production outside the conterminous United States.

2.5.1 Alaska

A variety of NTFPs are important for Alaska Native and rural residents. Over 75 forest plants, used in various parts of Alaska, have historical documented use maintaining cultural identity including meeting nutritional needs, supplying arts and crafts materials, and medicinal and spiritual purposes (Garibaldi 1999). Subsistence harvesting provides food, opportunities for exercise, fresh air, and social activity with others. Subsistence typically is a communal activity with group harvest, preparation, and sharing (Thornton 1998, 2001).

Subsistence harvesting of wild plants is important in meeting rural household nutritional needs and maintaining cultural identity. Alaska Natives have a long harvest tradition and maintain subsistence use of wild blueberries (*Vaccinium alaskaense, V. ovalifolium*), bog cranberries (*V. oxycoccos*), high bush cranberries (*Viburnum edule*), salmonberries (*Rubus spectabilis*), raspberries (*Rubus leucodermis*), currants (*Ribes bracteosum, R. laxiflorum*), nagoonberries (*Rubus arcticus*), gooseberries (*Ribes lacustre*), and watermelon berry (*Streptopus amplexifolius, S. roseus*). Syrup is produced from berries and also from the sap of paper birch (*Betula papyrifera*) and Sitka spruce bud tips (*Picea sitchensis*). Tea is crafted using spruce bud tips along with the fruit, leaves, and flowers of edible plants.

Arts and crafts produced from forest plants are integral to native culture and are used to express and preserve culture and history. The fiber of birch, aspen (*Populus balsamifera*), juniper (*Juniperus communis*), hemlock (*Tsuga heterophylia*), spruce, and red and yellow cedar (*Thuja plicata, Callitropsis nootkatensis*), and other plant organs including bark, limbs, roots, cones, berries, and boughs, provide material for artisan products. Alaska Natives have used wild forest products to craft totems, canoes, basketry, paintings, carvings, floral arrangements, and wreaths. NTFPs continue to be used to produce arts and crafts that convey Alaska Native history and cultural identity (Pilz et al. 2006).

Oral histories of Alaska Natives indicate plants have been used to treat a range of human injuries and ailments. Devil's club (*Oplopanax horridus*) is the most common and widely used medicinal plant used by coastal Alaska Natives (Garibaldi 1999). Skunk cabbage root (*Lysichiton americanus*) also is harvested and used for aches and pains, psoriasis, and other skin conditions (Garibaldi 1999). Labrador tea (*Ledum groenlandicum*) was used for colds, flu, stomach troubles, and tuberculosis (Garibaldi 1999).

2.5.2 Hawai'i

NTFPs in Hawai'i are used for food, decorations, construction, as well as landscaping (app. 4). Collection of NTFPs for hula and celebrations is a particularly important use of these products. Many of the NTFPs harvested from Hawaiian forests are indigenous or endemic to the islands and may require special attention. Some of the most valuable NTFPs come from trees that are harvested for their wood and used for specialty products. Descriptions of those are included here as the wood may not be of timber size or is used in production of fine arts and crafts.

The two most economically valuable trees in the Hawaiian forest are koa (*Acacia koa* A. Gray), and sandalwood (*Santalum* spp. L.). Koa is the largest tree in the Hawaiian forest and prized for its glossy, highly figured heartwood (Lowell et al. 2013). Sandalwood is harvested for the aromatic wood from which scented oil is derived. While neither koa nor the main commercial species of sandalwood (*Santalum paniculatum* Hook & Arn) are threatened with extinction, supplies of both will become rare unless conservation measures are improved.

Koa is a large, fast-growing legume tree that regenerates from seed or root suckers in forest gaps and is common in upland forests on all the islands (Baker et al. 2009, Friday 2010). Commercial koa stands today are limited mainly to the island of Hawai'i, and harvesting is done by only a few small-scale operations. Nonetheless, in 2000, koa represented about 75 percent of the value of the Hawaiian forest industry (Friday et al. 2006). Some landowners restrict harvesting to dead and dying trees only. Browsing by cattle and feral ungulates, competition from invasive plant species, and wildfires continue to limit regeneration. Nontimber products from koa include stock for fine arts and crafts. As Hawai'i's climate is expected to become drier and warmer (Giambelluca et al. 2008), koa is likely to retreat from the drier sides of the islands and become more vulnerable to wildfires, pests, and diseases.

Sandalwood is a slow-growing small tree of dryland forests. It was Hawai'i's first commercial crop after Europeans discovered the islands. Over-harvesting in the early 1800s led to a boom and subsequent bust as natural populations of sandalwood were decimated (Merlin and VanRavenswaay 1990). While there are six native species of *Santalum* in Hawai'i (Harbaugh et al. 2010), nearly all commercial harvest comes from *S. paniculatum*, the mountain sandalwood of Hawai'i island. Unlike koa, sandalwood forests with commercial quantities of sandalwood are restricted to a narrow belt of a few thousand acres on Hawai'i Island.

Because of the tree's scarcity, sandalwood harvesting in Hawai'i is controversial and few harvesting operations exist. One firm extracts sandalwood oil and sells the residual wood for incense production. Other products from sandalwood include wood for carving and furniture and bark for medicinal tea. While *S. paniculatum* is not listed as a threatened or endangered species, these forests are vulnerable to livestock browsing, wildfires, and conversion to other uses. Landowners have had some success in encouraging natural regeneration from root suckers by controlling feral animals; however, no planted sandalwoods have reached harvestable size and rotation ages of Hawaiian sandalwoods are unknown.

2.6 Production in the Caribbean and Pacific Insular United States

The jurisdictions considered in this section refer to the insular areas of the United States. The term *insular area* refers to a jurisdiction that is a U.S. territory but is neither one of the 50 states nor a Federal district (DOI 2015). We restrict the term to include only insular areas that are inhabited and unincorporated island territories of the United States. These include the Caribbean islands of Puerto Rico and the U.S. Virgin Islands (USVI) and the Pacific islands of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI).

2.6.1 Environmental Setting

The insular areas share a tropical maritime climate characterized by little annual variation in temperature and a pronounced seasonal rainfall within a rugged topography that helps defines the biota. They represent a very wide geographical range from the Caribbean Sea to the northwest and southern Pacific Ocean (Donnegan et al. 2004a, 2004b, 2011; FAO 2001; Weaver 2006a, 2006b). Exposure to similar types of natural hazards such as hurricanes and potential impacts of climatic variability characterize the Caribbean region (Chakroff 2010, Lugo 2000, UNEP 2008), while past volcanic eruptions, frequent tropical storms, hurricanes, typhoons, and soil erosion characterize the major natural disturbances within the Pacific (Donnegan 2004a, 2004b; Donnegan et al. 2011; FAO 2001).

The forests in Puerto Rico and the USVI are mostly secondary stands of young structure, representing natural regeneration after abandonment of agricultural land and covering approximately 55 percent of the area (Brandeis et al. 2007; Brandeis and Turner 2013a, 2013b; Marcano-Vega et al. 2015; Weaver 2006a). Forest cover is approximately 42 percent in Guam, 67 percent in CNMI, and 90 percent in American Samoa (Donnegan et al. 2004b, 2011; FAO 2010a, 2010c; Government of Guam 2010; Neville 2014).

2.6.2 Caribbean, Puerto Rico, and the U.S. Virgin Islands

Many people within the insular Caribbean use NTFPs as sources of nutrition and medical care (van Andel 2006). The production of NTFPs in the insular Caribbean is said to reflect the "cultural history rooted in the use of the region's biodiversity" (John 2005). The major NTFPs (app. 4) can be divided into medicinal and aromatic, edible, and material for fine arts and crafts (FAO 2000, Kicliter 1997). Forero-Montaña (2015) revealed that Puerto Rican artisans made use of 127 types of wood, more than 30 seeds, bamboo (*Bambusa vulgaris* Schrad. ex J.C. Wendl.), coconut (*Cocos nucifera* L.), two calabashes, four vines, and two fibers.

Some species commonly used by Puerto Rican artisans for the wood includes the American muskwood (*Guarea guidonia* (L.) Sleumer), Spanish elm (*Cordia alliodora* (Ruiz & Pav.) Oken), lignumvitae (*Guaiacum officinale* L.), Spanish cedar (*Cedrela odorata* L.) and mahogany (*Swietenia mahagoni* (L.) Jacq. and *S. macrophylla* King) (Kicliter 1997, Mari Mut 2013). Other plant species widely used for NTFPs include the calabash tree (*Crescentia cujete* L.), which has medicinal uses and is used for containers and crafts (Benedetti and Negrón-Flores 2012). The coconut palm, used for food, fiber, and wood, is mainly cultivated for its fruit (Parrotta 2000). Shade-grown coffee (*Coffea arabica* L., *C. liberica* W. Bull ex Hiern.) is still a traditional crop from the western central mountains, while mango (*Mangifera indica* L.) and breadfruit (*Artocarpus altilis* (Parkinson) Fosberg) are abundant fruit trees within forests (Marcano-Vega et al. 2015). Other species such as soursop (*Annona muricata* L.), sour orange (*Citrus ×aurantium L. subsp. aurantium L*), key lime (*Citrus ×aurantiifolia* (Christm.), and cure for all (*Pluchea carolinensis* (Jacq.) G. Don) have been identified as frequently used to treat health conditions (Alvarado-Guzmán et al. 2009). The native soursop and naturalized sour orange and lime can be found in secondary forests (Brandeis and Turner 2013a, Francis 2004, Marcano-Vega et al. 2015, Nuñez Meléndez 1982).

The use of NTFPs in the USVI is mainly for the production of jewelry, bowls, spoons, and items made from locally grown wood, bamboo, and palm fronds (FAO 2010e). Mahogany (*Swietenia* spp.) and tibet (*Albizia lebbeck* (L.) Benth.) are tree species used for artisanal work (Chakroff 2010). Medicinal plants are important crops in the USVI and medicinal trees like neem (*Azadirachta indica* A. Juss.), moringa (*Moringa oleifera* Lam.), and noni (*Morinda citrifolia* L.) are grown in agroforestry systems (Palada et al. 2003, 2005). Herbal teas locally known as "bush medicine" are consumed for medicine or food (Palada et al. 2003, 2005). In the USVI farmers actively produce NTFPs on their land and the majority of the products are fruits, especially mango, avocado (*Persea americana* Mill.), coconut, mamee apple (*Mammea americana* L.), and lime (Workman et al. 2004). The leaves and berries from abandoned stands of bayrum trees (*Pimenta racemosa* (Mill.) J.W. Moore), planted to supply the cosmetic and perfume industry in the 1940s, remain productive today (Weaver 2006a). The nonnative genip tree (*Melicoccus bijugatus* Jacq.) is present within the secondary forests of the USVI, offering a favorite fruit, and its wood is used to make charcoal (Brandeis and Turner 2013b, Chakroff 2010).

2.6.3 Insular Pacific—American Samoa, Guam, Northern Mariana Islands

Traditional agricultural production in the insular Pacific consists of agroforestry systems of cocoa (*Theobroma cacao* L.), coconut, breadfruit, and various other fruit trees inter-planted with the nitrogen-fixing erythrina (*Erythrina subumbrans* (Hassk.) Merr.), bananas, cassava, and root crops (American Samoa Community College 2010). Further, the fruits, leaves, trunk, and roots of coconut palm are sources of copra oil and soap, baskets and brooms, construction materials, and material for rope (Wilkinson and Elevitch 2000), but plantations are being abandoned due to a decline in the copra market (FAO 2005a, 2010a). Native tree species are harvested to create traditional handicrafts, traditional clothing, oils, and mats (FAO 2010a), as the flora has always been an integral part of the insular Pacific culture. In American Samoa, noni is used for medicinal purposes and moso'oi (*Cananga odorata* (Lam.) Hook. f. & Thomson) and laga'ali (*Aglaia samoensis* A. Gray) for making of perfume and cosmetics. Moso'oi and laga'ali are used as ornamentals (FAO 2000). Other species used in American Samoa include ifil (*Intsia bijuga* (Colebr.) Kuntze), reported to generate more than $400,000 per year in revenues for the national economy. Other trees used for the nontimber products include Javanese bishopwood (*Bischofia javanica* Blume) for dying and thatch screwpine (*Pandanus tectorius* Parkinson ex Zucc.) for utensils (FAO 2000). In Guam, the fruit of the betel nut palm (*Areca catechu* L.) is regularly collected (FAO 2005b, 2010b) and used as an astringent and stimulant. Fruits of breadfruit (*Artocarpus altilis*) and dokdok (*A. mariannensis* Trécul) are food sources as well. Some fruits and medicines are also collected within the forests of CNMI, and agroforestry systems include the coconut palm and a mix of native and introduced species used for sustenance (FAO 2010c).

2.6.4 Opportunities

The prospects for NTFPs to be more integrated into forest management are encouraging. NTFPs present alternatives for utilization of local forest resource and encourage rural economic growth. Promotion of sustainable forestry practices on private and communal lands can lead to better NTFP management and conservation. Integrating NTFPs into forest inventory and monitoring presents challenges that require additional research and investments.

Interest in traditional use of medicinal plants persists within the insular areas of the Caribbean (Alvarado-Guzmán et al. 2009, Benedetti 2009, Chakroff 2010, Weaver 2006b). An ethnopharmacological survey in the southeastern region of Puerto Rico revealed that 58 medicinal plant species, some of which are obtained from the forest, were used as remedies for ailments mostly affecting the respiratory and gastrointestinal systems (Alvarado-Guzmán et al. 2009). Medicinal plants from the USVI include 35 herbaceous, 11 tree, 12 shrub, and 10 vine species (Weaver 2006b). This interest offers opportunities to promote production of NTFPs as economic alternatives.

Integrating NTFPs into forest inventory and analysis is needed to ensure sustainable sourcing of products. Since the 1990s, there has been a call to integrate NTFPs in forest assessments within the Pacific islands to provide useful baseline data regarding sound management of forests (DeBell and Whitesell 1993). On the other hand, the Food and Agriculture Organization (FAO) of the United Nations global forest resource assessment highlighted the important role of NTFPs in the well-being of people worldwide but lacks assessment and monitoring of resources and utilization (FAO 2001). Major research opportunities include the need for inventorying NTFP resources and their habitat requirements. Also, there is a need to monitor markets and the amount of NTFPs traded as well as the sources of raw materials. Finally, research is needed to assess impacts of introduced animals and invasive species on NTFP resources.

2.7 Inventory and Analysis

The inventory and analysis of trees in forests are well embedded in forestry and forest health assessments. Methods to inventory trees harvested for timber are well developed and integrated into forest management. Information is available for some trees that provide NTFPs, but the data must be examined from an NTFP perspective. While the Forest Inventory and Analysis (FIA) program of the Forest Service (USDA Forest Service 2015) can provide data on some NTFPs, there are opportunities to expand research investments and data collection to improve information about these products.

2.7.1 Current Approach to Forest Inventory

Management and planning for sustainable production of all forest products requires knowledge of their spatial distribution, abundance, and change over time. Collection of this information for resources as biologically diverse and geographically dispersed as NTFPs presents challenges. Fortunately, much can be learned about NTFPs from conventional forest inventory, and there are opportunities to leverage existing data with additional information to gain insights about the status and expected trends of many NTFPs. A distinction can be made between national-scale inventories that are consistent, comprehensive, and repeated, versus inventories for specific purposes, places, and/or times.

The FIA program collects information on the status and trends of forest resources of the United States. The program is a national-scale inventory that collects data across all ownerships, across the entire United States, using standard sampling schemes and data collection protocols (Bechtold and Patterson 2005, Reams et al. 2005). Plots are remeasured in cycles; in eastern states, every 5-7 years and in the West every 10 years. At each forested sample plot, information about the site (i.e., location, physiographic condition, ownership, forest type, and stand age class) and individual trees (species, diameter, height, and condition) are recorded (USDA Forest Service 2014). These data, related to specific location by plot coordinates, enable spatial analysis of abundance and status of individual tree species.

Non-tree vegetation profile information may be collected from plots and, if collected, consists of percentage canopy cover of growth habit (tree, woody shrub/vine, forb, graminoid) and canopy layer. Also, up to four of the most abundant species per growth habit may be recorded. The FIA program produces summary reports and analyses from the plot data and also provides data and tools with which users can perform their own analyses of populations of specific interest.

2.7.2 Status of Nontimber Forest Product Inventory

Inventory protocols for commonly harvested timber and wildlife species are fully integrated into forest management. Wong et al. (2001) summarized much of the body of knowledge concerning inventory and resource assessments of nontimber forest resources and associated products in a seminal document. Vegetation inventories are used for biodiversity conservation (Elzinga et al. 1998). Market and economic inventories have been used to assess current and potential contributions to community development (Greene et al. 2000, Greenfield and Davis 2003). Inventory and monitoring NTFPs are essential activities in the sustainable management of these resources (Kerns et al. 2002) yet they have not been integrated into current programs.

Approaches and methodologies differ for the various products and desired information. Permanent plots have been used for mushrooms in the Pacific Northwest (Pilz et al. 1996) and medicinal plants in southern Appalachia (Chamberlain et al. 2013a, McGraw et al. 2003, Small et al. 2011). Protocols to inventory salal and other understory plants in the Pacific Northwest forests, which are harvested for the floral industry, have been tested (Barnes and Musselman 1996). Inventory and monitoring protocols have been developed for American ginseng and goldenseal (Gagnon 1999a, 1999b). A challenge with these is scaling up from research to production levels.

For NTFP resources where the desired products are belowground, such as tubers and roots, inventories are especially problematic as there is little or no way to correlate aboveground biomass to belowground yield. Chamberlain et al. (2013a) developed a method to model belowground biomass for black cohosh based on measurements of aboveground vegetation. The model serves as a tool to inventory NTFPs that are harvested for their roots. Efforts are under way to adapt this model to other medicinal NTFPs, such as blue cohosh (*Caulophyllum thalictroides* (L.) Michx.).

In general, FIA does not inventory specifically for NTFPs, although fortuitously information can be extracted from FIA data that are relevant to monitoring NTFPs derived from forest trees. Because tree records in the FIA database can be selected for a species of interest, a great deal can be learned about the abundance, distribution, and trends for a single forest tree species. FIA data have been used to estimate potential production of maple syrup from American forests (Collins 2001; Farrell 2009, 2013). The most recent of these studies used plot information on stand density (number of potential maple tree taps per hectare) as well as distance to nearest access road to include only those sites with potential for commercial production (Farrell 2013).

Slippery elm (*Ulmus rubra* Muhl.) illustrates what can be deduced from FIA inventory data on NTFPs from trees (Kauffman et al. 2015). Slippery elm is a tree species native to eastern North America from which bark is harvested for herbal remedies. FIA data enable the analysis of the abundance (numbers of trees), spatial distribution, and components of change (growth, harvest removals, and mortality) and to evaluate the change in inventory measures over time (figure 2.6). Tabular presentations of slippery elm inventory, growth, mortality, and removals indicated a net volume decrease of living slippery elm trees from 2007 to 2012, with annual mortality approximately equal to annual gross growth. At the same time, removals of slippery elm increased. Thus, the inventory data indicate there is cause for concern for the sustainability of slippery elm, with high levels of mortality (possibly related to Dutch elm disease) and increasing removals.

2.7.3 Using Forest Inventory and Analysis Data for Nontimber Forest Product Inventory

The FIA program has a broad user community, and many scientists are involved in improving and leveraging the information collected by FIA. Remote sensing data are being used to develop more spatial precision in estimates of FIA forest and tree species distributions. Substantial research efforts tied to FIA plot data can

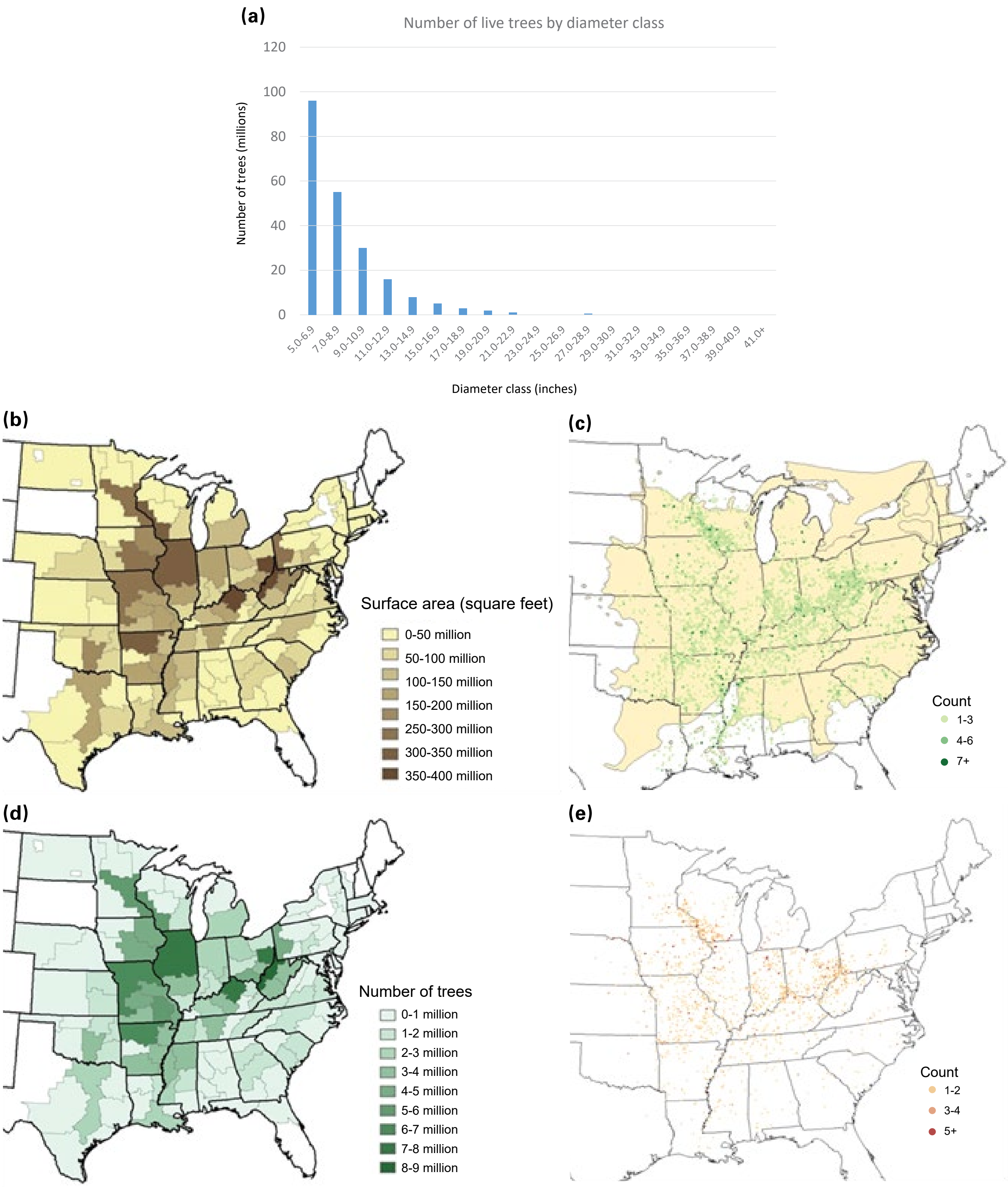

Figure 2.6—Slippery elm inventory. (a) Number of live slippery elm (*Ulmus rubra* Muhl.) trees (diameter 5 inches and greater) by diameter class in eastern United States. (b) Surface area of slippery elm boles by Forest Inventory and Analysis (FIA) inventory unit, 2012. (c) Approximate locations of FIA plots on which slippery elm trees were measured, 2012. Dot colors represent numbers of trees observed on the plot; the shaded region is the natural range of slippery elm (Little 1971). (d) Number of slippery elm trees by FIA inventory unit, 2012. (e) Approximate locations of FIA plots on which slippery elm mortality was observed, 2012. Dot colors represent number of dead trees observed on the plot. (Maps rendered by J. Kauffman, Virginia Tech.)

be immediately applied to NTFPs derived from trees. For example, modeling of the spatial distribution of tree species under a variety of future climate scenarios has been conducted for over 100 tree species, including some of NTFP importance (Iverson et al. 2008).

FIA data can be integrated with other datasets to gain insights into certain NTFPs. For example, Chamberlain et al. (2013b) combined FIA data with American ginseng harvest data obtained from the FWS to assess the relationships between ginseng harvest and timber inventory and harvest. Because FIA plot data and ginseng harvest data could be resolved to a county level, it was possible to examine correlations between the two datasets. They found ginseng harvest levels correlated with hardwood forest area, hardwood growing-stock volume, and timber removals.

Another approach to extending the value of FIA data for NTFPs involved augmenting FIA data with field inventory specifically designed for assessing paper birch bark resources for baskets and other fine arts (Emery et al. 2014). Integrating standard FIA data with a custom inventory and traditional ecological knowledge (TEK) yielded new information on the resource. Experts in bark harvest identified bark characteristics related to the potential utility of harvested bark for fine arts. Measurable features associated with these characteristics were then identified by ecological experts with extensive cultural expertise. FIA field crews collected data on these features when measuring paper birch trees. The variables, combined with traditional tree measurements such as diameter and height, enabled computation of estimates of harvestable bark and change over time.

Finally, often FIA plot measurements can be used to develop models that predict parameters of interest, but this may require more intense data collection from plots across the landscape. For example, modeling ginseng distribution is possible and requires extensive data on topography, soils, forest cover parameters, and other geographic variables such as aspect, slope, elevation, and soil acidity (McGraw et al. 2013). Research investments have improved the mathematical techniques for computing the inventory parameters of interest (e.g., biomass, growth, removals, and mortality). Similar efforts could lead to the ability to predict other parameters of interest for NTFPs, such as predicting fruit or seed yield from tree or site conditions.

In summary, while a great deal of information on NTFPs from trees can be derived from FIA data, there are opportunities to leverage investments in research and field data collection to improve the information on NTFPs. The FIA program has active support and interest from a broad user community, and expanding data collection to include more information on NTFPs will likely require similar strong support from the NTFP science and broader user communities.

Fundamentally, there is a strong and growing body of knowledge to build an inventory program for NTFP resources. Globally, there are insufficient data and a lack of common reporting methods to fully integrate NTFP inventories into forest management. Efforts are constrained by a lack of field skills, time, personnel and fiscal resources. Until these issues are addressed, the inventory and assessment of nontimber forest resources will be under-utilized in forest management in the United States.

2.8 Tracking Nontimber Forest Products

One of the greatest obstacles to creating effective NTFP policy is the lack of knowledge about the size and structure of the NTFP industry. These products have a great deal of cultural and economic value, but there are little consistent data on how much is harvested and where it originates (Vaughan et al. 2013). To effectively allocate resources for sustainable utilization of NTFPs, a better understanding of their economic impact and the impact of harvest on wild populations is necessary. This requires systems that track how NTFP resources get from forests to consumers. For the purpose of this section, *tracking* refers to methods for collecting data on NTFPs including estimates of harvest volumes and distribution and measurements of how production changes over time. Knowing the context of tracking data is vital for effective management decisions. This includes the structure of NTFP supply chains, the practice of harvesting and trading, and changes in price and consumer demand. NTFP economies vary from region to region, and within one sector there may be a multitude of species being harvested. Tracking programs should be efficient and focus on products that have high economic value, are harvested heavily, or that are rare or rapidly declining. This means that tracking is most effective when it is part of a system that also monitors plant populations and engages market participants.

A tracking program can benefit many stakeholders affected by NTFP production. Market participants, forest managers, and conservation organizations share an interest in ensuring the sustainable management of natural populations. For consumers, a more open supply chain can provide confidence in the quality and safety of products and whether the products are sustainably sourced. Tracking programs can be burdensome for harvesters and producers, but such programs can benefit them as well. Tracking programs that reveal the economic impact of NTFPs on what are often marginalized communities can help make an argument for greater institutional support for production. Unlike most businesses, NTFP market participants lack access to data on product supply and demand. Fluctuations in price and demand cause general instability within the market, resulting in greater risk for those involved. The lack of available market research is often cited as a barrier to entry for farmers, landowners, community organizers, and professionals interested in cultivating or managing their woodlands for NTFPs (Chamberlain et al. 1998, Gold et al. 2004). This section explores how NTFPs are tracked and the challenge of designing and implementing tracking programs.

2.8.1 Approaches, Methods, and Programs

Few institutions track NTFPs to any extent, and they employ different strategies including sales of harvesting permits (e.g., national forests), mandatory reporting (e.g., CITES), and voluntary surveys (e.g., AHPA). This section gives a brief summary of various tracking methods. All have advantages and disadvantages. They are tailored to certain products, markets, and land classes. A comprehensive large-scale tracking program would have to integrate multiple methods.

Permit programs—Permitting provides collectors with access to NTFP resources and landowners with an opportunity to manage NTFPs over large areas. The Forest Service and BLM issue permits to harvest NTFPs (USDA Forest Service 2015a). Permits typically are issued for specific volumes and time limits. Permit prices are based on estimated fair market value of the product and, in some cases, different permit prices are available for commercial and recreational harvesters (USDA Forest Service 2015a). The granting office assumes that the entire permitted amount, and only the permitted amount, is harvested. Permitted harvest volumes are totaled by district and by forest to achieve an estimate with a degree of regional distribution (Alexander et al. 2011). Permitted harvest volumes, as reported by the Forest Service and BLM, do not include private lands and are an imperfect measure of actual harvest volumes (Alexander et al. 2011, Muir et al. 2006). Table 2.1 summarizes the volumes of permitted harvest in 2013 from national forests and BLM lands. Enforcing permitting regulations requires significant resources, and given the expansive areas involved, it is unlikely effective. Income from permit fees can support enforcement, but because of slim profit margins for harvesters, the cost of permit fees can discourage their purchase and lead to illegal harvesting (Charnley et al. 2007). Permitted harvest data may provide a better description of harvest volumes in the West, where public ownership dominates, but is less useful in the East, where private lands dominate. Private landowners may grant leases to harvest, but data are not available.

Mandatory reporting and export data—In the United States, American ginseng may be the NTFP that has been tracked the longest and with the most detail because of its inclusion in CITES (Chamberlain et al. 2013b). Buyers of American ginseng root, who want to sell outside of the State in which they reside, are required to register with the appropriate state agency, keep records of each transaction, and have ginseng roots inspected and certified by the state agency before the roots can leave the state. The system was established to ensure that ginseng is legally harvested and allows the FWS to determine nondetrimental status of the harvest.

This mandatory reporting achieves high participation and has provided the most detailed data on volume and harvest distribution of any NTFP in the United States. Tables 6.2 and 6.3 (chapter 6) summarize the ginseng harvest volumes by state, year, and amounts. It is burdensome, however, for harvesters and buyers who use ginseng sales to supplement income. The tracking program is directly tied to regulations that are perceived by many buyers and harvesters as overly restrictive, ineffective, and created without their input (Blumenthal 2006). Negative associations with mandatory reporting may hinder future voluntary collaboration on efforts to track other NTFPs (Love and Jones 1997, McLain 2008). The ginseng program requires substantial resources for enforcement and administration in the respective state programs. Mandatory reporting should not be undertaken without exploring other possibilities and assessing the impact on participants (Robbins 2000).

Some NTFPs are exported and assigned an international export code under the Harmonized Tariff Schedule that is used by the U.S. International Trade Commission (ITC 2014) to track products. In most cases, wild-harvest products are lumped into broad categories such as "foliage," which also can include cultivated products (Alexander et al. 2011). Three exceptions to this are wild blueberries, wild ginseng, and mosses. Data from the ITC can be used to estimate harvest volumes at a national level, but do not allow for assessment of harvest distribution.

Industry tracking—Trade associations generate estimates of some NTFP sectors. Some are single-product oriented, such as the National Christmas Tree Association, which surveys its members (NCTA 2012). AHPA and the American Botanicals Council (ABC) publish quantitative data on wild-harvested medicinal plants. The ABC collects and summarizes data on retail sales of herbal products in its publication HerbalGram. Data derived from retail sales can provide estimates of the monetary value or economic impact of particular species or a category of nontimber forest end-products such as herbal supplements (Blumenthal et al. 2012). Retail data also can show trends in demand for NTFPs but are not effective at tracking actual product volume because manufactured goods containing NTFPs vary in price and the amount of raw plant material they contain. Presentations of these data also are one-time windows of dynamic markets that change with supply and demand.

AHPA surveys its members, some of which are the largest herbal companies in the United States, as well as primarily buyers of raw materials and publishes total volume for approximately 20 medicinal plants (table 2.2; AHPA 2012). The AHPA survey provides baseline estimates available for several species. The survey is repeated biannually, making it extremely valuable in providing insight into harvest and market trends. The AHPA data show dramatic fluctuations in volume of certain products from year to year, something that cannot be accounted for in a one-time study.

Household and voluntary surveys—Surveys have the potential for being an effective method for tracking NTFPs and can provide quantitative and qualitative data needed for management decisions. They are typically voluntary and confidential and can cover products harvested from public and private lands. The few surveys that have aimed at tracking NTFPs were directed at specific commercial product sectors, such as floral products in the Northwest (Schlosser et al. 1991), mushrooms in the Northwest (Schlosser and Blatner 1995), and moss in the Northwest and Appalachia (Muir et al. 2006). Surveying NTFPs from different market segments from the same region is another approach (Greenfield and Davis 2003). These were undertaken for research purposes and were not intended to track for long-term analysis.

Surveys are designed to target a point in the supply chain at which respondents are likely to know how and where their products are harvested. Some surveys have aimed to estimate the economic impact of NTFP markets by asking participants about prices for products. This makes it possible to describe economic value and volume of harvest, which is helpful when products have different physical properties (e.g., bark versus foliage). Surveys that are voluntary eliminate the need for enforcement, reduce cost, and are less burdensome to the participants. They, however, suffer from low response rates and nonresponse issues. Although surveys can be replicated, NTFP surveys in the United States have been short term, usually just covering one year. NTFP markets can be highly volatile, and new products are always emerging, meaning that to be effective, tracking systems including surveys should be updated and readministered.

Muir et al. (2006) used several data sources to project total estimates of product volume for mosses harvested from the Pacific Northwest and Appalachia. The authors found that export data indicated a much larger moss harvest than reported from permits. Moss dealers provided information on the proportion of their products for international versus domestic markets. To get a total estimate, they combined export data with a projection based on those percentages, demonstrating that using data collected from multiple sources can improve estimates.

2.8.2 Other Product Tracking Models

Other similar products are tracked effectively and provide insights into approaches that may be appropriate for NTFPs. As an example, the Forest Service FIA program has tracked timber production for more than 70 years. Other institutions track products sold through more informal markets, such as roadside stands and farmers' markets (e.g., USDA Agricultural Marketing Service [AMS]). Other countries have established systems for tracking some NTFPs. The methods used to track these products can provide valuable lessons for developing approaches for NTFPs.

Forest Service—Since the 1930s, the Forest Service has tracked timber production through the Timber Product Output (TPO) assessments, which are voluntary and confidential surveys of primary timber processors (USDA Forest Service 2015c). The TPO assessments collect data on the size, location, product, and production volume of each mill. TPO surveys also inquire about the origin of the raw material and if it came from public or private land. Data are collected at the county level and can be aggregated into multiple counties to preserve confidentiality if there are only a few operators that could be identified, which is often the case for NTFP buyers.

Designers of NTFP tracking systems can learn from the TPO assessments. The TPO collects data on harvest distribution, which can be correlated with data from FIA inventory plots such as measurements of timber removal and growing stock (Chamberlain et al. 2013b, Piva and Cook 2011). This ability to seamlessly integrate data from the industry and the forest makes the TPO a powerful tool for managers and policymakers analyzing the relationship between commerce, harvesting practices, and forest health. TPO assessments are done regularly, which allows for an ongoing analysis of trends and changes over time.

The TPO achieves response rates as high as 100 percent (Piva and Cook 2011), much higher than most surveys. When responses are missing, and the size and location of the mill is known, data are substituted from another comparable facility (Johnson et al. 2008). Part of the reason for the TPO's high response rates may be that the results are useful to participants. Reports are summarized by region and state and published in an easily accessible format. The public also can search and retrieve customized data through an interactive online database.

Other USDA programs—Farmers' markets share some of the informal characteristics of the NTFP economy. Cash transactions are common, and recordkeeping is inconsistent, making it difficult to create nationwide estimates of farmers' market sales and their economic impacts. The AMS commissioned a nationwide survey of farmers' market managers in 2006 (Ragland and Tropp 2009). The AMS maintains a directory of farmers' markets with the contact information of market managers, which serves as a sample frame, while a Web-based version allows market managers not in the directory to participate (Ragland and Tropp 2009).

This tracking method has the advantage of emerging from a larger institutional framework that provides resources for local food infrastructure, meaning the respondents were likely to benefit from participating. The lack of such a perceived benefit is a major obstacle for NTFP data collection. Finally, an important element of the farmers' market survey is that, like the TPO, it was designed to be repeated.

In addition to the AMS, the USDA National Agriculture Statistics Service includes NTFPs such as tree nuts, berries, and maple syrup in its annual reporting, which presents data on production volumes, prices, and producer demographics (e.g., NASS 2013).

NTFPs tracking in other countries—Looking at how NTFPs are tracked around the world can be instructive for assessing U.S. tracking methods. These programs face many of the same challenges that exist in the United States. In discussing the need to compile statistics on NTFPs for nations to use for policy decisionmaking, Vantomme (2003) argued that comprehensive data on product volume and origin is sparse and markets are informal and volatile.

One way Europe tracks NTFPs is through "The State of Europe's Forests" (SEF), a periodic report prepared by the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2007). In the SEF, signatory countries report on indicators of sustainability to assess the overall condition of European forests. One criterion is the measurement of NTFPs quantity and value. In 2007, 32 European countries reported on marketable NTFPs and the quality of assessments varied greatly between countries. There is no standardized, overarching method used by all countries, but the SEF is still able to publish information on total NTFP quantity and value (MCPFE 2007). The report breaks down that value by country and also by product categories such as mushrooms, berries, and medicinal or colorant products. One limitation of this approach is that it provides national-level statistics and not local data.

Finland has some of the most detailed NTFPs tracking. Since the 1980s, Finnish researchers periodically survey households about NTFP harvesting activities (Saastamoinen et al. 2000, Turtiainen et al. 2012). Surveys are distributed to households throughout the country, with special emphasis on communities close to known harvesting areas (Turtiainen et al. 2012). Respondents are asked what species they harvest and the proportions for personal and commercial use. While these surveys do not collect data on harvest location, the studies do look at distribution based on harvester location.

Household surveys are effective in Finland, where an estimated 60 to 90 percent of people collect berries (Saastamoinen et al. 2000). More than 40 percent harvest mushrooms (Turtiainen et al. 2012). The low population of Finland and small size of the country support this type of analysis. In the United States, this would be challenging due to the size of the country, the dispersed nature of NTFP harvesting communities, and divisions between recreational and commercial harvesters. However, by targeting clusters of the population with higher probability of NTFP participation, it may be possible to assess the rate of harvest for some products in the United States. This can be done by targeting populations who live close to forests, common users of public lands, or cultural communities with strong NTFP harvesting traditions. The National Survey on Recreation and the Environment and the National Woodland Owners Survey collect data on gathering natural products from forests for personal and economic use, including mushrooms, berries, and plants and flowers (Butler 2008, Butler et al. 2016, Cordell and Tarrant 2002). The demographic data collected for natural product gatherers could help more detailed survey programs target likely NTFP harvesters.

Finnish researchers also work with volunteers to actively monitor NTFPs in the wild. They create annual yield estimates for berries based on inventory and climate data (Wong et al. 2001) and survey NTFP buyers about market conditions (Paassilta et al. 2009). The approach indicates that having repeated periodic surveys of NTFP harvest combined with monitoring and production support can improve NTFP tracking.

2.8.3 Challenges and Considerations for Tracking Products

NTFP production systems have characteristics that should be considered in the design of programs to track product movement. The diversity of NTFP markets complicates these efforts. In one forest district in the national forests of North Carolina, products are harvested for the floral industry, craft industry, medicinal products, nursery stock, and edibles (USDA Forest Service 2015b). Many products are collected for personal use, some make their way to regional markets as specialty or niche products, and others, such as American ginseng, are commodities that may be bought and sold several times and end up in distant domestic or international markets. Tracking programs should prioritize products based on some metric such as amount of volume harvested, monetary value, and scarcity of the plant.

The informal nature of the NTFP economy is another obstacle to effective tracking of the volumes of products harvested. Many NTFP markets are seasonal, and harvesters may be difficult to identify or contact, or they may not want to be identified as their work provides undocumented or untaxed income (Alexander et al. 2002). At the primary point of sale, cash transactions are common, and the extent of accurate record keeping by market participants is unknown. Primary buyers may not advertise and rely instead on a large network of suppliers. Identifying participants and key products can be difficult. When buyers or harvesters are not publicly listed, chain referrals, or the *snowball method*, can help locate participants (Greenfield and Davis 2003, Schlosser et al. 1991).

Identifying the optimal place in the supply chain to concentrate tracking efforts is another difficult task. While some NTFPs are sold directly from harvesters to consumers, there is a great deal of variation from product to product. An hourglass may best describe the shape of the typical NTFP market. At the bottom, a large number of harvesters sell to local buyers, who in turn sell the raw product to a few regional aggregators. Depending on the product, aggregators may process the product themselves, export the raw material, or sell to domestic processors such as herbal supplement manufacturers. Products then reach a large number of consumers through numerous outlets such as grocery or health food stores, craft shops, florists, or restaurants (Greene et al. 2000).

Tracking programs that collect data on where products are harvested must be conducted close to the point of harvest. Harvesters have the most accurate information about where products come from but may be difficult to locate and less likely to participate. Primary buyers are easier to locate and likely to know the general location where products were harvested (at the county level, for instance), but they may not keep accurate records of transactions. Large regional aggregators have varying levels of familiarity with product origin, and they may be easier to locate, but at this level, raw materials often have been consolidated into large lots, making it difficult to identify harvest locations. There also may be trade between participants, meaning products could be counted twice. At the other end of the supply chain there may be more record keeping, but even less knowledge about where the raw materials originated. By choosing any point on the supply chain, a tracking system may miss outliers, such as harvesters who make their own value-added products, but this is likely a small portion of what moves through the supply chain. With the exception of permitting programs, which target harvesters, the tracking systems that collect geographic data rely on primary buyers.

Low participation in tracking programs is possibly the greatest challenge in creating effective methodologies. The NTFP community often is described as secretive or having a closed culture, but there are practical reasons some people choose not to participate and practical reasons for maintaining confidentiality for those who do. Some concerns may be rooted in the potential legal ramifications for under-reporting cash transactions or trading in products harvested illegally. Competition within the industry, where personal relationships in the supply chain form a currency, can heighten the desire to protect information and increase reluctance to participate. In marginalized NTFP communities, there may be linguistic or cultural barriers to participation.

Often, NTFP producers choose not to participate simply because they see no benefit, or none that outweigh the burden and perceived consequences of participation. Communities engaged with NTFPs often have a history of negative experiences with Government agencies and other institutions (McLain 2008). These are exacerbated when policies are made without input from market participants, by people who generally do not understand how NTFPs are harvested and sold, or other nonenvironmental forces such as land use changes and local economic conditions. There is concern that this lack of contextual knowledge will lead to data being misinterpreted.

Affiliation with a university or nongovernmental organization might make it easier to work with NTFP groups (Greenfield and Davis 2003), but as Love and Jones (1997) observed, regulation and research often go hand in hand. Unlike timber, which has a great deal of research and management resources devoted to its production, NTFP management strategies often are limited to restricting harvest. Giving up hard-earned knowledge about their livelihood can mean participants are relinquishing control over it, and may lose access to valuable resources (McLain et al. 2008).

To successfully track NTFP harvest volumes will require participation of stakeholders, who must feel that the program is effective, fairly applied, and beneficial. Knowing the context of tracking data is vital for effective management decisions. This includes the structure of supply chains, the practice of harvesting and trading, and changes in price and consumer demand. NTFP economies vary across regions and within sectors there may be a multitude of species. Effective tracking programs will focus on products that have high economic value, are heavily harvested, or that are threatened or declining. Tracking programs will be most effective when part of a system that also monitors plant populations and engages market participants.

2.9 Knowledge Gaps

Nontimber forests products are many and diverse. Our knowledge of them is basic and developing. Gaps in knowledge about the products and management are similar through the United States and insular territories. Silvicultural practices abound for timber and may be applicable to nontimber but need to develop further to deal with complexities created when NTFPs are integrated into management strategies. Forest farming these products is becoming attractive to landowners as an innovative income stream, yet research-based knowledge about growing and the profitability of NTFPs under trees is lacking.

NTFP science is rudimentary, at best. With some products, little more is known than basic ecology and botany of the plant or fungus whence the product originates. With others, such as American ginseng, our knowledge is more developed. There is a great deal of traditional and local ecological knowledge that guides stewardship and use of NTFPs. The science-based knowledge regarding these products, however, is wanting. Research that respects and integrates traditional and local knowledge with scientific analysis is warranted.

The species discussed in this document represent a collection of expert knowledge but not a complete list of NTFPs. The list will change with time as many products have yet to be identified or documented. The many uses of these products have to be explored. The volumes and values of these products are not fully defined, nor are the methods developed to collect these data. More important, there is a lack of knowledge on how to manage the resources whence the products originate to ensure that the resources are available in perpetuity.

The integration of NTFPs with established silvicultural practices can increase economic benefits for landowners and ecological benefits for forests. More information is needed on the ecology, life history, and demography of target NTFP species, across a variety of silvicultural treatments and site types with close attention to species responses to disturbance regimes resulting from timber management. The role of biotic and abiotic factors on regulating the growth of NTFP species could be better understood. There is an increasing body of knowledge related to microbial and fungal communities that needs consideration to apply these lines of inquiry to better elucidate the role they have in regulating the ecology and economies of managed forests. With the growing interest in NTFPs, research is needed to determine sustainable harvest levels for specific species, particularly when harvest kills the plant, across a variety of habitats, environmental conditions, and climates.

With changing climates, research must consider current data in the context of projected future conditions in an effort to add some level of confidence to long-term management scenarios. This is especially true in the cases of shifts in species phenology and asynchrony of pollinators and dispersers, reorganization of novel communities, and the expansion/contraction of climate envelopes. Silviculture should continue to move toward managing for increasing complexity and diversity (Puettmann et al. 2009). Managing forests as complex adaptive systems will benefit integration of NTFPs in silvicultural systems and increase resiliency in the face of climate change.

Much of the information available on how to forest farm NTFPs is based on experiences in specific parts of the country. Applied research is limited and has been used in only a few regions. Growers often assume that production methods that work in one region will work in another part of the country. This has not been adequately demonstrated. As there are regional- and state-level production practices for many established crops (i.e., fruits, vegetables, grains), regional production differences for NTFPs should be expected. Some production practices that need to be studied include propagation, planting dates, soil fertility, disease and insect control, weed and herbivore control, security, time and method of harvest, post-harvest handling, food safety, marketing, and economics.

More information on the monetary value of this industry within regions and across the country is needed. The knowledge about wild-harvested NTFPs in the South is predominantly based on one study (Greenfield and Davis 2003). This early study provides a foundation to understand the NTFP industry, but current and regular data are needed. Also, regional assessments are needed that examine the interactions of NTFP economies. As the forest-farming industry matures, raw material supplies should stabilize and their quality improve, which will influence demand and prices.

There is a lack of information to fully determine growth, yields, and costs needed to estimate optimal production. Forest farming is proclaimed to lead to better conservation of the NTFP, but the economics make wild-harvesting more attractive. Cultivated material should produce higher yields of uniform raw material that are positively identified (Davis and Persons 2014). More research is needed to optimize forest-farming systems to increase yields and reduce costs of priority products with significant market potential. Manufacturers and consumers using NTFPs need to be educated about the improvement in product quality and benefits to the forest and community economics of purchasing forest farmed products.

The impacts that policies and regulations have on NTFPs are not fully understood. Regulations affect various products at the international, Federal, and state levels. Should a plant become listed with CITES or as a federally endangered species, laws take effect that limit or restrict harvest and commerce of associated products. Nursery permits and inspections and export permits often are required depending on the product and state in which they are grown. Chapter 7 provides a comprehensive analysis of policies and regulations that impact NTFPs and provides valuable insights into the impacts that policies may have on the products.

The social and economic importance of NTFPs has been underestimated (see chapters 5 and 6) in the insular areas of the Caribbean and the Pacific. Data are usually not available on income produced from forestry-related activities and quantitative data for NTFPs are basically absent (Chakroff 2010; FAO 2000, 2005a, 2005b, 2005c). Major challenges and opportunities in the Caribbean region include the need for public education about the products, the need for a revival of a traditional knowledge about the plants and their uses (Alvarado-Guzmán et al. 2009, van Andel 2006), competition from imported souvenirs, and the need for improving marketing techniques. Building local capacity for the continuous operation of sound forestry programs and developing public awareness about sustainable forest management practices is essential (American Samoa Community College 2010, FAO 2001).

A confounding issue that affects NTFP inventory and monitoring is the tremendous diversity of plants and fungi that make setting priorities essential. Specific inventory methods may be required for each species or plant organ, but methods need to be tested and modified accordingly. With so many different products, developing and implementing standardized inventory protocols is challenging, but not impossible. Commonalities exist, however, between inventory methods that create potential for the transfer and sharing of techniques. The diversity of plants and fungi, and products, should not be a constraint undertaking inventory and monitoring programs, but impetus to prioritize products based on ecology, economics, and social and cultural importance.

FIA data do not provide sufficient information for thorough analysis of the sustainability of NTFPs under increased climatic variability. The main data are obtained from trees greater than 5-inch diameter, and smaller trees are recorded only in smaller nested plots and may be underrepresented in an inventory. As most NTFPs come from nontree plants and fungi, they are seldom, if at all, represented. Collection of vegetation profile information is optional, meaning it depends on funding and regional priorities and is not collected on all plots each cycle. Furthermore, vegetation profile data focus on the most abundant species, and important NTFPs that occur rarely may not be represented in the database. Fully and adequately representing NTFP species in forest inventory will require modified approaches that account for disparate population distributions.

The tree measurements that form the basis for many inventory parameters (e.g., volume and biomass) may not be related to measures of production of NTFPs (e.g., boughs, fruit, seed) but can be viable examples in the formulation of inventory systems. Thus, while the FIA data provide information on abundance and geographic distribution of trees, this information may not be readily translatable into data relevant to NTFP resource monitoring or management. Developing inventory or tracking systems for NTFPs will require a consideration of the phenology and ecology of diverse plants and fungi.

Another challenge with inventory of NTFPs is the difficulty of observing changes to individual plant species and populations over time. With trees harvested for timber products, it is a simple matter to determine whether a harvest has occurred: a tree that was measured on a prior inventory is no longer there, and usually a stump remains as an indicator of the removal. This is not true with many understory plants that may not be long lived, that may not be readily or easily identified, that may have unpredictable dormancy, and from which only portions are harvested. This is also the case for mushrooms, whose primary structure is underground. While mushroom fruiting body surveys are possible, they do not accurately represent the populations of the organisms. Finally, the sparse sampling intensity of FIA plots, while adequate for regional volume estimates for forests overall, leads to estimates that can be highly variable. This means that inferences about changes over time are only reliable at very large scales, which may not be adequate for NTFP species.

2.10 Implications of Increased Climatic Variability for Production and Management

Long-term effects on native NTFP resources will be challenging to predict and deserve significant examination. Projected shifts in forests imply that NTFP species will be impacted. Climate change models indicate warming and drier conditions that will affect trees such as pinyon pine, maple, and black ash that are the sources of valuable NTFPs. Understory NTFP species may be particularly sensitive to changes in forest structure. Coastal forests and insular forest ecosystems are particularly vulnerable to changes in climate and related stressors. Forest fragmentation with changing climate can have serious consequences on natural populations of NTFP resources and associated pollinators.

Increasing climatic variability has the potential to seriously affect populations and species of plants and fungi that provide NTFPs. Little is known about how climatic variability will affect understory plant communities. While shifts in precipitation regimes are likely more important than temperature on the forest floor, the lack of understanding of understory dynamics creates a great deal of uncertainty. Forest fragmentation combined with shifting climate envelopes can have serious consequences for demographics of wild populations of important NTFP species, specifically dispersal-limited myrmecochorous herbs. Phenological changes due to climatic variability could result in pollinator or dispersal asynchrony in species with highly specialized interactions (Hegland et al. 2009). Furthermore, changes in the intensity or frequency of climate-caused disturbances also can affect NTFP species distribution and levels of production (Dale et al. 2001). Further, environmental variability can affect the quantity and quality of some NTFPs, presenting additional challenges for management.

Interactions between climate and invasive species further complicate managing for NTFPs. Black ash (*Fraxinus nigra* Marshall), important culturally and economically to basket makers across the Northern United States, provides an exceptional example. The emerald ash borer (EAB) has killed millions of ash trees and is expanding its range. Because EAB has no known predators or natural resistance, all North American ash species are at risk of extinction (Herms and McCullough 2014). While duration of cold temperatures could slow the northern movement of EAB, occurrence and duration of low temperatures is declining even in the northern parts of the range (Crosthwaite et al. 2011). Black ash of the quality needed for basketry will become increasingly difficult to find, endangering a valued cultural tradition as well as the income generated by the sale of these baskets.

Other NTFPs may be impacted from climate, as well. Little is known about how ostrich ferns, which grow across a wide range of plant-hardiness zones and prefer hydric soil conditions, will respond to changing climates. Climatic variability is a concern for maple syrup producers, as production is primarily weather dependent and relies on predictable temperature swings below and above freezing to get sap to flow. Some researchers, however, have predicted that the habitat suitability for sugar maple will decrease in the Northeastern United States as ambient temperatures increase (Mohan et al. 2009). Climate change models indicate a warming and drier Western United States (Intermountain Society of American Foresters 2013) that could seriously impact pinyon production. Impacts to NTFP species is not limited to continental United States.

Climatic variability is likely to exacerbate many existing pressures and threats to the forests of the insular areas of the Caribbean and Pacific. Potential impacts of warming temperatures and altered hydrologic regimes include the loss of mangrove forests and arable land on the coast due to sea level rise, damage to terrestrial forests due to higher frequency of extreme events and fires, reduced agricultural yields due to decreased rainfall or droughts, and increased invasion by nonnative species as a result of higher temperatures (Neville 2014, UNEP 2008). If extreme meteorological events increase in frequency and intensity, changes of familiar species assemblages and availability of NTFPs are expected to occur due to variations in the time available for reproduction and senescence or selective pressure on organisms (Lugo 2000). In addition, future climatic variability could result in large changes in dust from African regions to the Caribbean, the effects of which on the vegetation have yet to be studied (Pett-Ridge 2009, Prospero and Lamb 2003).

Data released by NASA and NOAA verified that 2014 was the warmest year on record since 1880, and nine of the ten warmest years on record have occurred since 2000 (NASA 2015). Recent temperature trends and climate predictions have resulted in new terminology associated with climate issues, which will directly affect NTFPs. These include, “zone creep,” “season creep,” “simultaneous opposing temperature extremes,” “growing adaptation deficit,” “adaptive evolution,” “spring creep,” and “spring mismatches.”

Zone creep refers to changes in the USDA Plant Hardiness Zones Map, which is used to determine appropriate planting areas for crops. The revised 2012 Plant Hardiness Zones Map shows an average minimum temperature increase of 5 °F across the country as compared to the 1990 map. Changing the planting and growth boundaries and moving most zones northward will impact NTFP production, directly.

For example, Ohio was formerly within Zone 5 but now is almost entirely within the warmer Zone 6. As a result, NTFP growers and harvesters in these areas may have to reconsider their planting and harvesting choices in the future (Malcolm et al. 2012). The long-term results of zone creep will affect habitats associated with specific NTFPs, with some habitats and species being more vulnerable to climatic variability (USDA 2012). As a result, storing germplasm in the form of seed before more changes occur and predicting where and which species need to be prioritized for conservation are essential long-term strategies.

Season creep and *spring creep* refer to differentiation of first and last frost dates, which may alter pollinators (Schwartz et al. 2006, Sherry et al. 2007). Phenology is a sensitive biosphere indicator of climate. Long-term surface data and remote sensing measurements indicate that plant phenology has advanced by 2 to 3 days in the spring and been delayed by 0.3 to 1.6 days in the fall per decade over the past 30 to 80 years, which culminated in a significant extension of the growing season in 2015. As temperatures rise, spring seasons are arriving earlier while winters are shorter and more extreme. With this season change, frost vulnerability becomes more of a threat, where high spring temperatures create earlier flowering schedules, leaving blooms at risk of freezing (Inouye 2008, Souther and McGraw 2014). This is important to mountain-dwelling NTFP species, which are increasingly experiencing frequent frost damage due to early blooming.

Increased pests are yet another result of this phenomenon, wherein warmer, shorter winters provide favorable conditions for pest populations. Mild winters allow pest populations to increase instead of die out over the winter (Jamieson et al. 2012). For example, Gypsy moths, tent caterpillars (*Malacosoma* spp. Hübner), beech bark disease (*Neonectria* spp. Wollenw), and hemlock woolly adelgid (*Adeleges tsugae* Annand) are expected to expand their ranges due to the changing seasons, affecting crop and forest health (Dukes et al. 2009). Projections by the USDA speculate that the potential impact of this spread and redistribution of agricultural pests may reduce agricultural returns by $1.5 billion to $3.0 billion by 2030 (Malcolm et al. 2012).

Adaptational lag is another concern that will impact NTFP species as they adapt to changes in climate. If species cannot keep up with rapid climate alterations, populations and entire species may decline or go extinct (appendix 2—Assessment of Risk Due to Climate Change). In one European study, a common garden experiment tested lagging adaptation to a warming climate using banked seeds of the annual weed mouseear cress (*Arabidopsis thaliana* (L.) Heynh.) across the species' native climate range (Wilczek et al. 2014). Genotypes originating in southern climates, historically warmer than the planting site, had higher relative fitness than native genotypes at every site. This suggests that local adaptive optima have shifted rapidly with recent climate warming across the species' native range and that the potential for adaptational lag deserves consideration in conservation and wild harvest management decisions for many species.

The National Phenology Network reported that earlier spring dates create *spring mismatches* as some plants are budding earlier and the animals that depend on them have not adapted to this change (Fitzpatrick 2010). As example, bees may target specific habitats with plant populations they historically pollinate only to find those plants have already bloomed. These mismatches can be fatal. Many medicinal forest plants, such as bloodroot, are myrmecochorous: they have a specialized seed dispersal mutualism with ants. Warren et al. (2010) found that climate change differentially affects the phenology of hepatica or liverworts (*Hepatica nobilis* Schreb.) and their ant dispersers. Furthermore, Willis et al. (2008) found phylogenetic relationships between plant species with limited capacity to shift flowering time to respond to climatic changes. These species include a number of important NTFPs including orchids (Orchidaceae), mints (Lamiaceae), and roses (Rosaceae), suggesting that this lack of phenological plasticity may be a conserved trait and detrimental to long-term population maintenance under changing climate.

Long-term effects on native NTFP resources in the United States due to predicted climate trends will be difficult to forecast but deserve study to prepare for conservation of populations. Projected shifts, which were estimated using years for which data were available, in forest types for the United States (figure 2.7) suggest significant changes in structure that will affect NTFP resources (Karl et al. 2009). Depending on regional hardiness zones and habitat, long-term effects will vary by species and need to be prioritized based on predicted risk factors.

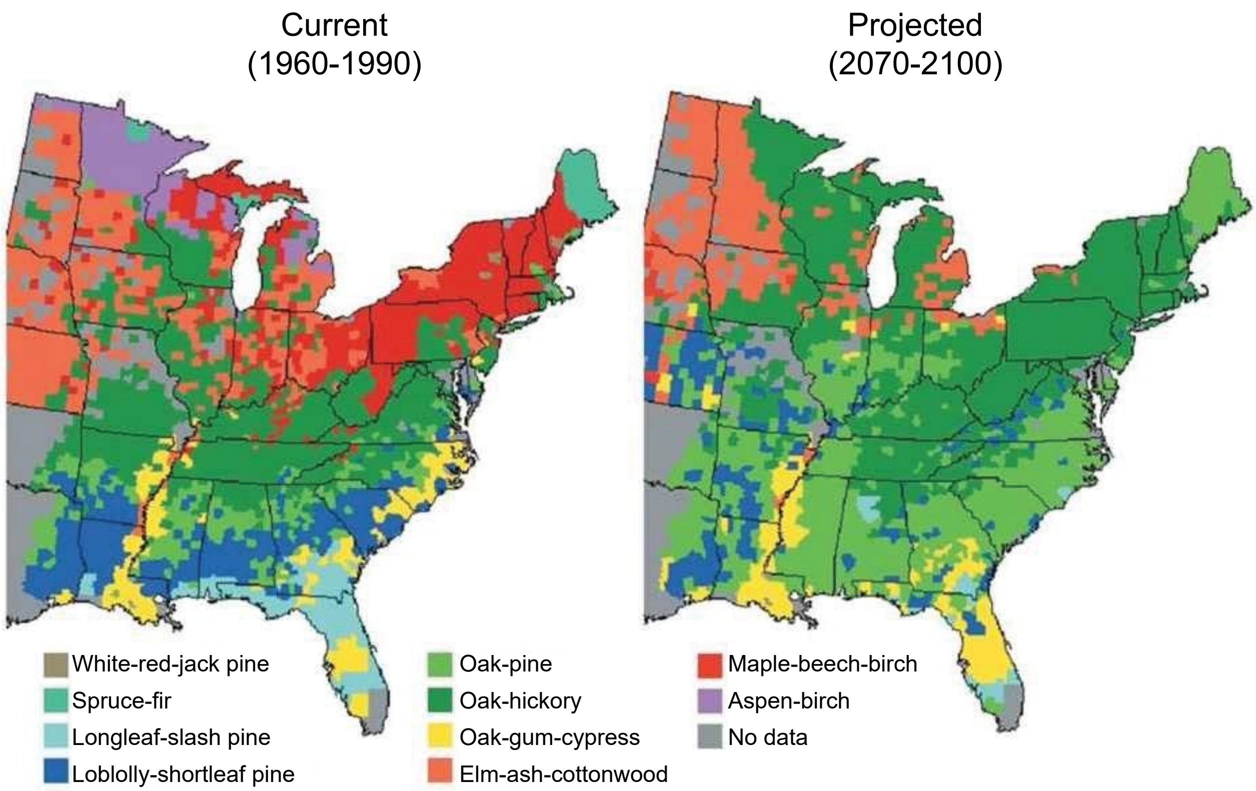

Figure 2.7—Current and projected shifts in forest types in the eastern United States with major changes. For example, in the Northeast, under a mid-range warming scenario, the currently dominant maple-beech-birch forest type is projected to be completely displaced by other forest types in a warmer future (Karl et al. 2009).

2.11 Key Findings

- Across all forest landscapes, throughout the United States and its insular territories, there is great variety of native plants and fungi, the organs of which are harvested for their nontimber values by a diverse group of people and for many different uses.
- There is rudimentary knowledge about the plants, products, people, and places, and evidence suggests significant ecological, social, cultural, and economic values.
- More is known about American ginseng than, perhaps, any other medicinal forest product, in part due to its listing in CITES, a mandatory reporting that has provided significant data useful for monitoring and management.
- Integrating NTFPs into forest management will require balancing multiple and often conflicting land use objectives; thinning and uneven-aged silvicultural treatments can lead to healthy stands valued for their NTFPs.
- Changes in forest dynamics, including soil moisture and temperature due to climatic variability and silvicultural practices, may impact growth and maintenance of natural populations of associated NTFP species, particularly understory spring ephemeral herbs.
- Silvicultural practices can address the complexities created when NTFPs are integrated with timber management that require understanding the interactions of NTFP species and the trees, which is essential for co-management of timber and nontimber products to continue providing benefits under climate change.
- Forest farming has potential for economic development of rural communities while improving conservation of native nontimber forest species, but production decisions often are based on anecdotal evidence that would be improved with science-based knowledge.
- To sustainably manage the utilization of NTFPs requires inventory data of the plants as well as the raw products, ways to track and monitor product volumes and values, as well as estimating and tracking demand for the final product.

- The complexity of forest management increases when NTFPs are considered, and that complexity should be viewed as an opportunity to improve forest management and other sectors of the forest products industry and constituents.

2.12 Key Information Needs

- There is an urgent need for a nontimber product output tracking system that will provide regular information on harvest volumes, whence products are harvested, prices, and other pertinent data that will generate better knowledge of the NTFP markets.
- Priority information needs exist that can only be realized through integration of NTFP species, prioritized by their ecological, economic, and cultural values, into all phases of Forest Inventory and Analysis.
- With growing interest in NTFPs, information is needed to determine sustainable harvest levels and practices for specific species, particularly when harvest kills or increases the likelihood of plant mortality, and how populations respond to harvest, across habitats, environmental conditions, and climates.
- Silviculture practices can encourage NTFP species growth and production, and information is needed on their ecology, life history, and growth and yield to coalesce the knowledge to encourage integrated forest management.
- Much of the information available on forest farming NTFPs is based on experiences with limited science-based knowledge on growth, yield, costs, and benefits needed to estimate optimal and sustainable products.

2.13 Conclusions

NTFPs originate from biological resources that are harvested from forests and may include fungi, moss, lichen, herbs, vines, shrubs, or trees. The Forest Service and BLM have promulgated official definitions of NTFPs and have policies and regulations to address the harvest and management of these products. By some estimates, a quarter of the U.S. population harvest NTFPs for their personal use as well as for financial gain through commercial markets.

The management of forests to include NTFPs is more complex and can produce a forest that is healthier and more resilient to climatic variability. Most NTFPs are harvested from natural populations with no science-based management of the resources to ensure long-term product sustainability. There are iconic NTFPs that provide insights that may be generalized to other NTFPs. Sustainable management of NTFP resources will require using local, traditional, and scientific knowledge. Silvicultural practices and treatments can be beneficial and detrimental to NTFPs. Integrating NTFPs into forest management requires understanding the ecology of NTFP species and the impacts of silvicultural treatments. Evaluating the sustainability of NTFP production requires integration of forest inventory data and market-based product tracking. Forest farming can provide landowners a means to generate revenues from their forests while retaining the forest cover.

The scale and extent of NTFP harvest are challenging to determine as there are few formal or institutionalized methods to track harvest or to inventory supply. Some data sources exist, but tracking of NTFPs is largely inconsistent, intermittent, and incomplete. Additional data are needed for adaptive management of NTFP production systems. Creating effective methodologies for estimating the scale and distribution of NTFP production is essential for sustainable utilization of these important resources. While some countries are implementing chain-of-custody tracking systems for NTFPs, such systems do not exist in the United States.

A collaborative approach to tracking products that emphasizes reciprocity can improve participation and participant investment in NTFP tracking and monitoring programs (Laird et al. 2010, McLain and Jones 2001). Future tracking strategies could benefit from a multi-method approach that integrates quantitative and qualitative data collection. Integrating data from various sources can be facilitated by greater communication between and across disciplinary boundaries and by creating standards and platforms for data sharing.

Nontimber forest species have critical functions in overall forest health. Their decline, extirpation, or extinction due to climate or lack of management will adversely impact biodiversity and the vigor and condition of forests across the country. NTFP production under increased climatic variability may not be fully predictable, but indicators suggest significant changes are likely. Plant

Hardiness zones may creep north with temperature fluctuations, thus reducing suitable habitats. NTFP species could decline or go extinct if they do not adapt quickly enough to changes in forest habitat. The biophysical changes will have significant deleterious impacts on the people who benefit from these products. The promotion of sustainable NTFP production should be seen as an adaptation and mitigation activity and economic opportunities for sustaining livelihoods (Wilkinson and Elevitch 2000). The development of appropriate interdisciplinary teams and approaches is vital to address the complex interactions between natural and socioeconomic systems regarding production of NTFPs under different climate change scenarios.

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