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Defining and Measuring Forest Dependence in the United States: Operationalization and Sensitivity Analysis

Gregory E. Frey [1,*], Chalisa Kallayanamitra [2], Philadelphia Wilkens [3] and Natasha A. James [4]

[1] USDA Forest Service, Southern Research Station, P.O. Box 12254, Research Triangle Park, NC 27709, USA
[2] Bank of Thailand, 273 Samsen Road, Watsamphraya, Phra Nakhon District, Bangkok 10200, Thailand; chalisak@bot.or.th
[3] U.S. Endowment for Forestry and Communities, 908 East North Street, Greenville, SC 29601, USA; delie@usendowment.org
[4] USDA Forest Service, Strategic Planning and Performance Accountability, 201 14th St SW, Washington, DC 22050, USA; natasha.a.james@usda.gov
* Correspondence: gregory.e.frey@usda.gov

Abstract: This manuscript helps bridge a gap between theoretical work that advocates for a broad view of forest dependence, and empirical work that has focused narrowly on economic measures. *Background:* Forest dependence has been widely recognized as a valuable concept for understanding human communities' well-being and vulnerability to shocks and changes. Past theoretical literature has highlighted the importance of recognizing various types of dependence—environmental, economic, and social—yet past empirical literature on the topic in the United States has almost exclusively relied on measures of economic dependence such as employment and earnings from the traditional forest products sector. *Objective and Methods:* As a first step to bridge the gap between the theoretical and empirical, we reviewed the existing, publicly available, reliable, wall-to-wall data sources to identify alternate proxy measures for forest dependence. Data availability made the analysis feasible only at the county level—the administrative subdivisions of the state—or higher. *Results and Conclusions:* We created environmental, economic, and social criteria based on threshold levels of the following proxy variables: forest area, earnings, employment, and indigenous population. Using these criteria, we identified 524 counties to be potentially forest-dependent of 3140 total counties in the United States. The largest concentration was in the Pacific Northwest and Southeast regions, and a higher proportion were non-metro counties than metro. Varying the threshold levels significantly changes the number of counties identified but does not alter the overall geographic trends.

Keywords: natural resources; economic dependence; social and cultural dependence; sustainability; communities; counties

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1. Introduction

On the basis that "forests provide a variety of social, cultural and economic goods, services and other benefits that contribute to meeting the needs of society", the 12 signatory countries of the Montréal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (Montréal Process or MP) have sought to track information related to multiple socio-economic benefits that help meet the needs of societies. Among the various indicators, information has been sought related to the "Resilience of forest-dependent communities" (Indicator 6.3.c, also called 6.38 in some contexts. Prior to 2007, similar information was reported in indicator 6.5.c: "Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities". Throughout this paper, we consider the old 6.5.c and the current 6.3.c to be equivalent.) [1,2].

Forest dependence generally is understood as the extent to which humans rely on forests for their well-being. It has been widely recognized as a valuable concept for

understanding human communities' well-being and vulnerability to shocks and changes. As broad initiatives and programs such as REDD+, payments for ecosystem services, carbon markets, and collaborative and community-based governance aim to alter how, when, and where humans modify, use, and interact with forests, forest-dependent communities are those that are likely to feel the impacts, whether positive or negative. The Montréal Process and similar work seeks to understand how forest dependency relates to communities' abilities to cope with change, using concepts such as resiliency, as well as "stability" or adaptability [2,3]. While much of the research on the topic of forest dependence has been conducted in the Global South, it is also relevant in countries such as the United States and Canada, which may not be considered forest-dependent as a whole, but individual communities and populations within them are.

One of the major challenges in understanding impacts on forest-dependent communities is defining and measuring the concept. Identifying forest-dependent communities is important for local and national government agencies, Non-Governmental Organizations (NGOs), and others that seek more targeted approaches to assist and provide resources. Numerous definitions and variables have been employed in the past, but generally only focus on one variable, or one aspect of forest dependence. While theoretical and conceptual research related to forest-dependence has highlighted broad swaths of types of dependence, empirical work in North America has focused almost exclusively on a narrow set of economic indicators [3–7]. This paper aims to help bridge the gap between theoretical and empirical work by taking a first step towards operationalizing a broader set of criteria for forest dependency in the United States. While focused on the U.S. and using some literature from the neighboring country of Canada, we believe the approach will be of interest to practitioners and researchers exploring forest dependency worldwide, as they likely deal with similar data availability and conceptual issues in their countries of interest.

Objectives

The genesis for this manuscript is the United States' report on sustainable forests for MP. In that context, we seek to:

1. Create a framework for understanding various forms of "forest dependence" in the United States, based on past literature;
2. Identify data sources of potential metrics of forest dependence, with complete geographic coverage, which are likely to be available in future years;
3. Determine reasonable thresholds of forest dependence for each metric and map these nationwide; and
4. Understand how changes in those thresholds affect the number and geography of communities identified as forest-dependent.

2. Background

All human communities, indeed all humans, are dependent on natural resources and natural ecosystems [2,8]. However, it is generally recognized that overdependence on any single resource can make those people vulnerable to natural, economic, or other systemic shocks. Whether due to relative abundance of a particular natural good or service, or lack of better options, a singular economic, social, or environmental focus on one particular resource can make a community subject to the impacts of ebbs and flows in supply and demand [9].

2.1. Forest Dependence, Conceptually

Data on forest-dependent communities assist government agencies, NGOs, communities themselves, and others in identifying areas of strength as well as areas of vulnerability that need to be addressed [10]. Forest dependence is frequently viewed from the lens of the economy [5]. This can include production of market-based goods and services such as timber, non-timber products, and tourism, but also subsistence-level household inputs [11,12]. However, Beckley [4] highlighted other types of human dependence on

forests, including recreation and other biophysical and psycho-cultural uses. Similarly, Newton et al. [13] explored the ways in which forest-dependent peoples are characterized, creating a taxonomy of definitions. The taxonomy's main divisions included groups of definitions focusing on "forests", on "dependence", or on "people", signaling that no single definition is sufficient to apply across studies. "Forests" referred to both products and environmental services, while "dependence" referred to a person's livelihood or their reliance on certain products, and "people" definitions focused on a spatial relationship [13]. These three types of definitions aligned closely with the three pillars of sustainability [14]: environmental (forests), economic (dependence), and social (communities).

Within the United States, Kusel [5] found that most existing definitions of forest dependence were entirely based on employment from tree harvesting. In line with Beckley [4] and Newton et al. [13], Kusel [5] suggested these be expanded to include, "those immediately adjacent to forestland or those with a high economic dependence on forest-based industries, including tourism as well as timber".

2.2. Communities, Conceptually

Individual and household economies, including subsistence uses, are nested within larger levels of aggregation, up to the national and global economy [4]. "Communities" are an intermediate, but nebulous level of aggregation. There is no single geographic, political, or administrative definition of "community" in the United States. Concepts such as towns, townships, villages, cities, municipalities, etc., are highly variable by state. On the other hand, counties and equivalents (such as independent cities or parishes in certain states), are the subdivisions of a state and are relatively uniform in concept across the country.

"Communities" in the U.S. are frequently perceived as something smaller than counties [4,6]. Kusel [5] argued that counties lack the level of social identification and cohesion one would expect from a "community", and that aggregating communities to county level obscures variability. While such arguments that counties do not align with the understanding of community are compelling, they still leave a lack of clarity about what a community is, at least in a way that can be operationalized with existing data across the geographic map. Furthermore, from a practical standpoint, federal and state policies, as well as other programs focusing on forest dependence, are more likely to target existing administrative units.

2.3. Identifying Natural-Resource-Dependent Communities in the United States and Canada, Empirically

Empirical work and policy making requires making practical decisions about variables and threshold levels that are not necessary in theoretical work. Table 1 reports several sources that use defined thresholds for determining natural resource dependence in both the United States and Canada. Although this manuscript focuses on the U.S., some relevant literature from Canada was included because of the many similarities in ecological, historical, cultural, and political context between the two countries. The list is not comprehensive but was chosen to be illustrative of the types of definitions used in the literature, among those that set numerical thresholds for identifying forest dependence in recent decades. Machlis and Force [7] reported that most studies of community forest dependence in the U.S. prior to 1988 were conducted at the county level and focused on economic measures of connection to the timber industry. As we can see from Table 1, the same holds true for more recent work, which has focused on primarily economic criteria, specifically, employment in or earnings from forest-related industries (generally, as defined by the national census bureau economic statistical agency).

Table 1. Variables and thresholds for community and natural resource dependence in a selection of past empirical studies in North America.

Study	Country	Resource	Community	Economic	Environmental
Hajjar, et al. [15]	Canada	Forest	Municipality	≥10% employment in the forest sector	>66.2% forest land
Haynes [16]	USA	Forest	County		
Stedman, et al. [17]	Canada	Forest industries	Census subdivision	No fixed threshold; proportion of employment in forest industries	
Rasker [18]	USA	Timber	County	≥20% of total workers' earnings from timber-related jobs	
USDA Economic Research Service [19]	USA	Farming	County	≥25% total earnings from farms; or ≥16% total employment from farms	
Deavers and Brown [20]	USA	Agriculture	County	≥20% labor and income from agriculture	
USDA Economic Research Service [19]	USA	Mining	County	≥13% total earnings from mining; or ≥8% total county employment from mining	
Deavers and Brown [20]	USA	Mining	County	≥20% labor and income from mining	
USDA Economic Research Service [19]	USA	Recreation	County	Composite score [a]	

[a] Based on percentage of employment in entertainment and recreation, accommodation, eating and drinking places, and real estate; percentage of total personal income for these same categories; and percentage of vacant housing units intended for seasonal or occasional use.

The only study in Table 1 to use a definition of dependency not centered on industry economic data is that of Haynes [16], which utilized percent forest land (as also reported in the 2003 U.S. report for this MP indicator [21]). The 2010 report utilized the Community Resilience Self-Assessment (CRSA) to measure a community's resilience [22,23]. However, no explicit methodology was used to identify forest-dependent communities, as the rich, but time-consuming CRSA approach was applied to only a limited set of three previously identified forest-dependent communities.

In terms of defining community, most of these studies, particularly in the U.S., relied on counties as the level of reporting (e.g., [18,19]). Many data sources do not report at smaller geographic scales or leave geographic gaps [16].

3. Materials and Methods

All data described in this section were compiled and published in an online, public database [1]. This public database provides data on several variables from public sources, including the information described below, as well as other indicators of community resilience [24]. The process for identifying data sources and variables to compile, in terms of the identification of forest dependence, is given below. A brief summary and some implications are included in the MP indicator report, "6.38: Resilience of forest-dependent communities" [24]. The unit of analysis selected for this research is the county or equivalent, the administrative subdivision of the state. Residents within a county (or equivalent) share many local government institutions at the county level, which frequently provide many types of social services (e.g., health departments, libraries, public safety). Furthermore, counties or equivalents offer full geographic coverage.

Following our interpretation of Newton et al. [13], we base criteria of forest dependence on the three pillars of sustainability: environmental (forest), economic (dependent), and social (community). A county must only meet one of the three criteria, as described below, to qualify as forest-dependent for this research. In order to operationalize each criterion in such a way that it would be comprehensive and likely to be replicable in future periods, we utilize data sources meeting the following standards:

1. Readily and publicly available;

2. Wall-to-wall geographic coverage for counties and county equivalents in the United States;
3. From a reliable source; and
4. Data collection and reporting has been conducted consistently and repeated over various time frames in the past and is likely to be continued in the future.

3.1. Criterion 1: Environmentally Forest-Dependent Communities

For purposes of this work, we consider an environmentally forest-dependent community to be one that relies on regulating and supporting ecosystem services [8] to support basic community functions. This might include protection of local water quality, wildlife habitat, or some other regulating or supporting service. Progress has been made in recent years toward modeling and mapping ecosystem services, e.g., [25,26]; however, these approaches are not necessarily focused on the geographic level of local communities, not geographically comprehensive, and likely to change over the coming years.

Exploring potential proxies leads us to one of the simplest measures—percent of forest land in a county. Two data sources are readily available: the USDA Forest Service, Forest Inventory and Analysis (FIA) program [27], and the National Land Cover Database (NLCD) [28]. There are several differences between the two, but we selected the FIA data because it documents land use, whereas NLCD documents land cover. NLCD may not recognize forest land that has been harvested, burned, or otherwise disturbed as the forest cover category, even though trees will regrow there. FIA, on the other hand, is more likely to maintain these areas within a forest land use category. For example, a natural or human disturbance such as fire, hurricane, or timber harvest may remove or destroy trees in an area—this area would still be considered a forest land use as long as it is expected to regrow trees. It is appropriate to keep such areas within the definition of forest dependence, since these shocks themselves are what could make forest-dependent communities vulnerable.

FIA uses a sampling framework for field-based plots to estimate numerous forest characteristics [29]. FIA in the past has been replicated at different frequencies in different states, and Interior Alaska is still an area of limited data. Although FIA has some limitations, it is a program with active improvement, increased frequency and intensity of measurement, incorporation of additional data sources, and modernization [30], and the authors' assessment is that it is likely to be available in the future with the same or greater reliability. For the 48 conterminous states and Hawaii, percent forest cover is determined by forest area divided by land and water area, based on forest inventories for the years 2014–2019 [27]. For Alaska, forest cover is based on the 2016 National Land Cover Database (NLCD) [28], by using the sum of land cover classes 41 (deciduous forest), 42 (evergreen forest), 43 (mixed forest), and 90 (woody wetlands), divided by the sum of all classes. Based on the authors' judgment, we set a baseline threshold of 75% forest land use in a county to meet criterion 1. As seen below, this threshold level is approximately twice the median (and mean) forest cover in the U.S., which is similar to the justification put forth by Haynes [16], although our threshold is higher in absolute terms (75% vs. 66.2%).

3.2. Criterion 2: Economically Forest-Dependent Communities

For purposes of this work, we consider an economically forest-dependent community to be one that relies on provisioning ecosystem services to support livelihoods and subsistence. This could include harvest of timber and non-timber forest products to generate income, for bartering, or for home consumption. Unfortunately, we are aware of no sources that track subsistence or similar uses. However, the Annual Economic Survey tracks employment in and earnings from various sectors [31]. Sum of employment and earnings from North American Industry Classification System (NAICS) industry classes 113 (forestry and logging), 1142 (hunting and trapping), 1153 (support activities for forestry), 321 (wood product manufacturing), 322 (paper manufacturing), divided by total employment and earnings. We have found no data sources on economic activity related to recreation that could be limited to forest-based recreation only.

Rasker [18] and USDA Economic Research Service [19] classified counties as economically dependent using employment thresholds in the range of 8–16% of total county employment, and earnings thresholds in the range of 13–25% of total county earnings (Table 1). Based on these previous thresholds, we set a baseline threshold of 10% of workers employed in the forest sector or more than 15% earnings from the forest sector to meet criterion 2.

3.3. Criterion 3: Socially Forest-Dependent Communities

Forests are utilized culturally and socially by many groups of people for many purposes. Forests can provide a deep connection between community and nature, and a sense of place [32]. People derive meaning from forest-based recreation, rites and rituals, and other cultural practices. We sought data sources for time spent in forest for recreation or cultural activities and found none that met the data standards above.

As a proxy for social or cultural dependence on forests, we used indigenous populations. Although certainly not the only people with deep cultural connection to forests, indigenous people have a long history in their native ecological regions and are recognized as having deep links to the natural world through religion, mythology, and psyche, as well as various cultural practices [33,34]. Percent of indigenous peoples among total population was calculated from American Community Survey data [35] and is defined as 100 times the sum of American Indian or Alaska Native and Native Hawaiian or Other Pacific Islander, divided by total population. However, not all indigenous peoples inhabit forested ecoregions, so we decided to use a combination of indigenous populations and forest land use. Based on the authors' judgment, we set a threshold of 5% indigenous and 30% forest land use to meet criterion 3.

3.4. Baseline Thresholds and Sensitivity Analysis

In summary, we set baseline thresholds for three criteria to be categorized as a forest-dependent community, at the county level, as noted in Table 2. Meeting any one of the three criteria was sufficient to be categorized as forest-dependent. We conducted a sensitivity analysis at ±5% for each threshold.

Table 2. Criteria definitions and thresholds used for the baseline and sensitivity analyses.

Criteria	Baseline Threshold	Sensitivity Analysis
1. Environmental: minimum forest land area	75%	70–80%
2. Economic: either 2.1 or 2.2		
Criteria 2.1: minimum employees in the forest sector	10%	5–15%
Criteria 2.2: minimum earnings from the forest sector	15%	10–20%
3. Social: both 3.1 and 3.2		
Criteria 3.1: minimum forest land area	30%	25–35%
Criteria 3.2: minimum indigenous population	5%	0–10%

3.5. Geographic and Metro/Non-Metro Variation

To get a better sense of the geographic distribution and spread of forest dependency across the rural–urban divide, we overlaid the new forest dependency definitions on established categories. For regional breakdown, we utilized the USDA Forest Service Resource Planning Act Assessment definitions for subregions by state as follows [36]:

1. Northeast: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia.
2. North Central: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Wisconsin.
3. Southeast: Florida, Georgia, North Carolina, South Carolina, Virginia.
4. South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas.

5. Great Plains: Kansas, Nebraska, North Dakota, South Dakota.
6. Intermountain: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming.
7. Pacific Northwest: Alaska, Oregon, Washington.
8. Pacific Southwest: California, Hawaii.

To understand forest dependency distribution across the rural–urban divide, we used the Office of Management and Budget definitions of metro and non-metro counties [37].

3.6. Limitations

Our approach has some inherent limitations. First, given the lack of available data that met our standards above, we were forced to rely largely on proxy measures. It is possible that some may view these proxies as insufficient. Furthermore, our baseline thresholds for forest dependence described above are somewhat arbitrary. Those perspectives are reasonable, and we recognize that our approach will not suit all contexts and purposes. Still, our view is that this approach does the best possible job of identifying data sources that meet the data standards above and falls within or near ranges of previous values used in the literature. The exception is criterion 3, which uses an approach not previously used in the literature on forest dependence in North America, to our knowledge.

Second, while most work in this area focuses on communities, the level of data analysis for this work is the county equivalent, which is not the same as "community" in many senses. Although counties offer many benefits for our analysis described above and can be considered a community in some senses, many in the U.S. would consider counties to be larger than "communities", so they are not perfect proxies, but useful, as described above. Shocks to annual county data, perhaps changes in forest sector employment or earnings due to natural disaster could mean that forest-dependent counties get left out, although the use of forest land use data in criteria 1 and 3 buffers against this somewhat. Additionally, individuals who cross county lines to access forests may not be correctly counted in this approach.

Third, in the modern U.S. forest economy, tourism and recreation are major contributors. Unfortunately, there are no data sources that separate forest-based tourism and recreation economic data from that which is not forest-based. We believe that many of the counties with high forest tourism economies will likely be captured in criteria 1 or 2, but possibly not all.

Finally, for the purposes of this work, we chose to use a binary criterion for "dependent" vs. "not dependent". In reality, dependence is a spectrum, and most communities that are in ecoregions where forests are present have some degree of dependence on them. Together these limitations mean there is some risk of wrongly classifying counties as "forest-dependent" or not when, in reality, the opposite is true.

4. Results

4.1. Data Summary

Table 3 presents the summary statistics of all counties in the 50 United States and the District of Columbia, for the four variables used to identify forest dependence. The median forest cover by county was 37.6%, so the selected threshold for forest dependence in criterion 1 (75%) was about twice the median, and the threshold for that variable in criterion 3.1 (30%) was slightly below the median. The other variables presented mean and median values that were much lower in absolute terms and in comparison to the threshold values.

In total, using these baseline thresholds, 524 (16.7%) of 3140 total counties (or equivalents) were identified as forest-dependent (Table 4). A total of 402 counties (12.8%) met criterion 1, 120 (3.8%) met criterion 2, and 103 (3.3%) met criterion 3. Many counties met multiple criteria, with 71 meeting both criteria 1 and 2, 29 meeting 1 and 3, and 10 meeting 2 and 3. Ten counties met all three criteria.

Table 3. Summary statistics of key variables, by county.

	Mean	Standard Deviation	Median	Minimum	Maximum
			percent of total		
Forest land use	38.6%	28.6%	37.6%	0.0%	100.0%
Forest industry employment	1.5%	3.8%	0.1%	0.0%	61.1%
Forest industry earnings	1.9%	4.8%	0.1%	0.0%	63.9%
Indigenous population	2.1%	7.8%	0.4%	0.0%	92.5%

Table 4. Criteria thresholds and number of counties meeting those thresholds, for the baseline and sensitivity analysis.

Criterion	Baseline	Counties Meeting Criterion	Sensitivity Analysis (−5%)	Counties Meeting Criterion	Sensitivity Analysis (+5%)	Counties Meeting Criterion
1. Environmental: minimum forest land area	75%	**402**	70%	**580**	80%	**273**
2. Economic: either 2.1 or 2.2		**120**		**268**		**59**
2.1: minimum employees in the forest sector	10%	118	5%	268	15%	50
2.2: minimum earnings from the forest sector	15%	87	10%	156	20%	50
3. Social: both 3.1 and 3.2		**103**		**1811**		**53**
3.1: minimum forest land area	30%	1756	25%	1901	35%	1632
3.2: minimum indigenous population	5%	210	0%	2992	10%	127
Counties meeting criteria 1, 2, or 3		**524**		**1819**		**347**

4.2. Geographic and Metro/Non-Metro Variation

Figure 1 presents the geographic location of forest-dependent counties in the United States. Table 5 shows the occurrence of forest-dependent counties by region and by metro/non-metro. The highest concentrations of forest-dependent counties are in the Pacific Northwest (33.0%) and the Southeast (24.4%), followed by the South Central (21.8%) and Northeast (20.6%) regions. The lowest concentrations are in the Great Plains (0.0%) and North Central (8.8%) regions.

Most forest-dependent counties are non-metro counties, with about 77.7% of forest-dependent counties being non-metro and 22.3% being metro. About 10.0% of metro counties were classified as forest-dependent and 20.6% of non-metro counties.

Table 5. Forest-dependent and non-forest-dependent counties by region and metro/non-metro distinction.

	Forest Dependent	Not Forest Dependent	Total	Forest Dependent
Region		*counties*		*percent of counties*
Northeast	80	308	388	20.6%
North Central	57	593	650	8.8%
Southeast	123	382	505	24.4%
South Central	182	651	833	21.8%
Great Plains	0	317	317	0.0%
Intermountain	37	244	281	13.2%
Pacific Northwest	34	69	103	33.0%
Pacific Southwest	11	52	63	17.5%
Total	**524**	**2616**	**3140**	**16.7%**
Metro	117	1051	1168	10.0%
Non-metro	407	1565	1972	20.6%
Total	**524**	**2616**	**3140**	**16.7%**

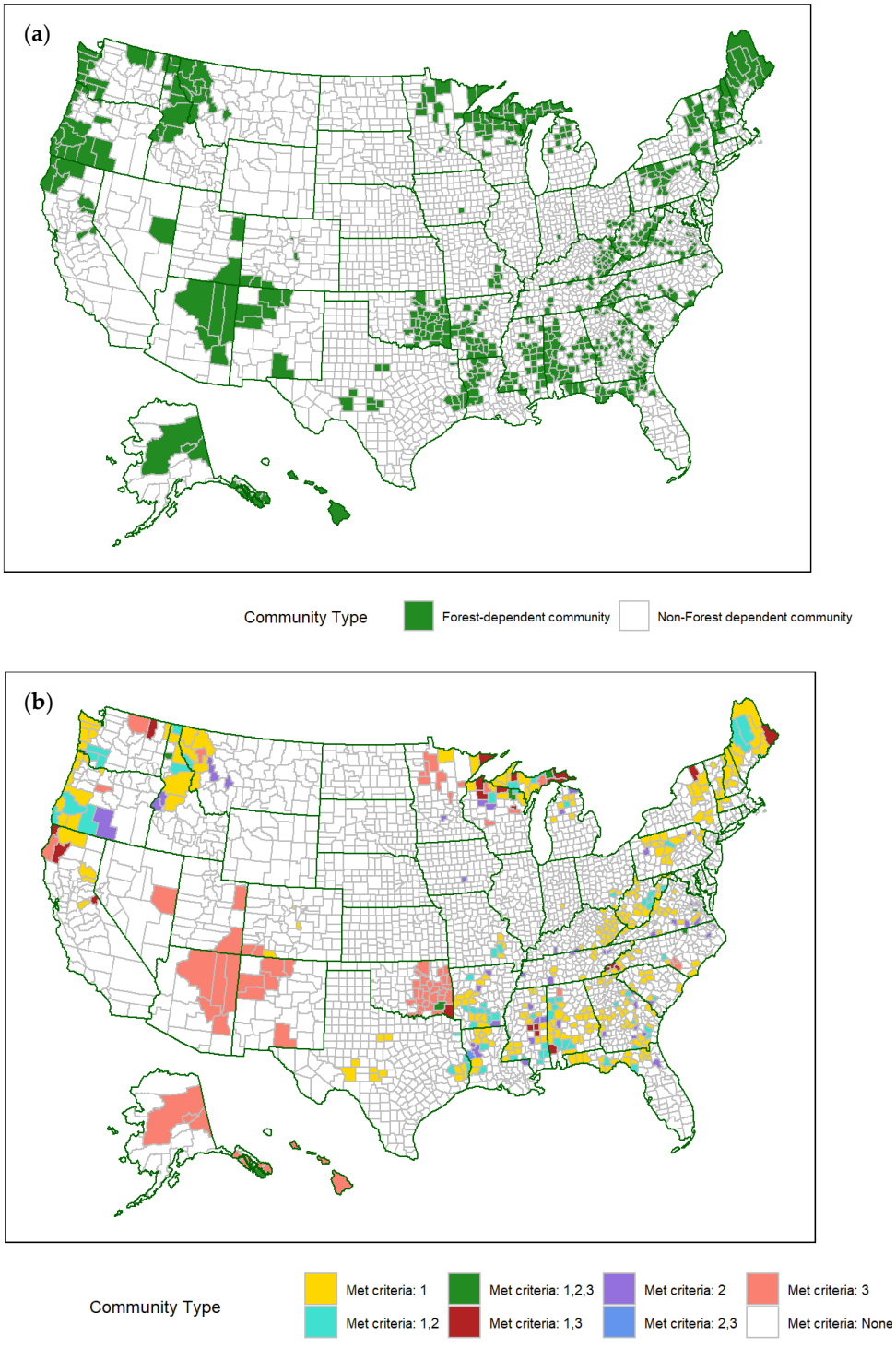

Figure 1. (**a**) Geographic distribution of 524 counties identified as forest-dependent under the baseline thresholds for all criteria. (**b**) Geographic distribution by criteria.

4.3. Sensitivity Analysis on Threshold Levels

Table 4 presents the sensitivity analysis for criteria and sub-criteria, by increasing and decreasing each by 5%. Increasing all thresholds simultaneously would decrease the number of counties from 524 to 347 and decreasing the thresholds simultaneously would increase to 1819 counties. Notably, decreasing subcriterion 3.2 from 5% indigenous population to 0% indigenous population expands the number of counties considerably.

This change in effect merges criteria 1 and 3, making the forest area threshold only 25%, which is below the median.

Figure 2 provides more detail on the impacts of changing threshold levels, showing the number of counties that qualify for each sub-criterion with thresholds ranging from 0 to 100%. This again highlights the fact that most counties have low levels of employment and earnings, and low indigenous populations and only a few counties have high levels. Conversely, forest cover is relatively high in many counties. Figure 3 shows the geographic distribution of counties identified as forest-dependent when varying each threshold by ±5%. Generally, regardless of the threshold levels, the same regions of the country—the Pacific Northwest, Southeast, Northeast, South Central, and some parts of the northern North Central and southern and northern Intermountain regions—tend to have relatively large numbers of forest-dependent counties. Increasing or decreasing the threshold simply lowers or raises the number of nearby counties that are included. The most extreme example is lowering sub-criterion 3.2 to 0% threshold, as noted previously.

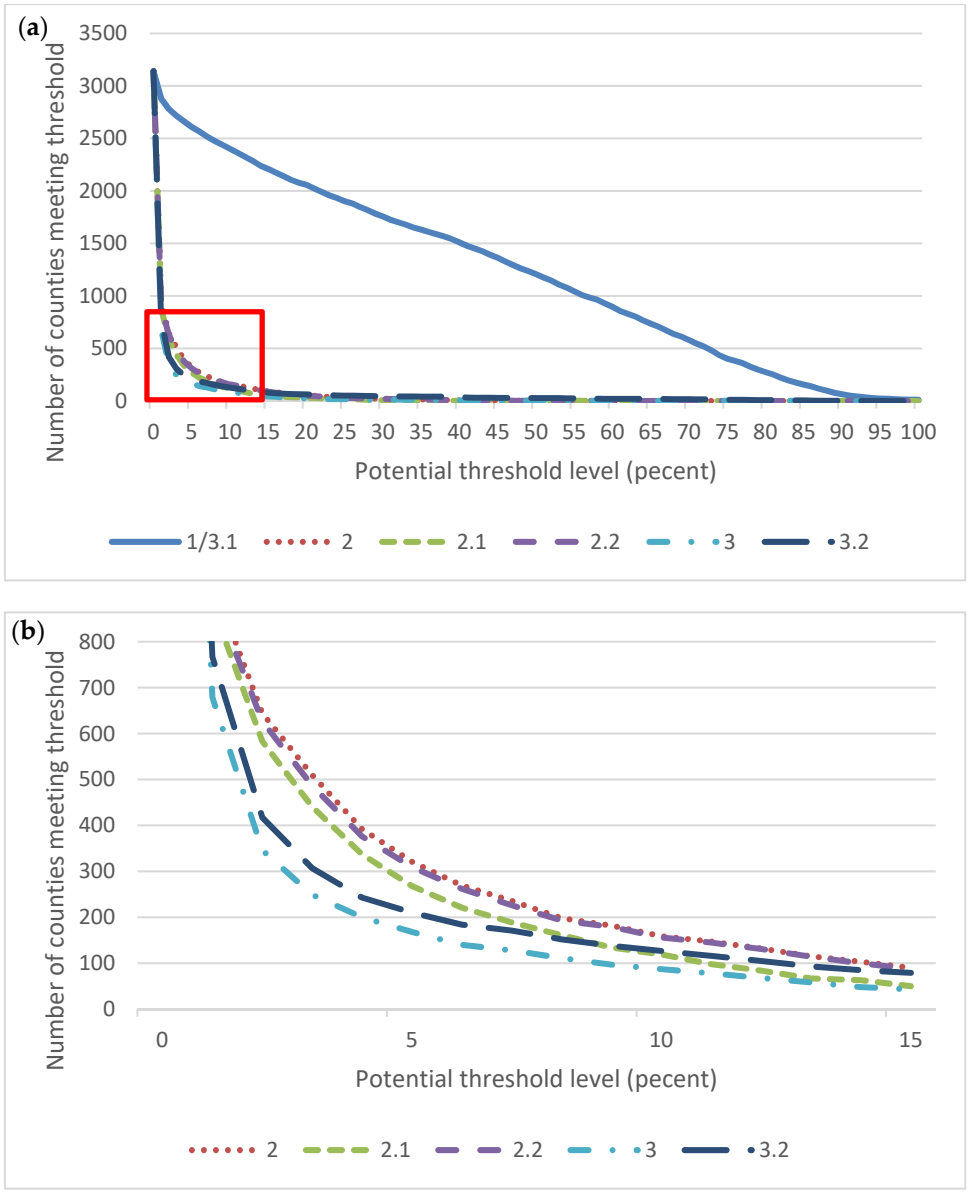

Figure 2. Number of counties that meet the threshold level for all potential threshold levels. (**a**) The 0–100% potential thresholds for all criteria. (**b**) Zoom-in of region from 0 to 15%, indicated by red box in (**a**).

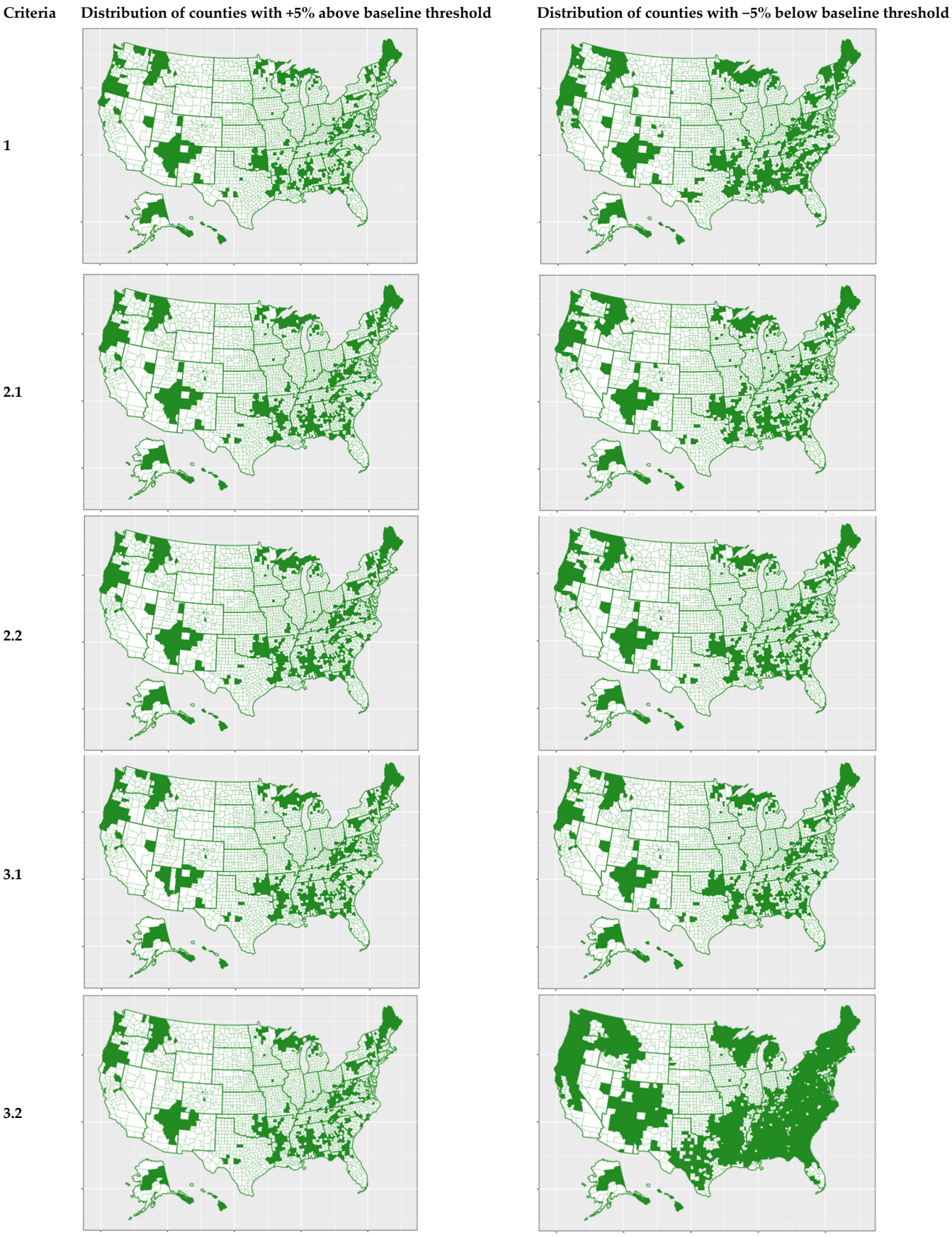

Figure 3. Distribution of forest-dependent counties with thresholds for each sub-criterion changed ±5% from the baseline level.

5. Discussion and Conclusions

This research is the first in the United States, to our knowledge, to use three distinct criteria for identifying forest dependency. While past theoretical work has identified various forms of forest dependency, past empirical work has focused almost exclusively on economic measures such as income and employment. The empirical criteria we created were based on the conceptual framework advocated in past literature and theory [4,5,13,16], which clearly identified the limitations of focusing solely on economic dependence and pointed to environmental and social forms of forest dependence. From that conceptual framework, we scoured data sources to find acceptable proxy measures for dependency, which are publicly available and likely to be replicable in the future. While the existing data variables certainly have limitations, not the least of which is that they are not all available at smaller spatial scales below the county, we believe that this approach is the best possible balance for national wall-to-wall reporting. Certainly, other purposes may use other variables and geospatial scales that match their objectives. As it stands, our approach demonstrates the possibilities and limitations of operationalizing the broad concepts of forest dependence discussed in the literature, for national reporting.

Our measures identified 524 forest-dependent counties, compared to 742 by Haynes [16]. Geographically, Haynes [16] identified more counties in the Southeast, Appalachian, and New England regions, as well as several additional counties in Colorado, while our method notably identified several counties in the southwest, associated with our criterion 3. While not identical, many of the same counties in the upper Midwest and Pacific Northwest were identified by both studies. Rasker [18] identified the top 25 historically timber-dependent counties in the west, 19 of which are consistent with the classification of forest-dependent counties by our criteria and data. Our criteria, however, found numerous other counties in the same states, many of which are adjacent or close to the counties identified by Rasker [18]. Furthermore, we identified several counties in the Southwest, primarily under criterion 3, that Rasker [18] did not identify as historically timber-dependent.

Counties are not the same as communities [4,5]. Still, residents within counties do share some aspects of community, and counties have been the commonly used proxy for communities in most empirical studies in the U.S. In Canada, other approaches have been used, notably census subdivisions [17,38] or municipalities [15]. In the U.S., for certain purposes, it may be possible to craft alternative criteria using other data sources available at the census tract level. Census tracts are subdivisions of a county, and there are about 73,000 in the United States (compared to 3410 counties). Census tracts certainly are themselves not perfect proxies for communities—they may be bigger than a community in some contexts, and smaller in others, or totally distinct—but may be a closer representation for some purposes. However, the FIA land cover and economic data are generally not available at that spatial scale.

Our approach has limitations, primarily due to lack of data on direct measures of many aspects of forest dependence, particularly at smaller spatial scales. This is true in terms of data on social and cultural uses of forests, ecosystem service mapping, as well as forest-based tourism and recreation. However, we believe it does the best job possible of balancing theory with practical challenges.

Forest dependence is a key issue for policies and programs of governmental and non-governmental entities. Those groups have proposed and implemented programs such as REDD+, payments for ecosystem services, carbon markets, and collaborative and community-based governance, which will alter human–forest interactions. Forest-dependent communities are those that are likely to feel the impacts, whether positive or negative. Therefore, identifying forest-dependent communities is the first step towards measuring potential positive and negative impacts on those communities. Past research has explored various interrelated topics in those regards, including community well-being, vulnerability, stability, adaptability, capacity, resilience, and capital [5–7,16,22,24]. Together, these frameworks focus on communities' ability to respond to change by enhancing positive outcomes and mitigating negative ones, or conversely, their inability to respond to changes

positively. Recent efforts have identified key concepts within these frameworks and sought to develop datasets and indices to measure and compare communities, counties, or other areas, particularly the topics of social vulnerability [39–41] and community capitals [42,43]. These approaches dovetail nicely with the data-driven approach to identifying forest-dependent communities described in this manuscript [24].

While our work was focused on the United States, the ideas expressed in the Introduction and Background are broadly relevant in all countries where identification of forest dependence may be important [13], and the process we used in the Materials and Methods to identify data sources may provide a guide for future work in those places.

In sum, we identified 524 counties, or 16.7% of all counties that met our criteria for forest dependence. The highest concentrations were in the Pacific Northwest and Southeast regions and were more common among non-metro counties. Future research can explore community resilience and capacity differences among forest-dependent vs. non-forest-dependent communities, as well as the spectrum of various degrees of dependence.

6. Disclaimers

The findings and conclusions in this publication are those of the author(s) and should not be construed to represent any official USDA, DOE, ORAU/ORISE, or U.S. Government determination or policy.

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Data Availability Statement: All data described in the Materials and Methods section have been compiled and published in an online, public database [1].

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