Estimating the value of forests for provisioning non-timber forest products to market: concepts, approaches, and case studies

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ABSTRACT

This manuscript describes estimation of the ecosystem service value (ESV) for provisioning of non-timber forest products (NTFPs) to market, with a focus on the United States. NTFPs are harvested throughout the U.S. for numerous purposes, and those sold in market contribute significantly to household and local economies. Knowing ESV aids decision-making, but NTFPs are generally neglected. We discuss challenges and approaches for prioritizing valuation, quantifying production, measuring costs and benefits, and finding data sources. Many NTFP markets are informal, and market players may have an interest in withholding information. Data about geographic and temporal distribution, production cost, quantity harvested, and price are limited. Two case studies explore the nuances of estimating ESV of forests for medicinal products.

KEYWORDS

Derived demand; Ecosystem service valuation; Markets; Non-timber forest products; Provisioning
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1 INTRODUCTION

Forests provide many tangible goods for human use. “Provisioning” of these goods is one of four categories of ecosystem service (ES) (Millenium Ecosystem Assessment 2005). Non-timber forest products (NTFPs) are a general category of goods provisioned by forests, which include food, medicine, decorations, landscaping, and arts and crafts (Chamberlain, Bush, and Hammett 1998, Chamberlain, Emery, and Patel-Weynand 2018).

NTFPs are harvested from private and public forests throughout the United States (Chamberlain, Emery, and Patel-Weynand 2018, Jones, McLain, and Lynch 2004), providing significant economic benefits to harvesters and related enterprises (Alexander, McLain, and Blatner 2001, Alexander, Oswalt, and Emery 2011, Chamberlain, Teets, and Kruger 2018), and are collected for personal as well as cultural purposes (Cordell et al. 2012, Robbins, Emery, and Rice 2008).

Perhaps one-quarter of the U.S. population harvests NTFPs, a portion of which is for non-market purposes such as home consumption, and a portion of which is for sale in formal and informal markets (Bailey 1999, Butler 2008, Butler et al. 2016b, Cordell and Tarrant 2002, Emery et al. 2003, Jones, McLain, and Lynch 2004, Robbins, Emery, and Rice 2008).

Despite manifold uses and widespread extraction, NTFPs are generally overlooked in forest management. Appropriate valuation can help decision-makers understand the potential impact of forest management on the welfare of surrounding communities. Lack of publicly-available data, informality, secrecy, and other interrelated factors make integrating market-based NTFPs into forest valuations particularly challenging.

We describe concepts and approaches for estimating the ES value (ESV) forests generate by provisioning NTFPs to markets. We recognize that non-market values including subsistence, cultural, spiritual, and recreational uses, are important to communities that practice NTFP harvesting; however, the scope of this paper is to consider approaches and challenges for estimating ESV for market-oriented NTFPs. We outline steps toward identifying which NTFPs
may be appropriate for estimating ESV, quantifying production, measuring costs and benefits, and finding data sources. We also explore methods with simple case studies.

2 BACKGROUND

2.1 Definition and Classification

While the definition of “non-timber forest product” can vary, most literature on NTFPs in the United States focuses on specific plants or fungi that grow in forests. NTFPs do not include “timber”, that is, wood utilized at industrial scales or sold in commodity markets, but do include firewood and wood for artisanal purposes (Belcher 2003, Chamberlain, Emery, and Patel-Weynand 2018). Most literature on NTFPs in the U.S. does not include animal wildlife, which typically receives separate treatment in forest management and scientific literature.

Five market “segments” define the NTFP sector (Chamberlain et al. 2018): edible products, medicinal and dietary supplements, decorative products, landscaping inputs, and supplies to arts and crafts. Examples of each segment illustrate the diversity of products and markets. Fruits, berries, nuts, sap, fern fronds, tubers and bulbs are edible products. Each year, sales of maple (Acer spp.) syrup contribute more than $100 million to the U.S. economy (Farrell and Chabot 2012). Thousands of kg of ramps (Allium tricoccum), a native forest onion, are harvested each year for the expanding foraged food market (Baumflek 2016). The medicinal and dietary supplement segment of the NTFP industry depends on large quantities of plant materials harvested from forests for their therapeutic values. Extract of Pacific yew (Taxus brevifolia) bark was found in the early 1990s to be effective for treating ovarian cancer (Chamberlain, Bush, and Hammett 1998). Forest plants and their parts are sold to the decorative segment as greenery in floral arrangements or as the main component of fresh and dried ornaments. In 1995, the U.S. exported more than $14 million in forest-harvested mosses and lichens, most of which originated from Appalachia and the Pacific Northwest (Goldberg 1996). Live forest plants are also collected for the landscaping industry. At one time, seedlings of Fraser fir (Abies fraseri), endemic to the Southern Appalachians, were ‘pulled’ from the forest floor for transplanting to Christmas tree farms. Collection of forest understory wildflowers for horticultural sales is a cottage industry in parts of the eastern U.S. (Cullina 2000). The number of NTFPs used for arts and crafts is limited only by the imagination of the artisan (Chamberlain et al. 2018, p. 17). In general, though, NTFP
extraction and sale for markets has been little studied relative to other forest goods and services, and the economic importance of these natural resources have, therefore, been underappreciated.

2.2 Methods of Production and Sale

Typically, NTFPs are sourced through two types of production methods. In traditional “wild harvesting”, people forage the products from forests, with few inputs except for their time, transport, and minor incidentals such as a digging tool. “Forest farming”, by contrast, is the cultivation of forests to produce NTFPs (Chamberlain et al. 2018). Several methods of forest farming are generally accepted (Chamberlain et al. 2009). “Wild-simulated” forest farming system, includes only limited site preparation and planting, whereas a “woods cultivated” forest farming system is more intensive, potentially incorporating tillage and soil amendments, and “woods grown” forest farming methods rely on more inputs and maintenance. The method of production clearly has direct implications for production costs, and, thus, the valuation of the provisioning ES.

The level of market formality and the method of sale also have implications for ES valuation. In a first case, the landowner and harvester may be one and the same. Second, the harvester may access sites without compensating the landowner (or indeed, in some cases without the landowner’s knowledge or permission). In this case, the first point of sale may be between harvester and dealer. Third, the harvester may compensate the landowner, but outside competitive markets. This may be particularly true for harvest permits on federal lands, such as the National Forests. Fourth, commercial harvesters may directly pay a landowner for access in a competitive marketplace, as seems to be true in certain instances for saw palmetto (*Serenoa repens*) in Florida, and pine (*Pinus* spp.) straw in Georgia. Fifth, the harvesters may be employees or contractors of a larger company and may be paid either per hour or per volume of product collected. Lastly, in many cases which are important for future work but not considered in this manuscript, no market transaction takes place at all. Rather, the product is directly consumed by the harvester or given to friends and family (Frey et al. 2018).
2.3 Conceptual Model

2.3.1 Derived demand

ES valuation has traditionally relied on revealed or stated preferences to estimate users’ willingness-to-pay for access or willingness-to-accept compensation to forgo a particular non-market service – their “compensating surplus” or “equivalent surplus” (Freeman 2003). Such welfare measures are equivalent to the area under a compensated (“Hicksian”) demand curve (Freeman 2003). The Hicksian demand curve represents the quantity demanded at each price, at a constant level of individual utility.

In cases where NTFP provisioning services are truly non-market in nature, appropriate revealed or stated preferences methods must be engaged. Many users directly harvest NTFPs for subsistence, recreational, cultural, or spiritual values. In many cases there is no monetary transaction, or a simple purchase of a harvest permit outside of a competitive marketplace (e.g., a fee determined by a government agency). For these situations, clear parallel to recreation demand exists, and traditional non-market valuation methods, including travel cost, hedonic pricing, stated preference, or other methods, can be applied. The travel cost method, in particular, has been used for NTFP ES valuation (e.g., Markstrom and Donnelly 1988, Starbuck et al. 2004). While important, such methods are not the focus of this study.

The demand for a market-based NTFP provisioning service is a “derived demand,” in the sense that it is an input to the production of a good for sale. We assume input demand to be based on the profit-maximizing behavior of the producer\(^1\) (McConnell and Bockstael 2005):

\[
\begin{align*}
\Pi(p, w, v) &= \max_{i,k,e} \left[ \pi(l, k, e|f_0) \right] \quad (2), \\
\pi(l, k, e|f_0) &= R - C = [p \cdot q(l, k, e|f_0)] - [w \cdot l + v \cdot k + g_0 \cdot f_0] \quad (1),
\end{align*}
\]

where

---

\(^1\) Many individuals or even small businesses apparently may limit their harvest simply to the satisfaction of particular needs or to meet specific objectives. Such behavior is not inconsistent the economic assumption of profit maximization; it simply means that the opportunity cost of continuing additional harvest is sufficiently high.
π(l, k, e | f_0) are the producer’s profits as a function of labor (l), capital (k), and the ES (e), given fixed inputs (f_0),

R and C are revenues and costs, R is the output price (p) times the quantity produced (q), and C is the sum of the costs of the inputs labor, capital, and fixed costs,

q(l, k, e | f_0) is the production function, mapping the quantity produced as a function of the inputs,

w and v are the input prices and \( g_0 \) the fixed input price, and

\( \Pi(p, w, v) \) is the profit function, which finds the maximum profit for any combination of input and output prices.

The input demand function for the ES can be derived from the profit function \( \Pi(p, w, v) \). To estimate the value of non-marginal changes of the ES (e), the production function \( q(l, k, e | f_0) \) must be known at all production levels and for all producers. Further, if the change in the ES ultimately induces a change in the price (p) of the consumer good, then, to fully estimate the changes in welfare, understanding the demand function for end-use consumer goods will be necessary (Freeman 2003, McConnell and Bockstael 2005).

Access to a resource affects who can harvest and how much they can take. In the extreme case, open access resources allow any harvester to take as much as desired, as appears to be the case for certain marine fisheries (Gordon 1954, Flaaten 2011), and, arguably, in a de facto sense for some NTFPs, when access is difficult to control and enforce (Bulte and Engel 2006, Frey, Chamberlain, and Prestemon 2018). In such situations, economic theory holds that economic overproduction\(^2\) will drive resource quasi-rent to zero (Flaaten 2011). If the landowner can control access, a harvest level lower than the open access equilibrium can be enforced, generating resource quasi-rents.

\(^2\) Economic overproduction does not necessarily imply biological or ecological overharvest. Economic overproduction means profits are not maximized, whereas biological overharvest means yields are not maximized (Flaaten 2011, Gordon 1954).
We focus here on how best to estimate the provisioning ESV at the margin – as the resource quasi-rent ($\rho$) from the natural resource to the human owner of the service (Flaaten 2011, p. 31, McConnell and Bockstael 2005):

$$\rho = \pi(l, k, e|f_0) + g_0 \cdot f_0 = R - VC = [p \cdot q(l, k, e|f_0)] - [w \cdot l + v \cdot k] \quad (3),$$

where $\rho$ is the resource quasi-rent, or ESV, equal to profit plus fixed costs, i.e., revenue minus variable costs of production ($VC$). In practical terms, the resource quasi-rent or provisioning ESV may be thought of as that portion of product value that is owed to ecosystem function, or the “residual value” after factoring out the value added through human labor and capital (Smith, Crone, and Alexander 2010).

### 2.3.2 Net present value

We define provisioning ESVs (quasi-rents/residual values) in terms of dollars per unit of area of by forest type – perhaps a bit of sleight of hand, as the area of forest is not the service itself, yet a reasonable simplification for the purposes of use in forest management choices. In the simplest case, if a price is paid directly from the harvester to the landowner per unit area of forest accessed, then the contract price is equal to $R$. If the landowner has no establishment or management costs (the case for a wild-harvested product), then the ESV per unit area of the contract determines the provisioning ES ($\rho_t$) for a given year $t$:

$$\rho_t = R_t \quad (4).$$

However, the situation is usually not so simple with NTFPs. In many cases, the first point of sale is not the harvester who pays a landowner per unit area for the right to access and harvest a product in the forest, but rather the harvester receiving payment from a dealer per unit of product. In some cases, as for harvest permits on a National Forest, permit fees are not set in a competitive market and do not reflect the true ESV. With such a non-market-based permit, or when no fee is paid to the landowner, the analyst should use the first point of sale ($P_1$) in the competitive marketplace for valuation, taking into account that the harvester may have added value to the product through harvesting, transacting (transporting, marketing, selling), and possibly processing (e.g., cleaning, drying) the product. These human costs must be factored out to accurately estimate residual price ($P_0$), which is the shadow price of the product in the woods:
\[ P_0 = P_1 - (HC + TC + PC) \]  \hfill (5),

\[ \rho_t = R_t = \left( P_{1,t} - (HC_t + TC_t + PC_t) \right) \cdot Q_t \]  \hfill (6),

where

\[ P_1 \] is the market price per unit of product at the first point of sale,

\[ P_0 \] is the residual or shadow price per unit of product in the woods,

\[ HC \text{ and } TC \] are the harvesting and transaction costs per unit of product, including time travelling, collecting, marketing, and selling the product, plus fuel for transportation, depreciation of equipment, vehicles, and other factors,

\[ PC \] is the processing cost per unit of product of value-adding activities taking place before the first point of sale, including cleaning, drying, etc., and

\[ Q_t \] is the quantity of NTFP produced in year \( t \) on a marginal unit of forestland of a given forest type and ownership class.

Forest farming and managing natural populations may incur costs associated with establishment, and management, which occur before harvest. These are variable costs, but are usually associated with costs per unit of land area, rather than costs per unit of product:

\[ \rho = R_0 - VC = \left[ (P_1 - (HC + TC + PC)) \cdot Q \right] - [EC + MC] \]  \hfill (7),

where \( EC \) and \( MC \) are establishment and management costs. However, because establishment and management costs occur many months or even years before harvest, analysis should consider the opportunity cost of time, by discounting future values relative to present ones. The quasi-rent, or residual value, over a finite period \( T \), considering the opportunity cost of time, is given by net present value (\( NPV \)), which can be converted to the soil expectation value (\( SEV \)) for an infinite time horizon, or the equivalent annual income (\( EAI \)) (Alexander et al. 2002, Cubbage et al. 2015):

\[ \rho_T = NPV = \sum_{t=1}^{T} \frac{R_t - C_t}{(1 + \delta)^t} = \sum_{t=1}^{T} \left[ \frac{(P_{1,t} - (HC_t + TC_t + PC_t)) \cdot Q_t}{(1 + \delta)^t} - [EC_t + MC_t] \right] \]  \hfill (8),

\[ \rho_\infty = SEV = NPV + \frac{NPV}{(1 + \delta)^T - 1} \]  \hfill (9),
\[ \rho_t = \frac{EAI}{SEV} \delta \]  \hspace{1cm} (10),

where

\[ NPV \] is the per unit area net present value over the finite “rotation” period \( T \), on forestland of a given forest type and ownership class, and

\[ \delta \] is the discount rate.

### 2.3.3 Geospatial variation

The harvestable quantity of a product is not constant over space, but varies according to population characteristics and site conditions. These differences are critical in marginal valuation since site production varies. Some sites \((i)\) will support more harvest \((Q)\) than others as:

\[ Q_{t,i} = q(H_i, Q_{t-p,i}) \]  \hspace{1cm} (11),

where \( H \) are the habitat characteristics affecting growth and yield of the plant.

Furthermore, harvest and transaction costs \((HC\) and \(TC)\) vary based on numerous factors as:

\[ TC_i = tc(D_i) \]  \hspace{1cm} (12),
\[ HC_i = hc(G_i, S, Q_i) \]  \hspace{1cm} (13),

where

\[ G \] is a vector of variables representing the difficulty of the topography and terrain at the harvest site,

\[ S \] is a vector of variables representing species characteristics affecting the difficulty of harvest, and

\[ D_i \] is a vector of variables representing distance from market or population center from access point, and distance and terrain from access point to harvest site.

These functions must be defined and integrated into the relevant equation (7) or (8), for a given species over multiple sites.
2.3.4 Producer expertise and harvest cost

A given forest area may have multiple NTFP harvesters, each with different price structures. Total harvest effort increases with the addition of more harvesters to an area. In this case, harvesters with lower costs achieve higher “intra-marginal” rents, which are distinct from the resource quasi-rents (Flaaten 2011, Sec. 7.1).

Consider ecological knowledge, recognized as a valuable input in the sustainable production and harvest of NTFPs and the conservation of the natural resources (Ballard and Huntsinger 2006, Lake et al. 2018, Hummel and Lake 2015, Watson et al. 2018). Many aspects of ecological knowledge can be difficult to categorize and quantify, but one example is knowledge of the location of a plant population that could be harvested. A “perfectly knowledgeable” harvester would park at the closest forest access point and walk directly to the plant population to minimize time and cost. A “perfectly unknowledgeable” harvester would wander the forest searching, wasting valuable time. Ecological knowledge itself thus creates value, attributable in this case to the harvester, not to the ecosystem.

More generally, the intra-marginal rent due to lower costs of production may be attributed to the lower-cost harvester, and the resource quasi-rent attributed to any additional difference between price (average revenue) and production costs of the highest-cost producer (Flaaten 2011, Sec. 7.1). In equations (7) – (8), the relevant costs per unit product are the costs of the highest-cost producer, but the quantity is the total quantity harvested by all producers.

2.4 Challenges in Valuation

Several related challenges lead to difficulties obtaining data and applying research at broader spatial and temporal scales.

Lack of data from official sources – Sources of data on NTFP harvest and transactions are frequently lacking. NTFPs are restricted in geographic extent and quantity demanded, compared to commodities like timber. Therefore, NTFPs are often considered minor in economic importance, so less emphasis is put on collecting the data needed to estimate their ESV. Lack of perceived need for data reduces the incentive of government institutions like the National Agricultural Statistics Service (NASS) or for-profit services to collect market-related data.
Exceptions exist for well-known NTFPs with large regional producer bases and long histories (e.g., maple syrup, wild blueberries [Vaccinium spp.]), which are tracked by NASS. American ginseng (Panax quinquefolius) is an exception to the rule – harvest volumes are tracked because it is considered vulnerable to overharvest, and regulated by international treaty (US FWS 2015).

**Difficulty obtaining information from market players** – For the many NTFP markets that are informal with few transaction records, gathering price and quantity data is particularly challenging (McLain, Alexander, and Jones 2008). Harvesters are many, dispersed, and challenging to contact. Furthermore, there appears to be a lack of trust among NTFP market players toward inquiring outsiders (Burkhart 2011, Greenfield and Davis 2003). Harvesters have an economic interest in keeping harvest locations, methods, quantities, and prices secret, and may also wish to avoid divulging information because they lack legal work authorization, or wish to avoid income reporting to limit taxes or maintain government assistance payments (Burkhart 2011, Hembram and Hoover 2008).

**Temporal variability** – The existing year-to-year tracking of NTFP markets suggests highly volatile and unpredictable supply and demand conditions (Chamberlain, Teets, and Kruger 2018, Frey, Chamberlain, and Prestemon 2018). Demand shifts due to changing societal norms and perceptions related to the safety and the desirability of “natural”, “traditional”, and “wild” products relative to alternatives. Media coverage of the purported benefits or negative effects of specific products also affects product demand. Supply is affected by ecological and social forces. Given the number of different products, each of which may have minor value, market players (e.g., harvesters, dealers, and other aggregators) often shift unexpectedly over time. For example, American ginseng harvest levels may be affected by local or regional unemployment levels (Bailey 1999, Frey, Chamberlain, and Prestemon 2018). Many NTFPs are only available for harvest for a short season. For example, ramp harvest is restricted to the few weeks between emergence of these spring ephemerals and canopy closure when ramp leaves senesce (Chamberlain et al. 2017). Also, major disturbances, such as wildfires, can have significant impacts on product quantity and quality. Some mushroom species, for example, fruit prolifically following wildfires (Pilz and Molina 2002). A final challenge related to temporal variability is that harvest rates may be unsustainable, so valuation of annual harvests may overstate the true ESV.
**Geographic variability** – Provisioning of NTFPs is extremely variable across the forested landscape. Many NTFP species have very specific habitat requirements, and are restricted to a single forest type. This specificity makes it challenging at best to apply valuation results across a forest landscape or from one site to another. Thus, if data on total harvest quantity comes from an off-forest aggregator, accurately attributing the harvests among various forest types in a county, state, or other regional level can be difficult.

### 2.5 Past Valuation Studies in the United States

Few studies fit the paradigm of NTFP provisioning ES valuation. Among those using the \( NPV \) framework (Equation 8) for NTFPs are those for wild mushrooms in the Pacific Northwest, which assume joint production of mushrooms and timber (Alexander et al. 2002, Pilz et al. 1998, Pilz et al. 1999). A particular challenge in this system, has been estimating harvest, transaction, and processing costs (\( HC + TC + PC \) in Equations 5-8). These include time scouting and travelling to harvest sites, harvesting, cleaning, and selling the product (Love, Jones, and Liegel 1998). To resolve this challenge, the authors assumed costs either to be a fixed percentage of the sale price or a range of estimates (Alexander et al. 2002, Pilz et al. 1998, Pilz et al. 1999). Depending on species, site, and assumptions about harvest costs, management and productivity, estimated \( SEV \)s for mushrooms have ranged widely from $17/ha to $2,478/ha (Alexander et al. 2002) at a 4% discount rate. In some cases, timber value was 10 to 100 times greater than mushroom value, while in other analyses, where timber values were low and mushroom values high, mushroom value equaled or exceeded timber value (Alexander et al. 2002, Pilz et al. 1999).

Forest farming incurs establishment and management costs (\( EC + MC \) in Equations 7-8). Burkhart and Jacobson (2009) estimated \( NPV \)s for forest farming of medicinal plants in the eastern U.S. and, with the exception of American ginseng, found them to be unprofitable. Determining an appropriate hourly cost for labor (wage rate) and a discount rate, as well as projecting product prices (which can be volatile) into the future proved particularly challenging. Wage rate was estimated using an opportunity cost of $13/hr, based on average wages for comparable types of work. A range of possible values was used for discount rate and product price.

### 3 GETTING STARTED
3.1 Define the geographic area

NTFPs are harvested from most forest types across every region of the U.S. Defining geographic boundaries and setting priorities as to products for estimating ESV are essential first steps (Chamberlain et al. 2017). Some forest types are more productive, and thus warrant higher priority for ES valuation. For example, Appalachian hardwood forests have a high diversity of plants harvested for food and medicine, supplying large quantities of raw materials to industry. These forests span most eastern states and estimating ESVs for the entire region is probably unrealistic. A better approach may be to focus on a particular state, forest type, or forested area. With more geographic specificity, it is more feasible to identify and evaluate sites known as sources of NTFPs (e.g., a well-known ramp or blueberry patch).

3.2 Recognize forest type, ownership, and accessibility

Within geographic areas of interest, understanding forest types, the habitat requirements of the NTFP, and factors related to harvester access is critical. Valuation efforts should also consider the resource base as it interacts with changing ownership and management (Chamberlain et al. 2017), which may affect NTFP availability and ESVs. For example, if the availability of NTFPs on public forests decreases due to increased regulation, ESV on private lands may increase. The relative importance of land ownership type varies across the U.S., as western states have more public lands and eastern states more private lands. Conversely, as private forest habitats are impacted by land use change (e.g., mountain top removal, timber cutting, residential development), the ESV from other ownerships will be affected.

3.3 Identify NTFPs for ES valuation

Deciding which NTFP ESV to estimate is a crucial step. Institutions have limited resources for estimating the ESV and must therefore be selective. Product demand, ecological vulnerability, the status of the geographic area in the broader market, and cultural importance are key criteria (Chamberlain et al. 2017, Emery and Ginger 2014).

Priority NTFPs may be those well-known locally, nationally, and internationally, for which demand has increased, or those vulnerable to over-harvesting or other threats. For example, it may be important in some states to estimate the ESV of wild American ginseng, given the
current high demand in Asia and potential for overharvest (Ticktin 2004). The plant part (e.g., roots vs berries) harvested may increase the potential for population declines from harvesting (Ticktin 2004), increasing priority for valuation.

Actual or potential harvest quantities in an institution’s geographic area of interest/influence, relative to other regions, may indicate to decision makers that valuation is worthwhile. This perception of importance may reflect actual market demand for the product(s), as well as standing stocks of species in the forest. If the standing stock is not known, estimation of the habitat for important NTFPs within the geographic area of interest may indicate relative potential for producing priority NTFPs. The uniqueness of a product and the market stature of a producer may factor into the decision as well. For example, the state of Florida is the major producer of saw palmetto, so it makes sense that this product would be a priority for that state, as opposed to Georgia that has saw palmetto growing, but is not a major producer. Conversely, Georgia is a major producer of pine straw, which makes this more of a priority for that state.

In setting priorities for product valuation, institutions may consider the economic and cultural importance of certain products to specific communities within a geographic area of interest. The perceived importance of a product to a region’s economy, or to a specific segment of the region’s population could be a justification for estimating the ESV of that product. For example, annual ramp festivals are important to the economy of western North Carolina. As such, estimating the provisioning ESV of this edible forest product may be warranted.

3.4 Understand method of production and sale; harvest site access; data availability

Before beginning the valuation process, recognize that the valuation method will depend on the method of production (typically wild-harvested or forest farmed) and sale, market chains, land ownership and access, size of the geographic area of interest, as well as data availability. For truly wild-harvested products, no establishment or management costs exist – people forage for products in forests that are not managed for that product. For woods-grown, woods-cultivated, or wild-simulated products, relevant establishment and management costs must be considered. For products from managed natural populations, establishment costs may be negligible, but there could be management costs.
4 PROPOSED APPROACHES

4.1 Production Costs

We identified five main types of costs (establishment, management, harvest, processing, transaction) in Equation (7). These costs may vary between harvesters and products. Establishment and management costs for forest-farmed products are typically associated with the landowner, given as costs per unit area. Woods-cultivated and woods-grown costs are higher than those of wild-simulated. Establishment costs are zero for managed natural populations, and both establishment and management costs fall to zero for wild-harvested products. Harvesting, processing, and transaction costs are associated with the harvester, and are given as costs per unit of product sold.

These categories provide a broad guide. A full accounting of relevant costs is needed to allocate expenses appropriately. The first step in estimating landowner and harvester costs is to identify and describe those costs. Understanding the actual processes, activities, and timing of the costs is critical (Cubbage et al. 2015). Magnitude of inputs for each activity can then be estimated, including hours of labor, quantities of supplies, services contracted, and equipment used. Finally, a price for each input must be determined to estimate the full cost.

Many commercial harvesters and landowners are self-employed, and do not pay themselves per hour worked, and may also employ unpaid family labor. These producers may not consider their time to be a “cost” in the financial sense. However, including this economic cost is essential when estimating a provisioning ESV. Human labor represents a cost distinct from the ecosystem input.

Permit fees for access to the resource are not among the costs in Equation (7), because permits often are not set in a competitive marketplace, and thus do not represent true economic value. On public lands, permit fees could be seen as the portion of the quasi-rent allocated to the landowner while the remaining quasi-rent belongs to the harvester. In this way, the permit fee offers a lower bound for total ESV, as the harvester would presumably not accept a permit fee greater than his or her own quasi-rent (excluding the fee). However, there may be cases where the permit fee or contract price to access and extract the product are set in a competitive marketplace, such as
when private landowners sell the right to access and harvest saw palmetto or pine straw on their land. In such cases, the permit or contract price may represent the full quasi-rent (Equation 4), or an estimate of the costs of establishment and management.

4.2 Harvest Quantity

To estimate the provisioning ESV of NTFPs requires that the volume harvested per unit area of habitat be determined. In general, this is done by 1) estimating standing stock volume of product in the forest, or 2) estimating rate of harvest (i.e., flow) from a defined forest area. Standing stock measures the potential for future harvests. However, estimating the ESV of standing stock is hypothetical by nature because harvesting a large volume of the standing inventory at once could impact market prices, and the sustainability of the resource. Moreover, determining the standing stock of NTFPs is challenging, particularly for products harvested for their roots, as there are few methods (Chamberlain et al. 2013).

The most straightforward approach, and one generally favored by researchers, is to estimate the rate of harvest from a forest. The flow approach quantifies the raw material removed from an area over a period, and accounts for the volume that reaches market. The best data is collected at the location of harvest, although this requires being onsite during harvest or having a relationship with trusted harvesters who will report accurately. As noted previously, one challenge with the flow approach is that rates of harvest may be unsustainable.

The approach to estimating quantity produced will depend on the forest area defined. Ideally, a specific harvest site of fixed area has been identified where the quantity removed can be closely tracked. If this is not the case, then precise characterization of the forest type, and habitat for the species of interest must be determined. Variables such as soils, elevation, slope, and aspect may be used to quantify habitat quality (Schmidt et al. 2019). The analysis should also include factors related to human access, such as trails, roads and proximity to harvester residences. The more precisely the site can be described, the more accurate the estimation of the area of potential forest habitat for a particular NTFP or suite of products. On-the-ground verification can further improve the accuracy of estimations.
4.3 Price

As mentioned, price of NTFPs at the location of harvest will lead to the most accurate ESV estimate. It is possible that sales occur at different places along the market chain, with some enterprises buying only from harvesters, and others buying from harvesters and other dealers (Kruger 2018). This can bias data as it opens opportunities for double-counting harvest volumes. The farther along the market chain that price is collected, additional steps of value adding present more opportunities for inaccuracies. Realistically, price data are collected at the first point of sale, when the harvester sells the product to a dealer. This first point of sale, though, includes value adding through harvesting, cleaning, and transport.

5 POTENTIAL DATA SOURCES

5.1 Existing Sources

Estimating production costs requires understanding of production methods, activities, and inputs, which to our knowledge are not tracked by any data service. Past research that includes estimates of production costs has elicited this information from expert knowledge, interviews with harvesters, or monitoring of forest farmer activities (e.g., Burkhart and Jacobson 2009, Davis and Persons 2014, Huyler 2000), and cooperative extension services sometimes produce “enterprise budgets” that provide a valuable reference point (e.g., Frey 2014). These offer cost estimates, but are generally not updated nor are they replicated at multiple geographic locations.

Once activities and inputs are known, a dollar value must be placed on each. The US Bureau of Labor Statistics provides data on average wages by occupation, which can be used to find an appropriate opportunity cost of time for a typical harvester by geographic area (Bureau of Labor Statistics 2019). The Internal Revenue Service provides standard rates that can be used to estimate travel costs from the forest to the first point of sale.

Few sources provide data on the quantity of NTFPs harvested. The main sources of harvest volumes from federal forest lands are the USDA Forest Service ‘cut-and-sold’ reports, and similar reports from the Bureau of Land Management (Chamberlain, Teets, and Kruger 2018). These reports record harvests permitted, but not necessarily volumes harvested. Data reported at the forest level may be tracked to the district level, but not disaggregated by habitat type. Thus,
estimates of habitat area are needed to complement harvest data from reports. Through the USDA Forest Service’s Forest Inventory and Analysis program, tree data is available, from which the inventory of some NTFPs can be estimated. For example, trees harvested for bark are inventoried, and this data can be used to estimate the volume of bark harvested across the range of the species (Kauffman, Prisley, and Chamberlain 2015). The USDA Forest Service’s National Woodland Owners Survey provides data on the proportion of private landowners who report the collection of NTFPs on their property, but does not give species, commercial harvest volume, or price (Butler et al. 2016a, b).

Other federal and state agencies collect data on specific NTFPs. The National Agricultural Statistics Service (NASS) collects information on production of maple syrup, blueberries, and other well-known commodities, and this may be used to estimate harvest volumes for states or regions (e.g., NASS 2018). The US Fish and Wildlife Service, the federal authority for implementation of the Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES) that regulates American ginseng exports, is the repository of data on harvests reported at the state and county level. Some states allow harvesting on their forest lands, and may have harvest permit information for some of the more common NTFPs (Frey and Chamberlain 2016). Georgia, for example, provides data on pine straw production through the farm gate value reports (e.g., Wolfe and Stubbs 2013, 2015).

Trade associations, such as the American Herbal Products Association (AHPA), collect information on harvest volume and price for specific products (e.g., Dentali and Zimmermann 2012). University, government, and independent research programs from time to time have tracked input cost, harvest volume, and price for NTFPs (e.g., Alexander et al. 2002, Davis and Persons 2014, Greenfield and Davis 2003, Huyler 2000, Kruger 2018, Pilz et al. 1998, Schlosser and Blatner 1995), typically relying on interviews with dealers and harvesters over limited periods of time.

5.2 Surveys and Interviews

Because existing sources of data related to production costs, harvest quantity, and price of NTFPs are generally lacking, it is often necessary to interview market players. The closer the data source is to the point of harvest, the greater the precision of the data. As those closest to the
ES, harvesters are the preferred sources of information. The most statistically defensible approach is to randomly sample as large a sub-population from the full population of harvesters. Permits on public lands may be a source of information about harvesters, who can then be sampled for a survey. Starbuck et al. (2004), for example, compiled the names and addresses of all holders of recreational use special forest product harvesting permits from two National Forest districts in 1996, and conducted a mail survey of a sample of this population to estimate consumer surplus based on the travel cost method of non-market valuation. A similar approach could be used to contact harvesters for information related to market-oriented uses and to elicit information on production cost, harvest quantity, and price.

Often there is no list of harvesters, so random sampling is impossible. In this case, using expert knowledge to identify key groups of individuals, and selecting a robust number from each stratum may be the best option. Failing a stratified sampling approach, a chain-referral approach may be used until saturation of the population or a substantial sample has been reached (Chamberlain et al. 2017).

In certain instances, reaching harvesters is not possible, and the first point along the market chain when the products enters the formal market may be the most feasible. In the case of medicinal plants in the eastern U.S., the list of registered ginseng buyers has proved an excellent source for identifying buyers of other medicinal plants (Kruger 2018), but covers only 19 states.

A survey of wholesale firms in a specific segment of the industry may provide insights into ways to access harvesters. A snowball sample of market participants will help to identify the majority of firms. A stratified sample of known market segments (e.g., wholesale distributors of food or floral products) may be possible by examining databases available through government agencies.

6 CASE STUDIES

The case studies below represent examples for which data are currently available. For some parameters, we supplemented with estimates by the authors. The purpose of these exercises is not to provide values for decision-making directly, as much more precise information would be needed, but rather, to provide the reader with a sense of workflow, and the types of data required.
6.1 Saw palmetto

Saw palmetto, typically found in the understory of pine forests, is endemic to the Coastal Plain from South Carolina to Louisiana. The berries of the saw palmetto are used for medicinal purposes with an estimated average of approximately 8 million kg/yr (18 million lbs/yr) of fresh berries harvested – almost exclusively from Florida (Dentali and Zimmermann 2012).

‘Independent’ harvesters were paid $0.22 - 0.24/kg ($0.10 - 0.11/lb) of fresh berries (Carrington et al. 2000). Mitchell (2014) recorded prices paid to harvesters ranging from $0.22 - 2.20/kg ($0.10 - $1.00/lb), noting that on average harvesters were paid $1.10/kg ($0.50/lb) of fresh berries. Landowners who hired crews to harvest received $0.44 - 0.46/kg ($0.20 - 0.21/lb) of fresh berries, and paid harvesters about $0.15/kg ($0.07/lb) (Carrington et al. 2000). The price of harvester labor is clearly dynamic, and, although challenging, accurately estimating labor costs requires the active monitoring of buying stations during the harvest season and direct communication with harvesters to determine how much they get paid.

However, the saw palmetto market is structured such that, in many cases, a harvest contractor will pay a landowner directly, in a competitive marketplace, per unit area per year for the right to harvest saw palmetto berries from their forest. In this instance, the value of the contract between the harvester and landowner already has factored out the harvester’s costs and, if the landowner has not invested any resources in establishing or managing the saw palmetto in the forest, the contract value can be considered equivalent to the quasi-rent or ESV at the margin. Carrington et al. (2000) reported harvest contract values ranging from $38 – 77/ha/yr ($15 – 31/ ac/yr), which would be the $EAI$, and translates to an $SEV$ of $760 - $1,540 per hectare ($308 – 625/ac) at a 5% discount rate (Equations 4 and 10).

6.2 American ginseng

American ginseng is an understory plant found in eastern hardwood forests. The roots are highly valued, particularly in East Asian cultures, for a variety of medicinal purposes. Because of a long history of widespread (destructive) harvest of roots, American ginseng is a species of conservation concern and listed under CITES, and therefore harvest for export is tracked by the U.S. Fish and Wildlife Service. Annually, an average of approximately 27,000 kg dry (60,000 lbs
dry) of wild American ginseng are harvested from eastern forests for export (Chamberlain, Prisley, and McGuffin 2013, Frey, Chamberlain, and Prestemon 2018).³

Approximately 0.5% of the American ginseng harvest comes from National Forests in Georgia, Kentucky, North Carolina, and Tennessee⁴. Let us consider the Pisgah and Nantahala National Forests in North Carolina (NFSNC) as a case study⁵. The NFSNC include 422,670 ha (1,044,000 acres) in the southern Appalachian Mountains. The USDA Forest Service cut and sold reports indicate that from 2009-2012, an average of 260 kg/yr (573 lbs/yr) of green American ginseng root were permitted for harvest from NFSNC (Table 1) (Chamberlain et al. 2017).

Davis and Persons (2014) interviewed ginseng buyers (the first point of sale after harvest) throughout the eastern U.S. each year, 1982-2012, during harvest season, and report a range of prices. From 2009-2012, the average midpoint price was $1,411/kg dry ($640/lb dry, Table 1), translating to approximately $470/kg green ($213/lb green).

As a rough first approximation, which is not sufficient for decision-making purposes, we estimated approximate average ESVs for ginseng in the NFSNC. We assumed that National Forest permits were equal to harvests, they were entirely from unmanaged populations with no resources were invested in either establishment or management, that the equipment and supplies used by harvesters were of negligible cost, and that the labor of harvesting, transacting, and processing roots was the only non-negligible production input and equaled 8 hrs/kg green at an opportunity cost of $10/hr.

We used Equation (7) to estimate an annual average value for American ginseng on the NFSNC (Table 1). Because the price and quantity could be correlated either positively or negatively, we did not simply multiply the annual average price minus cost by the annual average quantity

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³ An approximate equivalency is 3 kg green = 1 kg dry (personal communication: James Hamilton, NC Cooperative Extension Service).
⁴ Percentage is authors’ estimate based on an annual average of National Forest permitted harvest of 404 kg green (Chamberlain et al. 2017) divided by total U.S. harvest of 81,000 kg green.
⁵ The NFSNC include the Pisgah, Nantahala, Uwharrie, and Croatan National Forests; however, ginseng harvest is permitted only on the first two. We use the acronym NFSNC because it is used for administrative purposes and permit reporting, but for practical purposes with regard to permitted ginseng harvest, we only include information related to the Pisgah and Nantahala.
harvested. Rather, we calculate the ESV as an average EAI of $94,462/yr, or an SEV of $1,889,230 at a 5% discount rate, translating to $4.47/ha ($1.81/ac) or $0.22/ha/yr ($0.09/ac/yr).

Table 1. First approximation of average value estimates of American ginseng on the National Forests in North Carolina, 2009-2012.

<table>
<thead>
<tr>
<th>Year</th>
<th>Midpoint price at first point of sale ($/kg green)</th>
<th>Assumed cost of harvesting, processing, and transaction ($/kg green)</th>
<th>Quantity permitted for harvest (kg green)</th>
<th>Establishment and management costs ($/ha)</th>
<th>American ginseng estimated annual value for NFSNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>$349</td>
<td>$80</td>
<td>289</td>
<td>$0</td>
<td>$77,741</td>
</tr>
<tr>
<td>2010</td>
<td>$533</td>
<td>$80</td>
<td>208</td>
<td>$0</td>
<td>$85,617</td>
</tr>
<tr>
<td>2011</td>
<td>$393</td>
<td>$80</td>
<td>208</td>
<td>$0</td>
<td>$65,104</td>
</tr>
<tr>
<td>2012</td>
<td>$606</td>
<td>$80</td>
<td>284</td>
<td>$0</td>
<td>$149,384</td>
</tr>
<tr>
<td>Average</td>
<td>$470</td>
<td>$80</td>
<td>243</td>
<td>$0</td>
<td>$94,462</td>
</tr>
</tbody>
</table>

*Source: Adapted from Davis and Persons (2014)

*b American ginseng on the NFSNC is assumed to be wild-harvested, so there is no establishment or management cost. We include the column as a reminder to the reader.

To be of value for forest management decision-making purposes, more spatially explicit information on ginseng occurrence and harvest size needs to be included in the valuation model. Thus, to translate estimates of average value per ha into estimated marginal values per ha, we incorporated proxies for spatial variability in harvestable quantity and for harvest costs. We assumed that the probability of ginseng presence was determined by habitat factors including parent material, landform, climate, and soil taxonomy, as outlined in Schmidt et al. (2019). We used a raster (9 ha [22 acre] pixel resolution) of probabilities of ginseng occurrence generated by the species distribution model (SDM) developed by Schmidt et al. (2019). After clipping the SDM raster to the boundary of the NFSNC, we binned probabilities of finding ginseng on a given pixel as 0.1 (23,695 pixels), 0.5 (18,335 pixels), and 0.9 (3,089 pixels).

Although actual presence and total quantity of ginseng harvestable at any given pixel are unknown, the purpose of this exercise was to better understand the distribution of potential ESV within the NFSNC. First, using a random number generator and the probabilities above, we randomly assigned ginseng presence or absence to each pixel. This leads to an average of 14,317 pixels with ginseng presence out of 45,149 total pixels, or 32%. Second, for each of the resulting pixels with ginseng presence, we then generated a random harvestable quantity from a beta
distribution with mean 0.10 green kg and maximum of 0.60 kg per 9-ha pixel.\textsuperscript{6,7} Third, we randomly assigned detection by harvesters each year at each presence pixel with probability of 0.5,\textsuperscript{8} and assumed that at each pixel where harvest occurred, 100\% of the harvestable quantity was removed.

We modeled transaction and harvest costs as functions of distance to road, slope, and amount of ginseng present. Using the SDM raster as a template, we converted a shapefile of roads\textsuperscript{9} to a raster. Then, using the ‘distance’ command in the ‘raster’ package (Hijmans 2019) in R (R Development Core Team 2005), we converted the road raster into a raster of distance (m) from road. To create a raster of slope (degrees) at the same resolution as the SDM data for the National Forest, we downloaded high resolution elevation data (0.0225 ha) via the ‘elavatr’ package (Hollister and Shah 2017) in R, and derived slope using the ‘slopeAspect’ command. We estimated transaction and harvest costs for each pixel as

\[
TC_i = opp \cdot \left(\frac{d_{ist_i}}{sp}\right) \cdot (1 + s_i) + fc \tag{14},
\]

\[
HC_i = opp \cdot (hr \cdot Q_i \cdot (1 + s_i)) \tag{15},
\]

where

\(opp\) is the opportunity cost of time, set to $10/hr,

\(dist_i\) is distance from the pixel to road (m),

\(sp\) is the speed at which a harvester can traverse relatively flat forested terrain, set to 5,000 m/hr,

\(s_i\) is the speed adjustment factor based on slope, equal to 0 for slopes < 20 \(^{\circ}\), 0.5 for slopes 20-30 \(^{\circ}\) and 1 for slopes > 30 \(^{\circ}\),

\textsuperscript{6} With beta distribution parameters \(\alpha=2, \beta=10, \text{minimum}=0, \text{maximum}=0.6\).

\textsuperscript{7} Estimate of the amount of ginseng likely available at various sites, based on consultation with experts (personal communication, James Hamilton, NC Cooperative Extension Service), relevant literature (McGraw, Souther, and Lubbers 2010), and that multiple ginseng populations likely exist on many 9-ha areas where ginseng is present.

\textsuperscript{8} Based on McGraw, Souther, and Lubbers (2010).

\textsuperscript{9} Available from the North Carolina Department of Transportation https://connect.ncdot.gov/resources/gis/Pages/GIS-Data-Layers.aspx
$fc$ are fixed transaction costs, set to $15,$

$hr$ is the rate of harvest, set to 2 hrs/kg.

This simulation, which with additional research could be made more precise, yielded an estimate of 425 kg/yr of green ginseng harvested with a total ESV of $88,978/yr, mean ESV across presence pixels of approximately $1.90 /ha/yr ($0.77/ac/yr) or $38/ha ($15/ac), and maximum value of approximately $11.50 /ha/yr ($4.65/ac/yr) or $230/ha ($93/ac).

7 CONCLUSIONS

NTFPs are valued throughout the U.S. for food, medicines, decorations, landscaping, and arts and crafts, and are important to the cultural traditions and livelihoods of many people. As such, NTFPs are among the many ES provided by forest ecosystems, and, while sometimes assumed to be of lesser value than timber ES, this is not always the case (Alexander et al. 2002, Pilz et al. 1999). Here, we have outlined methods for valuation of the provisioning of market-based NTFPs. Quantifying the ESV of market-based NTFPs can lead land managers to a better understanding of the effects of their decisions on local communities. Non-market values also are significant for NTFPs, and remain an important parallel research topic.

Estimating the provisioning ESV of forests for marketed NTFPs requires finding the residual value of the product – the value remaining after factoring out human labor and capital inputs. Such an approach is applicable at the marginal level, that is, for small changes in forest area or to an enterprise.

Determining these residual values is challenging, as very little information on cost of production, quantity harvested, or product price is readily available. Moreover, incorporating marginal changes requires data on differences in production at relatively small scales (e.g., individual harvest sites) and, potentially, differences in cost structure between harvesters. Estimating ESV involves collection of data from institutional sources, expert knowledge, and surveys of harvesters and dealers. Although estimating the provisioning ESV for NTFPs is fraught with challenges, the benefits of addressing the challenges and undertaking valuation is needed to highlight the importance of these products.
Due to the challenges with data, difficulties eliciting information from market players, high levels of temporal and spatial variability, and perceptions of minor economic importance, ES valuation related to NTFPs is underdeveloped in comparison with other ESs such as provisioning of timber or regulation of air and water. To further the discussion and science of ESVs of NTFPs, we discussed case studies of saw palmetto in Florida and American ginseng in the NFSNC. These case studies demonstrate the types of data needed, potential workflows, and the high degree of spatial variability of ESVs over the landscape. Future work is needed to better understand presence and absence of NTFPs across the landscape, harvestable quantities including intertemporal dynamics, and harvester costs including the value of ecological knowledge.

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