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ORIGINAL PAPER

# Characterizing the Movement and Utilization of Federal Timber at the Sub-State Level: Method and Applications

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## Abstract

Accurate information on the movement and utilization of timber sold by the USDA Forest Service (Forest Service) has historically been difficult to access. Such data have useful applications in the appraisal process, for estimating the location and size of economic impacts to people and communities and for planning management actions. There is some evidence that agency utilization definitions lag improvements in industry utilization practices leading to a discrepancy between administratively determined uses and actual uses of timber sold. Furthermore, the relationship between the origin of harvested wood and the location of processing are increasingly important in the context of climate and clean energy policies as many rely on quantification of the greenhouse gas emissions from the harvest, transport and use of wood for various end products. In this study we compare available data on timber harvested from Forest Service administrative reports with mill-reported uses of federal timber collected by USDA Forest Service Research & Development's National Resource Use Monitoring program in order to demonstrate a method for estimating national forest timber movement and utilization "signatures".

**Keywords** USDA Forest Service · Administrative data · Forest management · Wood utilization · Wood products

## Introduction

Timber flows, or the relationship between the origin of harvested timber and the location of primary processing, is increasingly important at international, national and sub-national scales. In the context of climate change, life cycle analyses use wood flow information to account for the transfer of carbon emissions through consumption-driven imports (Zhang et al. 2020) and quantify the life cycle greenhouse gas (GHG) emissions from the harvest, transport and use of wood for various end products (Healey et al. 2009; Salazar and Meil 2009; Stockmann et al. 2012). Information on timber flows is also important for understanding and predicting wood product market characteristics

Extended author information available on the last page of the article

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such as stumpage rates, in-woods operational costs, and timber sale feasibility (Anderson and Germain 2009; Frey et al. 2024; Gebert et al. 1998). Public land managers and policymakers rely on timber flow and utilization information to establish base rates for stumpage and to estimate the economic contributions and related impacts of forest management and wood products manufacturing activities (Waters et al. 1994; Nielsen-Pincus et al. 2011; Nielsen-Pincus and Moseley 2013; Hjerpe et al. 2021).

Timber flow and utilization trends are dynamic, influenced by local and global market forces, ecological disturbances and shifting management paradigms (Woodall et al. 2011; White and Carver 2004; Anderson and Germain 2007). For example, the Great Recession that took place from 2007 to 2009 (National Bureau of Economic Research 2010), combined with structural changes already underway in the economy, drove significant changes in the number, type, and spatial distribution of wood-using mills – particularly in the western United States (Keegan et al. 2011; Woodall et al. 2012). These exogenous shocks have led to decreases in the diversity of the wood products industry and increases in the distance logs must travel to milling centers (Keegan et al. 2006; Haynes et al. 2016), all of which challenge traditional assumptions about the economics of timber sales and markets for harvested wood (Andersch et al. 2014; Anderson and Germain 2007; Anderson et al. 2011), as well as the size and geographic distribution of economic impacts (Gebert 2002; Sorenson et al. 2016; Hjerpe et al. 2021).

Changes in the goals and objectives of both public and private forest landowners can lead to significant changes in the volume and characteristics of trees selected for harvest. Shifts in management paradigms therefore have implications for wood-using industries and the types of wood products produced. In the case of federal policy for ecosystem management, the shift has been characterized by an increase in the proportion of smaller, lower-value timber harvested and sold from public lands as managers seek to improve the ecological condition of forests and mitigate wildfire hazard near communities (Fiedler et al. 1999; Andersch et al. 2014; USDA Forest Service 2022). Timber quality and size effect utilization in different ways, but smaller-diameter logs of poor form have been found to negatively affect salability and increase the occurrence of no-bid sales for public land managers (Frey et al. 2024; Gebert et al. 1998).

The primary sources of data on markets and timber flows used by public land managers, policymakers and other analysts are composite lumber price indices, individual sale data and compilations summarizing volume sold and harvested at multiple resolutions. Individual timber sale data are primarily available to land managers and are used to conduct stumpage appraisals and sale feasibility analyses (Gebert et al. 1998; Schuster and Niccolucci 1990, 1993; Combes et al. 1989; Haynes et al. 2016). Price indices and agency data compilations are publicly available and thus frequently used by policymakers and analysts interested in characterizing or predicting federal land management policy impacts. Yet, as Weiner (1982) and others have noted, care must be taken to understand the various measurement units, periods of reporting and other classifications used in order to avoid misrepresentations of USDA Forest Service (Forest Service) administrative timber sale data (Haynes et al. 2016; Wiener 1982).

Administrative data also have limitations. In the case of administrative data on timber management activities, the limitations have important implications ranging from estimating federal investments for forest management and assessing the fair market value of stumpage, i.e. standing timber to be sold, to contribution studies and agency reports attempting to estimate the location and size of economic impacts deriving from the manufacture of federal timber. Better information on the location of wood product manufacturing could improve studies seeking to characterize the nature and extent of community impacts resulting from changes in federal timber outputs (Haynes 1983; Waters et al. 1994; Pugliese, McCann, and Artz 2015; Lewis, Hunt, and Plantinga 2003; Hjerpe et al. 2021; Eichman et al. 2010), and the impact of forest policy on forest communities' social and economic well-being over time (Charnley, Donaghue, and Moseley 2008; Charnley and Long 2014; Donoghue, Sutton, and Haynes 2007) by differentiating the location and size of impacts and benefits among affected communities.

The objective of this paper is to describe a method for developing a set of national forest-level "composite signatures" that reflect the uses and spatial extent, or reach, of a national forest's timber program outputs. We begin by describing in more detail the limitations of using administrative data on timber harvest to inform management and policy decisions. Next, we describe a dataset developed and maintained by the Forest Service's research and development branch in fulfillment of its National Resource Use Monitoring Program (NRUM) and its relationship to Forest Service administrative data. We then propose leveraging these datasets to produce composite signatures for each national forest to apply to existing administrative data in order to characterize in more detail where and how timber from federal forests is utilized. The paper proceeds with a discussion of the benefits of integrating national forest composite signatures into planning and decision-making processes and concludes with a call for greater investment in tools for making NRUM data more broadly available.

## National Forest System Administrative Data

The National Forest System (NFS) branch of the Forest Service collects, compiles, and disseminates administrative data on its activities and accomplishments to meet reporting requirements and to support decision-making. Administrative data is collected from multiple agency applications and their databases. Key among them is the Timber Information Manager (TIM) application, a document management application used to generate forest product removal permits, conventional forest product sale documents, and stewardship sale contract documents. Data in the TIM application is the primary source of information available to analyze, maintain, track, and report data about forest product permits and contract sales, including those executed using stewardship and other authorities. Specifically for our purposes, summaries of the volume and value of forest products sold and harvested from national forests and grasslands are made available through the public report "Forest Products Cut and Sold from National Forests" (hereinafter 'Cut and Sold report') (USDA Forest Service, n.d.).

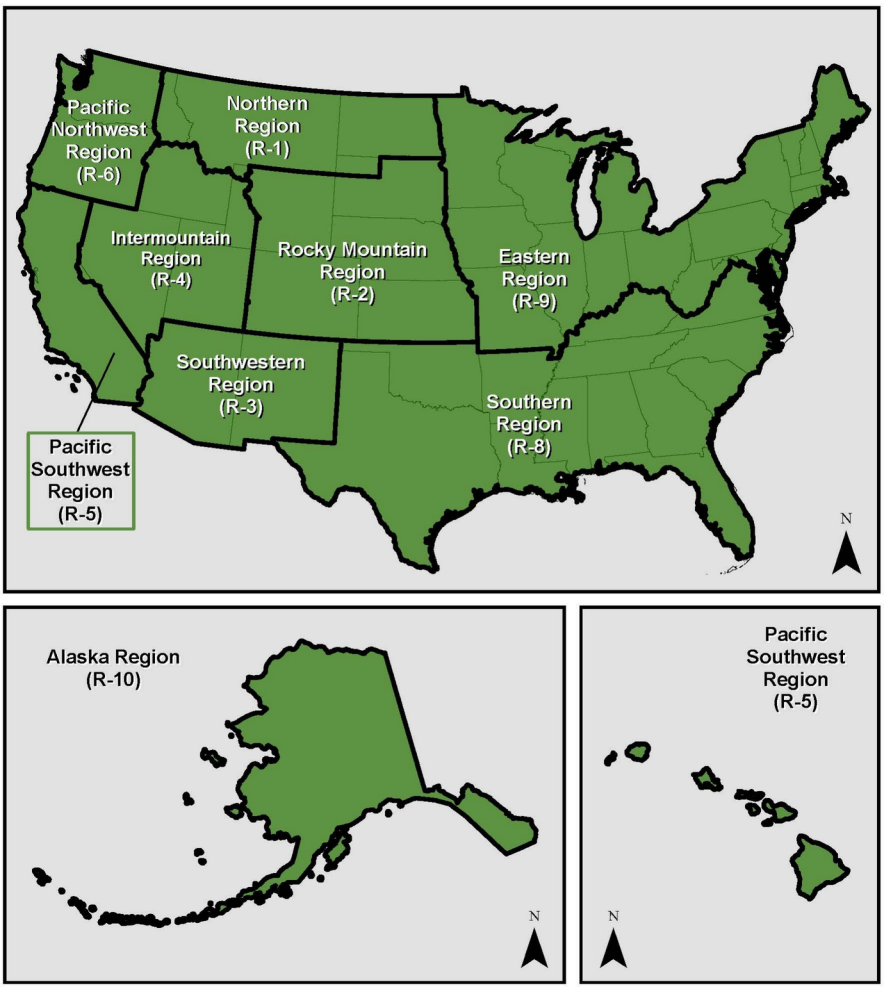



**Fig. 1** Forest Service National Forest System administrative regions

Data available in these reports are summarized by administrative units at the Region, National Forest and State level (Fig. 1) and by product. The design of these data compilations is driven by upward reporting requirements in which individual units within the NFS demonstrate that they are achieving program targets. The compiled data are issued for each fiscal year and quarter, for each national forest, region and state. Cut and sold reports provide data on the volume of timber sold and harvested, in two standard units (thousand board feet, MBF) and hundred cubic feet, CCF), which may have been converted from the original units used to sell the timber. Further, the report distinguishes between convertible and non-convertible volume, indicating whether the material can be converted into

a standard unit, e.g. board feet. Examples of non-convertible products include Christmas trees, roots, and ferns or greenery (Wiener 1982).

Two potentially useful variables for understanding federal timber utilization are statistics on timber volume sold and harvested (cut) by species and by product. Volume is reported in one of 13 product categories from sawlogs and pulpwood to categories such as fuelwood, non-sawtimber ("non-saw"), and miscellaneous convertible products (see Table 1 below). However, as Haynes et al. (2016) acknowledge, categories used to classify the volume of timber sold by the Forest Service do not necessarily serve as good proxies for the final use of that timber. For example, within the convertible timber product categories found in the Cut and Sold Report are volumes of personal use firewood not sold through competitive timber sale auctions like most products (e.g., sawlogs, non-saw, pulpwood). For this reason, the volume reported as harvested in Cut and Sold reports does not equal the volume utilized by manufacturers to produce finished products. Importantly, discrepancies between the administrative categories and the actual use by manufacturers can also occur due to outdated classification guidelines that have not kept up with industry advancements, and elasticities in final uses based on changes in market demand.

A second data point that is not reported in any standard administrative data compilation is the location of manufacturing. The location of timber harvest does not reflect the total economic impacts associated with its utilization– particularly those related to value-added processing. The capital-intensive nature of wood products manufacturing combined with the trend towards consolidation of capacity over the last half-century means that mills procure timber from more distant locations. Furthermore, while some timber sales result in load or "truck" tickets with information on the volume and final destination of harvested timber, these data are only collected for scaled sales and do not apply to tree measurement sales. Furthermore, information on receiving mills is not systematically entered into administrative databases,

**Table 1** NFS product categories and codes (convertible products only)

| NFS product code | NFS product name | Abbrev. |
|---|---|---|
| 01 | Sawtimber | Sawtimber |
| 02 | Pulpwood | Pulpwood |
| 03 | Poles | Poles |
| 04 | Pilings | Pilings |
| 06 | Posts | Posts |
| 07 | Fuelwood | Fuelwood |
| 08 | Non-sawtimber | Non-saw |
| 09 | Ties | Ties |
| 14 | Miscellaneous convertible | Misc.-conv. |
| 18 | Cull logs | Cull logs |
| 19 | Small Roundwood | Sm Rd Wd |
| 20 | Green Biomass Convertible | Grn Bio Cv |
| 21 | Dry Biomass Convertible | Dry Bio Cv |

nor aggregated and summarized in a centralized system that allows for regional or national-level reporting or analysis.

### The USDA Forest Service National Resource Use Monitoring Program

The research and development branch of the Forest Service also collects and maintains information on timber harvest, wood flows and utilization through its National Resource Use Monitoring (NRUM) Program. Monitoring of timber removed from US forests was authorized through the McSweeney-McNary Forestry Research Act of 1928 (45 STAT 699–702) and officially began in 1948 in response to timber supply concerns following World War II. Section 9 of the Act directs the Forest Service to, "make a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies, including determination of the present and potential productivity of forest land therein, and of such other facts as may be necessary in the determination of ways and means to balance the timber budget of the United States" (45 STAT 699–702). What was known as the "forest survey" was interpreted by agency officials to involve four main areas: "the timber inventory, an assessment of forest growth phases, a study of forest depletion, and the estimated requirements for forest products" (Doig 1977). Logically, early implementation of the survey focused on developing and implementing a system for accurately estimating the inventory, as it provides the foundation for each of the remaining three objectives.

The "forest drain" or Timber Product Output (TPO) component began in 1947 to calculate the drain on the nation's forest resources as compared to the inventory, growth and yield estimates. Data on the origin of all timber received by mills and the type and volume of finished products produced are collected via a census of wood-using mills. The frequency of censuses varies by region, and the program has recently added an annual sampling strategy to the data collection approach (Coulston et al. 2018). Implementation of the National Resource Use Monitoring program is divided between four regions: Pacific Northwest, Interior West, North and South (Fig. 2). The TPO component of the NRUM program is accomplished by or with cooperators. Delivery of the Pacific Northwest and Interior West programs are delegated to the Bureau of Business and Economic Research (BBER) Forest Industry Research Program at the University of Montana. State agencies and other entities cooperate with the Southern and Northern NRUM programs to assist with data collection.

Each NRUM region is responsible for collecting a common set of core TPO variables (see Supplementary Table 1). The NRUM programs in the South and North only collect data on the core TPO variables while the Pacific Northwest and Interior West regions collect core as well as "core optional" TPO variables including the ownership source of timber received by mills (e.g., national forest, private, tribal) and more detailed finished product information (Table 2). These latter data are particularly important in the West as many smaller facilities manufacture multiple products simultaneously or in response to market opportunities (Hayes et al. 2021; Marcille et al. 2021).

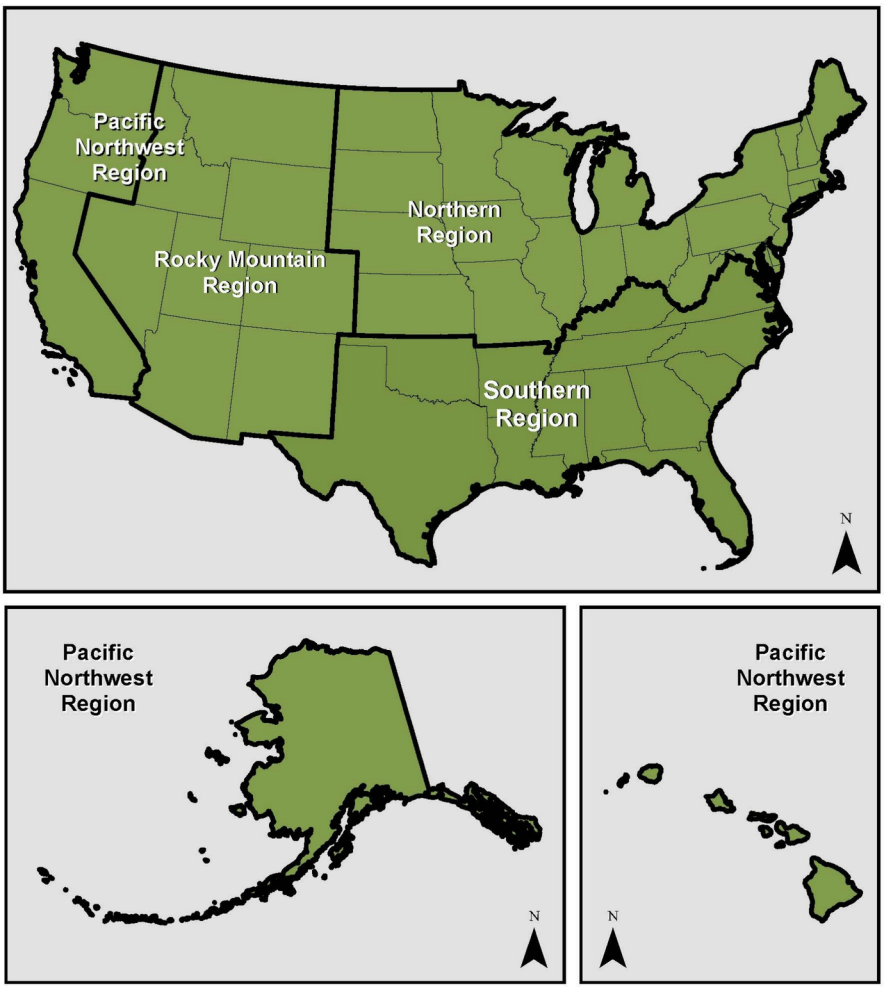



**Fig. 2** Forest Service National Resource Use Monitoring program regions

## Methods

### Data Sources

In order to create national forest "composite signatures" reflecting the type and location of wood product manufacturing resulting from Forest Service timber sale activity or changes in timber program policy, four basic pieces of information are needed: 1) the volume of timber harvested by product type (as defined by administrative product categories, see Table 1), 2) the origin of harvested timber (county, national forest), 3) the location of primary processing (county, mill address), and 4) the type of primary processing, i.e. primary wood products produced. We used NFS Cut and Sold data as our starting point to enable seamless application of our "composite

**Table 2** TPO product categories and codes

| TPO code | TPO final use categories | Abbrev. |
|---|---|---|
| 01a | Sawmill-softwood | Sawmill-sft |
| 01b | Sawmill-hardwood | Sawmill-hrd |
| 02a | Veneer/Plywood - softwood | Veneery/Ply-sft |
| 02b | Veneer/Plywood - hardwood | Veneery/Ply-hrd |
| 03a | Post & pole | Post & pole |
| 03b | Utility pole/pilings | Utility pole |
| 04 | Log home | Log home |
| 05 | Composite panels | Composite panels |
| 06 | Roundwood pulp-chip | Pulp-chip |
| 07 | Cedar products | Cedar products |
| 09 | Firewood (commercial) | Firewood |
| 10 | Log furniture | Log furniture |
| 11 | Biomass - electricity or energy products | Biomass energy |
| 12 | Viga & latilla | Viga & Latilla |
| 13 | Bedding & Shavings | Bedding & Shavings |

signatures" to currently available data. Cut and Sold data were downloaded for each national forest and year for which TPO data were available.

Next, timber flows were derived from mill-level TPO surveys indicating volume of timber received by mill and by ownership, county, and state. Species information was also used in hardwood states to distinguish between hardwood and softwood timber inputs. Based on regional differences in TPO data collection protocols—namely the lack of mill-level ownership data by the Southern and Northern programs—two additional data sources were used to approximate the ownership variable: Forest Service administrative records on national forest timber harvest by county (Forest Service, unpublished)[1] and the spatial file Forest Administrative Boundaries (USDA Forest Service, 2020).

Data on how federal timber was utilized were also derived from the TPO mill survey dataset based on the final products produced by mills receiving and processing national forest timber. In some cases, mills produced multiple products and the volume of federal timber received was allocated proportional to the total volume of finished products produced from all ownerships.

## Data Sets

Two datasets were constructed to enable creation of "composite signatures" linking NFS administrative data on timber harvest volumes and TPO data on the milling location and products produced from federal timber. The first dataset summarizes

[1] National Forest timber harvest data by county are not included in publicly available reports. These data were accessed through the Washington Office of the Forest Service.

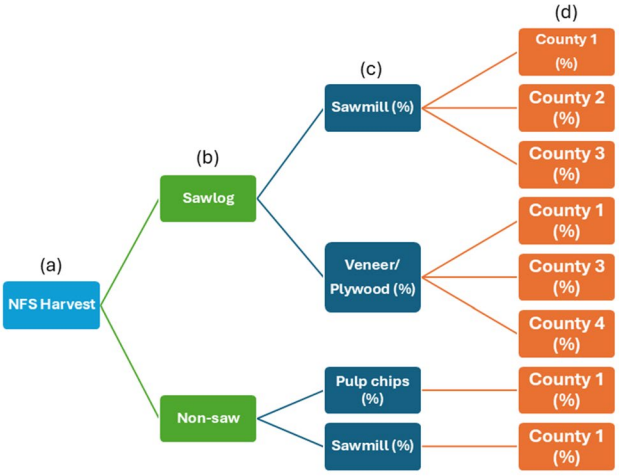
volume harvested (in thousand board feet (MBF), Scribner and hundred cubic feet (CCF)) for each convertible roundwood product class by national forest and year, compiled from the Forest Service Cut and Sold reports (USDA Forest Service 2014–2019) (Table 1). The second dataset uses TPO mill survey data to summarize the end-use and county of processing for timber volume received by mills from national forests. This dataset includes the county in which timber was processed as well as the product(s) produced from the most recent mill survey data year available. Species attributes were used to distinguish softwood and hardwood species. The data collection years used in this analysis varied by state but were no older than 2014 and as recent as 2019.

For regions that do not collect information on ownership (Southern and Northern regions, see Fig. 2), spatial ownership data were used to identify counties containing national forest land and NFS administrative data on timber harvest volume by county was used to apportion the volume to mills. For mills that reported receiving timber from a county containing national forest land, a proxy volume of national forest timber was calculated based on the volume of national forest timber harvested in that county and the number of mills reporting that county as an origin of received timber.

## Analysis

The purpose of the analysis was to develop composite signatures that could be applied to NFS Cut and Sold data summarized at the national forest level to provide greater detail on the end-uses of federal timber (Fig. 3). Composite signatures enable a one-to-many relationship whereby timber classified under any NFS product category can flow to multiple counties and be processed by mills into multiple primary wood products. For example, timber volume sold by a national forest under the category 'sawlog' may be processed by 5 different mills in 3 different counties to produce lumber, house logs and veneer. The signature for that national forest would provide two pieces of data: 1) the share of timber volume sold as sawlogs that was used to make each finished product, and 2) the share of volume, by finished product, that was processed in each of the 3 counties. For example, 50 percent of the total sawlog volume might go to sawmills to make dimensional products, of which 20 percent went to County 1, 30 percent went to County 2 and 50 percent went to County 3. Of the remaining volume of timber sold as sawlogs, 20 percent went to plywood or veneer manufacturers, which was then distributed among Counties 1, 3 and 4. The sawmill(s) in County 1 also received timber volume that was sold as non-saw material, as did a pulp-chip conversion facility in County 1.

A national forest's composite signature expresses the proportion of timber from national forest X (NFT) by NFS product category $a$ that is processed in county $c$ by TPO final use (primary processing) category $p$. This is accomplished by summarizing mill-reported roundwood timber received by national forest, county and TPO product and then comparing it with Forest Service timber harvest volumes by administrative product category from the Cut and Sold report for the same calendar year.




**(a)** Total volume cut on "x" national forest in "y" year, minus fuelwood. Data Source: NFS Cut and Sold Reports; **(b)** NFS product categories, or "predicted uses". Data Source: NFS Cut and Sold Reports; **(c)** Final use as a share of NFS predicted use. Data Source: NRUM-TPO mill surveys; **(d)** Share of volume by final use product and receiving county. Data Source: NRUM-TPO mill surveys

**Fig. 3** Visual representation of the application of composite signatures to Forest Service administrative data

$$TimberPortion_{NFT=} \sum_{i=1}^{n} NFT_{a,c,p}$$

As noted previously by Wiener (1982) and others, NFS product classifications are not precise and vary across regions. Thus, the second step involved matching the NFS administrative product classifications found in the Cut and Sold reports with the actual utilization by receiving mills. Similar to the product and appraisal groups developed by Haynes et al. (2016), where product discrepancies existed between NFS product categories and actual uses in the two data sets, higher value finished products (lumber, veneer, log homes, utility poles) were assumed to be derived from the NFS sawtimber product category, and medium-value products (paper, composite panel, wood pulp, posts, poles, log furniture) assumed to be derived from the NFS pulpwood, posts, poles, and non-sawtimber categories, while low-value products (biomass, industrial fuelwood) were assumed to be derived from the remaining NFS categories: miscellaneous convertible, cull logs,[2] small roundwood, green biomass, and dry biomass. Based on the experience and regional knowledge of the authors, exceptions to these general rules were made. For example, in Region One material sold as non-saw is utilized by mills to make a variety of products including studs and other sawn products.

The resulting national forest signatures characterize wood flows from the point of origin (national forest) to the point of processing (county of receiving mill) while also identifying the type of product being made, thus increasing the understanding of how and where national forest timber is being utilized. In the next section, we

[2] The cull log category is primarily used by USFS Region 5 (California) for material they are not able to sell as green saw logs (Richard Haynes, personal communication).

demonstrate the method's utility to aggregate data at the national and regional scales while also providing disaggregated data at the national forest scale.

## Results

### Timber Harvest by Forest Service Administrative Product Category

We begin by presenting descriptive statistics on timber harvest trends across the National Forest System using fiscal year 2018 as an illustrative example. As discussed in the methods section, one of the most basic barriers to using publicly available data summaries known as Cut and Sold reports is that they are published as portable document files (pdf) and are therefore not easily collected in a format appropriate for analysis. For this reason, the authors manually collected and digitized only one year of data for the entire National Forest System to describe variation in trends by region, which is presented below.

In 2018, the NFS reported harvesting approximately 512 million cubic feet of convertible timber nationally. Sawtimber was the primary product classification by volume, accounting for 59 percent of the total volume harvested (Fig. 4a). Pulpwood represented the second largest category by volume, accounting for 15 percent. Fuelwood accounted for as much as 11 percent of the total harvest of convertible products. Non-sawlog material accounted for 9 percent of the convertible harvest, followed by green biomass and miscellaneous convertible products, representing 4 percent and 1 percent of the total harvest, respectively.

As noted above, the relative importance of many administrative product categories varies among regions of the National Forest System (see Fig. 4b). The majority of timber categorized as pulpwood was harvested in Regions 8 and 9 where the pulp and paper industry is much larger than in the western US. Conversely, fuelwood was the second largest category by volume in the western states, although as noted earlier, there was little evidence that this volume was utilized for commercial products.[3] Non-sawtimber accounted for 14 percent of timber harvested from the Northern Region (Region 1) of the National Forest System, but less than one percent in the Pacific Northwest Region (Region 6). Timber categorized as miscellaneous convertible factored prominently in the Rocky Mountain Region (Region 2), accounting for 8 percent of the timber harvested.

In many cases, the use of specific NFS product categories indicated the value of stumpage offered for sale. For example, the greater use of the cull log category in the Pacific Southwest Region (Region 5) is likely a result of the large volume of dead trees harvested that exceeded market demand and thus were deemed to have minimal value (Marcille et al. 2020; Hayes et al. 2021). The Rocky Mountain Region (Region 2) has similarly been dealing with a wide-spread mountain pine beetle outbreak, which has resulted in the removal of a large volume of lodgepole pine trees

[3] Industrial firewood was generally considered to derive from the low-value NFS product categories (see methods section).

(Simmons et al. 2020), likely accounting for the region's frequent use of the miscellaneous convertible category, much as in Region 5.

### Utilization Signature – How Federal Timber is Used to Produce Products

The first component of a national forest's composite "signature" describes how federal timber is processed. As Figs. 5a and 5b suggest, the relative importance of various administrative product categories (left-hand side) varies by region, as do the primary uses of harvested timber (right-hand side). The former is a function of regional merchantability specifications (Haynes et al. 2016) while the latter is a function of the composition of the forest products industry in the timber-processing area for that region. Each of the previously mentioned factors as well as species, size and quality attributes and operational factors such as logging and hauling costs collectively inform the fair market value and minimum bid prices set by the Forest Service (Wiener 1982; Schuster and Niccolucci 1990; Haynes et al. 2016).

Discrepancies between NFS product categories and mill-reported uses were evident in our analysis. For example, sawmills in the NFS Northern Region consumed a substantial volume of non-sawtimber material, indicating that industry utilization capability has expanded faster than Forest Service merchantability specifications (Haynes et al. 2016). Further, our analysis revealed wide variation in the share of "convertible" volume harvested that potentially went unutilized. In some interior regions of the West—namely the southwest and intermountain regions—over half of the volume of timber volume reported as harvested in the Cut and Sold reports was not able to be matched with mill reported volume, indicating that timber may have been harvested but left in the woods due to lack of markets (Table 3). These trends relate to the size of the wood products industry in these regions, which in turn drives the share of volume that is sold and utilized versus the share of volume that is harvested and not utilized. In nearly all regions, portions of other product categories such as non-saw, pulpwood and the biomass categories also revealed volume that went unutilized when administrative records were compared with TPO end-use data (see supplemental data tables).

### Timber Flow Signature – Where National Forest Timber is Processed

The second component of each national forest's "signature" characterizes the movement of timber from the location of harvest to the location of primary processing. The aggregate of all wood flows from a national forest is known as a national forest's "timber-processing area" (TPA) (Keegan et al. 2006; Simmons et al. 2020). A TPA, or wood flow "signature", encapsulates all counties containing mills receiving timber from a region. TPAs can be analyzed based only on federal timber, or, as in the example in Fig. 6, timber from all ownerships in the counties containing the Custer-Gallatin National Forest. The TPA represents the broader economic impact area, the mills that use or could use federal timber, and those that may be affected due to changes in management objectives or policy regarding federal forests or surrounding ownerships.

The size of a forest's timber-processing area also varies considerably across regions, in part due to variations in the size of counties between the eastern and western US. TPAs are further influenced by the density of mills in a region, the relationship between the

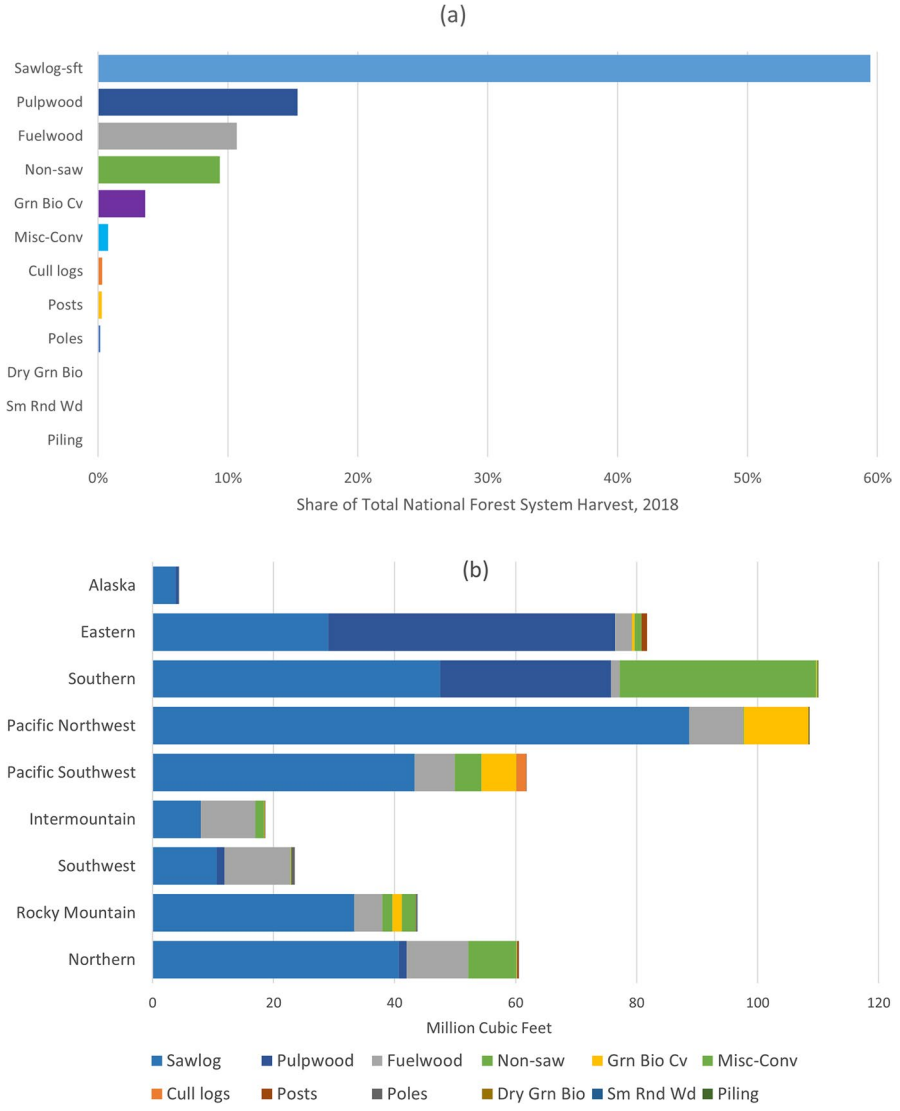



**Fig. 4** **a** Share of Forest Service timber harvest by NFS product classification (convertible timber products only), 2018. Source: NFS Cut and Sold Reports; **b** Forest Service timber harvest by product classification and Forest Service administrative region, 2018. Source: NFS Cut and Sold Reports

volume of timber harvested nearby and the capacity of mills to utilize that timber, as well as market variables influencing how much mills are willing to pay for delivered logs.

Both use and flow signatures are relatively stable over the short term but have seen considerable changes over longer time periods. Because the TPO program conducts a full census of the forest products industry on a periodic basis, the signatures can be updated as new information is collected, avoiding the pitfalls of point in time snapshots that are unable to capture the inherent dynamism in the forest products sector as mills

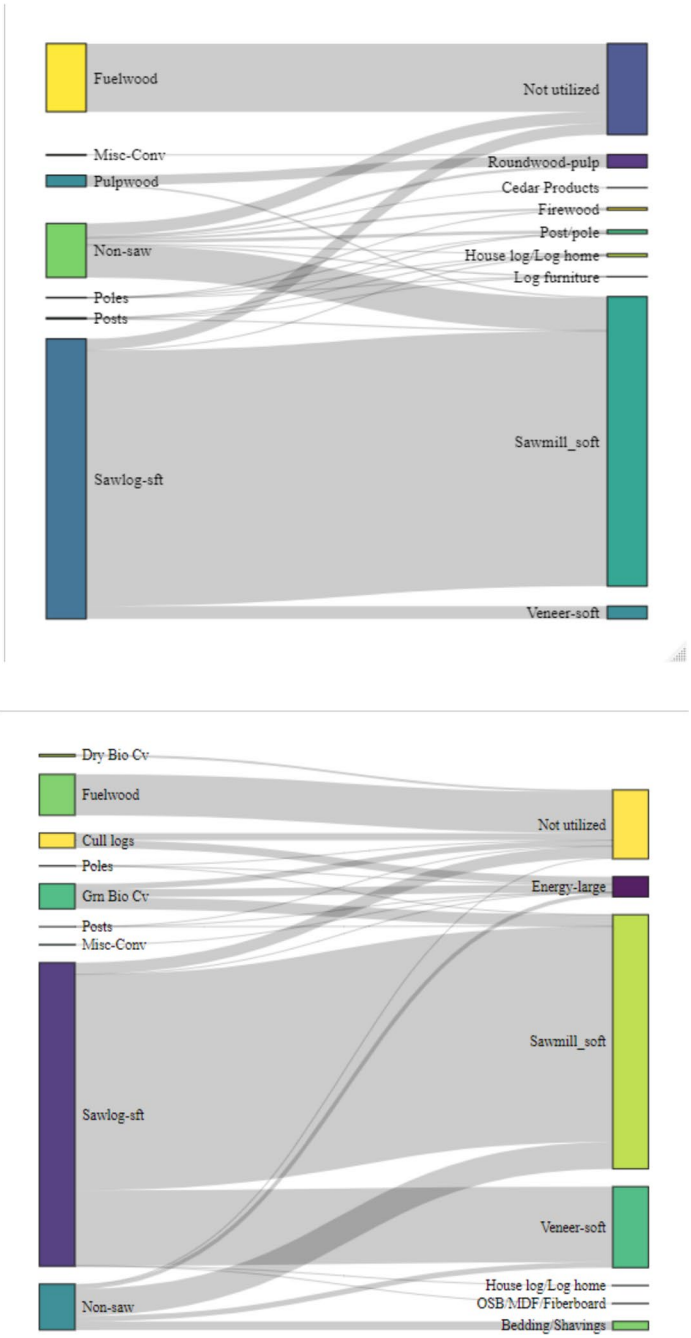



**Fig. 5** **a** Comparison of NFS "predicted uses" (from Cut and Sold reports) versus mill-reported uses (TPO) for NFS Northern Region (Region 1); **b** Comparison of NFS "predicted uses" (from Cut and Sold reports) versus mill-reported uses (TPO) for NFS Rocky Mountain Region (Region 2). Product category size and line weights represent harvest volume relative to the total

**Table 3** Unutilized/unknown volume as a share of NFS timber harvested, by region

| Region | Share |
|---|---|
| Northern Region | 19% |
| Rocky Mountain Region | 16% |
| Southwest Region | 51% |
| Intermountain Region | 53% |
| Pacific Southwest Region | 15% |
| Pacific Northwest Region | 13% |
| Southern Region | 3% |
| Eastern Region | 4% |
| Alaska Region | 48% |

open and close. In the next section, we will discuss and give examples of potential applications for timber flow and use signatures by land managers, planners and policymakers.

## Discussion

This paper presents a novel method for overcoming the limitations of Forest Service administrative data on timber program accomplishments by leveraging data collected through the National Resource Use Monitoring Program of the USDA Forest Service

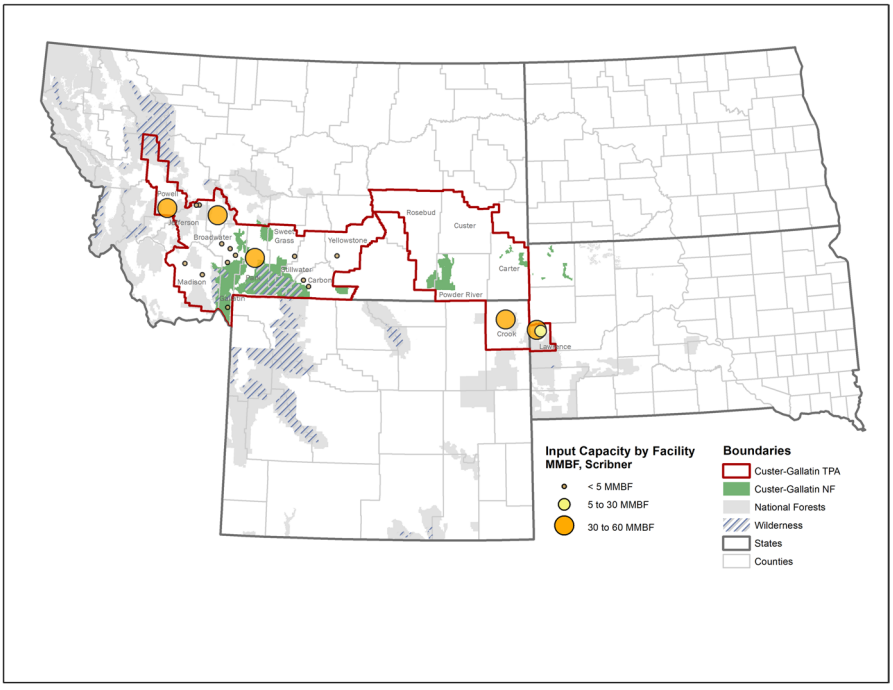



**Fig. 6** Example of a timber-processing area for the Custer-Gallatin National Forest combined planning area in Montana based on TPO log flow data. Source: Pennick McIver and Morgan 2022

Research and Development branch. The approach extends the utility of reports like the publicly available Cut and Sold Report's volume summaries by administrative unit and year by providing disaggregated and dynamic pictures of where and how federal timber is utilized by the forest products industry at the national forest unit level.

Our descriptive analysis and illustrative examples reveal a high degree of variability in the administrative product categories used across NFS regions, which reflect characteristics of the forest resource and industry in those regions. Our comparison of volume estimates derived from administrative data (TIM data summarized in "Cut and Sold" reports) and mill-reported data (TPO) also reveal questions about the proportion of volume harvested from national forests left in the woods and not utilized. Finally, analysis of the end-uses of timber harvested from national forest highlights the limited predictive utility of administrative product categories. This lack of specificity in the Forest Service's data system obscures the agency's ability to utilize end-use information to inform management decisions. For example, previous research by Wagner et al. (2000), Keegan et al. (2005, 2006) and others has quantified the increase in capability among sawmills in the western United States to efficiently utilize small-diameter and lower-value material that was once considered non-merchantable (Stewart et al. 2004). Access to more detailed information on end-uses could enable the Forest Service to update its merchantability specifications, bringing administrative product categories closer to industry utilization of such material.

This study also presents a number of ways in which timber flow and use signatures can support decision-making and prioritization by land managers. Because these data include greater detail on the location and end-uses of timber harvested from national forests, they are ideally suited to meeting the planning, analysis and disclosure requirements of multiple policies governing the management of national forests in the US (e.g. National Forest Management Act, 2012 Planning Rule, National Environmental Policy Act). The Forest Service's handbook for conducting social and economic impact analyses as part of NEPA analyses and Forest Planning processes suggests incorporating trade-based definitions as one of several considerations for defining impact areas.[4] The level of detail available in the timber flow signatures described in this paper could be used to answer questions about trade-based flows of timber by identifying the counties in which value is added to raw materials which in turn generates economic activity.

[4] Before constructing an economic model, the geographic area that forms the underlying local economic structure of the analysis must be determined. The geographic area should represent a functional economic area where there are activities supported by Forest Service land management. Counties containing Forest Service lands are the starting place for delineating economic impact areas. However, additional considerations are necessary for a reliable final impact area. USDA Forest Service handbook directs the inclusion of counties in impact areas based on trade patterns of raw-material outputs. Both "backward linked" and "forward linked" counties should be included (FSH 24.12). Additional methods to delineate analysis areas have built upon this handbook guidance to reflect continuous updates to agency analysis approaches to incorporate best practices. An important part of delineating an economic analysis area is to identify the counties where actual market transactions occur. Analysis area delineation should represent a functional economy that encompasses a contiguous set of counties where direct expenditures are made by the following groups: recreationists, range permittees, timber harvesters, timber processors, mineral and energy producers, local government (from revenue sharing and payments-in-lieu-of-taxes) and the National Forest or Grassland unit. Expanding the range and degree of expenditures included has changed the set of counties making up a forest or grassland's analysis area, broadening the definition beyond trade-based definitions and timber flow patterns.

Timber flow analyses also assist in identifying those communities for which federal forest management remains economically important by going beyond aggregate impact analyses and translating forest management activities into jobs and income that benefit local and regional economies (Charnley and Long 2014). Information derived from wood flow analyses can be combined with ratios of direct employment and labor income generated from the harvesting and processing of timber to estimate the size and geographic distribution of economic impacts (for example, see Sorenson et al. 2016, but also Keegan et al. 1993; Wall 1979). Wood flow data can also be used to characterize changes in demand for use in input–output economic models such as IMPLAN to further estimate the indirect and induced contributions of the forest industry as its effects ripple throughout the economy (Sorenson et al. 2016; Hjerpe et al. 2021).

A final example of the value of this data for decision-making is perhaps most obvious in regions such as the Black Hills of eastern Wyoming and western South Dakota that have experienced significant disturbances linked to insect and disease outbreaks, resulting in the need to adapt existing agency plans and programs of work (Graham et al. 2021). Changing ecological conditions and/or management prescriptions can have significant impacts on the species, size and quality of timber selected for removal. Detailed information on unused capacities within the wood products industry and opportunities for expansion of new capacities combined with robust governance networks can help Forest Service units as they recover from significant disturbances and address the implications for timber purchasers' ability to adapt to and capitalize on the volume and quality of timber sold in the region (Wagner et al. 1998; Keegan et al. 1999; Stewart et al. 2004; Simmons et al. 2020).

Novel applications of this data could include identification of timber flow and utilization archetypes to better understand the degree to which regions with similar signatures experience similar opportunities and constraints regardless of administrative unit or region. These archetypes could be applied within adaptation frameworks to better understand the specific attributes, such as overall capacity or level of diversity, that contribute to adaptation under conditions of variability and change. In a recent study by Abrams and others (2021), the existence of robust wood products infrastructure was shown to contribute to adaptive capacity for national forests engaged in networked governance regimes, leading to positive reinforcing cycles of social consensus, capacity, innovation and outputs (Abrams et al. 2021).

## Conclusion

This paper presents a methodology for integrating USDA Forest Service National Forest System administrative data with Timber Product Output mill survey data to support analyses conducted by public managers to meet a variety of regulatory and procedural requirements. Given TPO data coverage of the harvest and end-uses of timber from all ownerships, the method also has applications for analyzing policy or management scenarios by researchers and analysts outside federal agencies. The methodology described in this paper highlights a number of research questions worthy of further exploration including efforts to further characterize the disposition of

material categorized as fuelwood, methods for validating the volume of unutilized material harvested from national forests, and spatial analysis of average haul distances by region and product.

Currently, data on timber flow signatures are only made available to economists in the Forest Service's Policy Office. Access to this data by federal land managers and non-federal analysts is currently hindered by a lack of investment in data tools comparable to those developed for FIA plot data. The result is a lack of awareness and resulting under-utilization of TPO data by policymakers, land managers and scholars. Efforts to annualize TPO (see Coulston et al. 2018) seek to improve the temporal coverage and detail available through TPO, but will have little impact on data availability, particularly at the resolutions needed to support decision-making, without concomitant investments in data tools that meet the needs of stakeholders and public managers alike.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s44392-025-00046-9.

**Data Availability** The mill-level data from the University of Montana's Bureau of Business and Economic Research (BBER) and USDA Forest Service, NRUM program used in this analysis are developed from surveys of individual timber-processing facilities and contain confidential information that cannot be released to the public or shared. The publicly available information from the NRUM and BBER websites and various publications are summarized to protect confidential landowner, facility, and company information. The USDA Forest Service's NRUM program and BBER's Forest Industry Research Program can provide additional summarized information upon request but cannot release information that would reveal facility or company level confidential information.

**A digital file with 2018 NFS Cut and Sold data and additional summary tables can be found on the Open Science Framework at https://osf.io/f47dj/?view_only=edb51568b8b840d3a95e5c6003129648.**

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