Research Supporting Stemming the Loss of Family Forests across the United States

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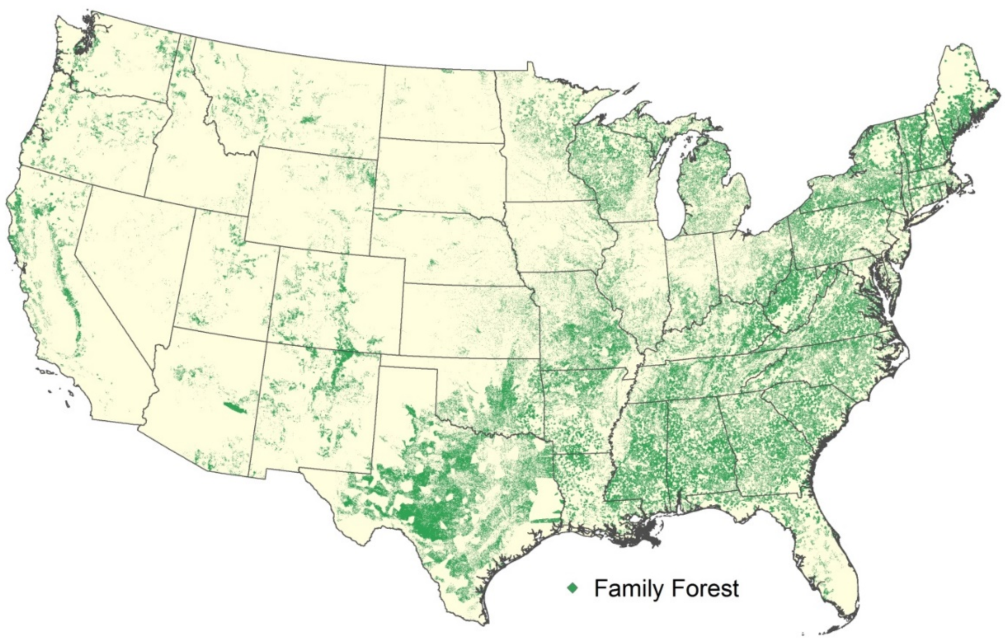

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Executive Summary

- Family forests provide many benefits to society. However, numerous threats to family forests put these benefits at risk. To evaluate the benefits of and threats to family forests, as well as potential solutions to these threats, a multiple methods approach was taken including: summarization of existing literature; survey of extension foresters across the U.S.; and spatial analysis of threats to and benefits of family forests across the U.S.

Literature review

- The body of literature relating to family forest ownerships is extensive, but unfortunately much of it is disjointed and does not provide some key information needed to advance forest conservation.
- We know a lot about ownership attitudes and behaviors. We know owners are strongly amenity oriented, but the research and existing policies and programs are strongly financially oriented. Research and policies should be better aligned with owners' values and needs in order to increase relevance and efficacy.
- Empirically, we know relatively little about what actually influences landowners' attitudes and behaviors. Many of the relationships included in the literature are correlations and while they may suggest causal relationships, they cannot be used to prove them.
- The theoretical underpinnings of landowner behaviors are weak. There is a need for a fuller understanding of the multifaceted factors that influence their actions.
- A confounding factor amongst the published literature is differences in populations of interest, methods, survey instruments, scales of analysis, and analytical techniques. By harmonizing landowner studies, greater comparability will be provided that will lead to stronger and more actionable conclusions.
- To make the findings of the peer-reviewed and non-peer-reviewed literature more useful, it would be beneficial to transform the work into information that is more readily available, more easily digestible, and ideally in a database that searchable and frequently updated.

Extension and American Forest Foundation surveys

- Extension foresters rated wildlife, water, and recreation as the greatest benefits of family forests. They rated insects and disease, invasive species, and parcellation/fragmentation as the greatest threats to family forests. Extension foresters rated education/extension, public awareness about family forests, and strong wood markets as the greatest potential solutions to the threats that face family forests.

- There were some regional differences in the way extension foresters rated the benefits, threats and solutions related to family forests. For example, extension foresters rated fire as a very important threat in the West and Southeast, while in the East and Midwest fire was rated as a low threat.
- American Forest Foundation staff and committee members rated water, wildlife, and air quality as the greatest benefits of family forests. They rated development, fragmentation, and parcellation as the greatest threats to family forests. They rated estate planning, peer-to-peer networking, and education/extension as the greatest potential solutions to the threats that face family forests.

Spatial analysis

- The importance of benefits depends on one's perspective – society may value a different set of benefits than owners.
- Benefits from family forests are not distributed evenly across the U.S.
- The threats to family forests depend on the specific benefit(s) being considered.
- Analyses in this report are restricted to available spatially explicit national data. Critical threats to family forests may be missing from these analyses due to this lack of data availability.

Metrics

- As the threats depend on the benefits, so to do the metrics for evaluating them.
- Metrics needs to be: aligned with the project goals; objective and repeatable; and transparent. Ideally, they would also be simple and straightforward and utilize data that are already being collected for other purposes or as at least, are inexpensive and easy to collect.
- For most forest conservation efforts, it will be necessary to establish short- and long-term metrics. The short-term metrics should be focused on what can be more readily and directly influenced, like landowners' awareness of a given program, and the long-term metrics should be focused on the ultimate goal, such as keeping forests as forests.

Next Steps

- With the body of literature that is now amassed it is time to bring together the key researchers and users of the researcher to fully digest what has been done and to plot a shared path forward.

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1 Introduction

1.1 Background

Families and individuals, collectively referred to as family forest owners, own 264 million acres of America's forests – more than the federal government or large corporations (Butler 2008). These lands provide countless benefits ranging from carbon sequestration and water recharge to recreational opportunities and timber supply. The fate of these lands lies primarily in the hands of the 10 million family forest ownerships that control it.

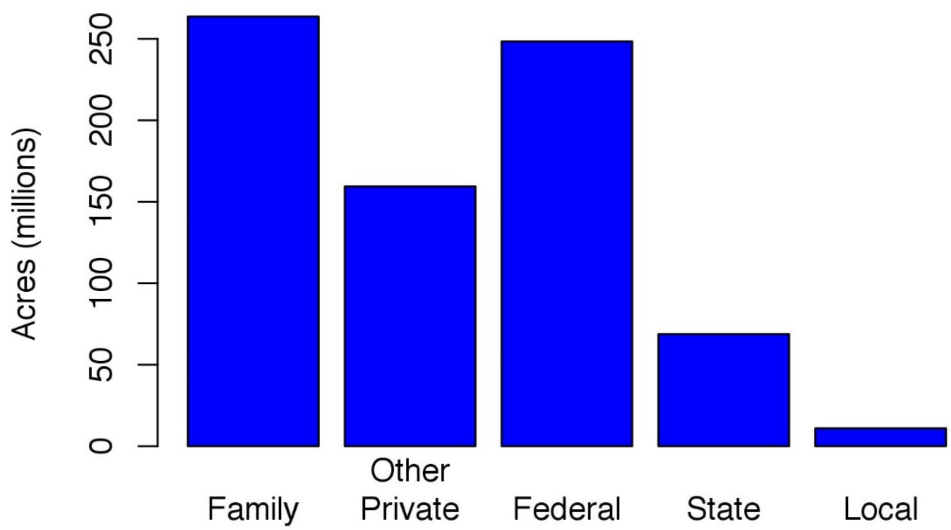

Figure 1. Percentage of forestland in the U.S. by ownership class, 2006 (Butler 2008).

Forest loss to development, invasive species, and wildfires are but a few of the challenges facing America's forests. The full extent of these threats on family forestlands is unknown, but it is likely these threats are as high, if not higher, on family forestlands as on other lands. The difference in the intensity of the threats has to do with family forestlands tending to be closer to where people live and the management challenges faced by owners with smaller parcels and less access to management knowledge and assistance. The U.S. Forest Service predicts that by 2060, an estimated 37 million acres of private forests will be converted to non-forest uses (Stein et al. 2005), and many, if not most, of these acres lost will be from family forestlands.

Public lands are largely protected by conservation laws and regulations, corporate forestlands are primarily managed to maximize financial return and are responsive to market forces, but the fate of family forests are dictated by a complex set of social, economic, and personal factors. Numerous research studies have examined specific aspects of factors influencing family forest owners' behaviors, but there has been little work that synthesizes this research.

1.2 Study objectives

This study was designed to evaluate the benefits of and threats to family forests as well as potential mitigating solutions that address those threats. The objectives were to:

1. Conduct a comprehensive literature review pertaining to: 1) the threats and challenges to family forest ownerships across the U.S.; 2) the benefits family forests provide to society; and 3) proposed solutions to mitigate the threats and challenges and enhance the benefits.
2. Based on the findings of Objective #1, quantify and display, via spatial products, the threats and challenges to family forest ownerships across the U.S. and the benefits family forests provide to society. Key research questions included:
    a. How much and where are family forests impacted by key threats, such as wildfire, invasive species, natural disasters, and conversion of forest to other land uses?
    b. What is the occurrence of forest fragmentation and parcellation as it pertains to family forest ownerships?
    c. How much and where are family forests expected to be at risk in the future due to the threats listed above? What are the relative intensities of these threats (i.e., where are the threats the greatest)?
    d. Where do family forest ownerships play a unique role in providing:
        i. Buffers to natural disasters, such as wildfires
        ii. Carbon sequestration
        iii. Fiber supply—for both traditional and emerging (e.g., biomass) markets
        iv. Recreation access
        v. Water quality and supply
        vi. Wildlife habitat—especially endangered and threatened species habitat
    e. How much and where do the threats and benefits overlap?
3. Propose metrics, gleaned through Objective #1, for determining if conservation efforts are impacting the threats listed above at both landscape and national levels.

1.3 Study components

To achieve these objectives, this study is comprised of the following elements:

- Literature review (Chapter 2): A review and synthesis of literature regarding family forests in the U.S. published between 2000 and 2013.

- Extension forester and American Forest Foundation surveys (Chapter 3): Results from a survey of extension foresters on the benefits from, threats to, and solutions for family forests. In addition, results from a parallel survey of American Forest Foundation staff and committee members are presented.
- Spatial analysis (Chapter 4): Using existing data sources, the benefits from family forests are quantified and the distributions are spatially displayed. These benefits are intersected with threats to family forest to identify how much and where benefits will potentially be impacted.
- Conclusions (Chapter 5): In addition to a summary of the findings of this report, this section includes implications of the findings for metrics of forest conservation, and next steps for this body of research.

2 Literature Review

2.1 Introduction

This chapter summarizes the literature published from 2000 through 2013 that is focused on family forest ownerships in the U.S. At the end of this chapter is summary of the scientific literature's current understanding of: 1) the threats and challenges to family forest ownerships across the U.S.; 2) the benefits family forests provide to society; and 3) proposed solutions to mitigate the threats and challenges and enhance the benefits.

Literature reviews are a common feature of most scientific articles, but literature review conducted as part of this project is unique because of the breadth of its scope – all U.S. family forest literature from 2000-2013, and its structured, systematic approach. On a periodic basis, the Yale School of Forestry publishes "annotated bibliographies of the literature on family forest owners" (Hodgdon and Tyrrell 2003, Hodgdon et al. 2007, Hodgdon et al. 2011). These reports provide brief summaries of each article, but there is no formal analysis and the bulleted list of conclusions is cursory. From the literature they conclude:

- The number of family forest ownerships is increasing (i.e., parcellation is occurring).
- The average age of owners is increasing.
- Family forest owners are primarily interested in the amenity values, e.g., aesthetics and recreational opportunities, provided by their forests.
- The attitudes towards environmental issues are more aligned with those of the general public than forestry professionals.
- Most owners do not have a management plan and have not sought professional advice.
- They question whether the studies, primarily conducted at the state or sub-state level, can be combined to understand national trends.

A more formal literature review is provided by Fischer et al. (2010) who compare the research on family forests conducted in the U.S. and Sweden. They note a number of similarities amongst the studies in the two countries and observed that the literature has evolved from a focus on timber supply to one focused on broader ownership behaviors and attitudes. They also conclude the field is "ripe for new multidisciplinary approaches."

In reference to studies of family forest owners, Amacher et al. (2003) asked "Is there anything left to study?" Based simply on the sheer number of research articles that continue to be published on this topic, the research community appears to believe there is still much more to learn. But what do we know so far and where should we head? The work summarized in this chapter attempts to address these questions.

2.2 Methods

A systematic literature review is one that is "standardized, structured, [and] protocol-driven" (Jesson et al. 2011). Through this approach, the results will be more "objective, balanced and unbiased" and should lead to stronger and more insightful conclusions. This differs from standard literature reviews because the structured approach is more transparent, repeatable, and altogether more rigorous. Hart (1998) outlines the basic steps in conducting a systematic literature review: defining the scope, identifying all of the relevant sources, and methodical summary of findings.

2.2.1 Scope

The scope of this structured literature review was peer-reviewed research articles focusing on family forest owners in the U.S. that were published between 2000 and 2013, inclusive. While the concept of family forest owners has been around for decades, the terms used to describe them have changed. Some papers use the term non-industrial private forest owners and others use the broader term private forest owners, although in actuality just referring to a subset of them. All of these terms, family forest owners, non-industrial private forest owners, and private forests owners were included in the literature searches, but only those focusing on family forest owners, regardless of terminology, were ultimately included in the analysis. In addition to peer-reviewed journal articles, research published as U.S. Forest Service, General Technical Reports were also included as these too go through a peer-review process and represent a substantial proportion of the scientific research published on this topic.

As important as the inclusion criteria are the *exclusion* criteria. Due to a lack of formal peer-review and inconsistent access (e.g., indexing in citation databases), opinion pieces, such as letters to the editor, theses and dissertations, U.S. Forest Service bulletins, and other gray literature were excluded. Unless they were analyzed in conjunction with family forest ownerships, papers examining community forestry, industrial forest owners, tribal/indigenous forest owners, and public ownerships were excluded. Selected researcher papers focusing of family forest ownerships in other countries are mentioned in the discussion below, but were excluded from the structured literature review.

2.2.2 Article Identification

Based on the criteria outline above, articles were identified using the lead author's personal citations database, database searches, and snowball sampling. For the past decade the lead author has been maintaining a literature citations database on family forest owners. He amassed over 5,000 references from various previous projects, reading journal articles, and perusing tables of contents of relevant journals. Many of the articles fell outside the criteria for this structured literature review, but it did provide a good starting point. To augment this database, a formal search of literature citation databases was conducted by a librarian at the U.S. Forest Service's National Library. Using the search criteria provided by the authors, as outlined in the scope section above, the librarian searched the Scopus (www.elsevier.com/online-tools/scopus) and ProQuest (www.proquest.com) databases.

The 1,000s of citations amassed were then screened based on the scoping criteria outlined above. Snowball sampling was then conducted where the literature cited sections of each of the qualifying articles were reviewed and new articles added to the database. The new articles were in turn snowball sampled. This process was repeated until no additional references were identified.

The literature database was continually updated as the project was being conducted and new additions snowball sampled. This was necessary to incorporate newly published literature and the small number of articles that were missed through the other citation identification methods.

Electronic copies of all articles were obtained. In addition to the basic bibliographic information, the keywords and abstracts were input into the database. All citations were stored in the EndNote citations database software (http://endnote.com).

The full list of articles used in this article is available in Appendix 2-A. In addition, these citations, along with the broader literature identified (i.e., those not meeting the inclusion criteria) will be available in a searchable online database at: www.familyforestresearchcenter.org/publications/search.html. It is our intention to periodically update this online database.

2.2.3 Analysis

The emergent themes from the literature were identified using qualitative analysis techniques – namely open coding. The titles, keywords, and abstracts were exported from EndNote and imported into the NVivo qualitative analysis software (www.qsrinternational.com/products_nvivo.aspx). A codebook was drafted prior to coding and then modified after an initial coding of all of references. In addition to the coding of the titles, keywords, and abstracts, key articles were (re)read to glean further insights.

2.3 Results

2.3.1 General Information

Between 2000 and 2013, there were 445 articles published that focused on family forest owners in the U.S. This works out to an average of 30 articles per year, but the publication rate has not been constant over this time period (Figure 2). There was nearly a doubling of the number articles published per year between 2000 and 2013. These fluctuations may be a result of increased interest in the topic, increased funding for this type of research, or a combination thereof.

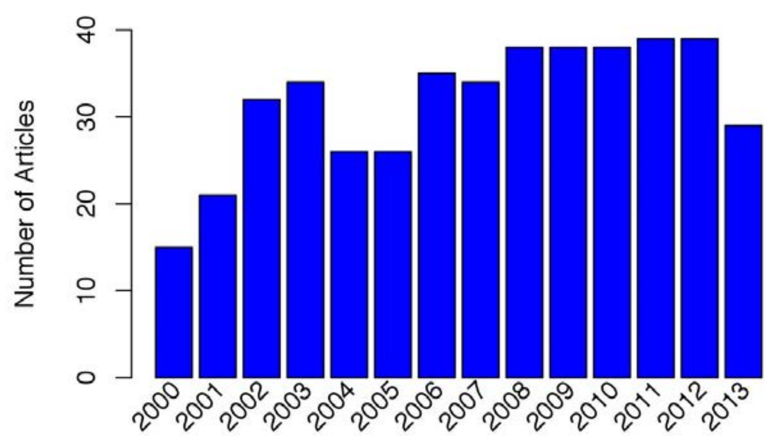

Figure 2. Number of peer-reviewed articles on family forest owners in the U.S. published between 2000 and 2013 by year.

The papers with the greatest influence, i.e., the highest impact factors as measured by the number of citations in other literature reviewed here, are listed in Figure 3. Examining impact by this metric does have the downside of not being able to capture the potential influence of papers that have been more recently published and simply have not had as long a time to be cited. The most commonly cited papers, Butler and Leatherberry 2004 and Butler 2008, provide broad national statistics that are often cited in the introductions of many of the other papers to set the context. A number of the highly cited papers, including Butler et al. 2007, Finley and Kittredge 2006, Kluender and Walkingstick 2000, and Majumdar et al. 2008, deal with means of segmenting or classifying owners. Two of the top ten studies, Amacher et al. 2004 and Beach et al. 2005, look at family forest owners from an economic perspective and both summarize results from previous literature. The other papers deal with forest management decisions (Joshi and Arano 2009), characteristics of new family forest owners (Kendra and Hull 2005), extension education (Kittredge 2004), and another broadly addresses forest parcellation (Sampson and DeCoster 2000).

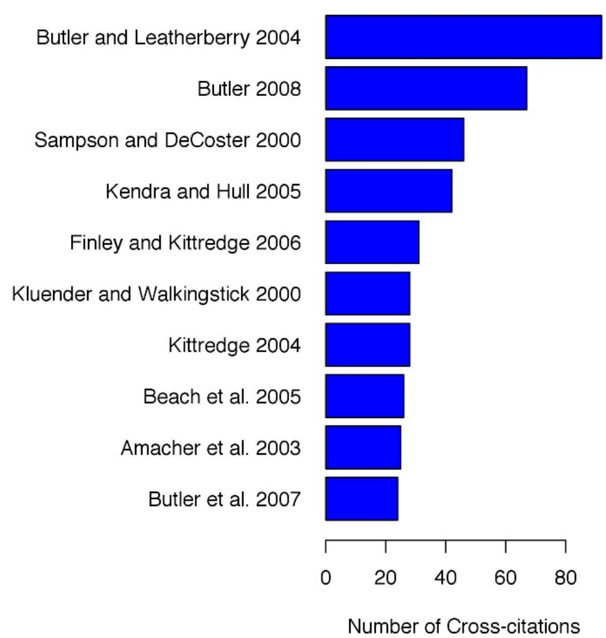

Figure 3. Impact factors (number of citations) of the ten most cited papers pertaining to U.S. family forest owners published between 2000 and 2013.

There were a total of 657 authors across the 445 articles reviewed. The top ten authors have authored or co-authored 179 papers (Figure 4). Many of these authors were co-authors on the same papers so this represents something less than the 40% of the papers the simple math would imply, but the data are not coded to determine how much less.

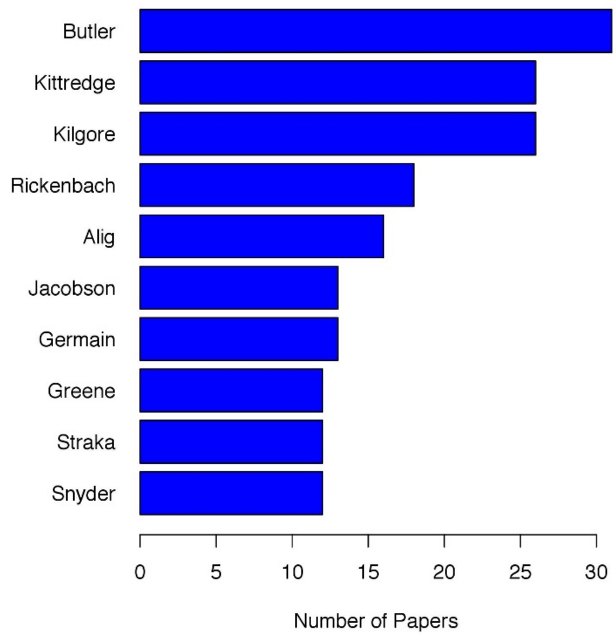

Figure 4. Number of papers related to U.S. family forest owners published between 2000 and 2013, by author.

Different outlets for the papers specialize in different topics and approaches. The *Journal of Forestry*, the most common outlet with 17% of the published articles (Figure 5), is aimed at a broad swath of the forestry community and strives for relevance amongst forestry practitioners, educators, and researchers. Other outlets are aimed at specific types of researchers, such as *Forest Policy and Economics* and *Journal of Forest Economics* aimed at policy analysts and economists. Others are aimed at specific types of practitioners such as foresters (i.e., *Northern* and *Southern Journal of Applied Forestry*) or educators (i.e., *Journal of Extension*). There can also be a difference in the approaches of the articles that varies by outlet. For example, papers published in *Society and Natural Resources* tend to have stronger theoretical grounding and more likely to have a qualitative component versus *Forest Science* papers that tend to be more model and quantitative oriented.

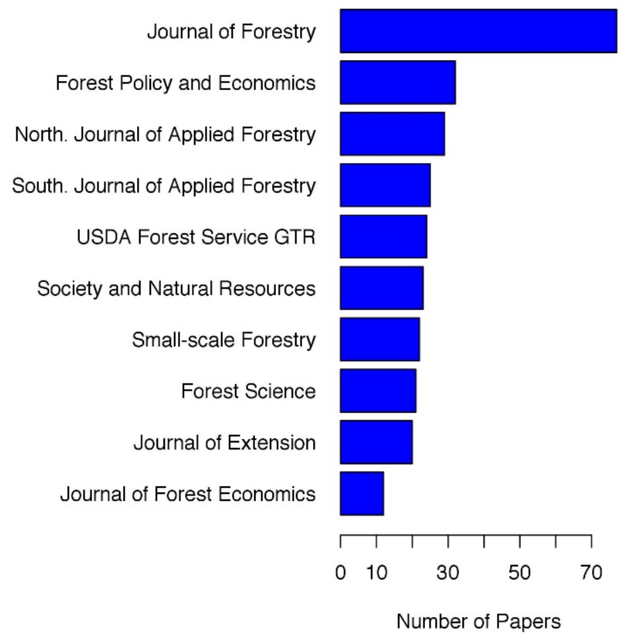

Figure 5. Number of publications related to U.S. family forest owners published between 2000 and 2013, by outlet.

2.3.2 Populations of Interest

Although all of the articles examined family forest owners of the U.S., most focused on a subset of these owners. There were relatively few articles that were national in scope, most were state-level and some covered just specific portions of a state (e.g., Becker et al. 2010). Among the sub-national papers, the majority was in the North (41%) or the South (39%), with the remainder being in the West. Often the papers only focused on a subset of owners, such as those participating in specific programs (e.g., Baumgartner et al. 2008). While allowing for examination of participants, this approach limits studies' abilities to make comparisons to non-participants, an important aspect for understanding differences and how to expand programs and services. Other studies have focus on specific demographics of owners, such as African-Americans (Gan and Kebede 2005) or new landowners (Kendra and Hull 2005).

2.3.3 General Approaches

A diversity of approaches has been used to study family forest owners in the U.S. Many studies have relied on primary data collection, while others have relied on secondary data. The latter is usually quicker and often allows for multiple data sets to be combined, but many times the exact questions being asked by the researchers are not precisely addressed and proxies are needed. Primary data collection does not have this drawback, but it is more expensive and time-consuming. Most articles use a quantitative approach to data collection and analysis, but a fair number also use qualitative and a small number use a mixed-methods approach that combines quantitative and qualitative methods.

Meta-analyses are a structured way to make comparisons across studies, but differences in populations of interest, analyses, and other issues complicate the comparisons. Beach et al. (2005), discussed further below, is an example of how this method can be applied, in this case for timber harvesting, reforestation, and timber stand improvement behaviors. There are few other true meta-analyses within the family forest literature.

Most commonly, in over 100 studies, quantitative studies utilize surveys administered to landowners, but a dozen or so studies rely on surveys of those who provide services to the owners or administer landowner assistance programs. The U.S. Forest Service's National Woodland Owner Survey (NWOS) is a national survey that primarily uses self-administered, mail-back surveys of landowners (Butler et al. 2005). The NWOS has the advantage of being administered consistently across states, being implemented periodically to allow for time trend analyses, and being based on a random sample of all family forest owners to provide unbiased population-level estimates. Studies of experts and administrators (e.g., Ellefson et al. 2007a) allow for both a different perspective on family forest owners and an understanding of how programs and services are being implemented, but they should not be used as direct indicators of owners' perceptions.

Quantitative data, properly collected, is amenable to statistical analyses and modeling. Many studies (e.g., Butler 2008) are largely descriptive, but other have employed an array of statistical approaches. For basic analyses about what characteristics are correlated with a given behavior, logistic regression is the most common modeling approach (e.g., Gan and Kebede 2005), be it of the logit, probit, or tobit variety. To help differentiate among types of family forest owners, segmentation analyses are often conducted. This most commonly involves starting with a principal components analysis to reduce the dimensionality of the ownership characteristics, often ownership objectives, followed by k-means clustering to group the owners (e.g., Majumdar et al. 2008). To assess owners' willingness to pay or accept hypothetical programs, such as carbon sequestration, contingent valuation and similar approaches have been used. Assessment of the results of these approaches should take into account the "hypothetical bias" (Markowski-Lindsay et al. 2011) which means that people are more likely to accept a hypothetical offer than a real offer. Insights can still be gained from their responses, such as preferential program attributes, but their willingness should not be used as a direct proxy of what would happen if the program was actually offered.

Qualitative approaches allow for more in-depth and nuanced understanding of owners' attitudes and behaviors. Through personal interviews (Cacciapaglia et al. 2012), focus groups (Daniels et al. 2010), or other qualitative approaches, researchers are able to delve deeper into specific topics. The disadvantage of qualitative approaches is that the results cannot be easily extrapolated to the whole population due to how the samples are often drawn and the inherently small sample sizes associated with these intensive methods.

Mixed-methods, combining quantitative and qualitative approaches into a single study, is a solution to overcoming the weaknesses of these approaches and allows the retention of the strengths of both (Bliss and Martin 1989). However these approaches are difficult to effectively implement and analyze.

Another type of mixed-methods approach is the combining of field surveys with landowner surveys (Brinckman and Munsell 2012, Caron et al. 2012). This approach allows the close coupling of land and landowner characteristics, but it is expensive to implement and hence not likely to have large sample sizes, and it may suffer from some sample selection biases, as it is a rather intrusive technique.

2.3.4 Theoretical Approaches

In general, the theoretical basis for explaining family forest owner behaviors, or other attributes, is limited, cursory, or, more commonly, not explicitly stated. Some of the theories invoked include:

- Grounded theory
- Theory of planned behavior
- Theory of diffusion of innovation

Grounded theory implies there is no *a priori* theory that can be applied and it must therefore emerge from the research. More often this means the researchers did not identify a specific theory before conducting their research and are simply adding a *post-hoc* theory to satisfy peer reviewers. That being said, grounded theory can be applied effectively and some do, such as Domínguez and Shannon (2011), which is admittedly a European study and outside the scope of this literature review. The Theory of Planned Behavior is cited in some of the more recent literature, but, again with the exception of a European study (i.e., Karppinen 2005), it is rarely fully imbedded in the analyses. This theory states that a behavior is influenced by one's intentions which are in turn influenced by attitudes, norms, and perceived controls (Ajzen 1991). The Theory of Diffusion of Innovation is often invoked by papers focusing on programs and education as it describes the progression of how new ideas are adopted as individuals progress from acquiring knowledge to seeking additional information to deciding to take action to doing the action and to finally assessing the outcomes of the action (Rogers 1995). This theory can also be used to classify individuals into when they are likely to take an action, be they the first ones to do so, the innovators, or the last, the laggards.

2.3.5 Topics

The topics covered by the literature are vast, but there are some topics that are much more common. On a general level, the most common topics, addressed in at least 20% of the articles, are: forest management, threats to forests, markets, and policies (Figure 6). Other, less common, topics include: education, ownership characteristics, ecosystem services, taxation, social capital, and threatened and endangered habitats and species. After discussing the findings that are a part of each of these topics, we present the topics in terms of benefits from, threats to, and solutions for family forest owners in order to facilitate analyses in others parts of this project.

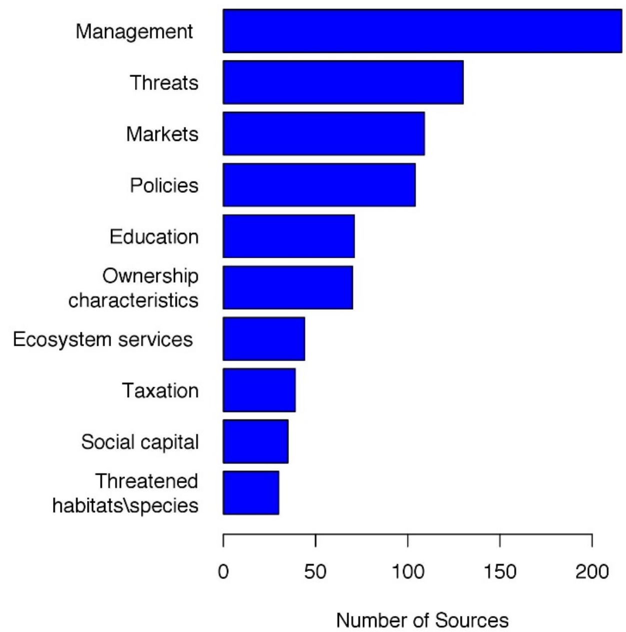

Figure 6. Frequency of topics addressed in the family forest literature.

2.3.5.1 Forest Management

Forest management is a broad topic. Some papers deal with it broadly and discuss general conservation attitudes and practices, while others are more specific and deal with, for example, management plans, timber supply, or habitat management. One reason for a paper to focus on timber harvesting is that it is currently one of the largest disturbances in forests and influences many other processes, such as carbon sequestration (Alig 2003) or biomass supply (Aguilar et al. 2013b). Beach et al. (2005) provide a comprehensive, although now somewhat dated, synopsis of econometrics studies looking at timber harvesting behavior, reforestation, and timber stand improvement by family forest owners using a meta-analysis approach – i.e., formally summarizing previous studies. The variables most commonly reported to be *positively* correlated with timber harvesting are size of forest holdings, amount of growing stock, site quality, and land accessibility. The most common variables to be *negatively* correlated with timber harvesting are income, owner age, and amenity values. Stumpage prices have been largely shown to be positively correlated with harvesting, but a number of studies have found this variable to insignificant, or even negative. This may be due to poor stumpage data, researchers' inability to know what the owner was actually offered, or it may be a reflection of owners being less financially motivated than economic theory would suggest.

The concept of ecosystem or landscape-level management has been addressed in a few studies. According to Belin et al. (2005), owners "showed favorable attitudes toward: unique, small-scale ecological features like rare species and wetlands; management at spatial scales larger than the individual parcel; and ownership beyond a single generation." Likewise, Creighton et al. (2002) also found some interest in these approaches, but pointed out the need for self-governance, i.e., the owners being part of the decision making process.

2.3.5.2 Threats to Family Forests

Potential threats to family forests are numerous. A few that have received attention in the literature are climate change, wildfires, land use conversions, and parcellation.

Climate change is discussed in general terms as a threat to forests, but there is little work examining how this will specifically impact family forest owners and how family forest owners will react to climate change. Grotta et al. (2013) conducted focus groups with family forest owners on this topic and found that most have no plans to mitigate the potential impacts of climate change.

Across many parts of the U.S., particularly the West and South, wildfire is a major issue. This topic is indeed perceived by many owners as a major threat with many reporting having taken some action to mitigate the likelihood or severity wildfires (Jarrett et al. 2009). Jarrett et al. (2009) noted that program awareness would not be sufficient to motivate action of non-active owners and suggest other stimuli will be needed. Factors that increase owners' likelihood of conducting fire hazard reduction measures include living on the land and being aware of the landscape conditions (Fischer 2011). Perceived wildfire threats appear to be framed "almost entirely at larger scales and explained by broader worldviews and political ideologies" than actual conditions on an owner's land (Cacciapaglia et al. 2012), and some owners are skeptical of parcel-level approaches (Brenkert-Smith 2011). Having incentives for conducting fuel reduction practices, such as markets for low quality wood, is often cited as a potential solution, as well as cost-share programs and increased information (Amacher et al. 2006).

Historically, most forest loss in the U.S. was due to conversion to agriculture, but conversion to residential or commercial uses is an increasing threat (Bettinger et al. 2013). Population pressures and individuals' preferences for living in rural environments are causing the development pressures (Kline et al. 2004). Commodity prices, expanded markets (e.g., corn for ethanol), and new technologies cause the conversion of forestland to and from agricultural land (Alig 2003).

Parcellation is the process of breaking up holdings that were owned by a single ownership into smaller holdings controlled by multiple ownerships and has been identified as a major threat to family forests (Sampson and DeCoster 2000, Kittredge 2004). Parcellation has implications for timber supply due to economies of scale, recreational/hunting access as it requires gaining permissions from more owners, and for development. Anderson et al. (2012) found that, as has been long assumed but never fully quantified, parcellation does indeed lead to more homes being built and an increase in the associated infrastructure. One reason for increased parcellation is that, for many forests, the non-timber value now exceeds the timber value (Zhang et al. 2005).

2.3.5.3 Markets

Looking strictly at the financial aspects of family forests, traditional forestry is unable to cover holdings costs (i.e., property taxes) in at least some parts of the country (D'Amato et al. 2010) and in other parts of the country, forest uses may not be competitive as compared to agricultural uses (Frey et al. 2010). This means that in order for family forests to be profitable, either timber values need to rise or additional revenue streams need to be found, such as carbon sequestration and biomass. But it should also be noted that most family forest owners do not own their land primarily for financial purposes (Butler 2008), and the amenity values provided by the standing trees may greatly outweigh any potential gains from extractive harvesting or other markets that infringe upon owners' uses and enjoyment of their property.

Although timber is not a primary objective of most family forest owners, many owners have commercially harvested trees from their land (Butler 2008). The importance of timber supply from the U.S., and in particular the family forest dominated Southern U.S., is likely to increase in the future as global demand rises (Arano and Munn 2006). Increased timber prices should increase the supply of wood from family forestlands either directly through owners being more willing to harvest trees for a higher price or indirectly through more proactive procurement programs, but the degree of the response, i.e., the elasticity, is unknown.

Selling the carbon sequestered by a forest has gained attention over the last decade. Carbon markets have fluctuated in fits and starts with the establishment and subsequent collapse of the Chicago Climate Exchange and various state-level programs, such as the Regional Greenhouse Gas Initiative and the California cap and trade systems. Although many owners would likely not object to receiving money for sequestering carbon, there are numerous barriers to entry including: low prices, high costs of entry, long time commitments, and requirements that may seem onerous or overly restrictive, such as management plans and certification (Diaz et al. 2009, Charnley et al. 2010, Markowski-Lindsay et al. 2011, Dickinson et al. 2012). Many of these issues are exasperated by the relatively small holding size of most family forest owners.

Harvesting woody biomass for energy is another market option that has been explored, but again with limited applicability to most family forest owners. In theory, biomass markets should help owners remove low-value wood, but the current markets are largely insufficient for doing so (Conrad et al. 2011), and most biomass harvesting needs to occur in conjunction with the removal of higher value products, i.e., sawlogs. There are numerous factors that are limiting family forest owners' willingness and ability to provide biomass including: concerns over environmental impacts (Aguilar et al. 2013a), depressed prices (Aguilar et al. 2013a), and attitudes towards forest management (Butler et al. 2010). Social marketing that stresses the "benefits to the local economy" and similar messages may increase landowners' willingness to harvest biomass, at least in some regions of the U.S. (Brinckman and Munsell 2012).

2.3.5.4 Policies (Excluding Taxation)

Public policies, be they financial, regulatory, or assistance oriented, are one of the dominant tools that society has to encourage family forest owners to continue to provide the benefits on which society relies and minimize the negative impacts from timber harvesting or other activities on wildlife, water quality, and other benefits (Kilgore and Blinn 2004). Taxation is one of the most prominent policy tools and is dealt with in a separate section below. The combination of regulatory and non-regulatory policies influences forest use and management (Bettinger et al. 2013), but the magnitude and additionally of these influences is not well understood. There is a disconnect between the objectives of many ownership objectives and the financial assumptions underlying many forestry programs that is hindering their ability to engage more owners (Daniels et al. 2010). Other obstacles include "cumbersome administrative procedures, lack of common vision for nonfederal forests, and inadequate resources of various kinds" (Ellefson et al. 2007b).

The most commonly studied forestry program in the U.S., in the period covered by this analysis, is the U.S. Forest Service's Forest Stewardship Program. Butler et al. (2014a) found FSP to be effective at encouraging owners to conduct management activities more effectively and over larger areas, but it was ineffective at encouraging non-active (i.e., unengaged) owners to become active. They also found that light touches, such as advice, may be just as effective as heavy touches, such as management plans. Shifts in the emphasis away from heavy to light touches would allow an exponential increase in the number of owners impacted. An innovative take on the standard FSP implementation is Washington State's coached management planning program (Baumgartner et al. 2008). Instead of a professionals writing the plans, the owners writes the plans with guidance provided by professionals through a series of workshops. These plans may not be quite the same level as plans written by professionals, but they have the added benefit of the owners having much more ownership of the plans and the process.

2.3.5.5 Education

Education is provided to landowners in the hope of increasing their awareness of forest conservation options and how to implement these options to better meet their needs and improve their land. The dominant source of education to forest owners is university-employed extension foresters, based at either the university campuses or in field extension offices. Other groups, such as non-governmental organizations or state forestry agencies, also offer educational opportunities. The educational programs and materials are offered through workshops, direct mail materials, the Internet, and other channels. To be most effective, the methods used to communicate the education materials with the owners should be tailored to their objectives, needs, and personal circumstances (Bardon et al. 2007). Although natural disasters are a most unwelcome event, they provide an opportunity for educating landowners about forest management options (Connelly and Smallidge 2003).

A tool used in an increasing number of states are master forest owner programs, where landowners are given training and empowered to help other owners improve the management of their lands. Evaluations of these programs has shown these owners benefit from the programs by increasing their personal knowledge of forest management, and they do indeed share this knowledge with other owners (Allred et al. 2011).

2.3.5.6 Ownership Characteristics

Characteristics of the owners and their land have been shown to be important factors correlated with many landowner behaviors. In general, current family forest owners are older, more likely to be retired, have higher incomes, and more educated than their predecessors (Butler and Ma 2011). Of all the owner attributes, size of forest holdings is the single best indicator of numerous other attributes. Size of holdings is positively correlated with, for example: timber harvesting (Beach et al. 2005, Butler 2008); having a management plan (Butler 2008); and forest conservation awareness (Caron et al. 2012).

2.3.5.7 Ecosystem Services

Family forests provide numerous ecosystem services, such as clean water, carbon sequestration, and wildlife habitat. From an economic perspective, ecosystem services are largely public goods and therefore owners have little incentive to maintain them (Matta et al. 2009). Further, the provisioning of these services can be complicated by the fact that they occur at scales larger than an individual owner's property (Rickenbach et al. 2011). Environmental advocates hope to encourage the provision of these goods and services for which landowners are traditionally not compensated for through payments of ecosystem services (Sedjo 2007, Jack et al. 2008) or potentially other mechanisms, such as ties to others, particularly forestry professionals (Knoot and Rickenbach 2011). The financial payments required to change owners' behaviors depends on their financial expectations from their land – for example, timber oriented owners require higher payments to defer harvesting than recreation oriented owners (Kline et al. 2000).

The preservation of water quality is the focus of a number of studies, principally focused on the implementation of Best Management Practices (BMPs). The New York City Watershed is a prominent example of how one municipality has selected to rely on forests, most of them family owned, to provide clean drinking water to millions of people in lieu of expensive water treatment facilities (LaPierre and Germain 2005). As such, it is not surprising that many studies on BMPs, and other issues, have taken place in this watershed. Instead of a regulatory approach, the New York State government has opted to use educational, technical, and financial incentives (i.e., cost-sharing) to encourage BMPs (Munsell and Germain 2007). Owners with larger parcels were found to be more aware of water quality issues and resident owners were found to have more deleterious impacts on water quality, largely through more impervious surfaces, than absentee owners (Caron et al. 2012).

According to analysis by Adams et al. (2011) "the largest carbon increment response would come from changes in forest management: extending rotations, shifting silvicultural regimes, and reforestation to hardwood forest types (in some regions)." Through the carbon sequestration programs discussed above, it is hoped that these types of actions can be encouraged on family forestlands.

2.3.5.8 Taxation

Taxation is one of the most prominent government policies and as such, it is discussed separately from the other forest policies above. The primary taxes potentially impacting family forest owners are property, income (including harvesting), and estate taxes. Butler et al. (2012) concluded that:

> *"tax policies, in and of themselves, are not causing forest owners to take unplanned actions such as prematurely selling their land or harvesting trees. However, in combination with other factors, tax policies, especially property tax policies, can influence ownership and forest management decisions."*

It is property taxes that account for the greatest annual expenses of most family forest owners (Arano et al. 2002). All states have some form of preferential treatment of forests under property tax assessments, but the restrictions can mean many owners do not qualify (Butler et al. 2012) and for others, they are simply too onerous to justify the savings (Bagdon and Kilgore 2013). In general, there is a "lack of awareness, confusion, and misinformation about these programs and their often complicated and/or restrictive requirements are preventing them from reaching their full potential" (Butler et al. 2012). Enrollment in preferential property tax programs tends to be low, but could be increased if the programs were better aligned with owners' values and the programs were simpler and more transparent to both the owners and those who implement them (Fortney and Arano 2010). Reform of the property tax laws could potentially help address poverty in some areas, such as Appalachia (Fraley 2012).

2.3.5.9 Social Capital

The decisions of family forest owners are not made in a vacuum, they are influenced by numerous outside factors including the organizations and individuals who provide them with information and support – the social capital of the community (Floress et al. 2011). One way to examine social capital is through social network analysis by identifying who owners receive information from and the relative weight they provide to the different sources (Rickenbach 2009). This requires different research methods than are traditionally used. Some networks cater to specific segments of the ownership population, for example the Women Owning Woods Network in Oregon (Redmore and Tynon 2011).

2.3.5.10 Threatened Habitats and Species

Wildlife is an important reason for many individuals to own land, and nature protection is an important, often moral, tenet (Raymond and Olive 2008). The negative consequences of restrictions resulting from the identification of a threatened or endangered species or habitat are worrisome to many owners. For some owners, the concern is financial due to restrictions on timber harvesting (Drake and Jones 2002), but for others the bigger concerns are loss of power and control (Giampaoli and Bliss 2011). As the command and control system of the Endangered Species Act is apparently failing on many private lands, the role of alternative approaches have been explored (Langpap 2004). Fischer and Bliss (2009) identified conservation easements, habitat mitigation banking, and voluntary grass-roots initiatives as the most promising solutions.

2.3.5.11 Other Topics

Although not addressed in a high percentage of the literature, there are numerous other topics related to family forest owners that are the subject of papers ranging from recreation to cross-boundary cooperation to common pool resources. Some of these are topics that are just beginning to emerge and others will likely remain unique.

Recreation. Recreation is a common activity by owners on their own land, but allowing the public access to family forestland is far less common (Butler 2008). Hunting is a common activity, especially in certain parts of the country, such as Wisconsin (Christoffel and Craven 2000). Hunting leases can be an important source of income to owners (Mozumder et al. 2007, Munn et al. 2011), but these leases, as with general access, can be problematic to many owners who may own the land primarily for these opportunities. Barriers related to allowing public access are related to the owners' uses of the land, past problems with hunters or other recreationists, size of forest holdings, concerns about property rights, liability concerns, noise, and safety concerns (Jagnow et al. 2006, Zhang et al. 2006, Kilgore et al. 2008, Becker et al. 2010). Posting is not always synonymous with not allowing hunting. Some owners do this as a means to control who is on their land (Snyder et al. 2009), as allowing access to family and friends is very different than the general public (Becker et al. 2010).

Cooperation. Cooperation amongst family forest owners is important for obtaining landscape-level impacts, can be necessary for addressing some threats, such as fire, and can provide benefits to the owners in terms of more recreational opportunities and higher economic returns due to economies of scale (Rickenbach and Jahnke 2006, Schulte et al. 2008). Owner "age, affluence, personal values, and attitudes" have been shown to be correlated with owners' willingness to cooperate (Finley and Kittredge 2006). Their willingness to participate also depends on the types of activities being considered with non-financial activities, such as recreational trails, being, in general, more palatable than cooperation involving financial matters, such as timber harvests.

Common Pool Resources. Spurred on by the work of Elinor Ostrom, the topic of Common Pool Resources, has received increased attention. A common tenet of the traditional "tragedy of the commons" is that private property rights will solve the dilemma of individual actors over-exploiting a resource. Ostrom (1990) argues that community resources can be wisely managed and outlines some tenets of ones that have been successful including clearly defined boundaries, community established rules, monitoring, sanctions, and self-governance recognized by higher authorities. Acheson (2000) discusses how private property rights may not be a panacea and cites the case of extensive clearcut logging in Maine as an example. Although this practice is largely confined to industrial forestlands, it does have implications for some family forestlands that are managed equally intensively. The basic message from Acheson is that additional constraints may be required for private lands in order for society to maximize the shared benefits from these lands.

2.3.6 Benefits, Threats, and Solutions

The topics covered by the literature over the past 13 years can also be classified according to the benefits from, threats to, and solutions for family forests. Although relative frequency of these topics is presented here, these frequencies should not be interpreted as the relative importance of these topics. No studies of family forests have comprehensively looked at these topics, apart from the extension forester survey conducted as part of this project and presented below, and these counts simply represent the number of articles that have somehow addressed the given topic. The categories used to summarize the benefits, threats, and solutions were selected so the results can be integrated with the other parts of this project. Details of the specific topics are provided above.

Benefits. The most common benefits topics, in terms of number of papers in which they are discussed, are financial gains by the owners, timber production, carbon sequestration, wildlife habitat, ecosystem services, water quality, biomass productions, hunting, biodiversity, and recreation (Figure 7). Other benefits discussed include nontimber forest products, vernal pools, tourism, and maple syrup production.

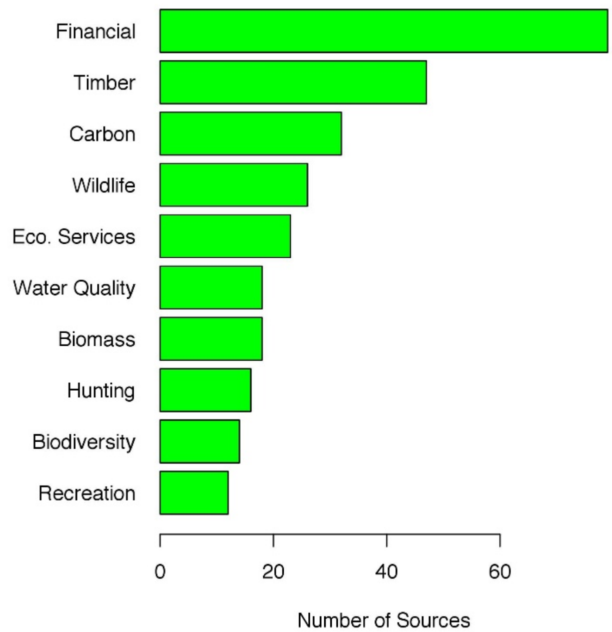

Figure 7. Frequency of the benefits from family forests addressed in the U.S. family forestry literature published between 2000 and 2013.

Threats. The primary threats to forests, according to the number of papers discussing the issue, are development, parcellation, wildfire, climate change, land-use conversion, fragmentation, insects and diseases, invasive plants, pollution, and impervious surfaces (Figure 8). Other topics discussed, but less commonly so, are intergenerational transfer, zoning, natural disasters, ignorance, and high grading.

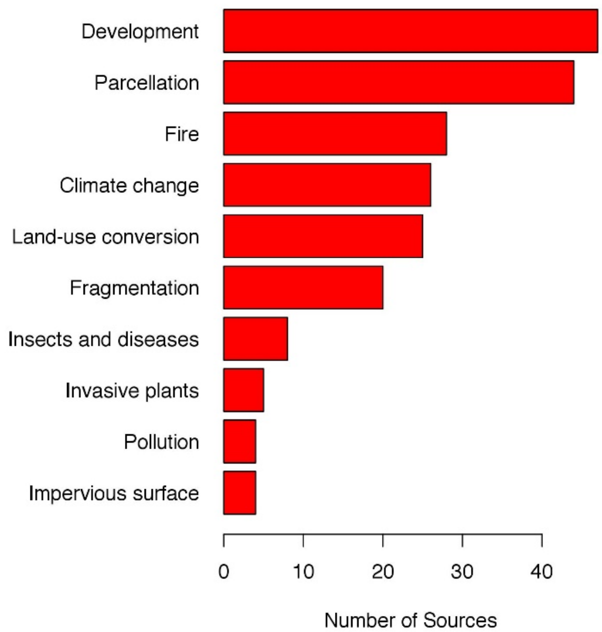

Figure 8. Frequency of the threats to family forests addressed in the U.S. family forestry literature published between 2000 and 2013.

Solutions. The most commonly cited solutions were programs and policies, education, forest management, social capital, new and improved markets, and better communication materials. Unfortunately, most of these potential solutions are given short shrift in the papers, often as a passing statement in one of the last paragraphs. There is little empirical evidence on if and how the solutions will actually change owners' attitudes and behaviors.

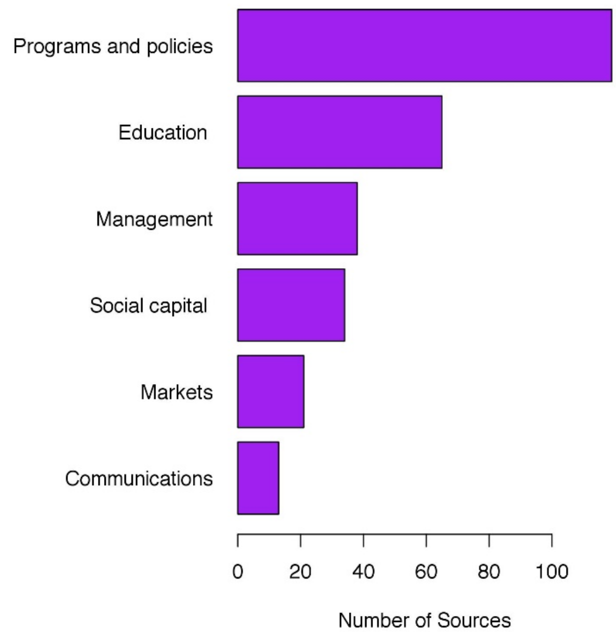

Figure 9. Frequency of the solutions for family forests addressed in the U.S. family forestry literature published between 2000 and 2013.

2.4 Conclusions

The body of literature relating to family forest ownerships in the U.S. is extensive, but unfortunately much of it is disjointed and does not provide the information needed to advance forest conservation. We know a lot about ownership attitudes and behaviors. Owners are amenity oriented. Most don't have a management plan, but are amenable to management, as evidenced by the high proportions that have harvested trees. There is a lot of focus on management in the literature, particularly on timber harvesting. The disconnect between researcher and owner objectives is analogous to the disconnect between owners' objectives and policies. A focus on financial aspects is not well founded – research and policies should be better aligned with owners' values and needs. Indeed, there may be major differences in how owners and forestry professionals perceive some basic concepts, such as forest management (Davis and Fly 2010). With the body of literature that is now amassed it may well be time to bring together the key researchers and users of the research to fully digest what has been done and to plot a shared path forward.

The theoretical underpinnings of landowner behaviors are weak. There is a need for a fuller understanding of the multifaceted factors that influence their actions. Kittredge (2004) provides a starting point, but this can be greatly expanded upon by considering a broader set of actions and influences and incorporating psychological and social theories such as the Theory of Planned Behavior. Figure 10 may provide direction for the next iteration of the landowner decision model. Although it will be difficult to fully parameterize such a model, using non-traditional statistical approaches, such Bayesian statistics (Kruschke 2011), may help us make these types of models practical.

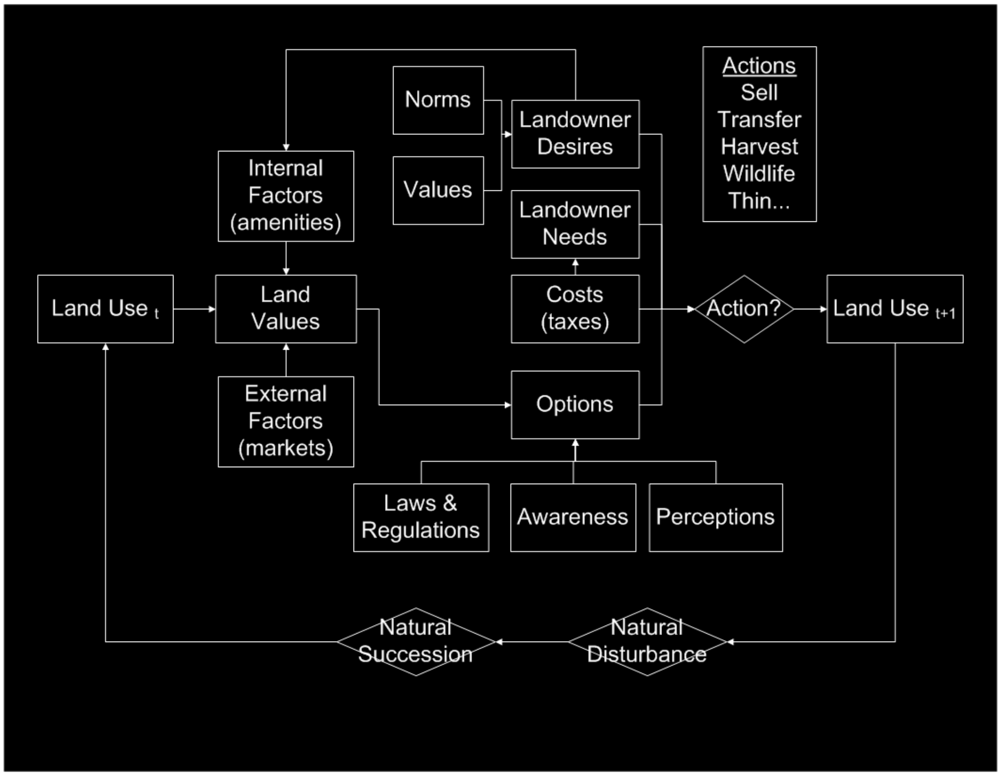

Figure 10. Generalized behavioral model of family forest owners.

There is a strong need for research that empirically tests the efficacy of programs, policies, and services. Many of the relationships presented above are correlations, and while they may suggest causal relationships, they cannot be used to prove them. In addition to stronger, more carefully designed analyses, a greater use of mixed-methods approaches may be useful in overcoming these shortcomings.

A confounding factor amongst the published literature is differences in populations of interest, methods, survey instruments, scales of analysis, and analytical techniques. As with the harmonizing that is being done among forest inventory programs (McRoberts et al. 2009), harmonizing among landowner studies will allow for greater comparability among studies, and hence stronger and more actionable conclusions. A first step in the process may be to require meta-data to be published with all studies. A next step could be the development of a shared pool of methods and questions.

From a forest conservation perspective, it may be beneficial to follow the example pioneered by the medical field, and now used in many other fields, of Evidenced Based Practices (EBP; Kitson et al. 1987). EBP allows for the rigorous examination of existing evidence and coupling of it with clinical/expert opinion and the values of the patient/owner. The steps in the EBP process include: project assessment, formulating the appropriate question, acquiring evidence, assessing the evidence, applying the findings, and evaluating the results.

Although excluded from this paper, the gray literature has much to contribute to our understanding of landowners. In general, the gray literature is more applied and more readily available to forestry practitioners, and it may be read by many more individuals, often magnitudes of order higher, than peer-reviewed articles. Many of the papers reviewed here, and in science more broadly writ, suffer from not being readily accessible. Placing more emphasis on translating peer-reviewed articles into easy to digest formats will help bridge this gap. Coalescing all of the information into a searchable database would help facilitate the sharing and dissemination of this often fragmented information.

3 Extension Forester and American Forest Foundation Surveys

3.1 Extension Forester Survey

To better assess the benefits of and threats to family forests as well as potential mitigating solutions that address those threats, we surveyed extension foresters across the U.S. Extension foresters are educators hired by universities to convey scientific information to forest owners. As such, they have a unique and insightful understanding on these benefits, threats, and solutions topics.

We surveyed extension foresters in 47 states. There were no designated extension foresters in Maine, Wyoming, or Nevada. We compiled lists of extension foresters in the remaining 47 states and, where there was more than one extension forester identified, randomly chose one forester from each state to participate in the survey. The survey was conducted in two phases, and both phases were implemented online. Phase one asked the extension foresters to list and explain the benefits from, threats to, and solutions for family forests in his/her state via open-ended questions. The responses were reviewed and categorized in order to facilitate the subsequent phase of the survey. In the second phase, the extension foresters were asked to rate the compiled lists of the most common benefits, threats, and solutions as determined from phase one. They were asked to rate each topic on a scale from 0 to 10, with 0 being the least important and 10 being the most important. To look at regional variation in the responses to phase two, the country was divided into 10 regions – Northeast and New York, mid-Atlantic, Midwest, upper Lake States, Southeast, South Central, Great Plains, northern Rocky Mountains, southern Rocky Mountains and Pacific Coast, as depicted in the maps below. We calculated and mapped the average rating for each region's benefits, threats and solutions.

3.1.1 Phase One Results

The survey response rate was 89% (42 extension foresters responded).

The most commonly mentioned benefits of family forests by extension foresters were wildlife (13%), water (11%), recreation (11%), rural aesthetics (11%), and wood products (10%). The remaining 43% of responses included benefits such as ecosystem services, income, hunting, jobs, wellness, and spirituality. The top listed threats to family forests included development (10%), parcellation and fragmentation (9%), invasive species (7%), insects and disease (7%) and lack of forest product markets (7%). Other top responses included lack of active management, taxes, fire, lack of estate planning, and climate change. The top solutions listed by extension foresters included increased tax incentives and changes to tax programs (12%), increased extension programs (9%), increased state landowner assistance (8%), increased education (7%), and increased cost-share programs (6%). Other solutions included woodland owner organizations, changes to legislation, increased incentive programs, increased conservation easement programs, more peer-to peer networking, increased product markets, and increased state programs. A complete list of benefits, threats, and solutions from the phase one survey can be found in Appendix 3-A.

Extension foresters also had the option of providing illustrative examples of benefits, threats and solutions in their state. For example, the extension forester from Vermont described one benefit of family forests as "Cultural connection/sense of place: Vermonters identify strongly with a heavily forested landscape.” When describing threats to Alaskan family forests, the extension forester said, “Climate change is affecting forests in Alaska. There are increased wildfires and insect infestation. Forests aren't managed for timber because there is a minimal forest products industry, so they get old and […] burn or get infested with insects which are becoming more prevalent.” The extension forester from Virginia describes a solution to the threats facing family forests as, “I'd love to see the public start to come behind forestland owners like they have recently for farmers. ‘Love a woodland owner with every drink of water ... from their forest, to your faucet.’” A complete list of the illustrative examples is included in Appendix 3-B.

3.1.2 Phase Two Results

The response rate to the second phase of the survey was 79% (37 extension foresters responded).

Extension foresters rated a list of 11 benefits of family forests on a scale of 0 to 10, with 0 being the least important and 10 being the most important. The highest rated benefits were wildlife and wildlife habitat (average rating = 8.6), water (8.2), recreation (7.6), rural aesthetics (7.6), and biodiversity (7.5) (Figure 11). Low rated benefits include air quality (5.4), bioenergy (5.0) and carbon sequestration (4.7). Extension foresters rated a list of 15 threats, with the highest rated threats including insects and diseases (8.0), invasive species (8.0), parcellation and fragmentation (7.5), development (7.5), and lack of public understanding (7.4) (Figure 12). The lowest rated threats included regulation (4.8), climate change (4.7), and pollution (2.6). Extension foresters rated a list of 14 solutions, with the highest rated solutions including education and extension (8.7), increase public awareness (7.8) and strong wood markets (7.5) (Figure 13). The lowest rated threats included legislation (5.8), ecosystem service markets (4.8), and forest certification (4.0). See Appendix 3-C for a full list of average ratings.

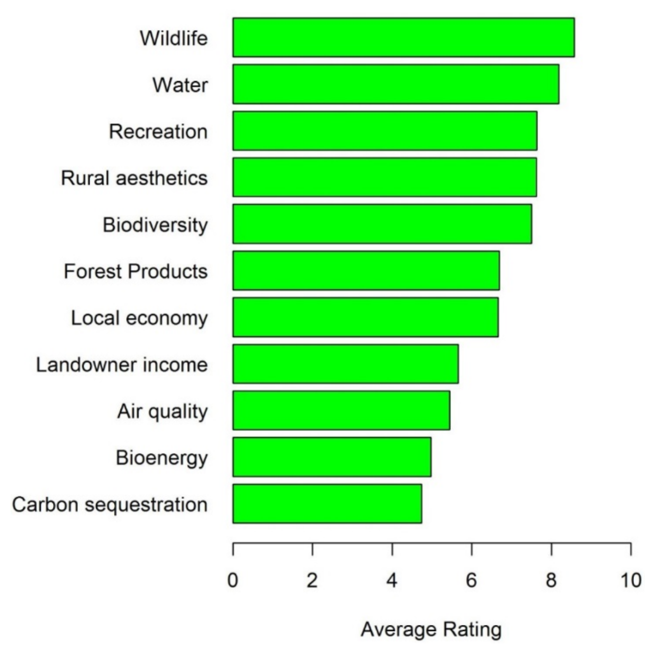

Figure 11. Extension foresters' average ratings of benefits from family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

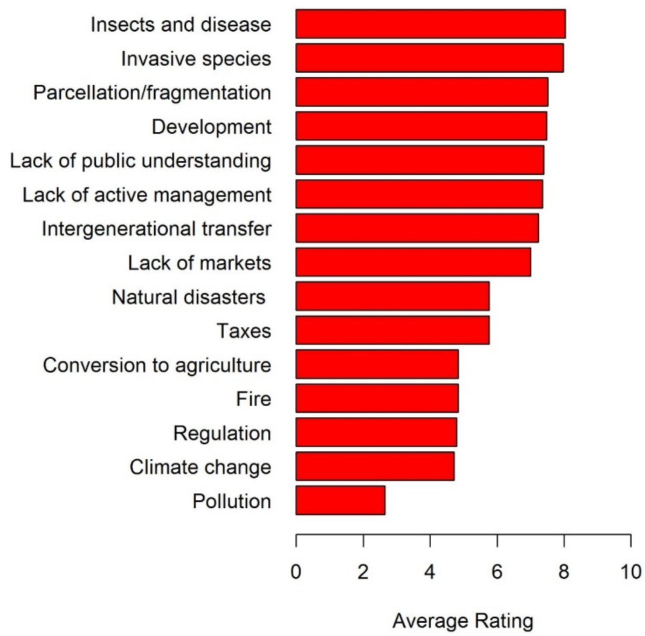

Figure 12. Extension foresters' average ratings of threats to family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

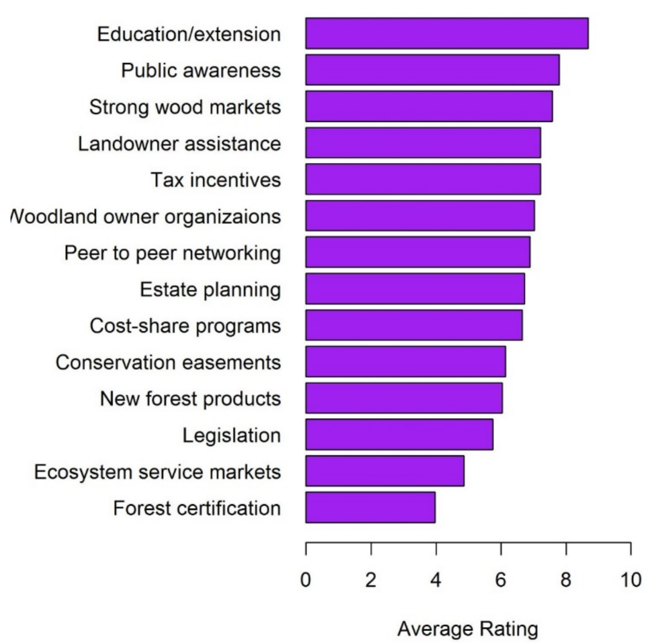

Figure 13. Extension foresters' average ratings of solutions for threats facing family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

Regional patterns were seen for some responses to family forest benefits, threats, and solutions. For example, extension foresters rated fire as a more important threat in the Pacific Coast, northern Rocky Mountain, southern Rocky Mountain, and Southeast regions (Figure 14h). Other regional patterns are depicted in Figure 14 - Figure 16.

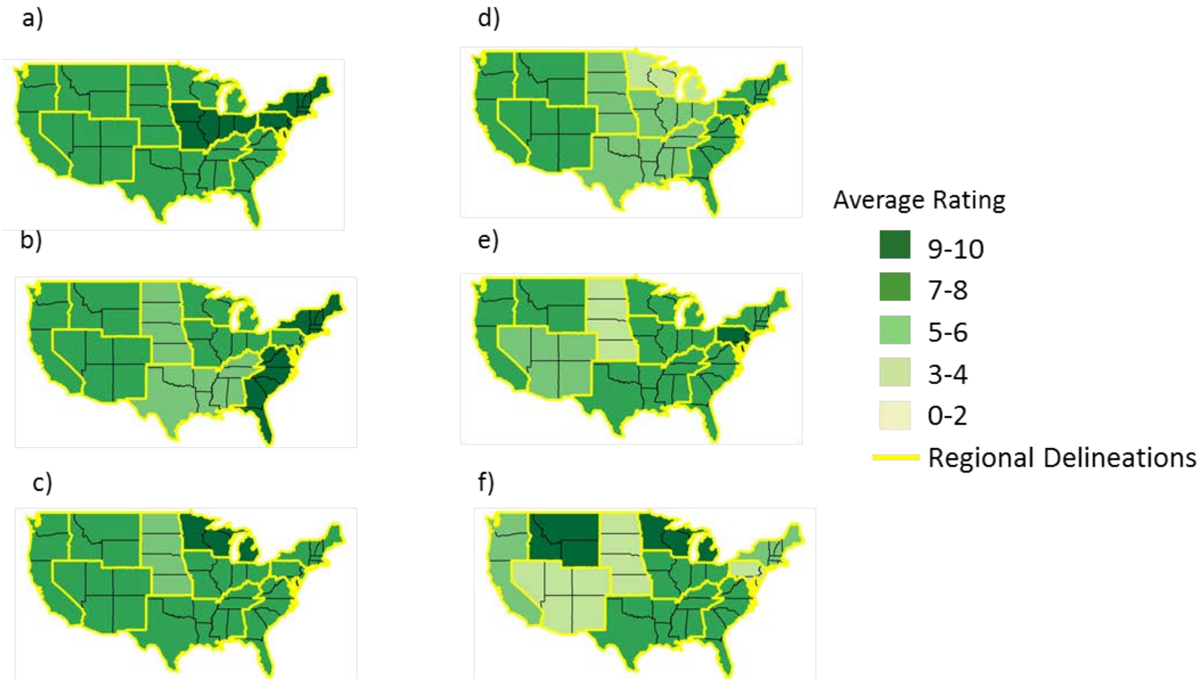

Figure 14. Extension foresters' regional average ratings of benefits from family forests. Benefits are a) Wildlife and wildlife habitat, b) Water, c) Recreation, d) Rural aesthetics, e) Biodiversity, and f) Wood. Alaska and Hawaii are included in the Pacific Coast region.

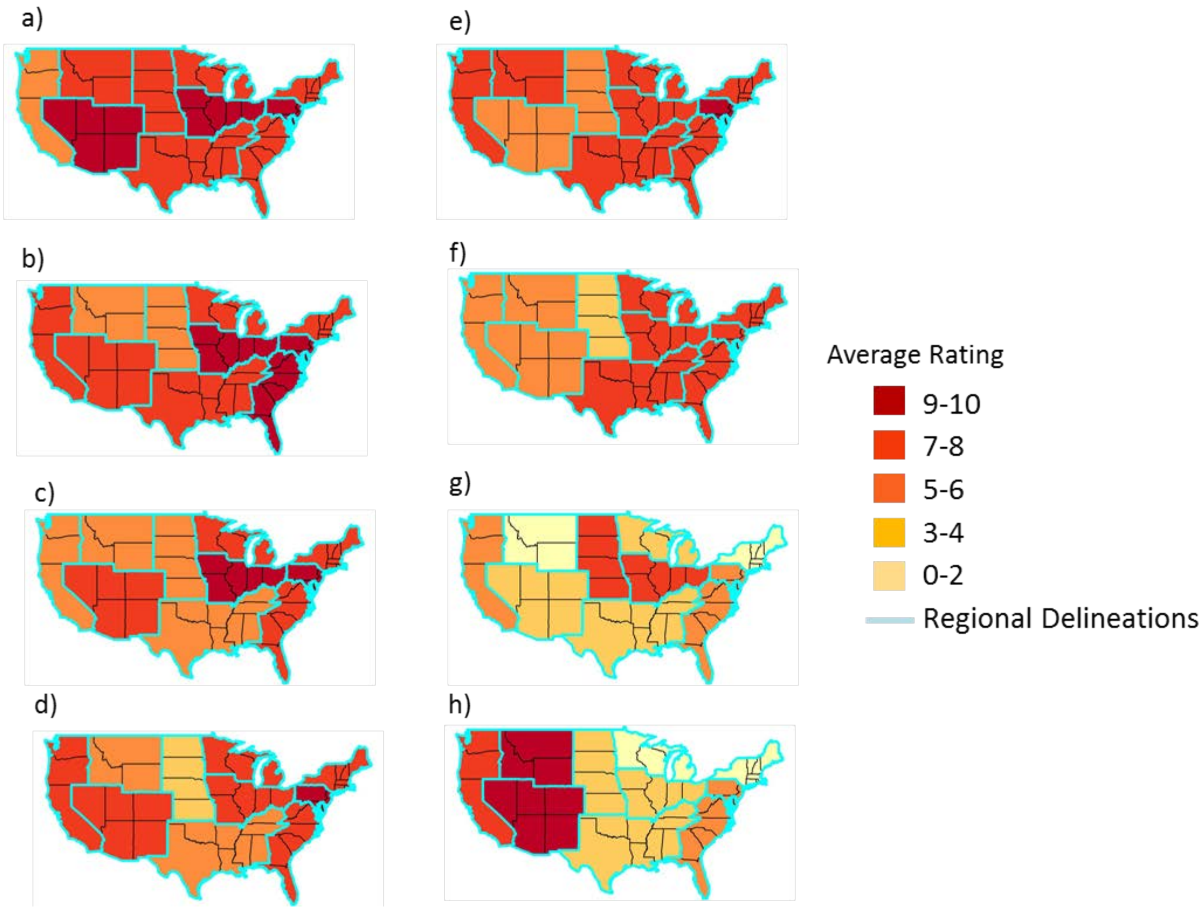

Figure 15. Extension foresters' regional average ratings of threats to family forests. Threats are a) Insects and diseases, b) Invasive species, c) Parcellation and fragmentation, d) Development, e) Lack of public understanding, f) Intergenerational transfer g) Conversion to agriculture, and h) Fire. Alaska and Hawaii are included in the Pacific Coast region.

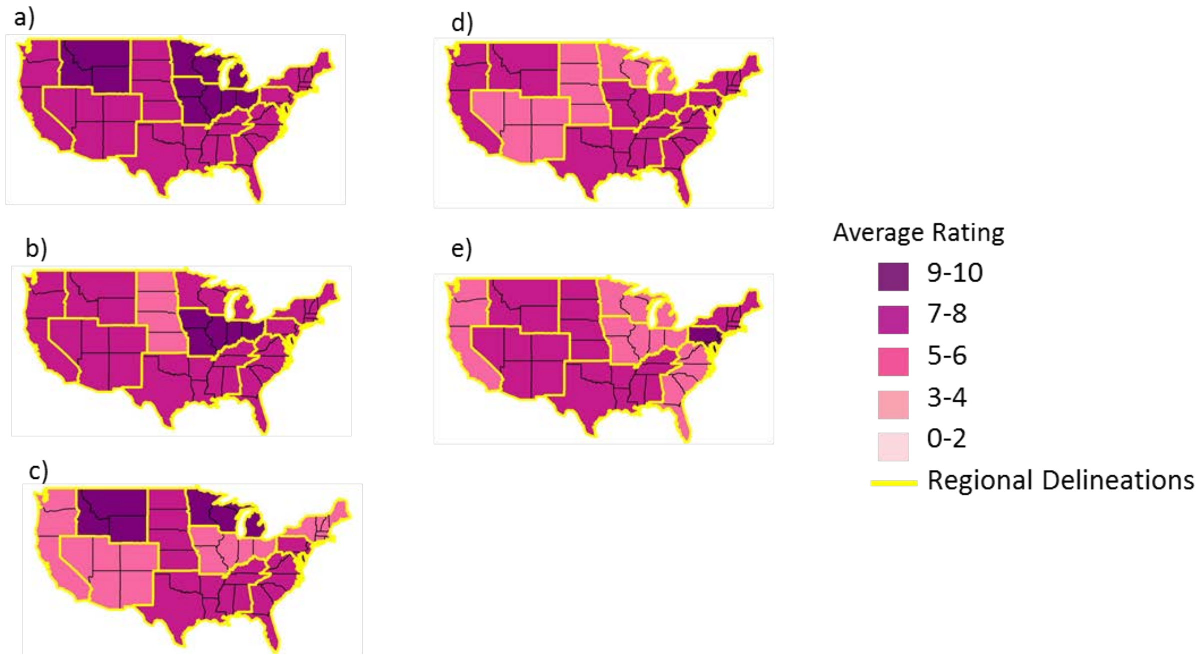

Figure 16. Extension foresters' regional average ratings of solutions to threats facing family forests. Solutions include a) Education and extension, b) Public awareness, c) Strong wood markets, d) State landowner assistance programs, and e) Tax incentives.

3.2 American Forest Foundation Staff and Committees Survey

We surveyed 18 people from the staff and various committees of the American Forest Foundation to assess their expert opinion on the benefits of and threats to family forests, as well as potential mitigating solutions that address those threats. We used the same compiled lists of benefits, threats and solutions from phase 2 of the extension forester survey (see Section 3.1.2), and we asked the group to rate the compiled lists on a scale from 0 to 10, with 0 being the least important and 10 being the most important. They were asked to complete this exercise after they were presented the preliminary results of this project in order for their opinions to more fully informed.

The highest rated benefits were water (9.6), wildlife (8.4) and air quality (8.1). The lowest rated benefits were rural aesthetics (5.5), landowner income (5.2) and bioenergy (4.6) (Figure 17). The highest rated threats were development (8.6), fragmentation (8.2), and parcellation (7.7). The lowest rated threats were natural disasters (5.0), conversion to agriculture and grazing (4.7), and regulation (3.9) (Figure 18). The highest rated solutions were education and extension (7.4), peer to peer networking (7.4), and estate planning (7.4). The lowest rated solutions included legislation (5.7), forest certification (5.1), and ecosystem service markets (4.6) (Figure 19). See Appendix 3-D for a full list of the average ratings for benefits, threats, and solutions.

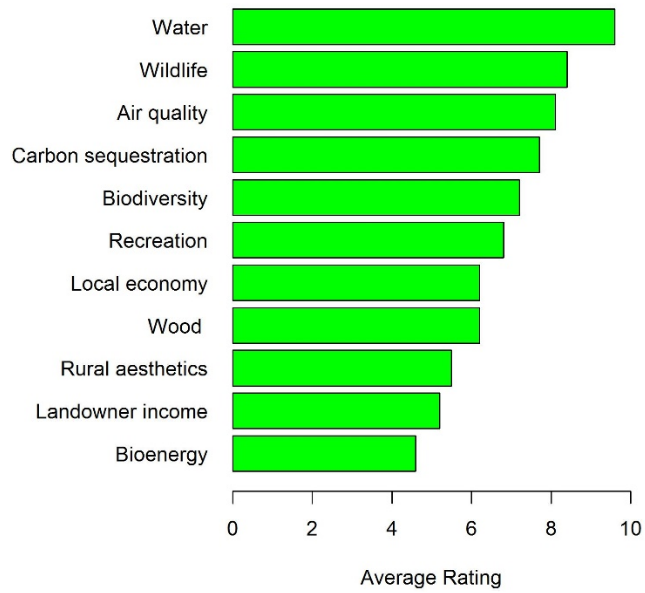

Figure 17. AFF staff and committee members' average ratings of benefits from family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

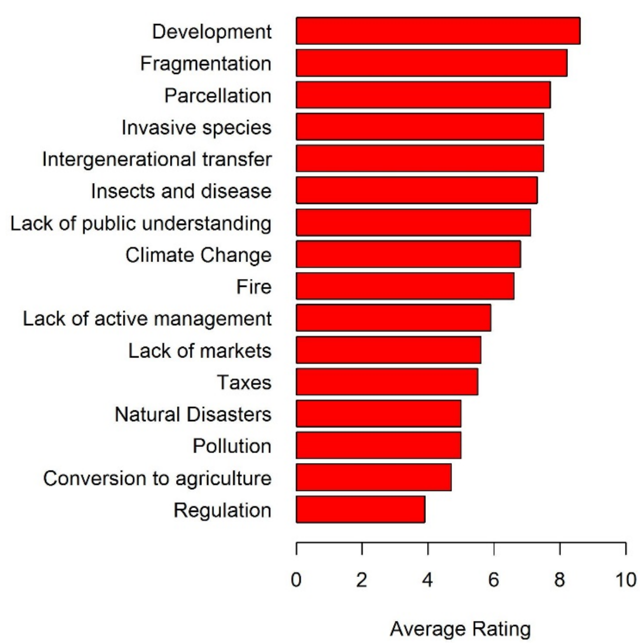

Figure 18. AFF staff and committee members' average ratings of threats to family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

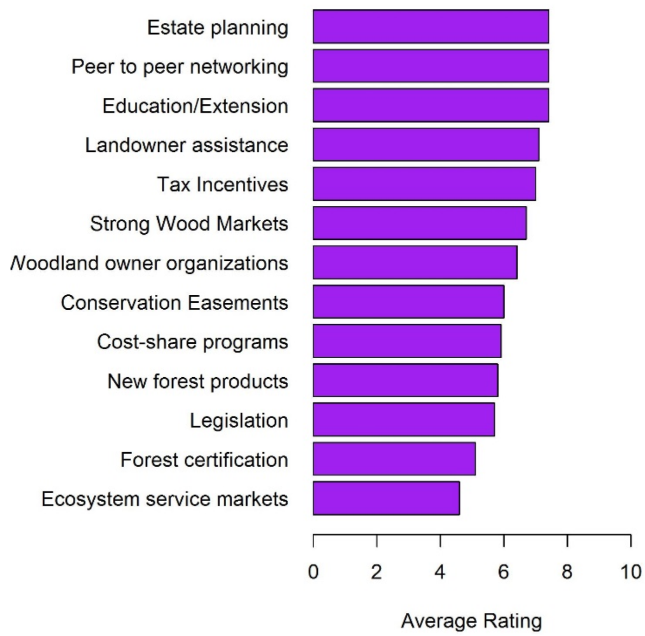

Figure 19 AFF staff and committee members' average ratings of solutions for threats facing family forests on a scale from 0 to 10, with 0 being the least important and 10 being the most important.

The AFF survey provides another unique set of insights on the greatest benefits, threats and solutions related to family forests. These average ratings were used to weight the benefits and threats in the spatial analysis portion of the project.

4 Spatial Analysis

4.1 Introduction

Building on the methodology of the *Forests on the Edge* publication series (Stein et al. 2005, Stein et al. 2009, Stein et al. 2010a), the goal of the spatial analysis component of this project is to quantify and display, via spatial products, the benefits of and threats to family forests in the U.S., with the intention of identifying areas of overlap between the two.

Due to limited data availability depicting the extent of family forests, the geographic scope was limited to the conterminous U.S. (the lower 48 states).

4.2 General Methods

Efforts were made to assemble the most complete and up-to-date spatial data illustrating the benefits family forests provide such as water quality, carbon sequestration, wildlife habitat, fiber supply, and recreation; as well as threats to those benefits including development, forest fragmentation, forest parcellation, likelihood of ownership transfer, insects and disease, climate change, wildfire, and natural disasters. Unfortunately, due to a lack of nationally consistent available data, it was not possible to incorporate spatial data on all threats and benefits (e.g., invasive plant species, lack of markets, taxes).

Following the *Forests on the Edge* methodology, analyses for this study were restricted to a subset of 8^{th}-level watersheds, areas roughly the size of half of Long Island. Watersheds included in our analyses had at least 10% forest cover according to the 2006 National Land Cover Database spatial dataset and at least 10,000 acres of family forest (Hewes et al. 2014). Restricting analyses to these watersheds enables a focus on landscapes with significant areas of family forest. The 10% cover and 10,000 acres criteria result in the inclusion of 1,385 watersheds across the conterminous U.S. (Figure 20).

Watersheds fitting the study criteria averaged 209,000 acres of family forest per watershed and ranged from just over 10,000 acres in the Butte watershed of north central California, to 1,340,000 acres in the Landreth-Monument Draws watershed spanning the border of Texas and New Mexico.

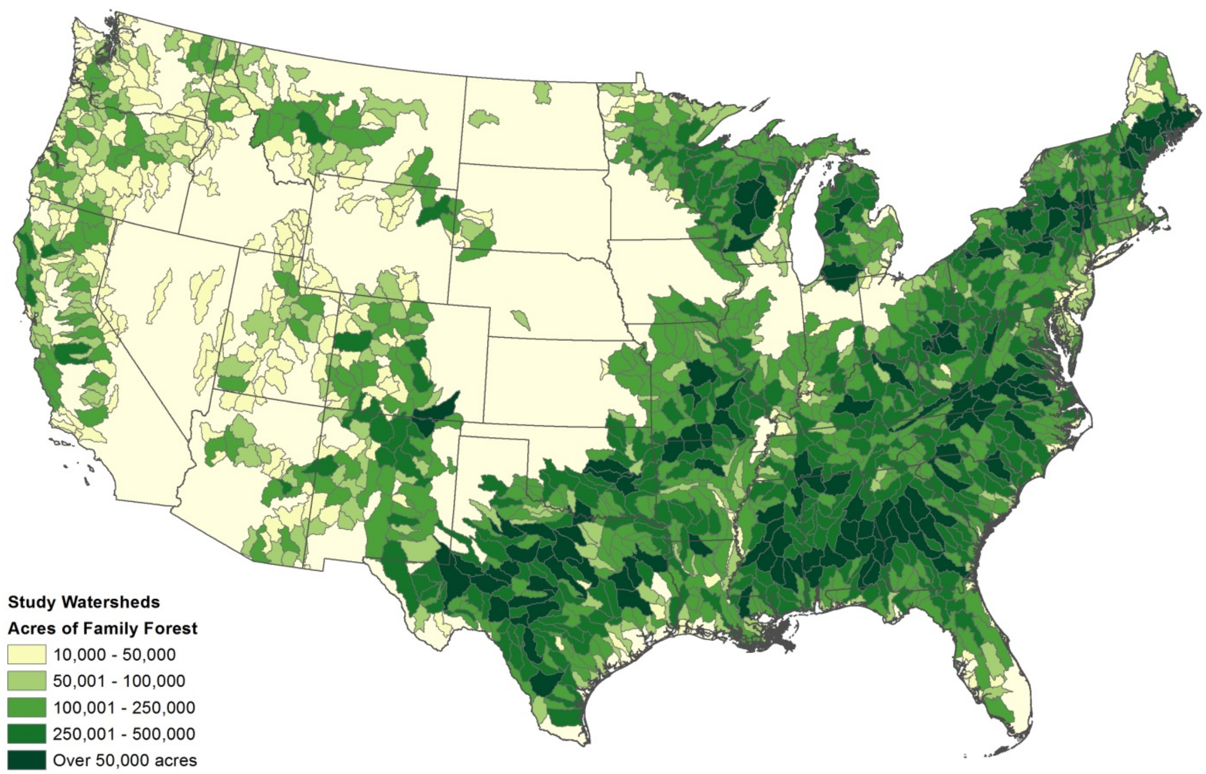

Figure 20. Area of family forestland in watersheds included in this analysis.

Apart from data layers originating from National Woodland Owner Survey data (Butler et al. 2014b), raw threat and benefit spatial layers were first clipped to the extent of family forest cover prior to subsequent analysis. Where source data enabled meaningful analysis of the area (number of acres) of family forestland affected by a particular threat or benefit, these were quantified. Once the extent of the phenomena of interest were spatially limited to family forest, the data were summarized at 8th-level watershed units, with the intent of evaluating the phenomena of interest at a bio-physical rather than socio-political level, as was done with *Forests on the Edge*.

Data derived from the National Woodland Owner Survey were summarized by 8th-level hydrologic unit where the threshold of 10 responses per watershed was met. For watersheds where there were less than 10 responses, data was summarized at the next highest level meeting the ten responses per unit of analysis criteria.

After the zonal summarization of data for each watershed, individual benefits were combined with the suite of threats impacting a particular benefit. This was done using the R statistical package to relate predefined threat weights to particular benefit and threat couplings (Equations 1-3). To quantify an individual benefit, the values are summed across the areas in a watershed. Threats were converted to proportions and separate weights, reported below, were applied depending on the benefit. For the individual benefits, the threats and associated weights were determined by the research team. For the weights used to combine multiple benefits and threats (Section 4.4.4), the weights were taken from the American Forest Foundation staff and committee survey described in Section 3.2.

$$\text{Benefit}_i = \Sigma(\text{Value}_i \text{ x Area}) \qquad \text{(Equation 1)}$$

$$\text{Threat} = \Sigma(\text{Probability}_j \text{ x Weight}_j) + \Sigma(\text{Probability}_k \text{ x Weight}_k) + \ldots \qquad \text{(Equation 2)}$$

$$\text{Benefit}_i \mid \text{Threat} = \Sigma(\text{Benefit}_i \text{ x Threat}) \qquad \text{(Equation 3)}$$

4.3 Family Forestland Base Layer

All spatial analyses performed in association with this project were based on the extent of family owned forestland as modeled in the "Distribution of Forest Ownership Types in the Conterminous United States" raster dataset (Hewes et al. 2014) (Figure 21). This dataset depicts the spatial distribution of ownership types across forestland in the conterminous U.S. circa 2009. The distribution of ownership types is derived, in part, from Forest Inventory and Analysis (FIA) data that are collected at a sample intensity of approximately one plot per 6,000 ac across the U.S. (Bechtold and Patterson 2005). Ownership categories were mapped to the landscape using Thiessen polygons and a forest/non-forest mask derived from a forest probability dataset (Wilson et al. 2012) was applied to limit ownership portrayal to forested areas (Butler et al. 2014c).

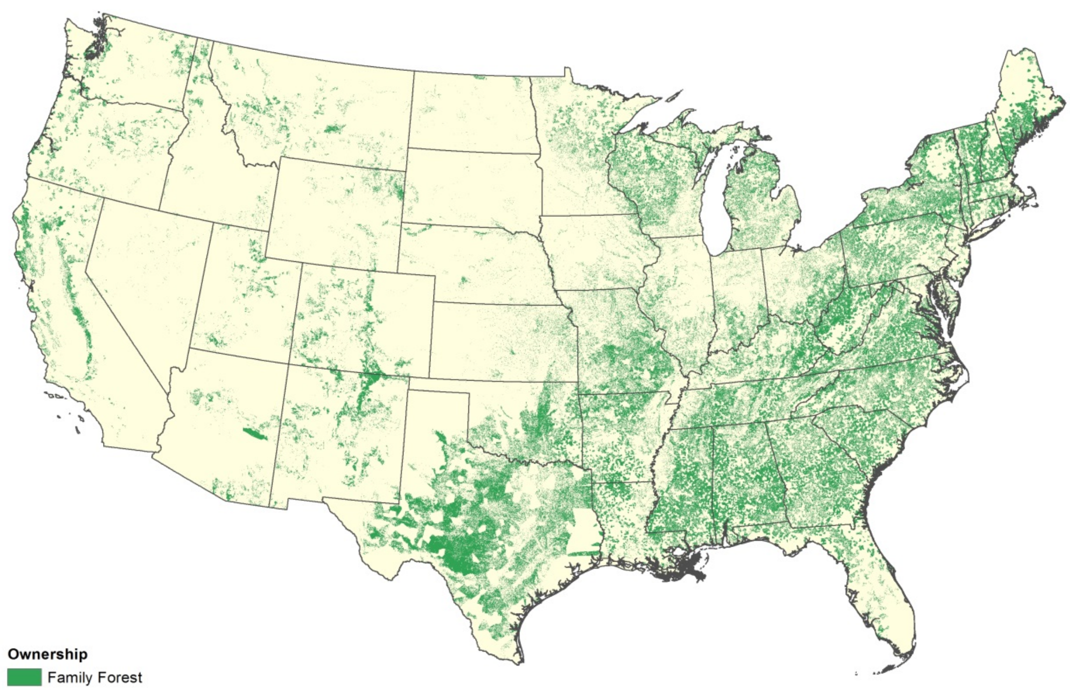

Figure 21. Distribution of family forestland across the conterminous U.S.

When interpreting the maps that follow it is worth emphasizing that many of the variables are based, in part, on the number of acres of family forestland within the watershed. As such, where there are fewer acres of family forest, there are likely to be relatively lower total amounts of carbon, acres in core forest habitat, etc. reflected in those watersheds. As an example, it could very well be that while certain watersheds (i.e., in northern Maine) have higher total timber volumes than others (those along the New York/New England border), the maps will depict higher total timber volumes in watersheds along the New York/New England border because more of the land in those watersheds is in family ownership, whereas more of the forestland in northern Maine is held by corporate owners.

4.4 Mapping of Benefits, Threats, and Solutions

4.4.1 Benefits

Forests provide a myriad of benefits at a range of levels, from base ecological functions, to those impacting society, all the way up to benefits accrued only to individual landowners. For this report, our analyses are constrained to forest benefits impacting ecological functions and societal values, for which spatially explicit data were available for the conterminous U.S.

4.4.1.1 Water Quality

4.4.1.1.1 Data Description and Source

Family forest contributions to water quality within a watershed were determined by calculating an index score based on total amount of family forestland in the watershed and the amount of family forest within riparian buffers within the watershed. Following Stein et al. (2009), the water quality index (WQI) for a watershed was calculated as:

$$WQI = 0.6[A_1 + (A_1A_2)] + 0.4(0.48B_1 + 0.24B_2 + 0.16B_3 + 0.12B_4) \quad \text{(Equation 4)}$$

where
A_1 = percentage of watershed in family forestland
A_2 = percentage of total forestland in watershed that is family owned
B_1 = percentage of family forestland category one buffers (nearer head of hydrologic network headwater)
B_2 = percentage of buffer in the second category buffers
B_3 = percentage of buffer in the third category buffers
B_4 = percentage of buffer in the fourth category buffers (farthest down-stream from the head of hydrologic network)

Variables A_1 and A_2 represent family forest coverage throughout the watershed, and variables B_1 through B_4 represent family forest coverage in the buffers. Hydrography data, i.e., location and order of water bodies, came from the U.S. Environmental Protection Agency Office of Water/U.S. Geological Survey's NHDPlus database (www.horizon-systems.com/nhdplus/).

4.4.1.1.2 Results and Discussion

Water is paramount to life. From ecosystem integrity to human consumptive needs, clean and abundant water is a critical benefit from forests.

Water quality at the watershed level, as measured by the Water Quality Index (WQI) score, represents the contribution of family forestland to the production of clean water based on the amount of family forestland in the watershed and riparian buffers located on family forestland. As such, the distribution of watersheds with higher WQI scores closely follows the pattern seen in Figure 20, with watersheds having a greater proportion of family forestland throughout the watershed. The second component of the WQI amount of family forestland in riparian buffers, is sensitive to hydrological patterns such that more arid forest areas with fewer rivers and streams have lower WQI scores than do mesic forest areas.

Water Quality Index scores at the watershed level ranged from 0.007 in the San Rafael watershed in Utah to 1.770 in the Nueces Headwaters watershed in Texas, with an average of 0.304 (Figure 22).

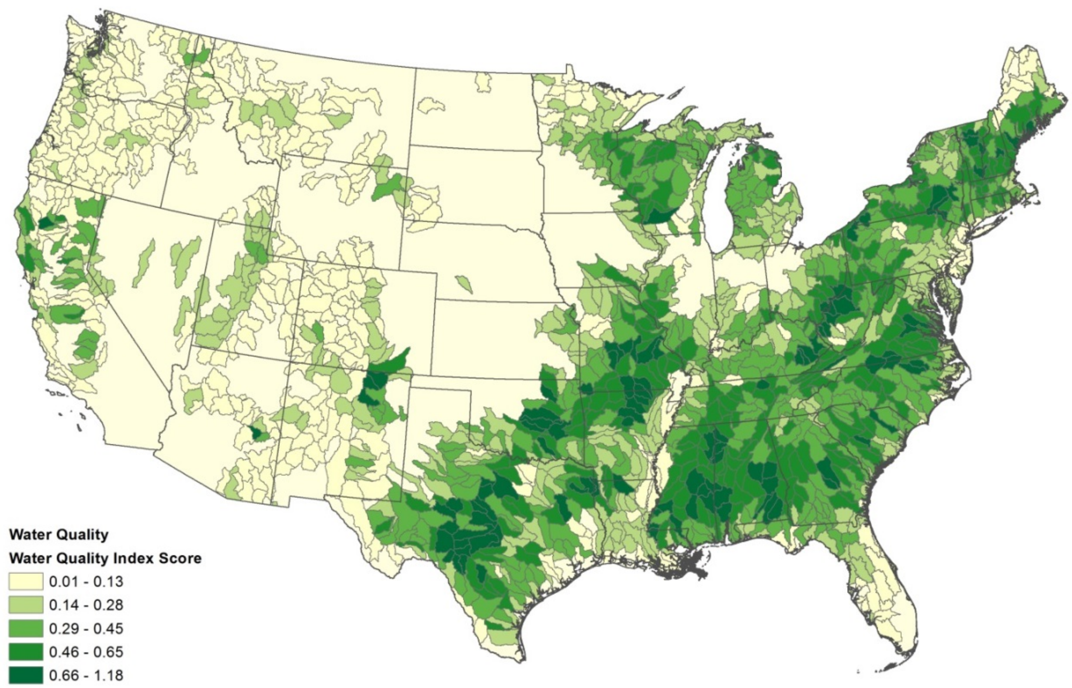

Figure 22. Water quality index for family forestland by watershed.

4.4.1.2 *Carbon Storage*

4.4.1.2.1 Data Description and Source

Although carbon sequestration rates are what would be ideally included, only data on carbon storage were available in a format suitable for this analysis. Estimates of the amount of above and below ground storage carbon were taken from U.S. Forest Service, Forest Inventory and Analysis GNN (Gradient Nearest Neighbor) 2009 EVALIDS models (Wilson et al. 2012). This process basically takes FIA plot data and assigns it to every pixel in a remotely sensed image based on spectral, topographic, and other biophysical attributes (Wilson et al. 2012). Source data measured carbon in terms of tons per acre. Per acre values were translated to per pixel values (250 meter pixels; equivalent to 15.4 acres per pixel) and summed to yield total carbon mass on family forestland within a watershed (Figure 23).

4.4.1.2.2 Results and Discussion

Trees play an integral role in the capture and storage of atmospheric carbon dioxide, which would otherwise persist in the atmosphere and contribute to climate change. The carbon is stored in tree trunks, branches, foliage, and roots, as well as forest soils.

The amount of carbon estimated to be on family forestlands in the study area watersheds totals over 14 billion tons. Total carbon mass at the watershed level ranged from 206,100 tons in the South Fork Humboldt watershed in Nevada to 79,010,000 tons in the Lower Kennebec watershed in Maine, with an average 10,150,000 tons per watershed (Figure 24).

As a significant component of carbon exists in standing timber, the distribution of watersheds with greater total carbon stocks follows closely those with higher wood volumes. Other watersheds have relatively higher total levels of carbon on family forestland owing to slower rates of nutrient cycling, storing more carbon in the leaf litter and soil, while for some, an abundance of vegetation in the understory or in small size classes results in greater overall carbon stocks.

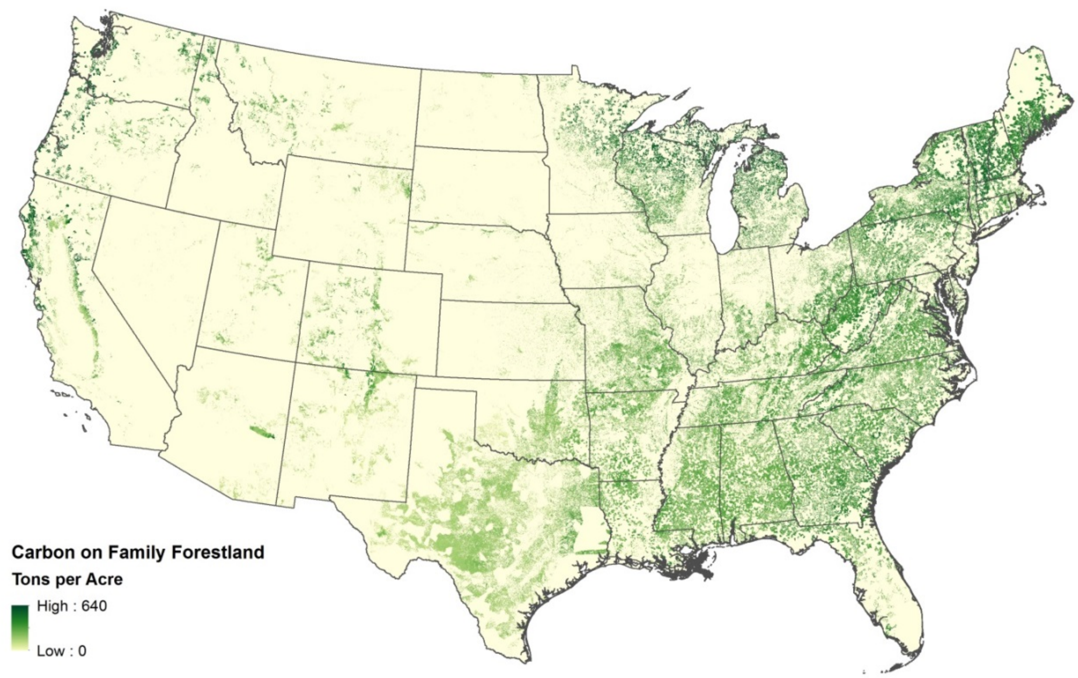

Figure 23. Mass of carbon on family forestland.

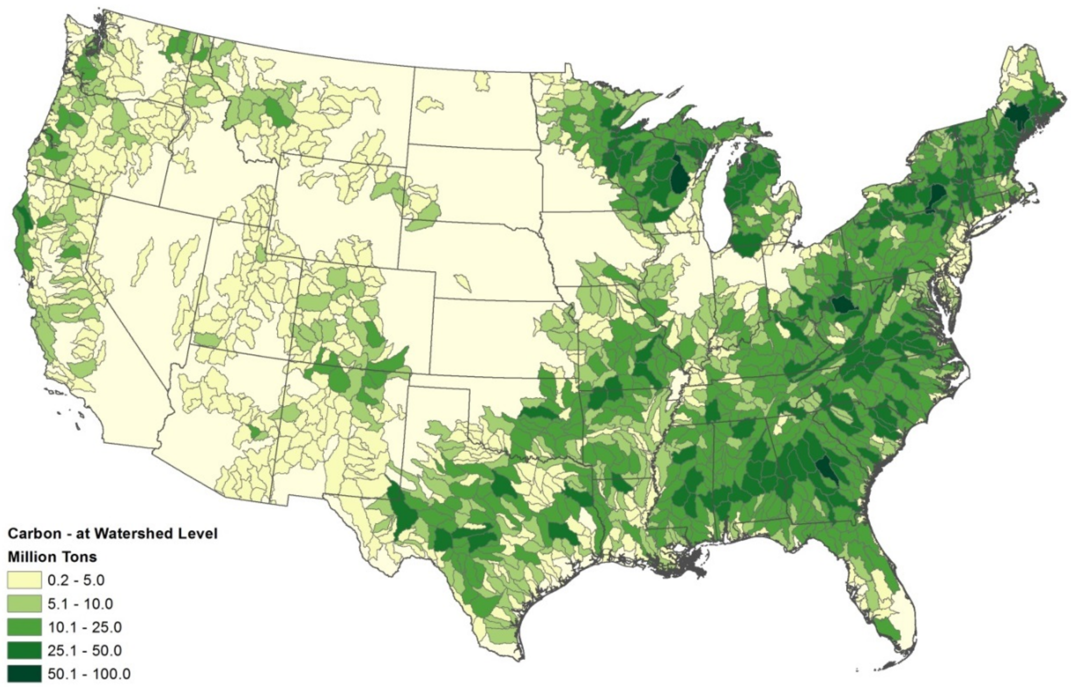

Figure 24. Mass of carbon on family forestland – aggregated to the watershed level.

4.4.1.3 Wildlife Habitat

4.4.1.3.1 Data Descriptions and Source

Two measures of wildlife habitat were examined: core forest and threatened and endangered species. Core forest is the percent of family forestland in a watershed that is at least 394 ft (120 m) from a forest/non-forest edge. The data to calculate this originated as separate state-wide 98 ft (30 m) pixel raster grids of forest morphology (Riitters 2011; http://data.forestthreats.org/fhm_grid_states/fhm_grid_states_index_new.htm#).

The threatened and endangered species data represents the count of species recognized as critically imperiled, imperiled, and vulnerable at the global scale (including all those with federal protection). This data layer was compiled by NatureServe specifically for this project. Location of actual sites where species were found is sensitive information and was not provided to the research team. NatureServe supplied counts of these species on family forestland by watershed.

4.4.1.3.2 Results and Discussion

Wildlife habitat has value from a variety of perspectives. In part, quality habitat fosters biodiversity. It provides cover, nest and den sites, foraging opportunities, and other structural and functional elements critical to wildlife. In turn, wildlife have their own intrinsic value, and are also valued for what they offer society - opportunities for subsistence and recreational hunting, as well as observation and appreciation.

4.4.1.3.2.1 Core Forest

Core forest habitat is critical to certain wildlife species needing large tracks of unfragmented forest, such as interior dwelling migratory songbirds and mammals requiring large home range territories.

There are more than 78 million acres of core forest on family forestland within the watersheds included in this study (Figure 25). The amount of family forest within core forest habitat across watersheds ranged from 0 acres in thirteen watersheds (ten of which are located in west Texas) to 633,300 acres in the Lower Kennebec watershed of Maine, with an average of 57,020 acres per watershed (Figure 26-Figure 27).

By definition, core forest exists where there are expanses of intact, unfragmented forest. These are characteristically in more rural areas with less development, such as along the Appalachian corridor.

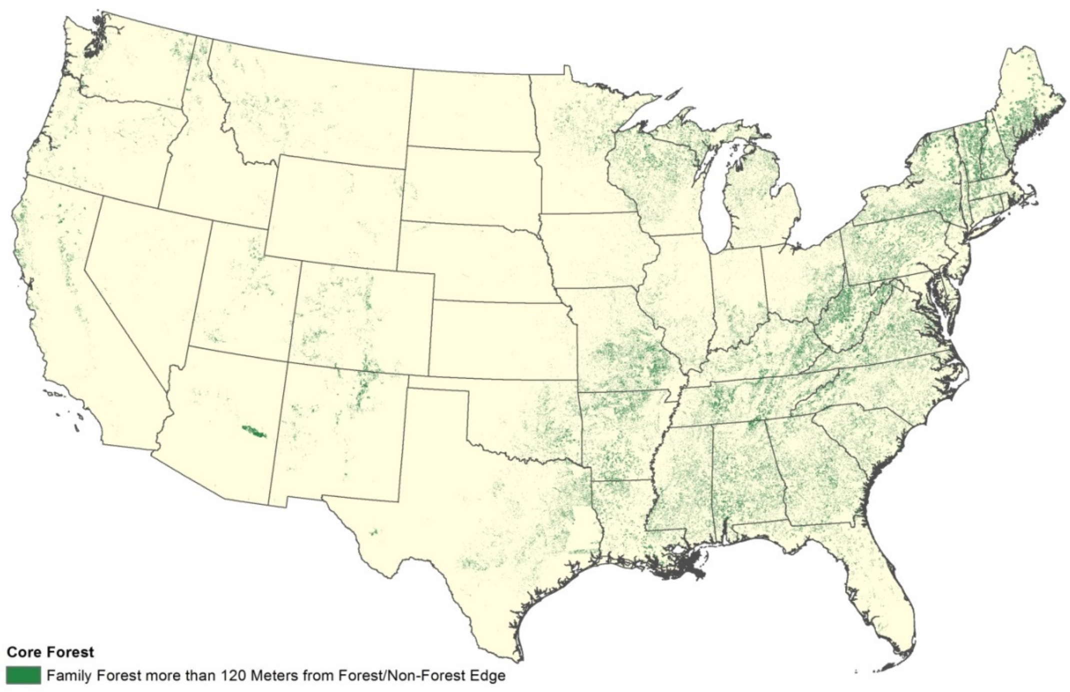

Figure 25. Extent of core forest habitat on family forestland.

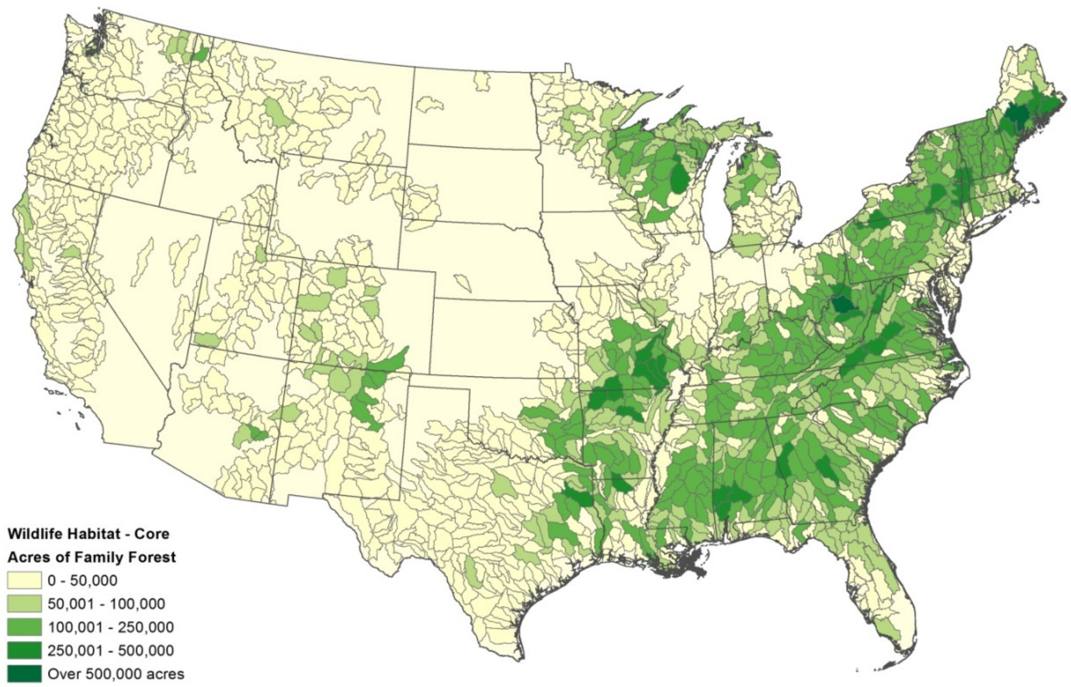

Figure 26. Area of family forest in core forest habitat (at least 120-m from forest/non-forest edge) - aggregated to the watershed level.

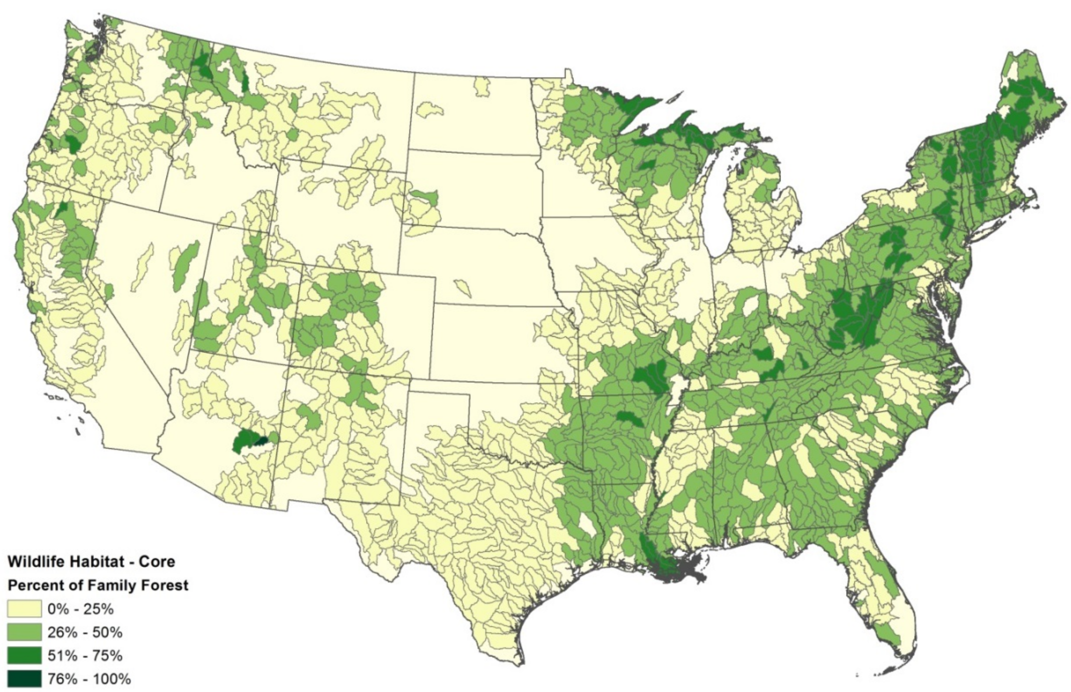

Figure 27. Percent of family forest in core forest habitat (at least 120-m from forest/non-forest edge).

4.4.1.3.2.2 Threatened & Endangered Species

Family forestlands provide valuable habitat for a wide range of animal species, including those that have been designated as threatened or endangered. According to NatureServe, there are more than 14,000 occurrences of threatened and endangered species on family forestlands within the subject watersheds; however, because of the sensitive nature of the data we are unable to determine the number of unique threatened and endangered species within these watersheds.

Counts of individual species presences ranged from zero in seventy-one watersheds scattered across the country to 94 in the Upper Clinch watershed spanning Tennessee and Virginia, with an average 10.15 threatened or endangered species present per watershed (Figure 28).

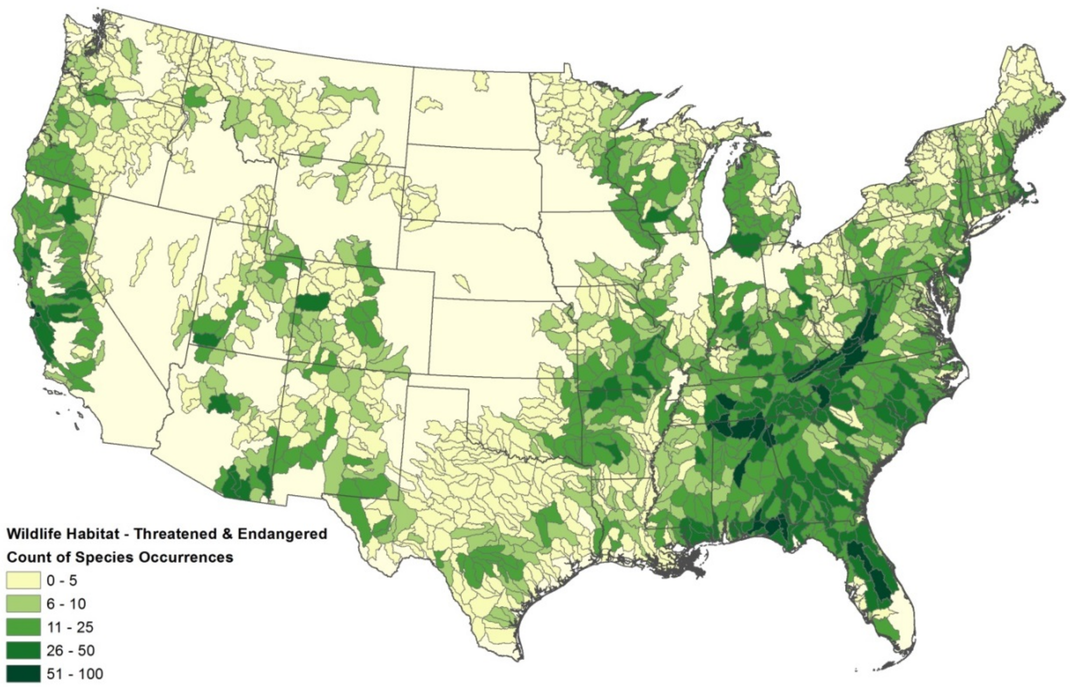

Figure 28. Number of threatened and endangered species on family forestland by watershed.

4.4.1.4 Wood Supply

4.4.1.4.1 Data Description and Source

Similar to the carbon data, wood supply data originated from U.S. Forest Service, Forest Inventory and Analysis GNN (Gradient Nearest Neighbor) 2009 EVALIDS models (Wilson et al. 2012). The estimates of the volume of wood were taken from FIA plots and assigned to pixels using this GNN method. As defined by FIA (Woudenberg et al. 2010), these values include the net volume of wood in the central stem of timber species trees of sawtimber size (at least 9.0 inches in diameter for softwoods and 11.0 inches for hardwoods), from a 1-foot stump to a minimum top diameter (7.0 inches for softwoods and 9.0 inches for hardwoods). Source data were reported in terms board foot volume per acre. Per acre values were translated to per pixel values and summed to yield total volume on family forestland within a watershed (Figure 29).

4.4.1.4.2 Results and Discussion

Wood fiber is one of the quintessential products associated with forests. From building materials to paper pulp, wood is a commodity highly valued by society for its multitude of uses. We estimate the amount of timber on family forests in the study area watersheds to be in excess of one billion board feet.

Timber volumes at the watershed level ranged from 0 in forty watersheds located in or partially in west Texas to 6.9 billion board feet in the Lower Eel watershed of coastal northern California (Figure 30). The reason so many watersheds in Texas appear to have no wood volume has to do with the minimum tree diameter required for sawlogs.

The ownership patterns coupled with productive soils in the east, and the moisture regimes and tree species in the west account in large part for the distribution of the heavily stocked watersheds.

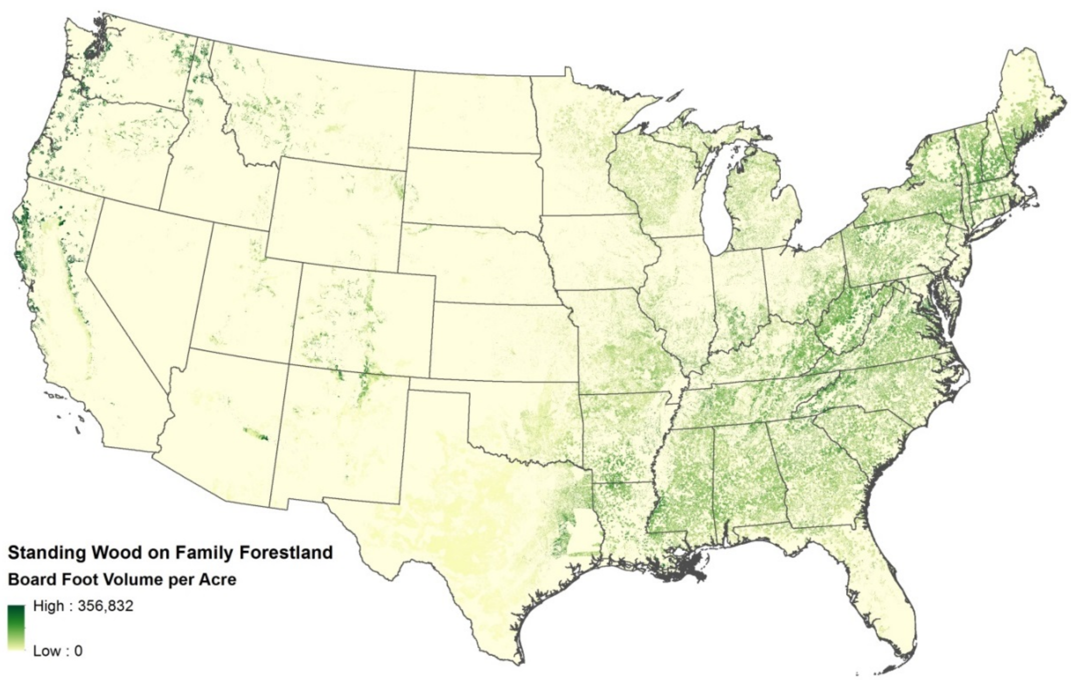

Figure 29. Volume of standing wood on family forestland.

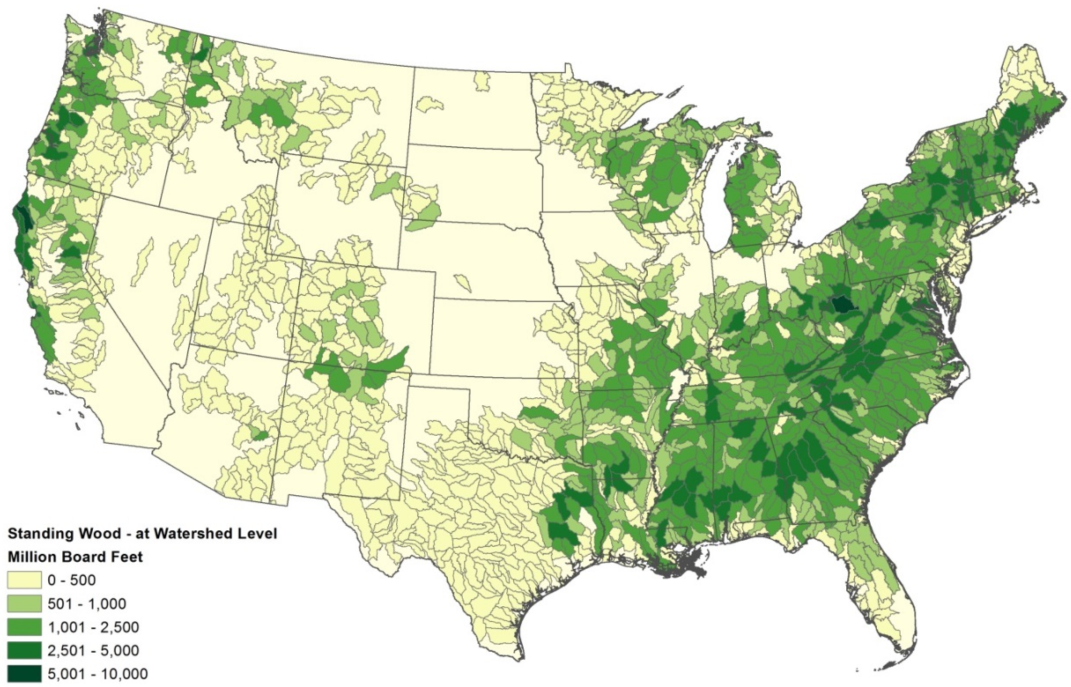

Figure 30. Volume of standing wood on family forestland - aggregated to the watershed level.

4.4.1.5 Biomass Supply

4.4.1.5.1 Data Description and Source

As with the carbon and wood estimates, biomass supply estimates originated from U.S. Forest Service – Forest Inventory and Analysis GNN (Gradient Nearest Neighbor) 2009 EVALIDS models (Wilson et al. 2012). The estimates of the biomass of wood were taken from FIA plots and assigned to pixels using this GNN method. FIA calculates biomass as the gross cubic-foot volume for tree species greater than 5 inches in diameter from a one foot stump to a minimum 4-inch top diameter and for woodland species (Woudenberg et al. 2010). Source data was reported in terms of cubic foot volume per acre. Per acre values were translated to per pixel values and summed to yield total volume on family forestland within a watershed (Figure 31).

4.4.1.5.2 Results and Discussion

In addition to timber resources on family forestland, biomass, which includes trees of a smaller dimension than those included in estimates of wood supply, as well as non-timber species, can be used to produce heat and biofuels.

Within the study area watersheds, biomass volumes ranged from 777,000 cubic feet in the Maravillas watershed of west Texas to 1,765,000 cubic feet in the Little Kanawha watershed of West Virginia (Figure 32).

The spatial distribution of watersheds with high biomass volumes follows closely that of timber.

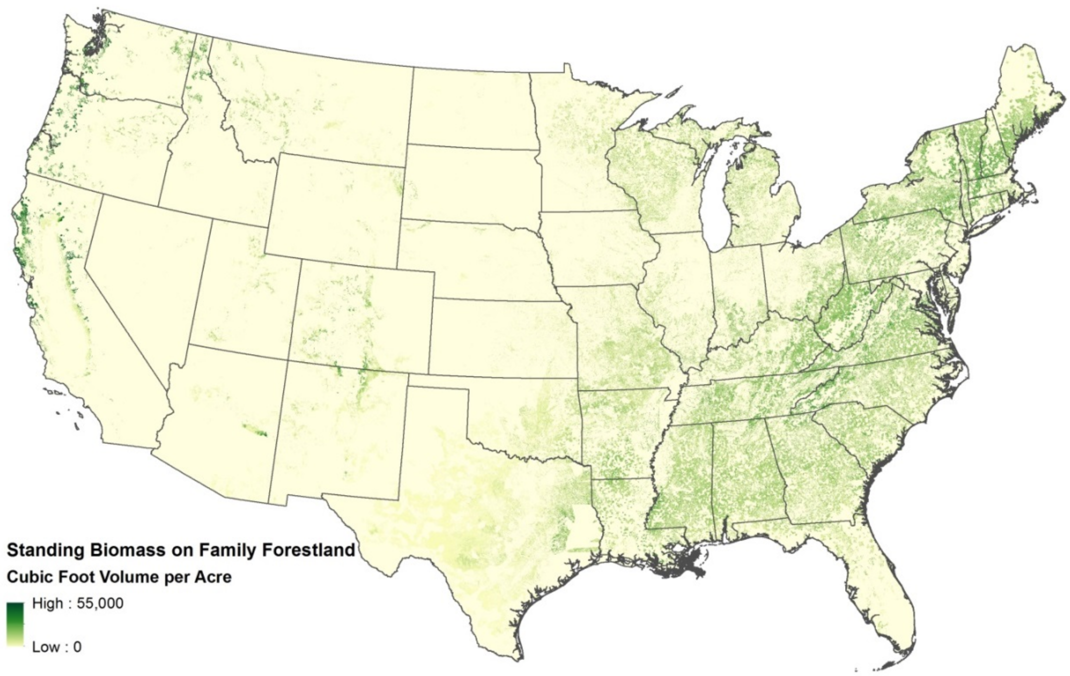

Figure 31. Volume of standing biomass on family forestland.

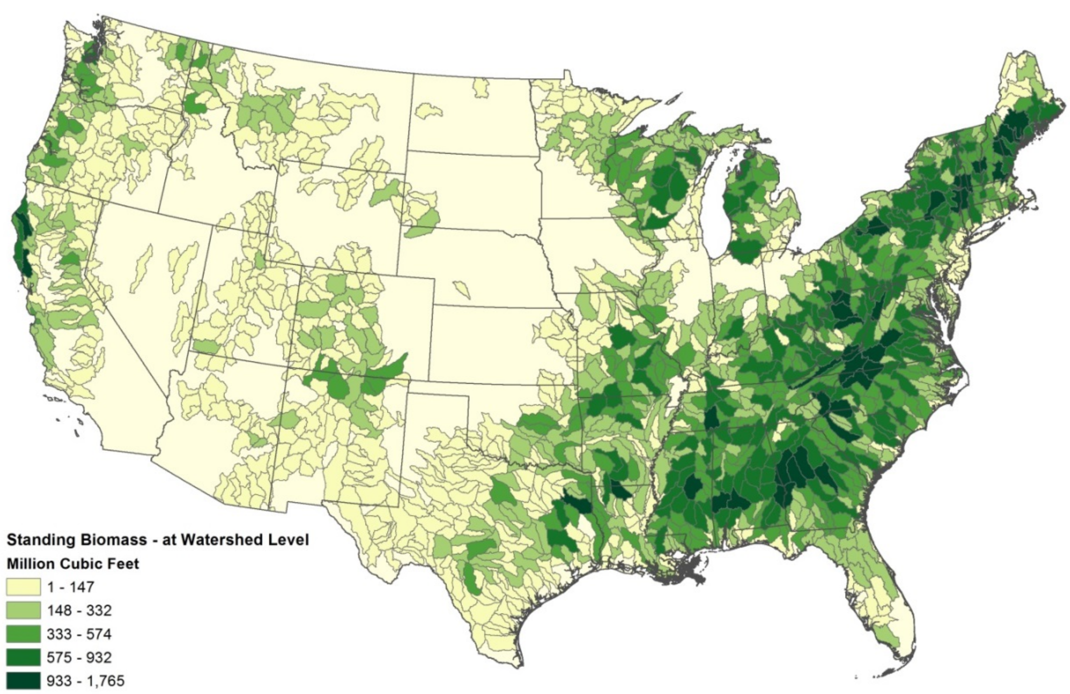

Figure 32. Volume of standing biomass on family forestland - aggregated to the watershed level.

4.4.1.6 Recreation

4.4.1.6.1 Data Description and Source

Recreation on family forests was measured as the percent of NWOS respondents in a watershed who indicate they allow public access on their land (Butler et al. 2014b).

4.4.1.6.2 Results and Discussion

Family forestland that is open to public recreation can provide opportunities to increase health and fitness, promote well-being, and foster a connection to nature. According to estimates generated here from NWOS data, nearly 34 million acres of family forestland in the study watersheds are open to the general public for recreation, with individual watersheds ranging from having no open land in 158 watersheds scattered across the country to 494,800 acres in the Upper Devils watershed of Texas, with an overall average area of 24,438 acres open to the public per watershed (Figure 33 - Figure 34).

There appears to be some clustering of watersheds with a higher percentage of open land in west Texas, the southern Rocky Mountains, and the Northern Forest region of New York and New England.

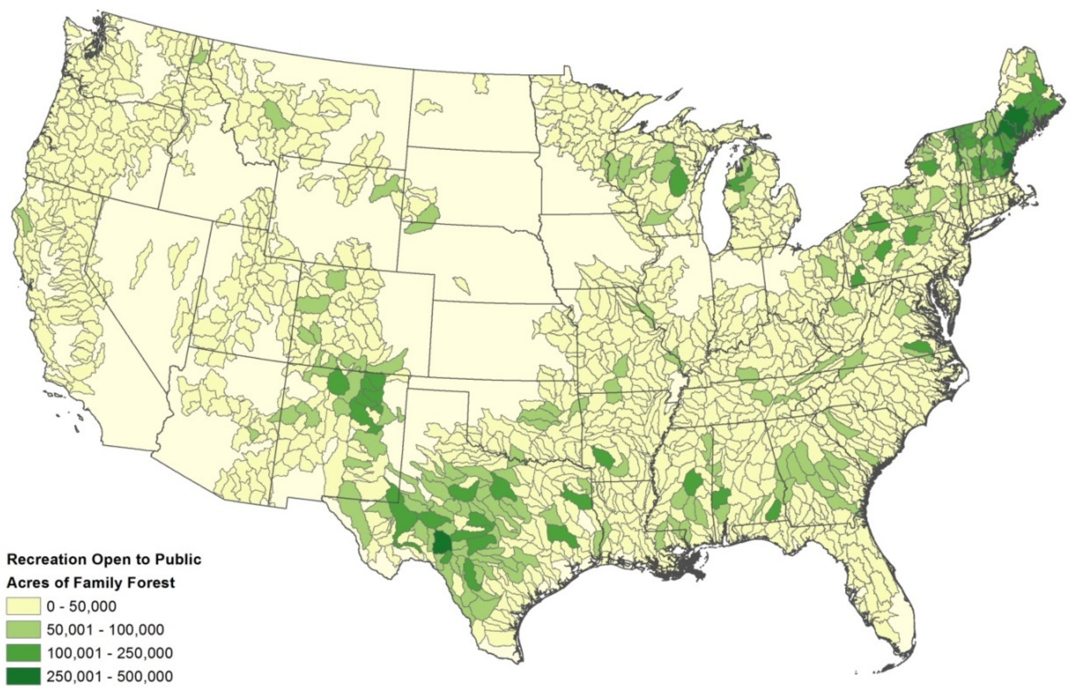

Figure 33. Area of family forestland open to public recreation – aggregated to the watershed level

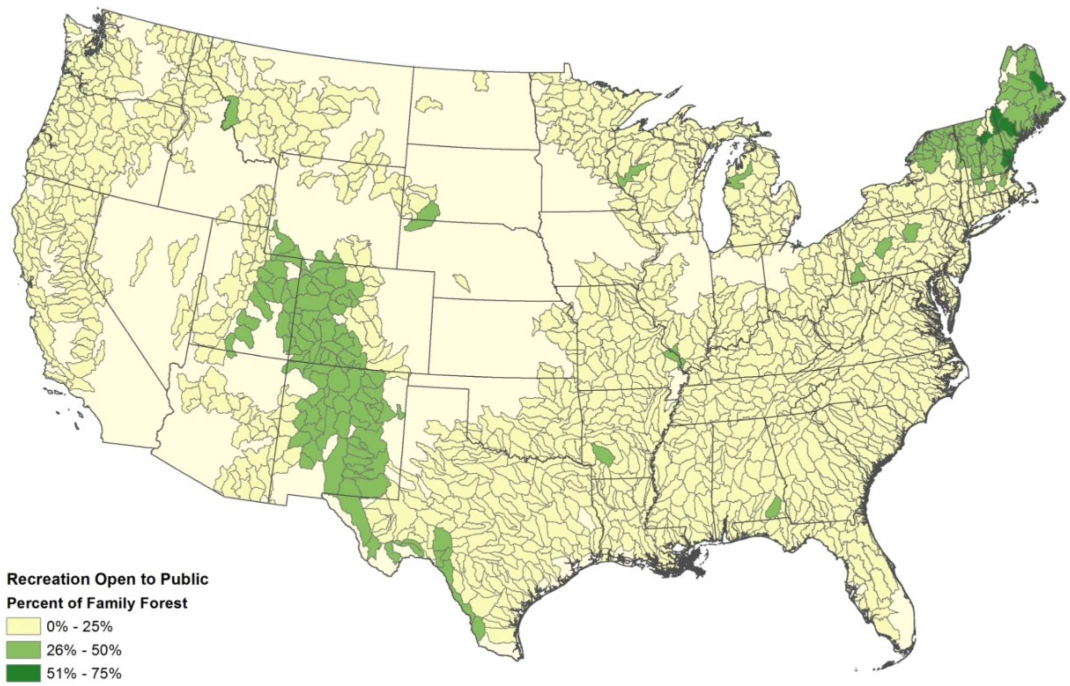

Figure 34. Percent of family forestland open to public recreation

4.4.2 Threats

While there are a wide variety of phenomena that threaten to negatively impact the benefits from forests, and in particular family forests, we were limited to those threats for which we were able to obtain spatially explicit data with wall-to-wall coverage for the conterminous U.S.

We also chose to focus on the threats that are poised to impact those forest benefits that function at either the ecological or socioeconomic scale, omitting those threats that might have greatest impacts on the benefits enjoyed at the individual landowner level. Different sets of threats will be more or less or more important depending on the time frame. The general timeframe considered was the next 10 years. This timeframe was the most compatible with the available datasets.

4.4.2.1 Development Pressure

4.4.2.1.1 Data Description and Source

Predicted change in housing density, measured as the percent of family forestland in a watershed that is projected to increase in housing density between the years 2010 and 2020 under the baseline scenario, was used as an indication of development pressure in an area. Housing density projections were taken from the Integrated Climate and Land-Use Scenarios (ICLUS) project data distributed by the USGS Center for Integrated Data Analytics as a 100-meter pixel raster grid (Figure 35; http://cida.usgs.gov/thredds/catalog/ICLUS/files/housing_density/catalog.html?dataset=cida.usgs.gov/ICLUS/files/housing_density).

4.4.2.1.2 Results and Discussion

Development is poised to threaten all benefits forests provide as it implies the conversion from forest to non-forest use. As a proxy for future land conversion we utilize projections of increased housing density that incorporates climate models and future land use. Although an increase in housing density at the watershed level doesn't mean that all land will be developed, it does indicate the likelihood of a degree of conversion to non-forest.

In total, 28,300,000 acres of family forest are threatened by increased housing density projected to occur in the next ten years. Area impacted ranged from no increases in housing density in 115 watersheds scattered across the country to 354,000 acres in the Upper Neuse watershed of North Carolina (Figure 36 - Figure 37).

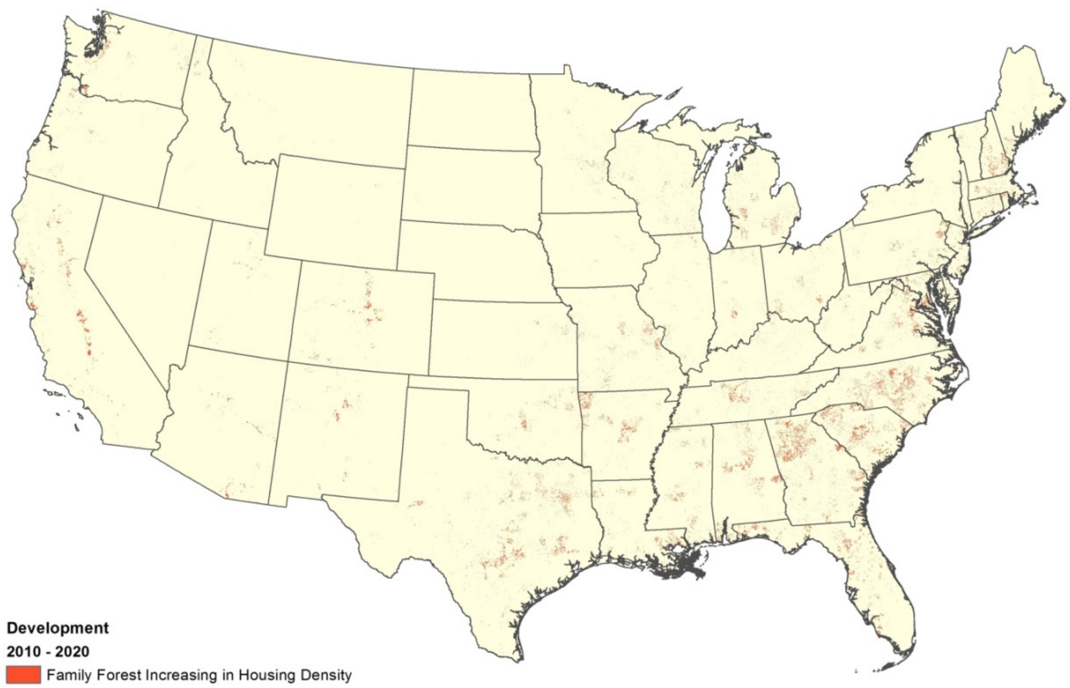

Figure 35. Extent of development as predicted in terms of projected increases in housing density between 2010 and 2020.

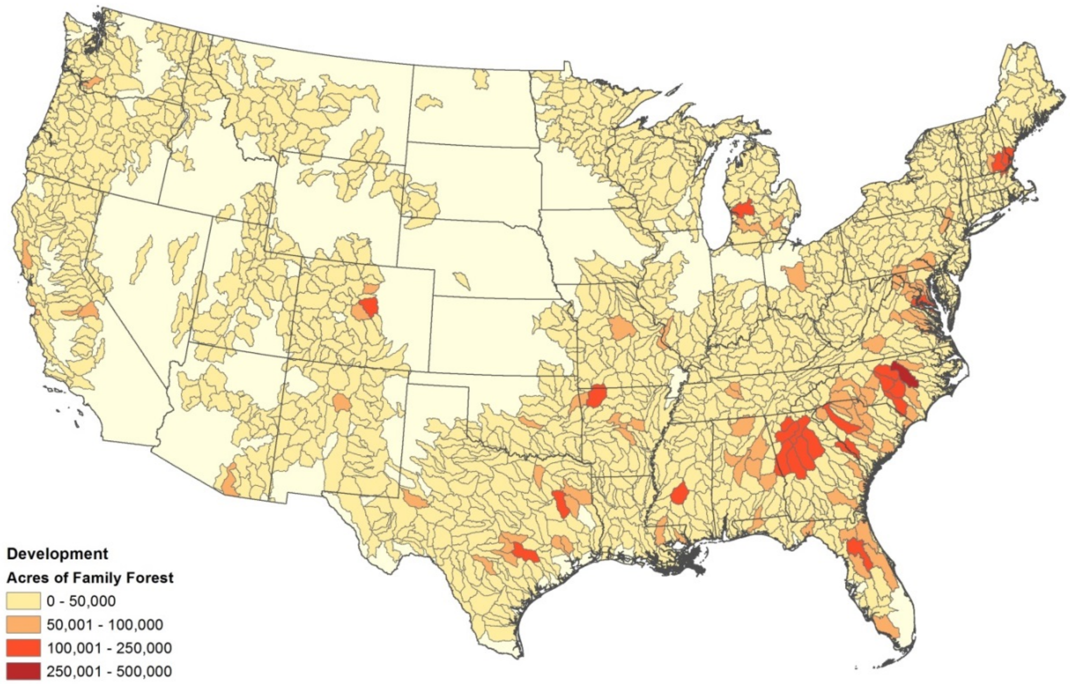

Figure 36. Area of family forestland projected to experience an increase in housing density between 2010 and 2020.

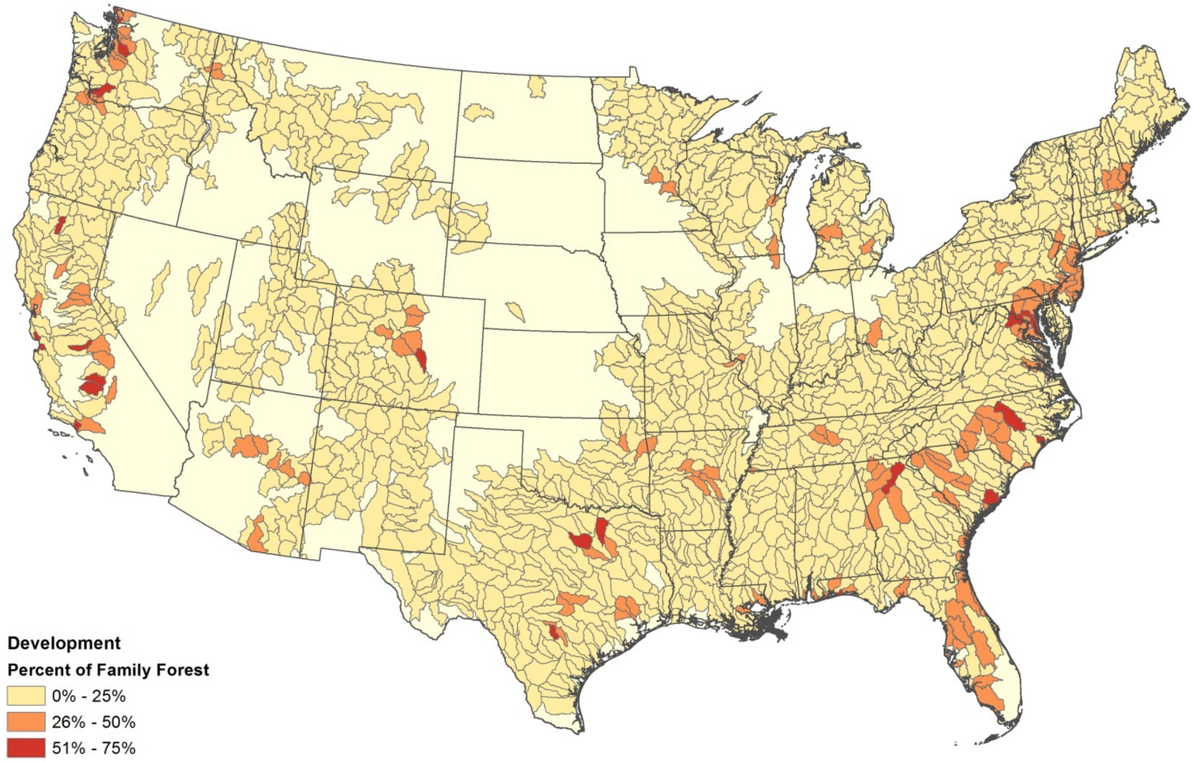

Figure 37. Percent of family forest expected to experience an increase in housing density between 2010 and 2020.

4.4.2.2 Forest Fragmentation

4.4.2.2.1 Data Description and Source

Fragmentation is the percent of family forestland in a watershed that is less than 98 ft (30 m) from a forest/non-forest edge. The data to calculate this originated as separate state-wide 98 ft (30 m) pixel raster grids of forest morphology (Figure 38; Riitters 2011; http://data.forestthreats.org/fhm_grid_states/fhm_grid_states_index_new.htm#).

4.4.2.2.2 Results and Discussion

Fragmentation of forestland has the potential to threaten a number of forest benefits, but is perhaps most detrimental to wildlife, particularly those species requiring large expanses of forest in order to survive and thrive.

Roughly 147,000,000 acres of family forest in these watersheds are within 30 meters of a non-forest edge. The Swan watershed in Montana has the fewest acres of fragmented family forest with 3,300 acres fragmented, while the Landreth-Monument Draws watershed spanning Texas and New Mexico has the most with 1,340,000 acres of fragmented forest (Figure 39).

Texas appears as having high levels of fragmentation, but this should be interpreted with a degree of caution. As mentioned previously fragmentation is the inverse of core habitat (though in this study we use a 120-meter edge with which to define core forest, and a 30-meter edge with which to define fragmented forest). Due to the type and distribution of vegetation in west Texas there simply is not much forest that is far from a non-forest edge.

Ideally a measure of fragmentation would address the process of edge creation as they occur over time, rather than a single snapshot of forest/non-forest edge conditions at a single point in time. Unfortunately we do not have data from two time periods to be able to compare and illustrate where the rates of fragmentation are greatest.

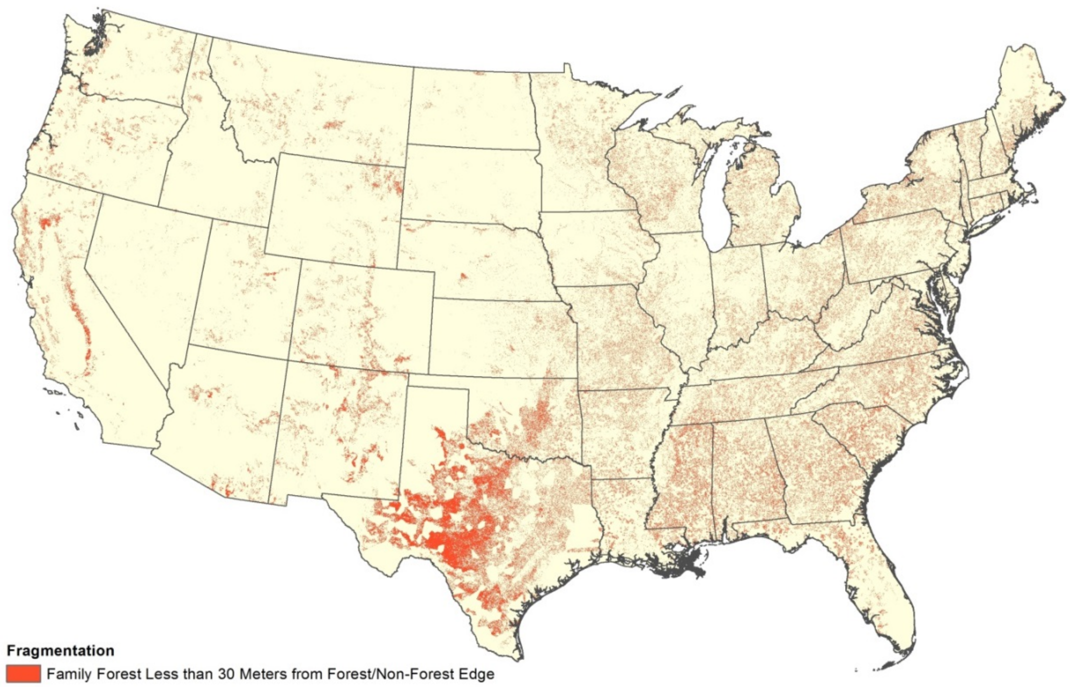

Figure 38. Extent of fragmented forest on family forestland, as defined by being less than 30 meters from a forest/non-forest edge.

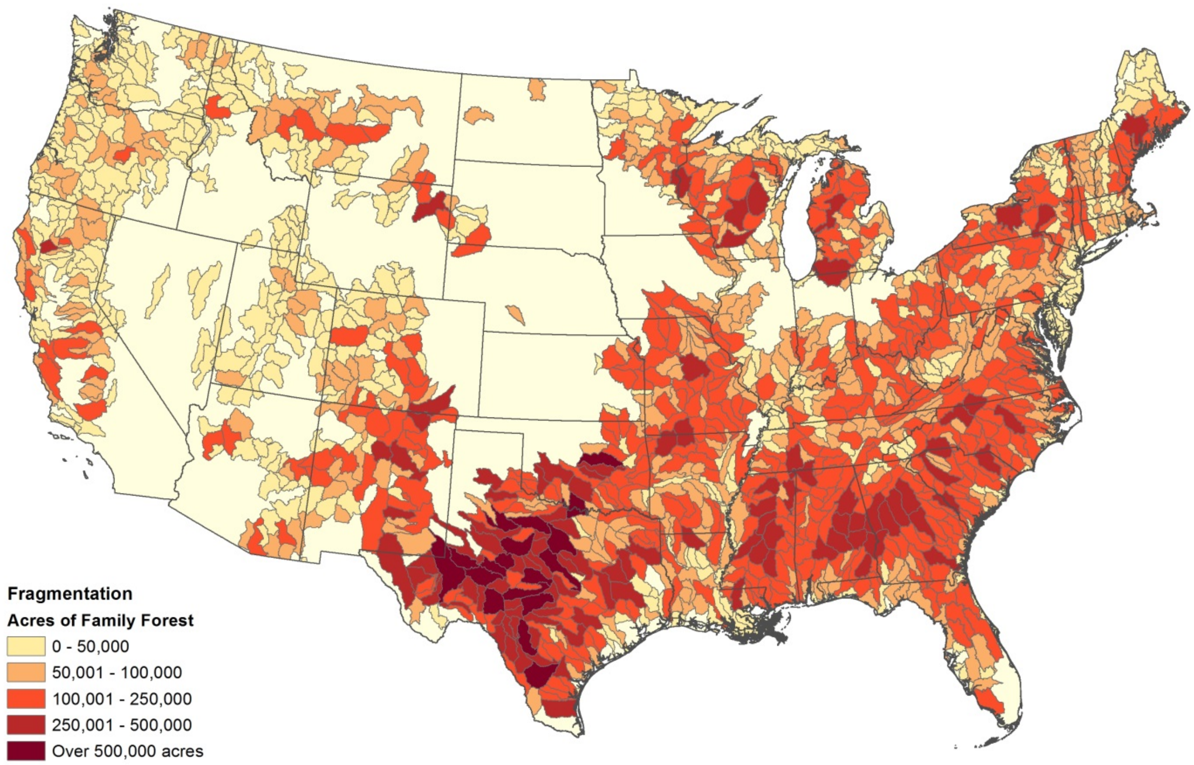

Figure 39. Area of family forest less than 30 meters from a forest/non-forest edge.

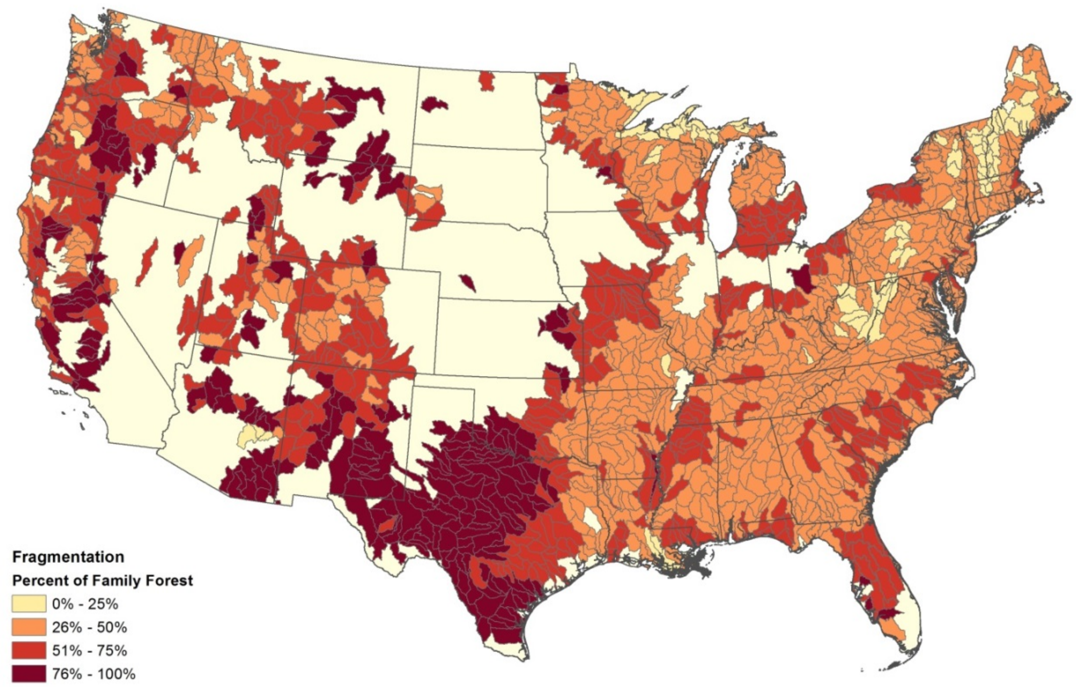

Figure 40. Percent of family forest less than 30 meters from a forest/non-forest edge.

4.4.2.3 Forest Parcellation

4.4.2.3.1 Data Description and Source

The process of breaking larger parcels of ownership into smaller ones is referred to as parcellation. Ideally parcellation, like fragmentation, would be measured as a process occurring over time. However, lacking such data, we calculated the degree of parcellation as the percent of land in a watershed held in forest holdings smaller than 50 acres in size. These data originated from responses to the most recent iteration of NWOS (Butler et al. 2014b).

4.4.2.3.2 Results and Discussion

Parcellation threatens a number of forest benefits, including the likelihood of forest management, smaller parcels are generally less economically viable units from which to harvest.

Not surprisingly, we find the greatest degree of parcellation in areas of higher population density. Also parcellation appears to be a greater issue along the eastern region of the U.S., in part because there is simply so much more forestland that is owned by families and individuals, as compared to the West.

In total we calculate there to be 94,200,000 acres of family forestland in the study watersheds that are in forest holdings of less than 50 acres in size (Figure 41 - Figure 42). Across watersheds, the average amount of family forest in holdings less than 50 acres is 68,000 acres, with the least amount of parcellation at zero acres in the Pea watershed spanning the Florida/Alabama border, and the greatest degree of parcellation at 467,000 in the Little Muskingum-Middle Island watershed spanning West Virginia and Ohio.

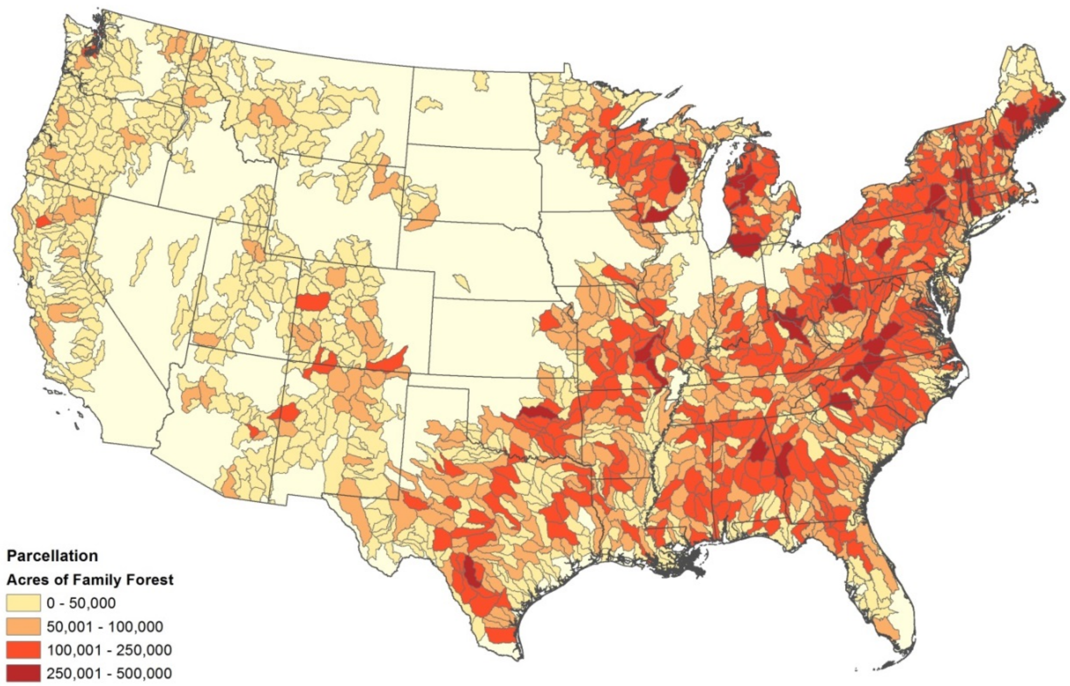

Figure 41. Area of family forest owned in parcels less than 50 acres in size.

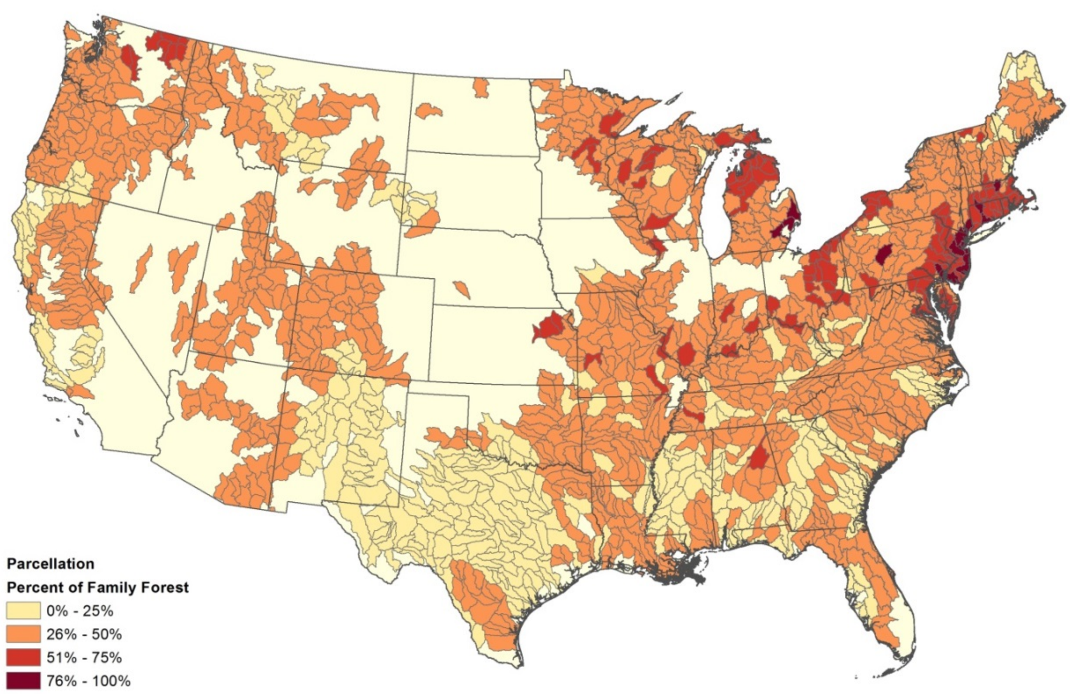

Figure 42. Percent of family forest owned in parcels less than 50 acres in size.

4.4.2.4 Likelihood of Ownership Transfer

4.4.2.4.1 Data Description and Source

Likelihood of ownership transfer was based on the percent of NWOS respondents in a watershed who reported the primary owner as being 75 years or older (Butler et al. 2014b).

4.4.2.4.2 Results and Discussion

Although land changing hands does not necessarily jeopardize the benefits forests provide, it does present an opportunity for major changes to occur in terms of ownership objectives, management regimes, and may increase the likelihood of parcellation and/or fragmentation to increase.

Although an imperfect metric to predict ownership transfer, owner age provides insight to where shifts are likely to occur in the near term, as odds of dying increase with age.

Using NWOS data responses for age of the primary owner, we estimate that a total of 63,400,000 acres are held by owners 75-years of age or older (Figure 43 - Figure 44). Across watersheds the average was 45,800 acres, and ranged from watersheds with no owners 75 and older (12 watersheds scattered across the country) to 647,000 in the Upper Devils watershed of west Texas.

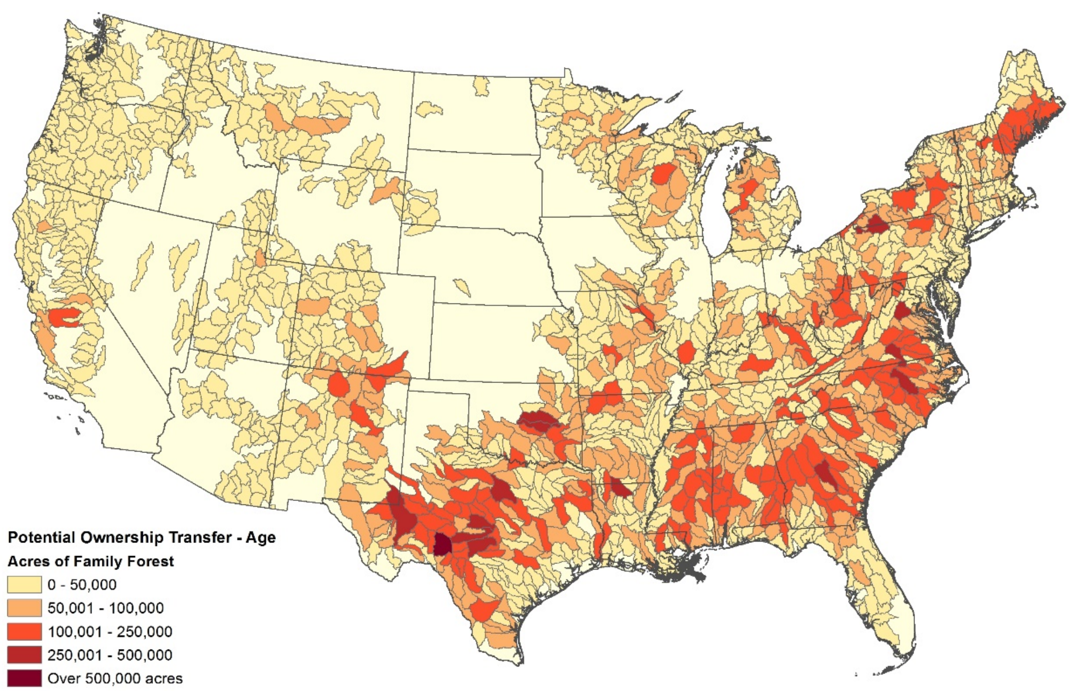

Figure 43. Area of family forest held by owners who are 75 years and older.

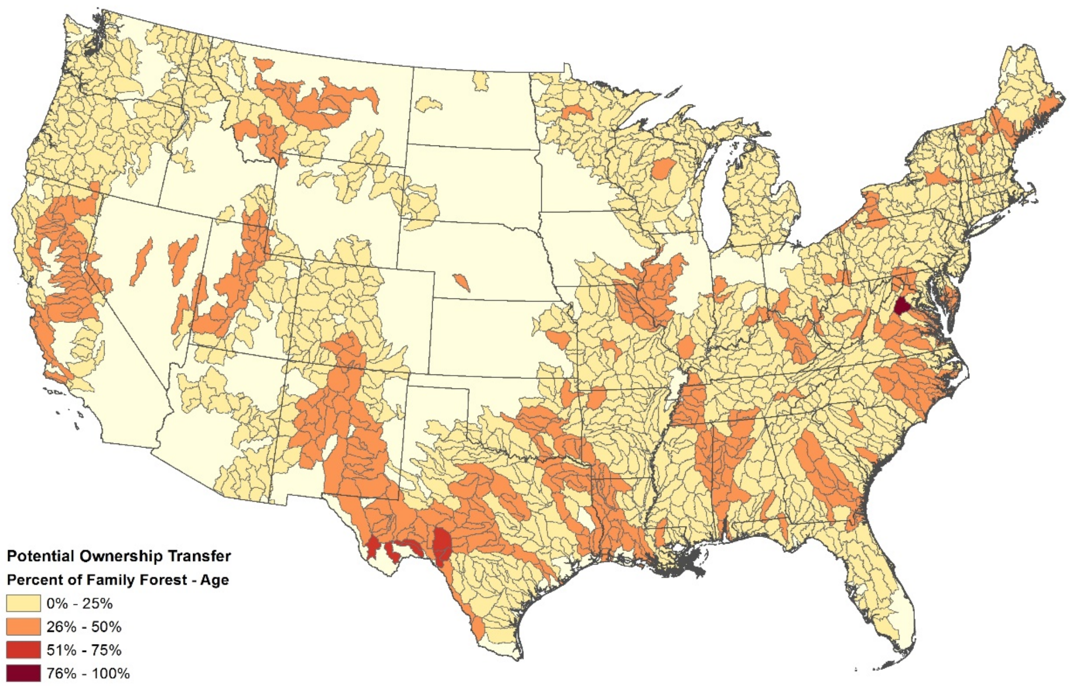

Figure 44. Percent of family forest held by owners who are 75 years and older.

4.4.2.5 Insects & Diseases

4.4.2.5.1 Data Description and Source

The insect and disease threat was quantified as the percent of family forestland in a watershed where 16% or more (high threat), or 25% or more (very high threat) of the basal area was at risk of mortality due to insect and disease infestation. The insect and disease layer originated from the U.S. Forest Service – Forest Health Technology Enterprise Team as the National Insect and Disease Risk Map (NIDRM) as a 787-foot (240-meter) pixel raster grid (Figure 45; http://www.fs.fed.us/foresthealth/technology/nidrm.shtml)

4.4.2.5.2 Results and Discussion

Pests and pathogens have tremendous capacity to damage and kill individual trees, and sometimes entire stands. Effects of tree mortality due to insects and diseases can be wide reaching, including causing a significant increase in the risk of wildfire.

Utilizing the U.S. Forest Service's National Insect and Disease Risk Map, we estimate a total of 36,800,000 acres of family forest within the study watersheds are at risk of losing at least 16% of the standing basal area to due mortality caused by insects or diseases (Figure 46 - Figure 47). Watersheds ranged from having no family forestland at risk of insect and disease mortality in 80 watersheds, predominantly in the West, to having 299,520 acres under threat in the Maine Coastal watershed.

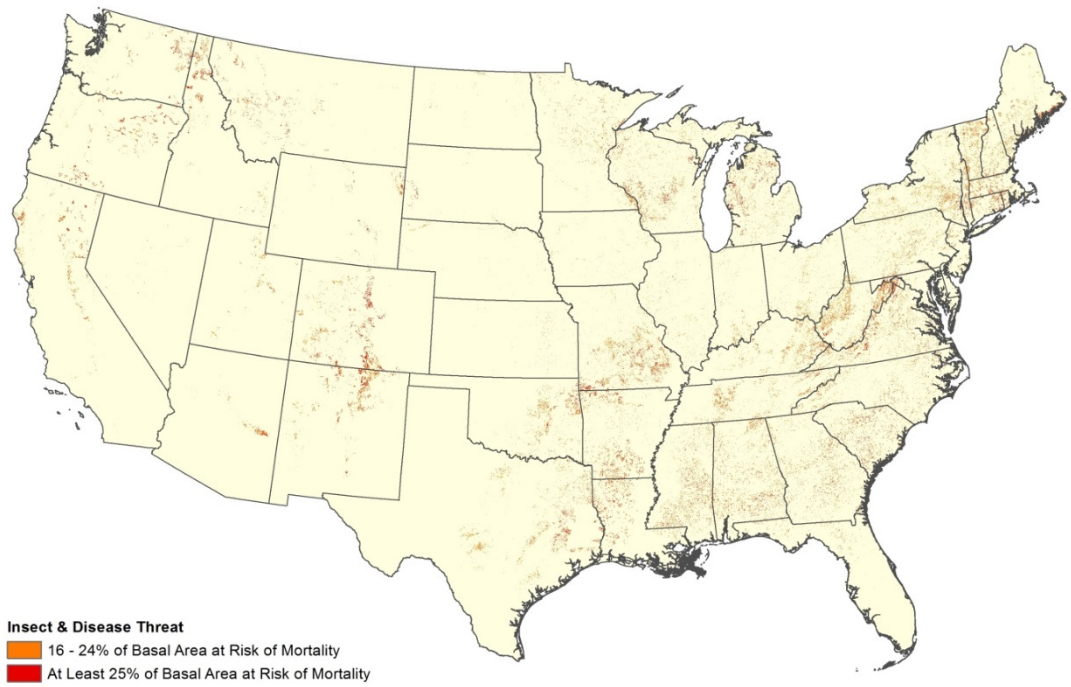

Figure 45. Extent of high and very high risk of tree mortality owing to insects and diseases.

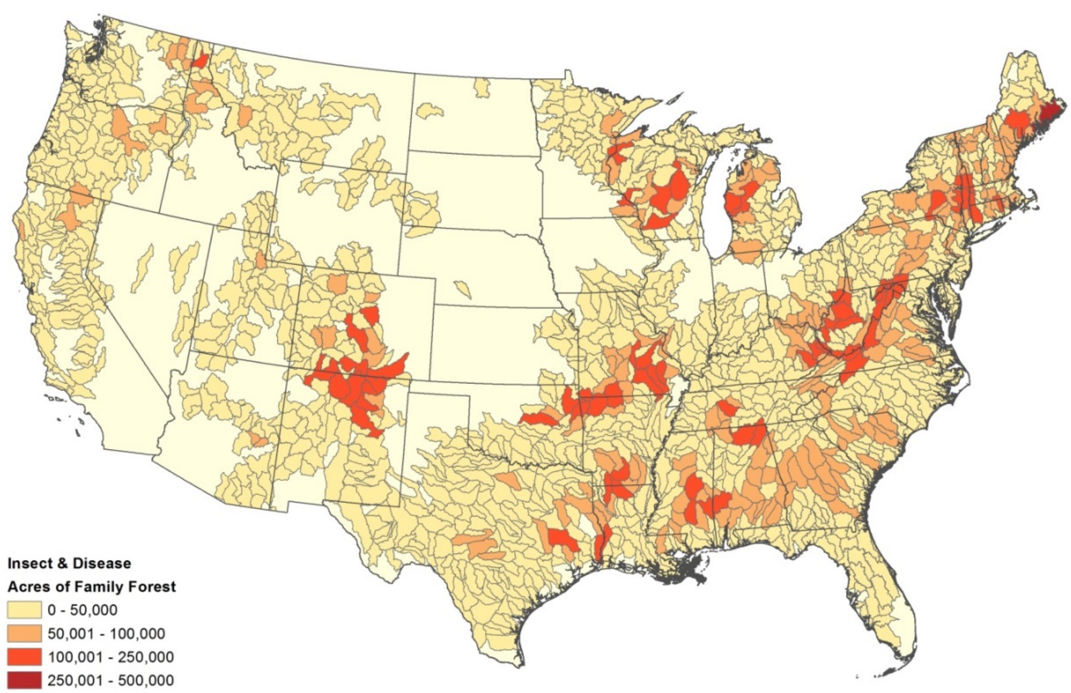

Figure 46. Area of family forest at high or very high risk of tree mortality owing to insects and diseases.

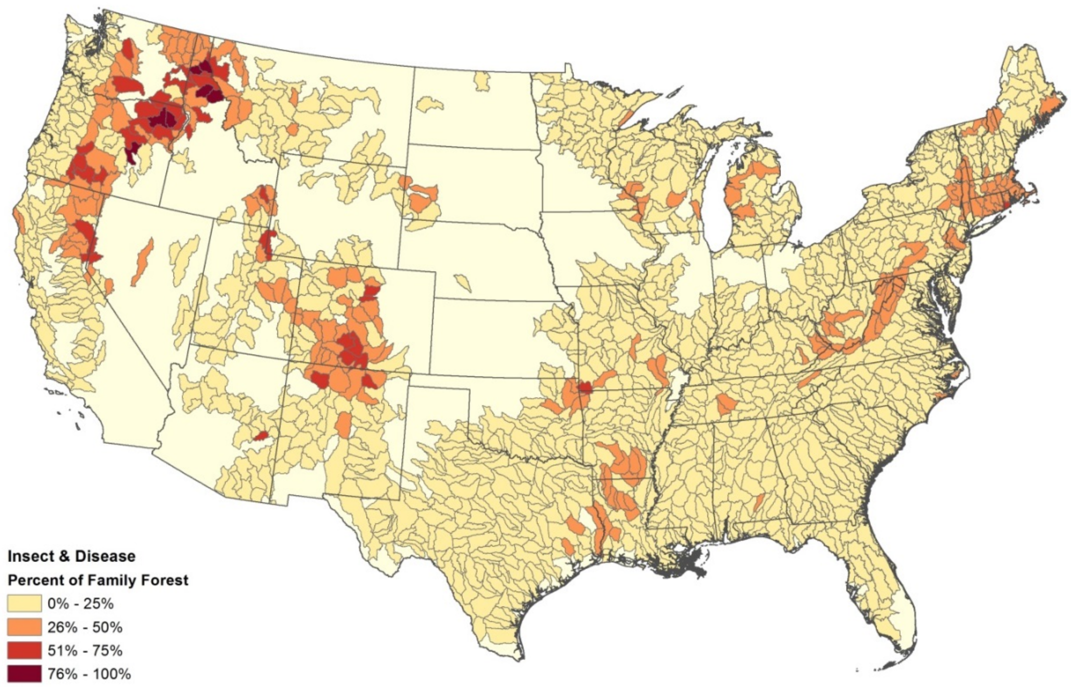

Figure 47. Percent of family forest at high or very high risk of tree mortality owing to insects and disease.

4.4.2.6 Climate Change

4.4.2.6.1 Data Description and Source

Vegetation Shift was used as a proxy for potential changes to forests due to climate change, and quantified as the percent of family forestland in a watershed that is projected to change vegetation type by the end of this century. Vegetation shift was determined by comparing: Vegetation Type for the Conterminous United States Simulated for Historical data for the years 1961-1990 by the MC1 Model (VEMAP version) and Vegetation Type for the Conterminous United States Simulated for HAD2 data for the years 2070-2099 by the MC1 Model (VEMAP version) produced by the U.S. Forest Service – Pacific Northwest Research Station as a 0.5-degree pixel raster grid (Figure 48; http://databasin.org/datasets/c6d0ddb447d045548d05f8e1b12ff907).

4.4.2.6.2 Results and Discussion

Climate change has the potential to alter patterns of vegetation across the landscape over time. Changes in temperature and moisture regime are likely to be the primary drivers that cause changes in vegetation distribution. In the long term this may impact markets, species value, and products extracted from the wood grown on family forests.

Due to a combination of the coarseness of the source climate data, and the broad bands of vegetation type modeled, the resulting maps of where vegetation is projected to shift has a striking visual effect (Figure 49 - Figure 50).

According to our calculations, roughly 85 million acres of family forest are predicted to change vegetation type by 2070, with an average of 62,000 acres per watershed. That figure may be misleading however, as there are 540 watersheds without any family forestland project to shift vegetation type. In contrast, the Middle Brazos-Palo Pinto watershed of north central Texas is projected to see 874,000 acres shift vegetation type.

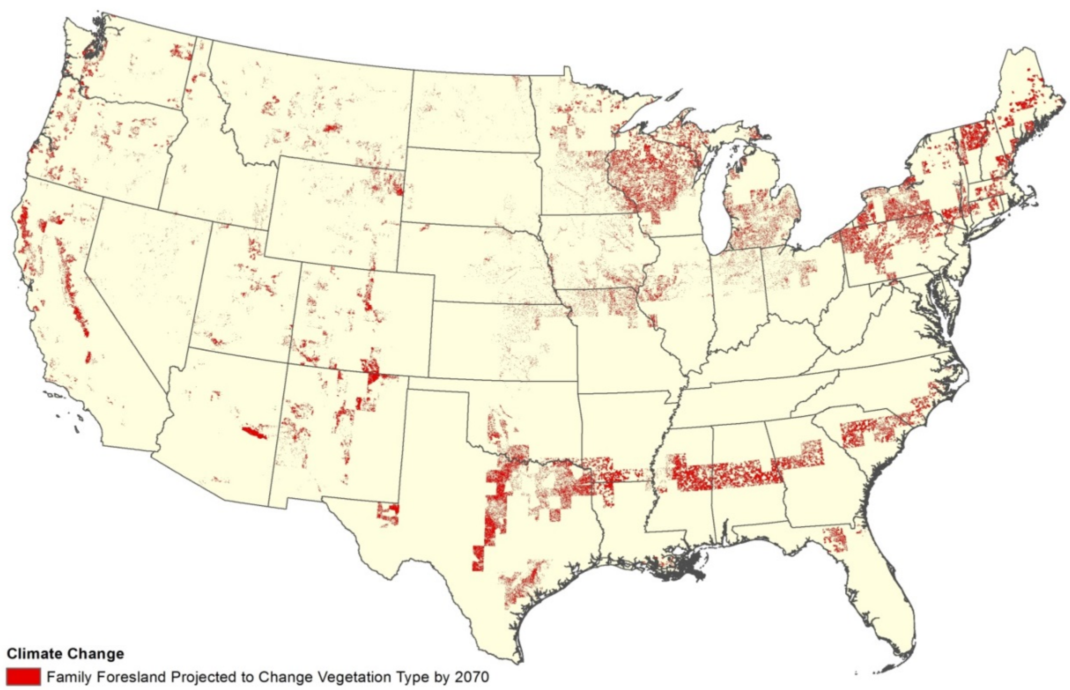

Figure 48. Extent of family forestland projected to shift from one vegetation type to another due to climate change by 2070.

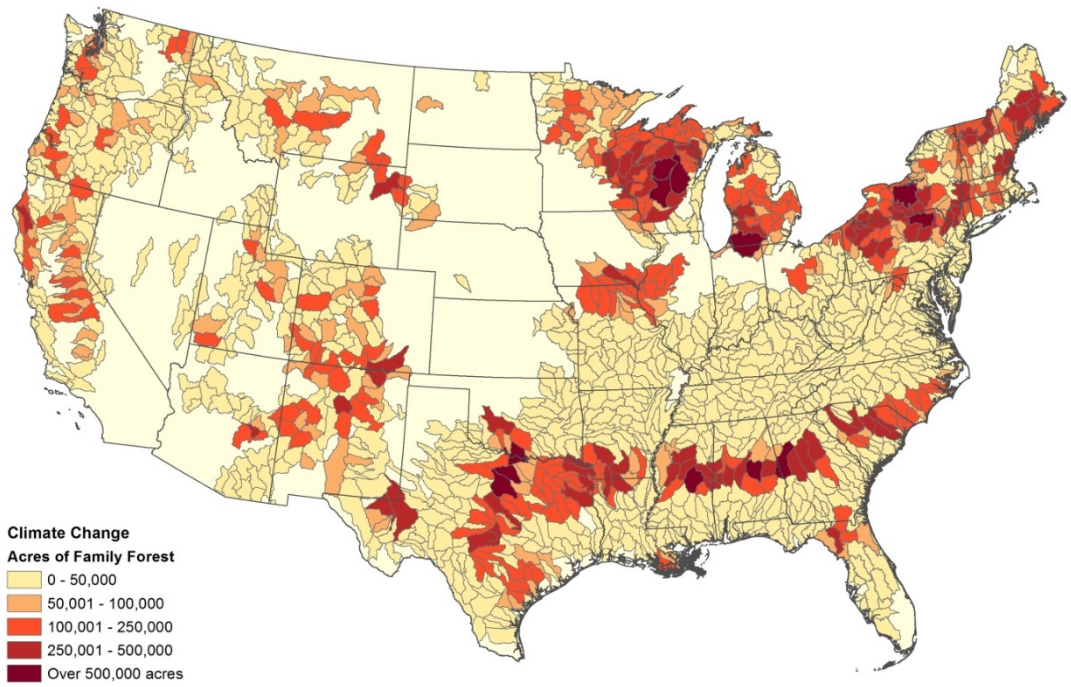

Figure 49. Area of family forestland projected to shift from one vegetation type to another due to climate change by 2070.

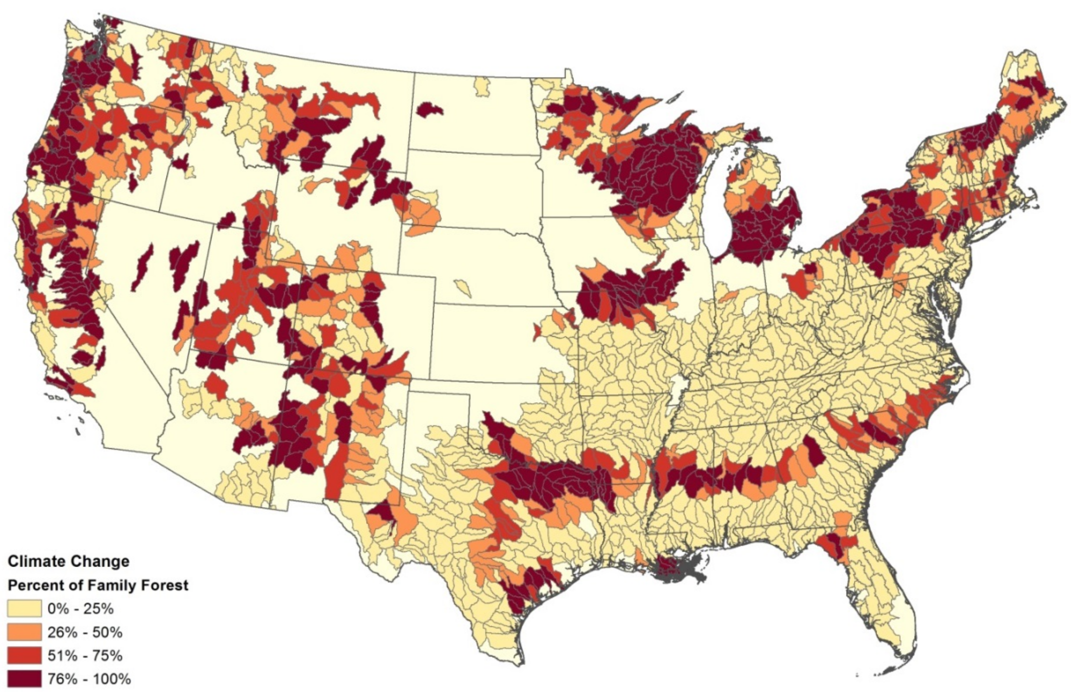

Figure 50. Percent of family forestland projected to shift from one vegetation type to another due to climate change by 2070.

4.4.2.7 Wildfire

4.4.2.7.1 Data Description and Source

Wildfire risk was quantified as the percent of family forestland in a watershed with high to very high wildfire potential. The source wildfire layer originated from the U.S. Forest Service – Firelab's Wildland Fire Potential Version 2012 and came as a 886-feet (270-meter) pixel raster grid (Figure 50; http://www.firelab.org/fmi/data-products/229-wildland-fire-potential-wfp).

4.4.2.7.2 Results and Discussion

While depending on intensity and severity, wildfire has the potential to diminish or destroy many of the benefits from family forests. Although many ecological communities are adapted to fire regimes, wildfire can alter or damage habitat, release stored carbon back into the atmosphere, and reduce or eliminate the commodity value of standing timber.

Wildfire threats are greatest in the southern and western regions of the U.S. (Figure 52 - Figure 53). Across the study watersheds there is a total of 29,100,000 acres of family forest at high or very high risk of wildfire. Three hundred and sixty-eight watersheds have no family forestland threatened by wildfire; most of these are located in the north central and northeastern regions of the U.S. The watershed with the greatest number of family forest acres threatened by wildfire is the Lower Oconee in Georgia with 369,000 acres threatened.

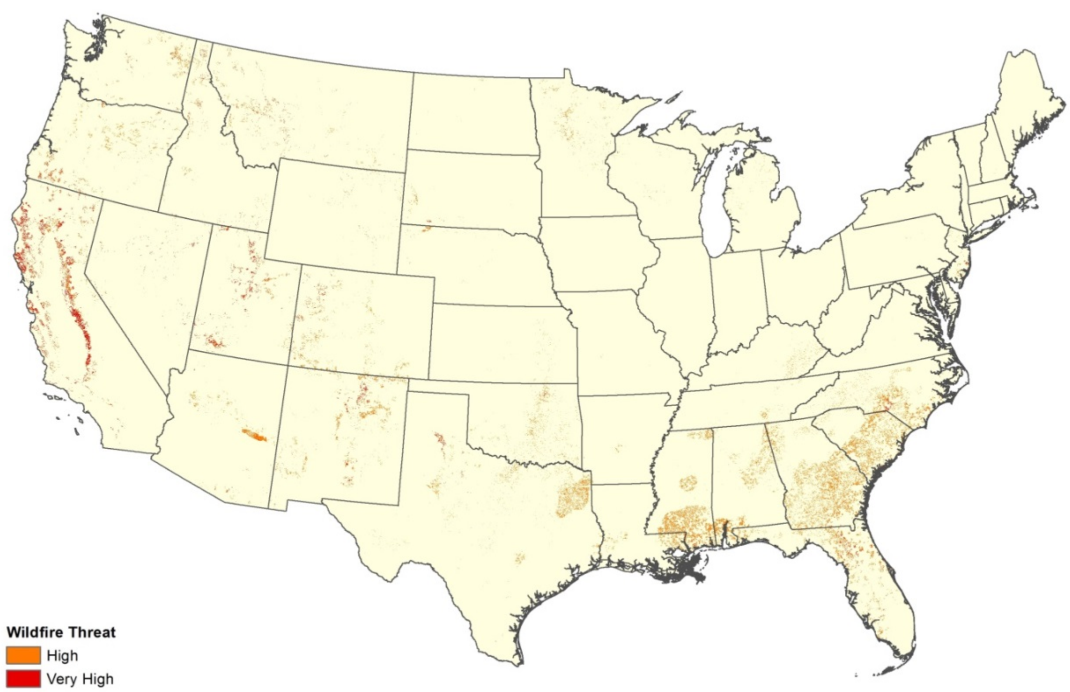

Figure 51. Extent of high and very high threat of wildfire on family forestlands.

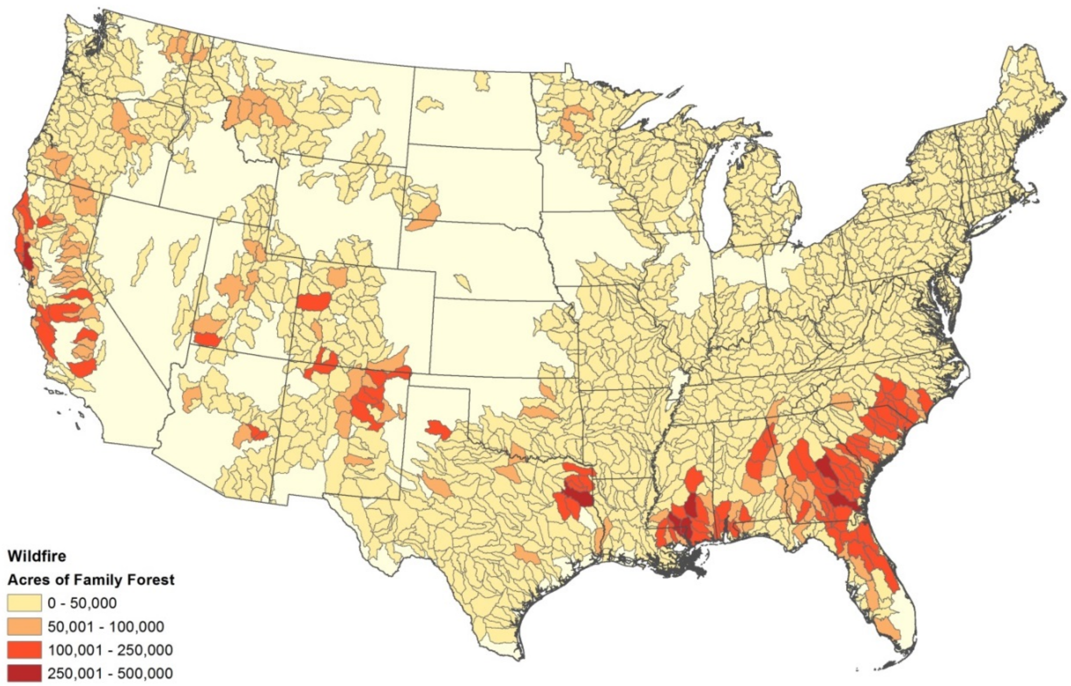

Figure 52. Area of family forest under high or very high threat of wildfire.

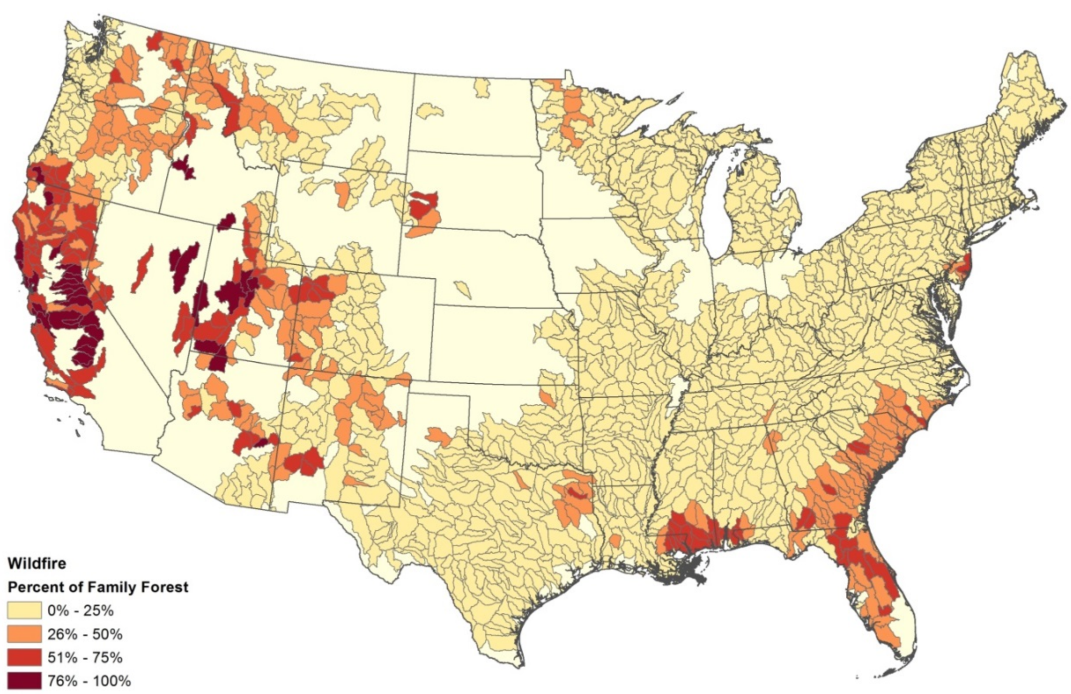

Figure 53. Percent of family forest under high or very high threat of wildfire.

4.4.2.8 Unavailability of Forest Products

4.4.2.8.1 Data Description and Source

Unavailability of forest products was measured as the percent of land in a watershed held by family forest owners who have never harvested forest products in the past, do not intend to do so in the future, and do not have timber management as a primary ownership objective, according to data from the NWOS (Butler et al. 2014b).

4.4.2.8.2 Results and Discussion

Wood and biomass on family forests are only useful from a commodity perspective if they can be harvested. Research by Butler et al. (2010) suggests that the availability of wood is constrained by social and biophysical factors, with the vast majority of the reduction in availability due to owner attitudes. As such we used data from the NWOS to calculate by watershed the percentage reduction in availability.

In sum we estimate a total of 24,400,000 acres of family forest within the study watersheds that have a low probability of having wood products harvested from them (Figure 54 - Figure 55). Individual watersheds ranged from no land theoretically off limits to harvesting due to landowner attitudes in six watersheds (five in the South and one in Montana), to 820,000 acres essentially closed to harvest in the Llano watershed of central Texas, with an average of 65,600 acres closed across study watersheds.

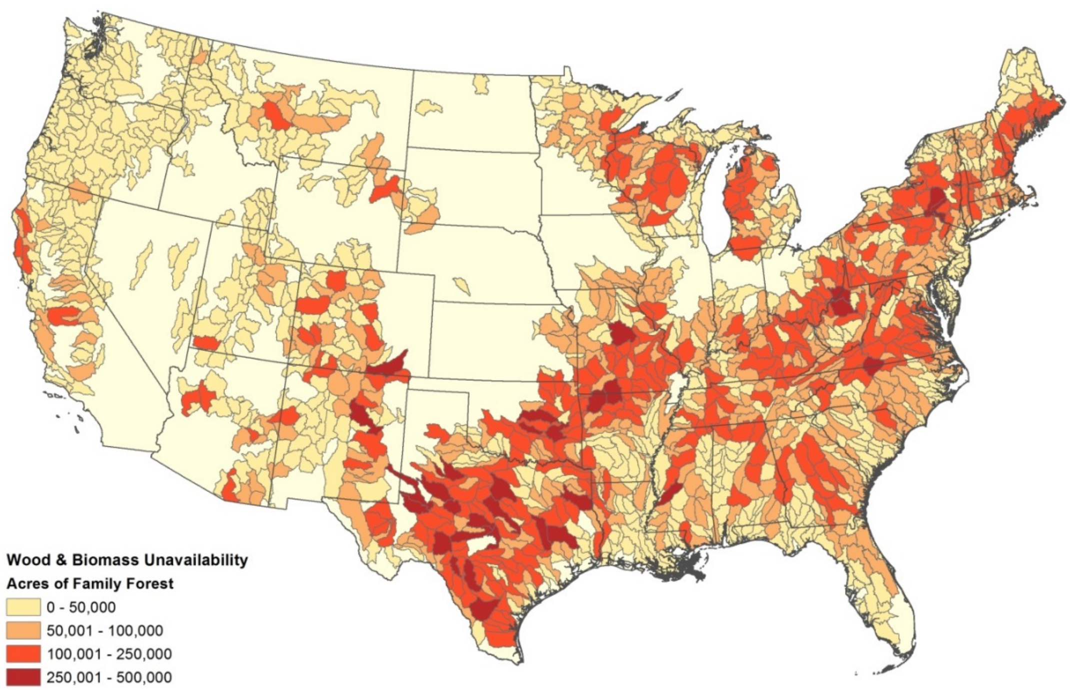

Figure 54. Area of family forestland held by owners who have never harvested, never plan to harvest, and do not cite timber production as primary motivation for owning forestland.

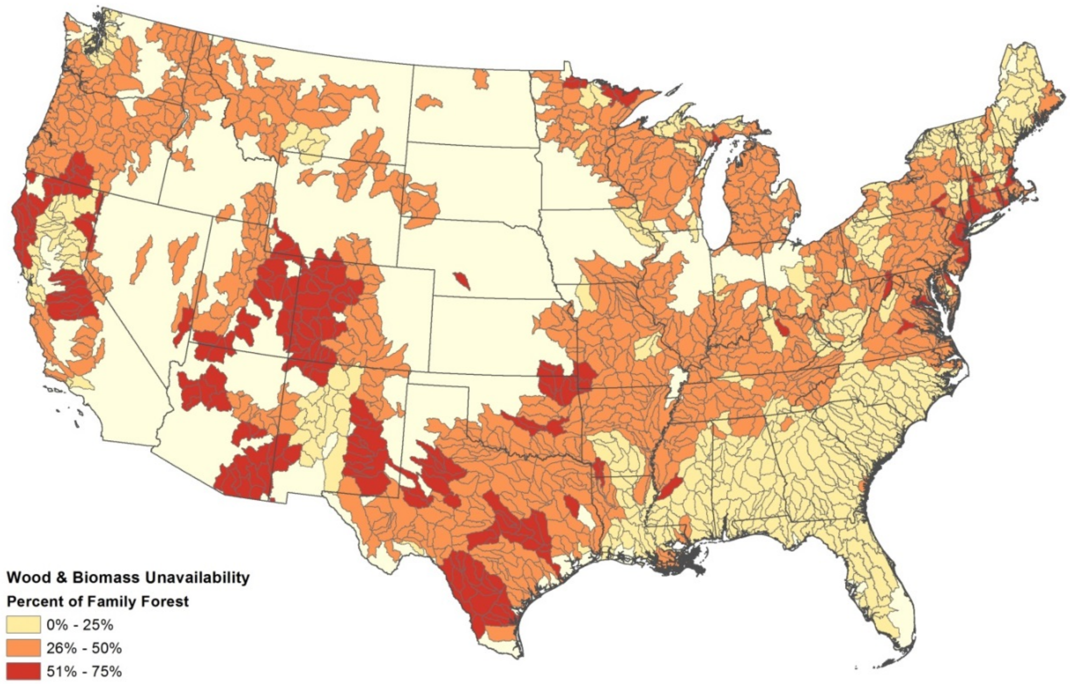

Figure 55. Percent of family forest held by owners who have never harvested from their land in the past, do not intend to do so in the future, and do not report timber production as a primary objective of land ownership.

4.4.2.9 Natural Disasters

4.4.2.9.1 Data Description and Source

Three types of natural disasters possessing the capacity to significantly damage forest resources were examined: hurricanes, tornados, and ice storms. The probability of a hurricane occurring within the subject watersheds over a ten-year period was based on historic hurricane activity from 1851-2011, derived from the NOAA Storm Events Database (http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=-999%2CALL). The probability of a tornado occurrence was based on historic tornado activity from 1950-2011, which was derived from a NOAA SVRGIS shapefile data containing storm paths (http://www.spc.noaa.gov/gis/svrgis/). Finally, the probability of an ice storm occurrence within a watershed over a ten-year period was based on historic storm activity from 1996-2013, derived from the NOAA Storm Events Database (http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=-999%2CALL).

4.4.2.9.2 Results and Discussion

Natural disasters can be wide spread, but they often vary considerably in the amount of devastation they produce on the landscape. Meteorological events such as hurricanes, tornados, and ice storms, like fire and insects and diseases, have the capacity to damage as little as a few branches from a single tree, to an entire stand or larger area.

Using historic data from NOAA we estimated a probability of future occurrence during a ten-year period.

4.4.2.9.2.1 Hurricanes

For this analysis we utilized hurricane path data which restricted our focus to areas where storms were still classified as a tropical disturbance, therefore while storms may still have impacts upon the landscape after losing that designation, we have no data to address the distribution of those impacts.

Having their origins in oceanic waters, hurricanes typically impact coastal areas to the greatest degree, with the southern region of the U.S. seeing the most activity, and many areas of the country seeing no hurricane activity whatsoever; 507 watersheds primarily in the West and North Central regions of the U.S.

Of those watersheds with historic hurricane activity, the average number of events expected in a ten-year timeframe is 0.95, with a maximum of 7.1 in the Albemarle watershed off the coast of North Carolina (Figure 56). In total, we estimate 836 hurricanes paths to intersect the subject watersheds in a ten-year timeframe.

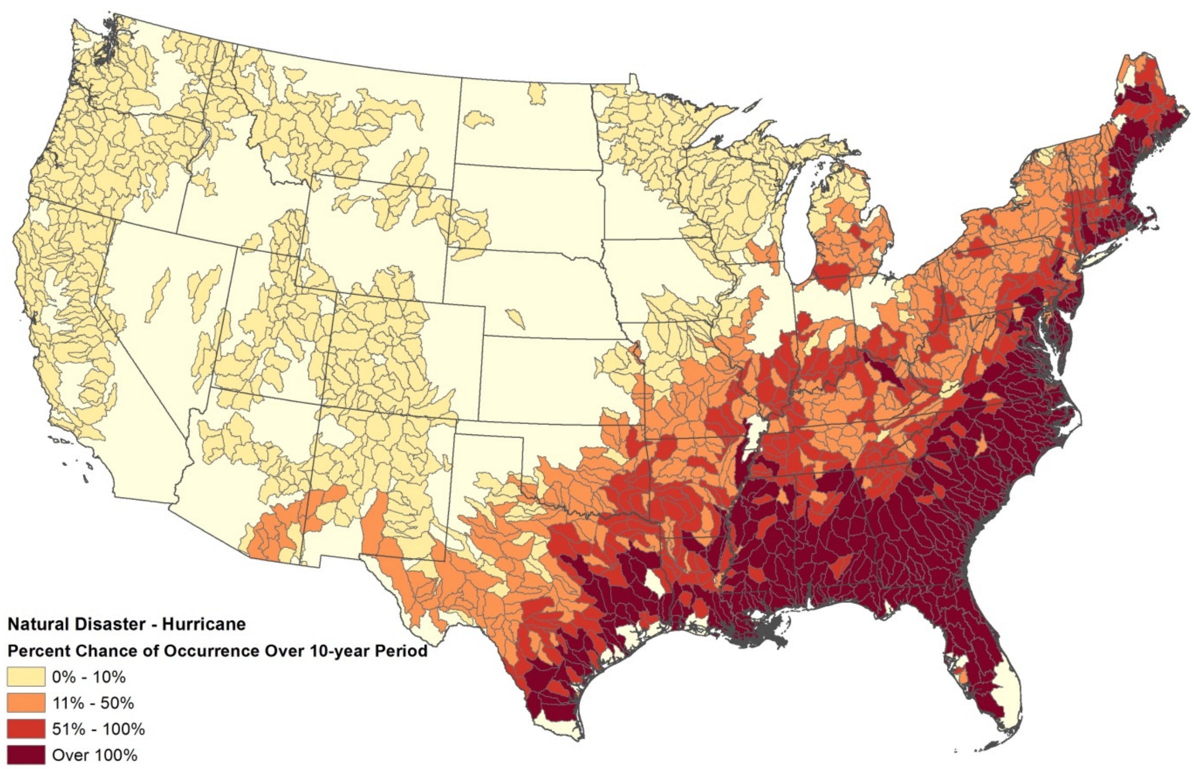

Figure 56. Predicted chance of being in the path of a hurricane in ten years.

4.4.2.9.2.2 Tornados

As meteorological events, tornados are much more widespread in their occurrence than hurricanes, but more localized with respect to where they inflict damage.

The estimated average number of tornados per watershed in a ten-year period is 2.4 and ranges from zero in 298 watersheds to 21 in the Wheeler Lake watershed of northern Alabama (Figure 57). In total, 3,300 tornados are anticipated to affect the subject watersheds in a ten-year period.

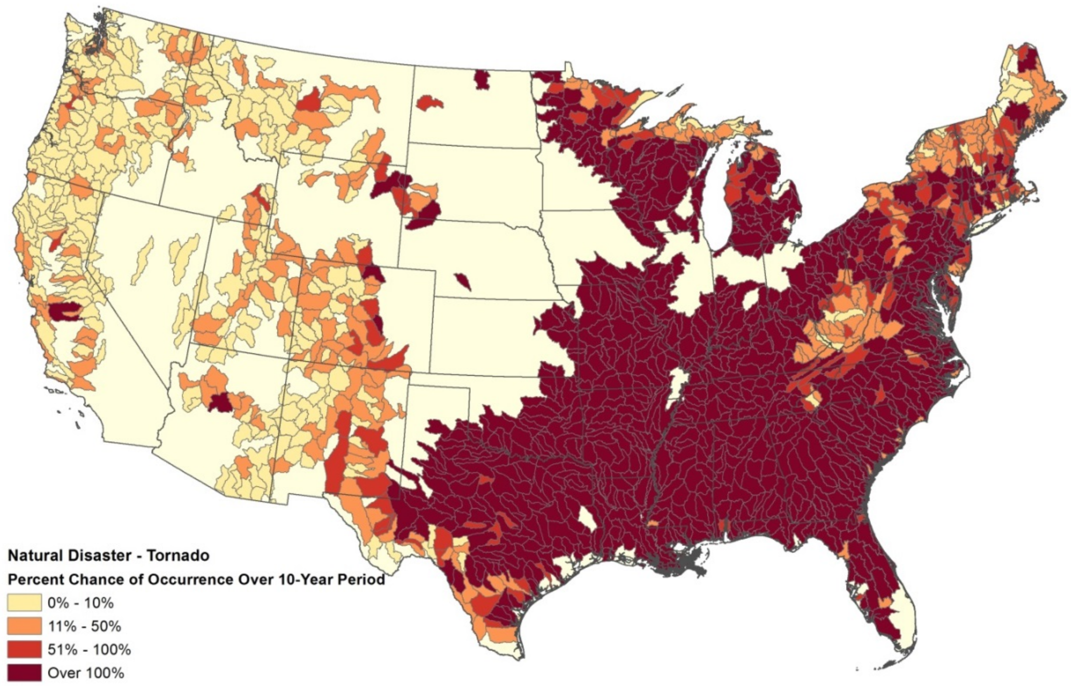

Figure 57. Predicted chance of being in the path of a tornado in ten years.

4.4.2.9.2.3 Ice Storms

Of the three natural disasters listed in this report, ice storms are probably the most variable in terms of the impacts to forests. The severity of damage due to an ice storm is affected by the amount of precipitation, duration of sub-zero temperatures, wind speed and direction, type of vegetation, and numerous other factors.

Based on historic patterns, we estimate a total of 13,000 ice storms in a ten-year period across the subject watersheds, with an average of 6 storms per watershed (Figure 58). Four-hundred nineteen watersheds, primarily in the West and Gulf Coast are predicted to see no ice storm activity in a ten-year period, during which time the Upper New watershed spanning North Carolina and Virginia is expected to see over 80 ice storm events, the maximum of all subject watersheds.

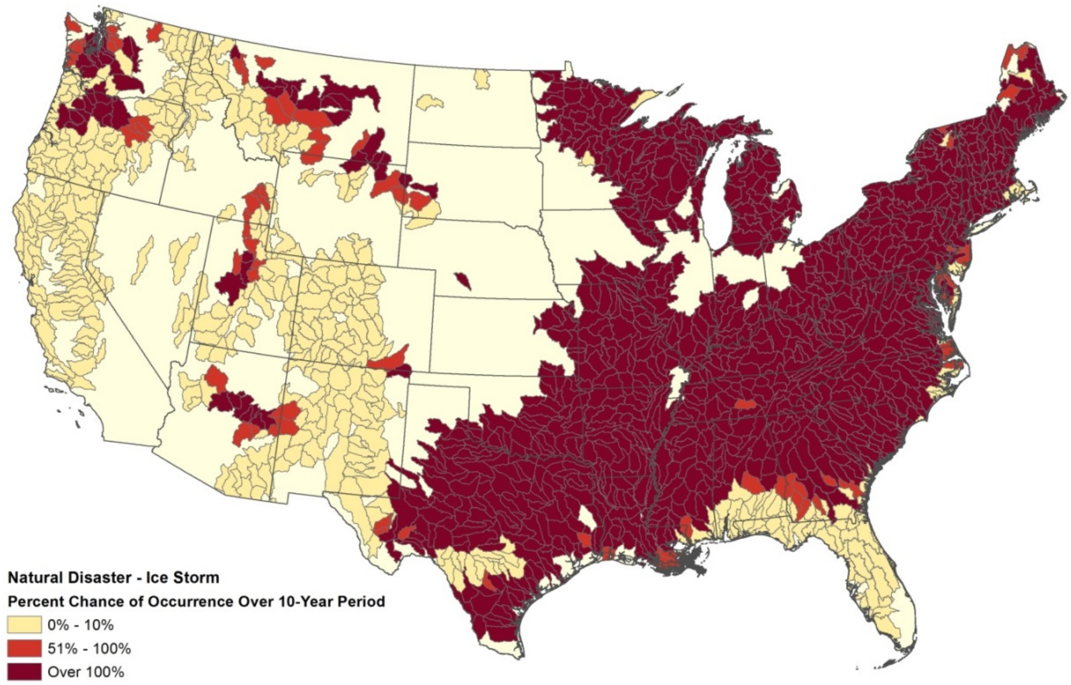

Figure 58. Predicted chance of experiencing an ice storm in ten years.

4.4.2.10 Comparisons of Threats

The total area potentially impacted varies considerably among the threats (Figure 59). Fragmentation and parcellation are estimated to impact the greatest area areas of family forestland. The ultimate impact of any of the threats depends on the specific benefit being examined and the severity of the threat. It is also important to remember that the greatest threats in localized areas may be very different than the greatest threats at the national-level.

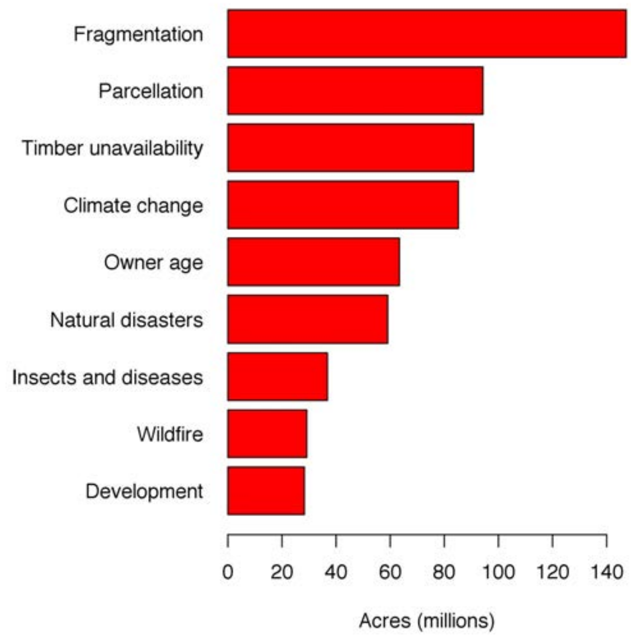

Figure 59. Area of family forestland threatened.

4.4.3 Threats to Benefits

To this point we have presented the benefits of family forests and the threats to family forests separately. This has allowed us to look at overall spatial patterns and get a sense of the general extent of these phenomena, which is valuable for understanding the general landscape of threats and benefits. Now, however, in order to get a more in-depth understanding of how specific benefits are threatened, and to what extent, we look to each benefit in turn and examine the relative impacts of threats (for those we have spatial data) hypothesized to have negative impacts on the benefits family forests provide. In thinking about the threats to forest benefits, the analyses are restricted to those anticipated to have a deleterious effect within a ten-year time period. The relative impact of threats will vary by benefit and weightings were used to account for these differences (Table 1).

Table 1. Weightings of threats to family forests by benefit.

Threat	Water Quality	Carbon Sequest-ration	Core Habitat	T&E Species	Wood Supply	Biomass	Recrea-tion
Development	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fragmentation	-	-	0.50	0.50	-	-	-
Parcellation	0.10	-	-	-	0.50	0.50	0.50
Insects	0.10	0.10	0.25	0.25	0.50	0.50	-
Fire	0.10	0.50	0.25	0.25	0.50	0.50	0.10-
Timber unavailability	-	-	-	-	1.00	1.00	-
Hurricanes	0.10	0.10	0.50	0.50	0.50	0.50	0.10
Tornados	0.10	0.10	0.50	0.50	1.00	1.00	0.10
Ice	0.10	0.10	-	-	0.25	0.25	0.10

By and large, the patterns of the individual threats to each benefit follow the distribution and intensity of the threats themselves. It is the overlap between the two from which we are able to get a sense of the relative impacts of each threat on a particular benefit.

4.4.3.1 Threats to Water

Water quality may be negatively impacted by numerous factors, including the loss of forest (development), the breaking down of ownerships into smaller parcels (parcellation), degradation of the resource from insects and diseases (reducing cover), and wildfire (also reducing cover and negatively impacting forest vegetation's filtration and retention capacity).

4.4.3.1.1 Development

Of the threats for which we have spatial data, water quality is likely to suffer most directly from development, as the bulk of forest vegetation is permanently removed and along with it, the storage and filtration capacity of forested land is substantially diminished. Although somewhat difficult to interpret, the Water Quality Index (WQI) is a measure of the amount of family forest in the watershed and the amount of forested stream buffers on family forestland.

The average reduction in WQI among study watersheds due to projected development was 0.04 and ranged from no reduction in 115 watersheds scattered across the country to 0.31 (Figure 60).

We can see that the greatest reductions in WQI are located in areas projected to see the greatest increases in housing density, which are concurrently experiencing the highest demand for clean and abundant water.

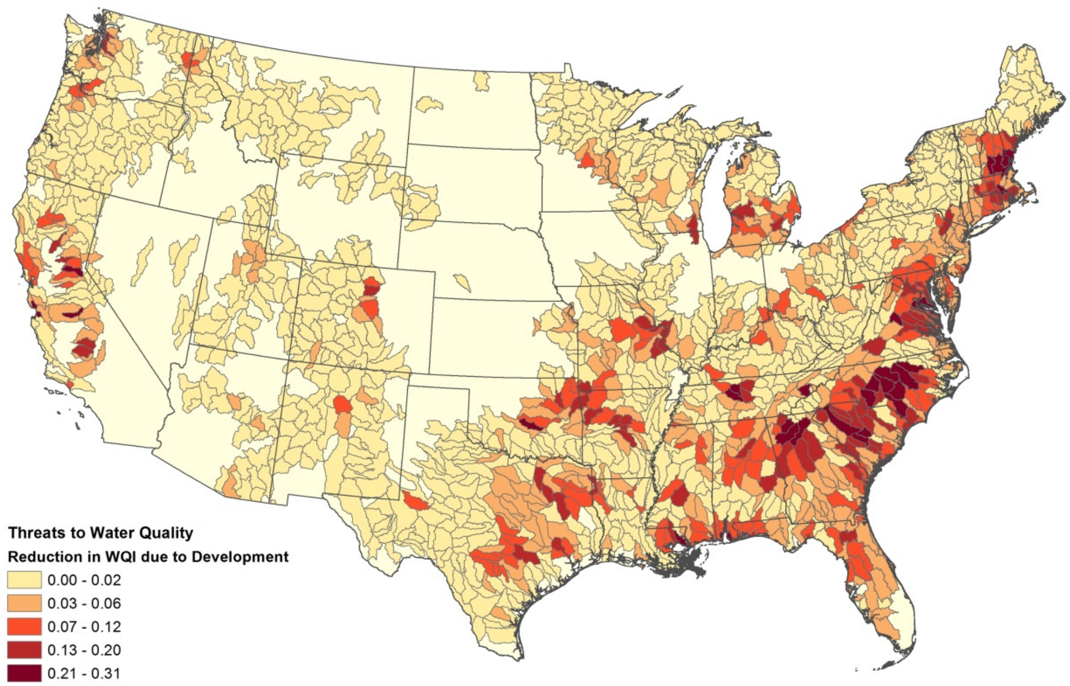

Figure 60. Reduction in Water Quality Index score due to development.

4.4.3.1.2 Parcellation

The breaking down of landholdings into smaller parcels is problematic to the continued provision of water from family forest lands. This is due in part to an increased number of owners being accompanied by an increase in competing desired uses, such as conversion to open areas and household ancillary uses (driveways, out buildings, and other impervious surfaces).

The average reduction in WQI due to parcellation was 0.01 and ranged from 0 to 0.05. Greater reductions in WQI appear to occur in the north and eastern regions of the US where parcels are smaller and there are abundant rivers and streams on family-owned lands (Figure 61).

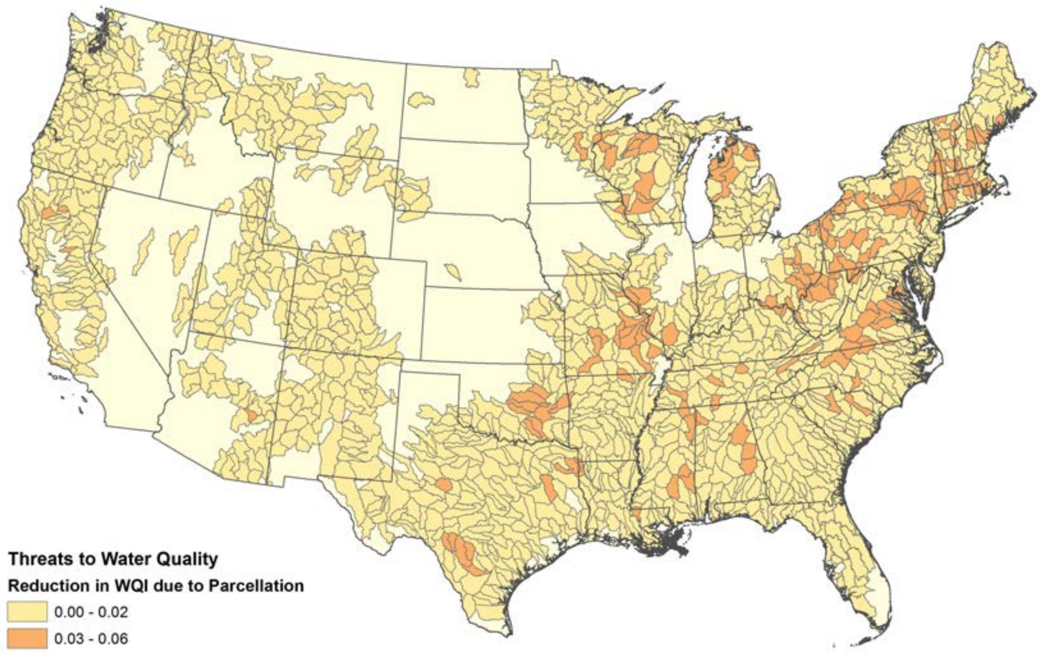

Figure 61. Reduction in Water Quality Index Score due to parcellation.

4.4.3.1.3 Insects & Disease

Damage to forest vegetation from insects and disease activity can result in decreased tree vigor and death. Stressed or dying vegetation is less able to maintain its water filtration and retention functions.

The threat of damage by insects and disease is predicted to decrease WQI in individual watersheds, on average, 0.004 points, and ranged from 0 in 84 watersheds to 0.04 (Figure 62).

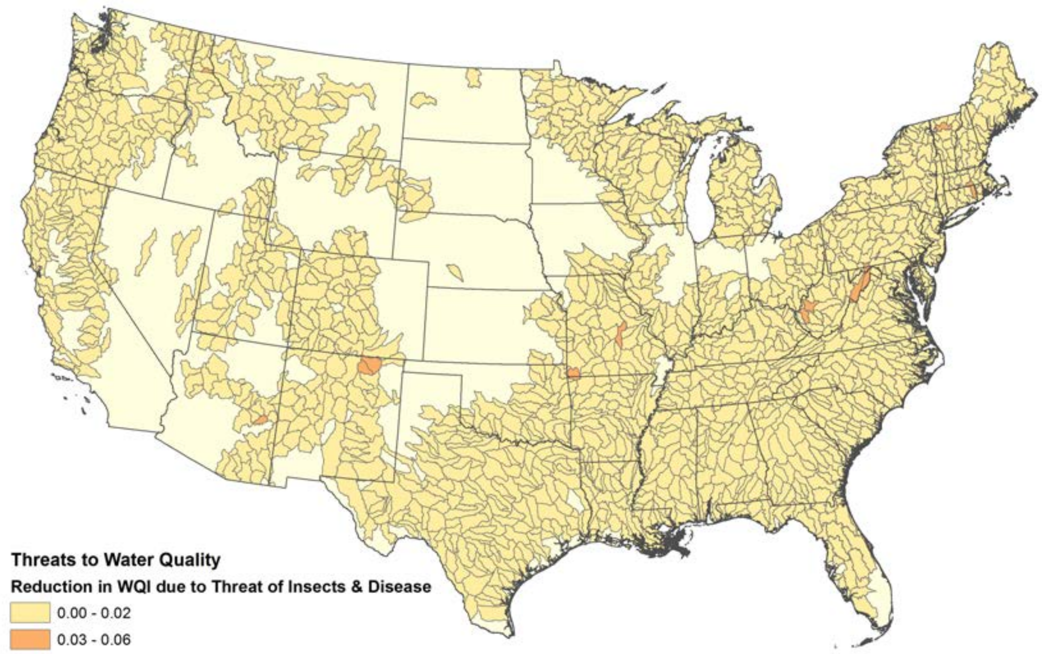

Figure 62. Reduction in Water Quality Index score due to insects & disease.

4.4.3.1.4 Wildfire

As with insects and disease, wildfire threatens water quality by decreasing vegetation's ability to store and filter water. Reductions in WQI owing to wildfire ranged from 0 to 0.06 points, with an average of 0.003 across watersheds (Figure 63).

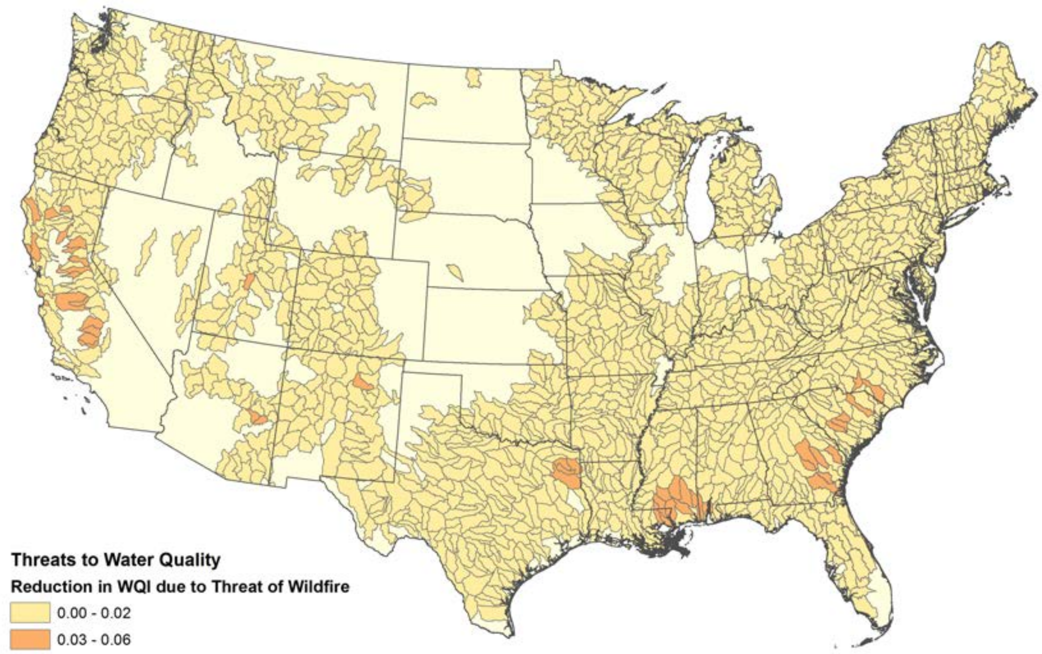

Figure 63. Reduction in Water Quality Index due to wildfire.

4.4.3.1.5 Natural Disasters

Loss of forest vegetation due to hurricanes, tornados, and ice storms can cause a temporary reduction in the ability of a forest to positively contribute to water quality. Based on historical data, it is projected that on average hurricanes will reduce water quality scores by 0.004 points over the next ten years. Tornados threaten a reduction of 0.0001, and ice storms of 0.002 points (Figure 64 - Figure 66).

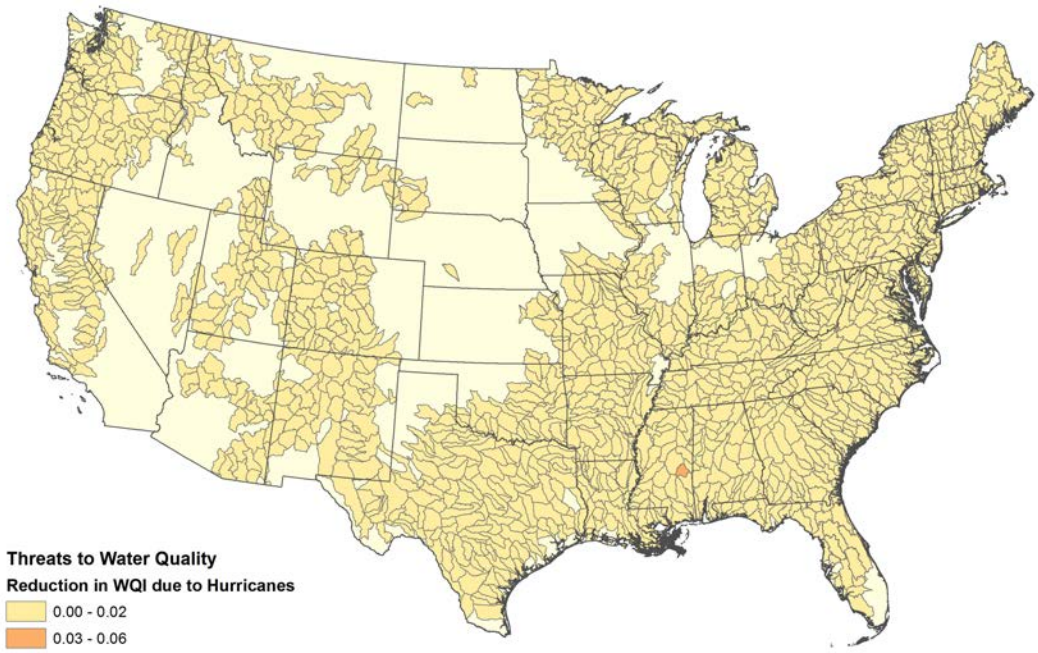

Figure 64. Reduction in Water Quality Index due to hurricanes.

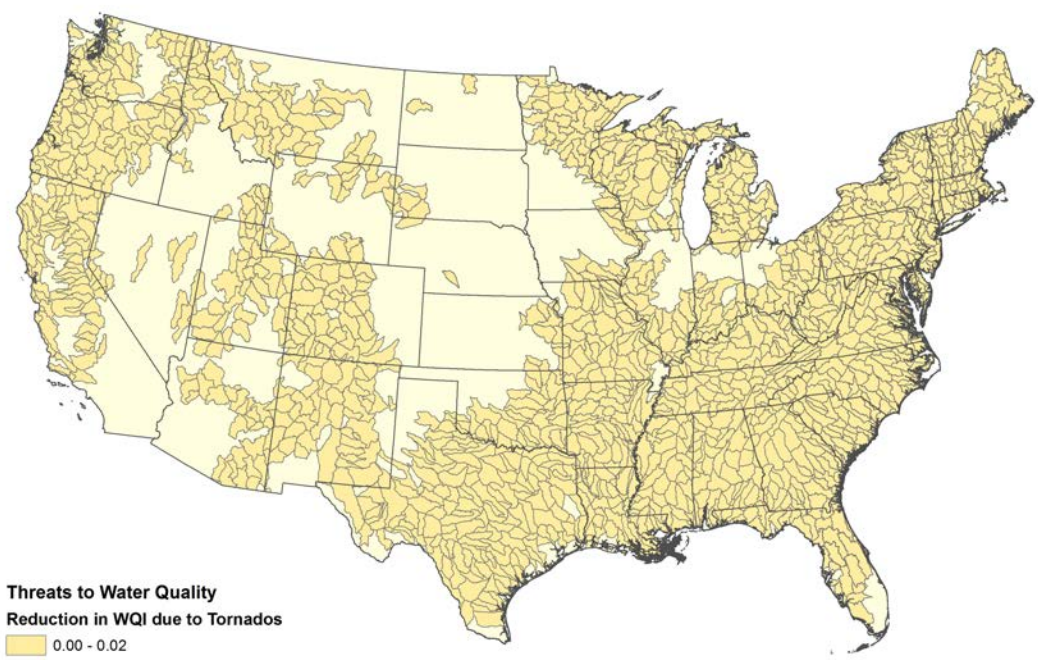

Figure 65. Reduction in Water Quality Index due to tornados.

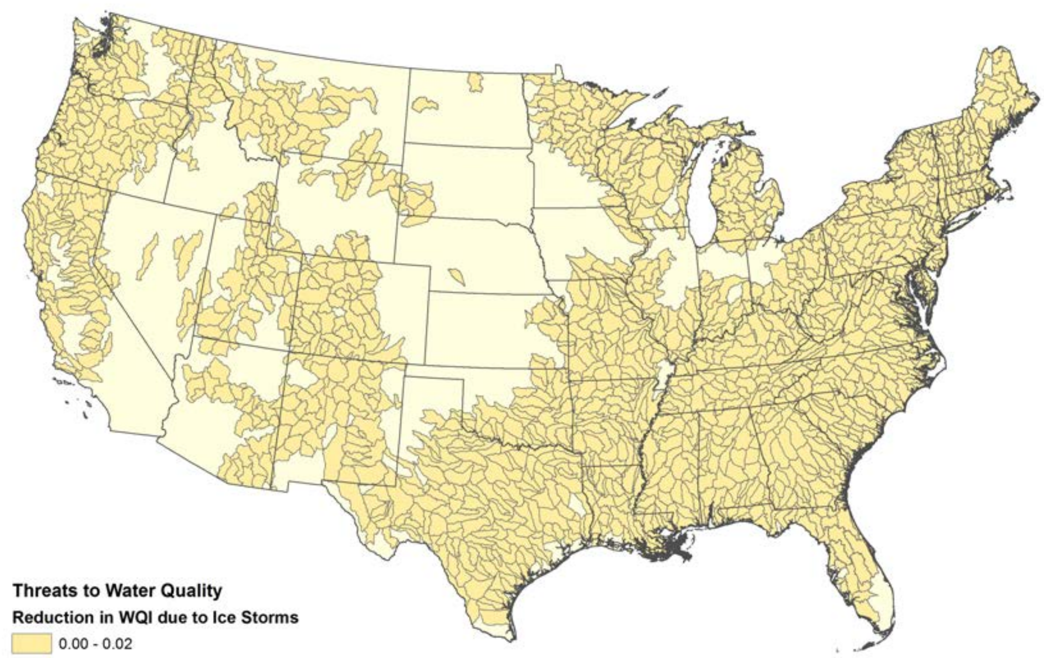

Figure 66. Reduction in Water Quality Index due to ice storms.

4.4.3.1.6 All Threats Combined

All together, we estimate that threats to water quality on family forestland are poised to decrease WQI scores from 0.0003 to 0.38 points, with an average of 0.06 per watershed (Figure 67).

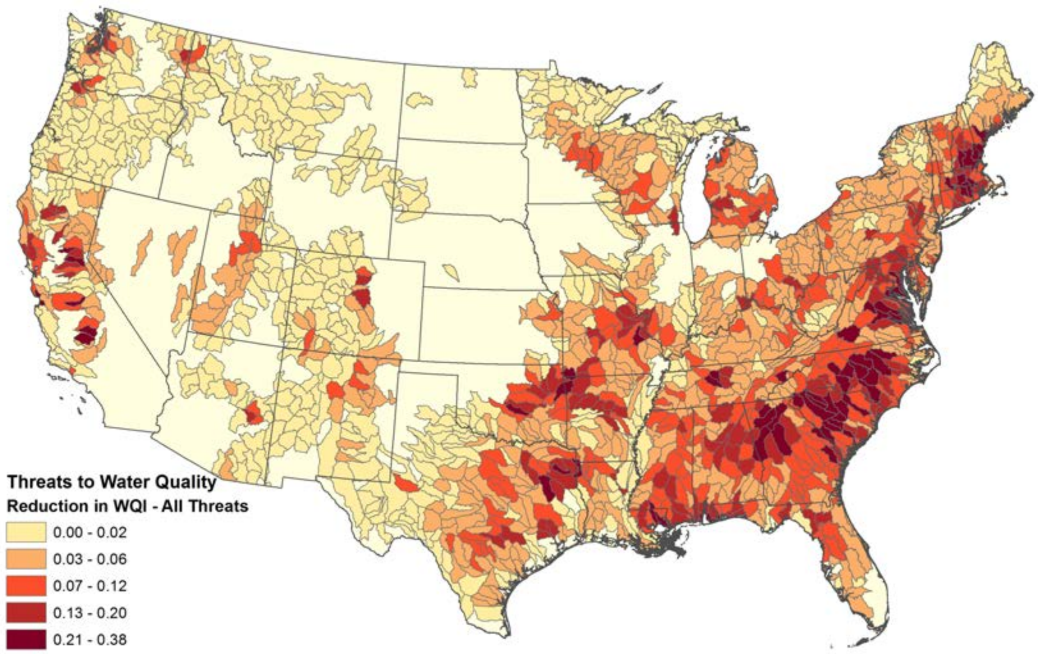

Figure 67. Total reduction in Water Quality Index due to all threats.

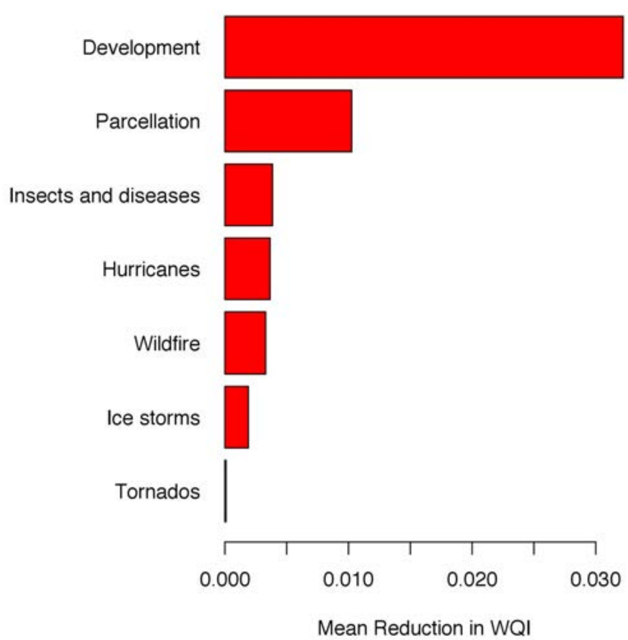

Figure 68. Mean reduction in Water Quality Index (WQI) on family forestland by threat.

4.4.3.2 Threats to Carbon Sequestration

Forests will continue to sequester carbon no matter the species composition, ownership patterns, degree of fragmentation, etc. What significantly impacts the ability of forests to maintain sequestered carbon, is the presence of forest vegetation. Both development, the loss of forest to a non-forest use, and wildfire, which threatens to release stored carbon back into the atmosphere, have the potential to impact carbon storage.

4.4.3.2.1 Development

We calculate that projected increased in housing densities between 2010 and 2020 is poised to threaten over 1.4 billion tons of carbon on family forestland. As with threats to water quality, increases in development did not occur on 115 watersheds and therefore does not pose threats to carbon on those family forestlands. On average, one million tons per watershed are threatened by development, while the greatest amount of carbon threatened by development was over 18 million tons (Figure 69).

The overlap between carbon stocks on family forests and areas where development is likely to occur results in a pattern of more highly threatened watersheds along the eastern seaboard centered on the major interstate corridors.

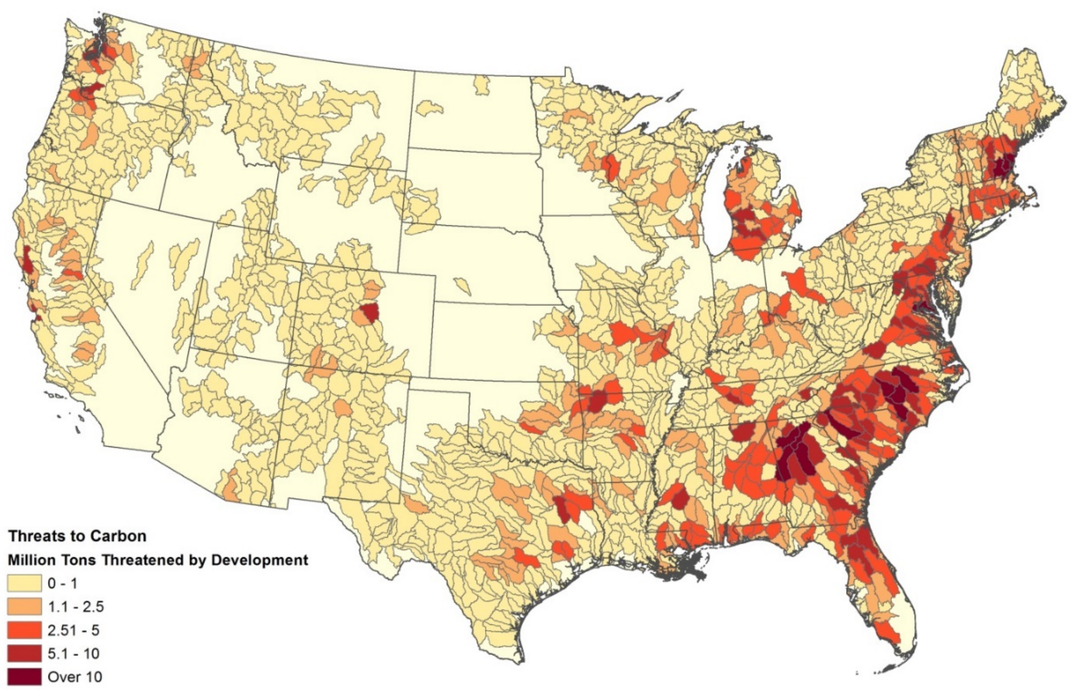

Figure 69. Amount of standing carbon on family forestland that is threatened by development.

4.4.3.2.2 Insects & Disease

Insect and disease infestations causing tree mortality have the potential to release carbon into the air and soil, and as such, are a threat to sequestered carbon.

Within study watersheds, insect and disease damage threatens approximately 195,000,000 tons of carbon on family forests (Figure 70). Watersheds with the greatest mass of carbon at risk are located in downeast Maine, Michigan, the Hudson River Valley, and western Virginia, and Virginia. On average 140,000 tons of carbon are threatened at the watershed level, with individual watersheds ranging from 0 to nearly 2 million tons.

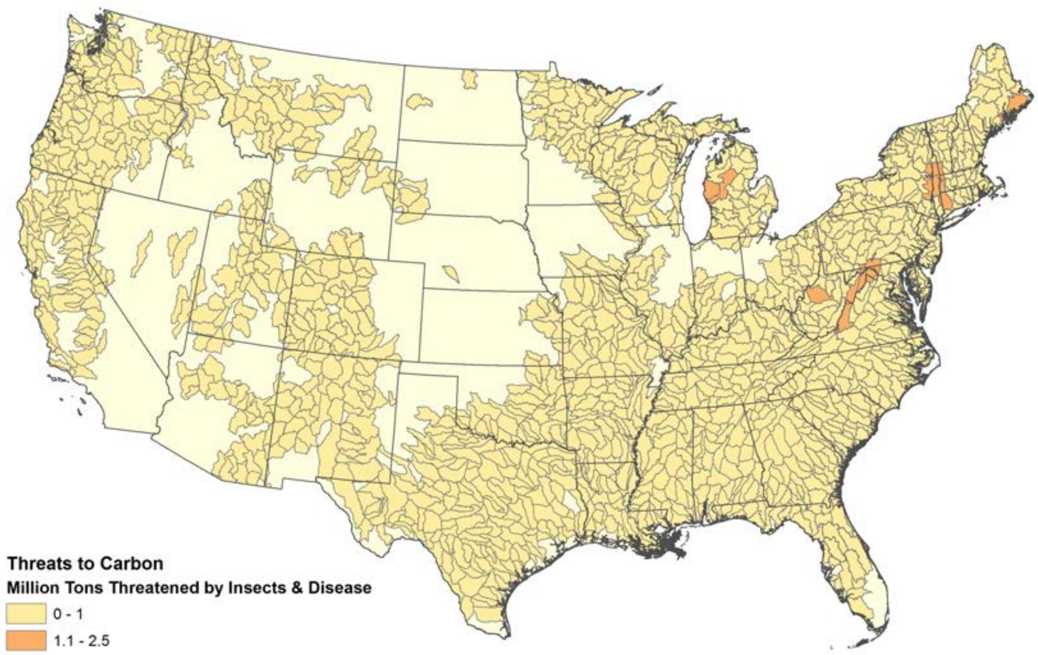

Figure 70. Amount of standing carbon on family foresland that is threatened by insects & disease.

4.4.3.2.3 Wildfire

Roughly 705,000,000 tons of carbon are threatened by wildfire within the watersheds of interest (Figure 71). Wildfire threatens less carbon on family forestland in part because the area wildfire is predicted to impact is not as widely distributed as the impacts of development. However, in certain areas, particularly along coastal California where there are large trees and high risks of fire, more carbon is threatened by fire than by development. Among study watersheds, an average of 509,000 tons of carbon are threatened by wildfire, with the highest threat within a watershed of 10,700,000 tons.

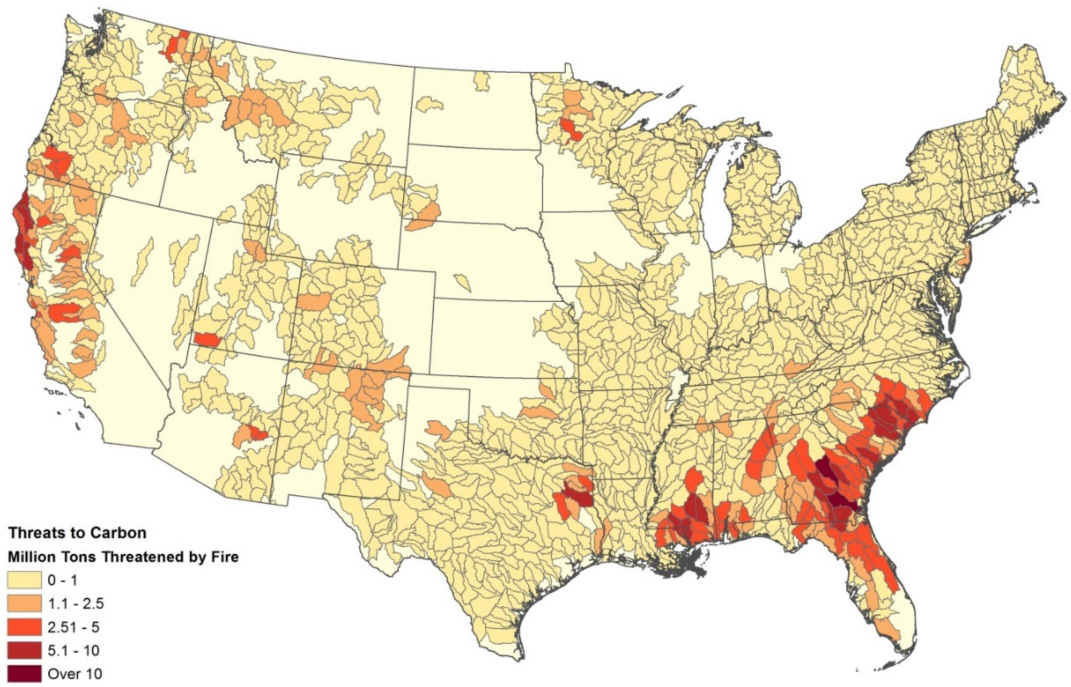

Figure 71. Amount of carbon on family forestland that is threatened by wildfire.

4.4.3.2.4 Natural Disasters

When natural disasters, such as hurricanes, tornados, and ice storms damage or remove forest vegetation, the carbon stored in that vegetation may be released back into the atmosphere over time. Given current carbon stocks and historic storm patterns, we predict that over the next ten years 184 million tons of carbon will be threatened by hurricanes, 4.5 million by tornados, and 101 million by ice storms (Figure 72 - Figure 74).

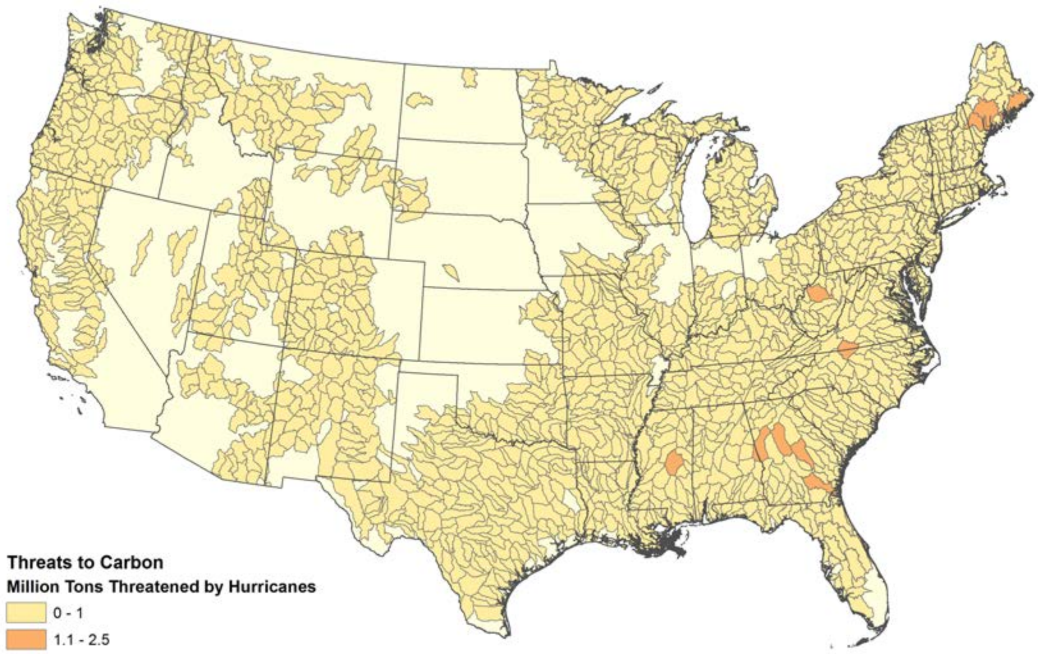

Figure 72. Amount of carbon on family forestland that is threatened by hurricanes.

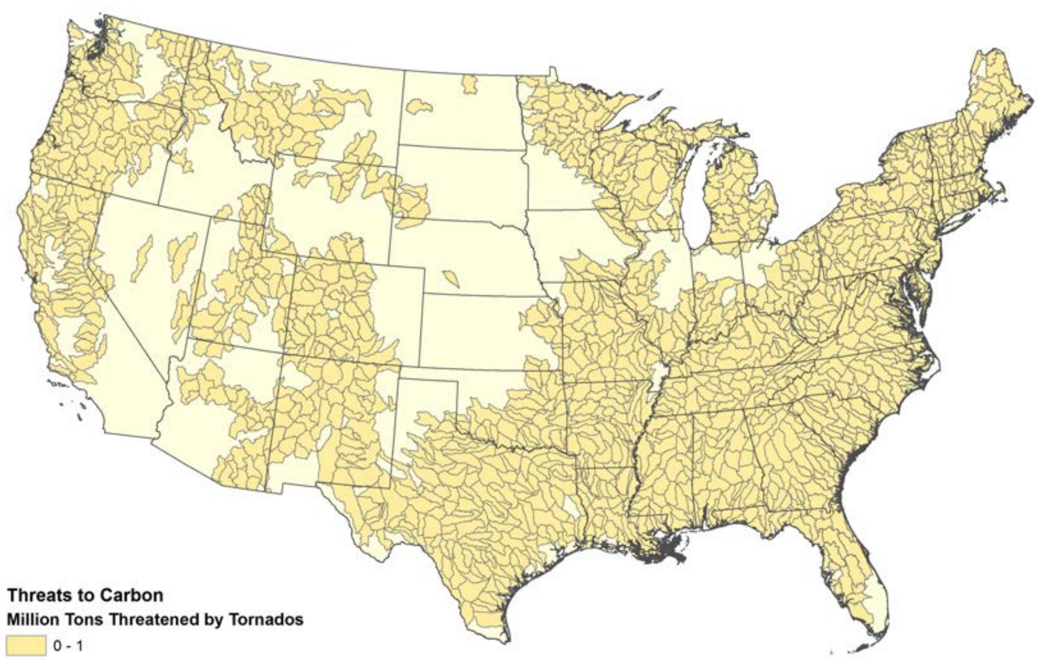

Figure 73. Amount of carbon on family forestland that is threatened by tornados.

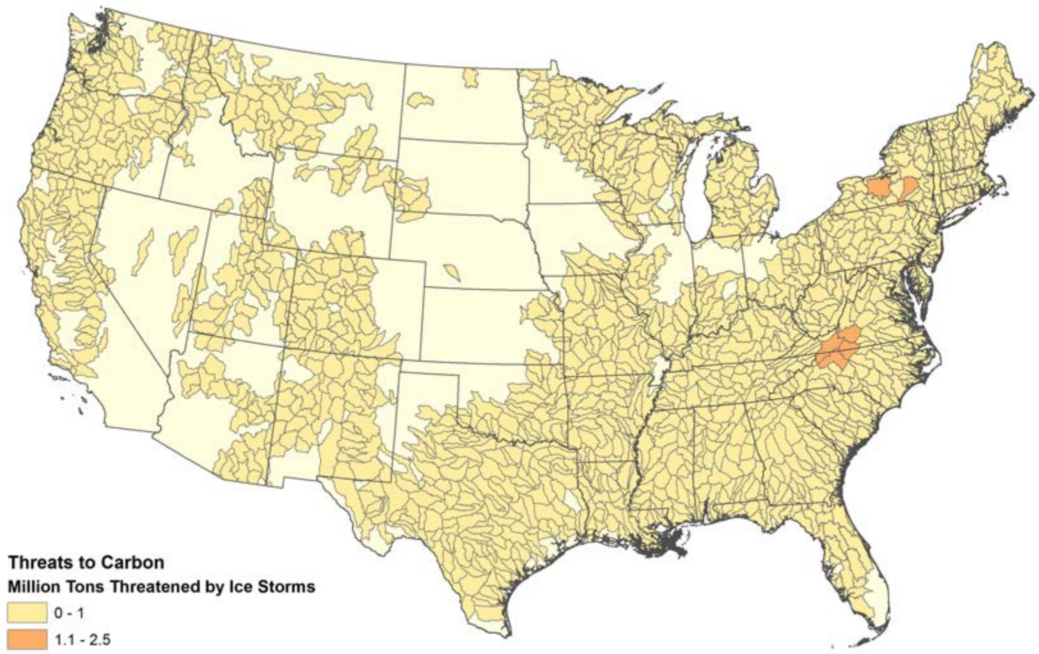

Figure 74. Amount of carbon on family forestland that is threatened by ice storms.

4.4.3.2.5 All Threats Combined

Together, development, insects & disease, wildfire, and natural disasters threaten to impact over 2.6 billion tons of carbon on family forests, with an average of 1.89 million tons threatened per watershed. Carbon that is removed due to development may end up in long-term storage via building materials or other wood products, while carbon that is released owing to insects & disease, wildfire, or natural disasters may be recaptured over time as vegetation regrowth occurs. Of these threats, development threatens more carbon sequestration than any other agent (Figure 76).

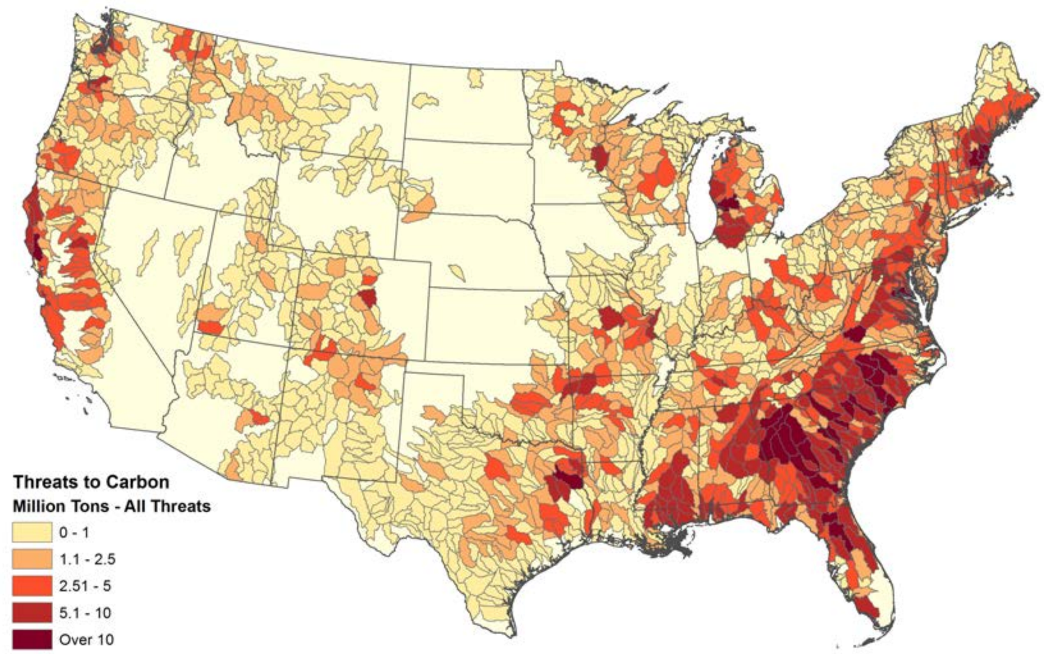

Figure 75. Total amount of carbon that is threatened on family forestland.

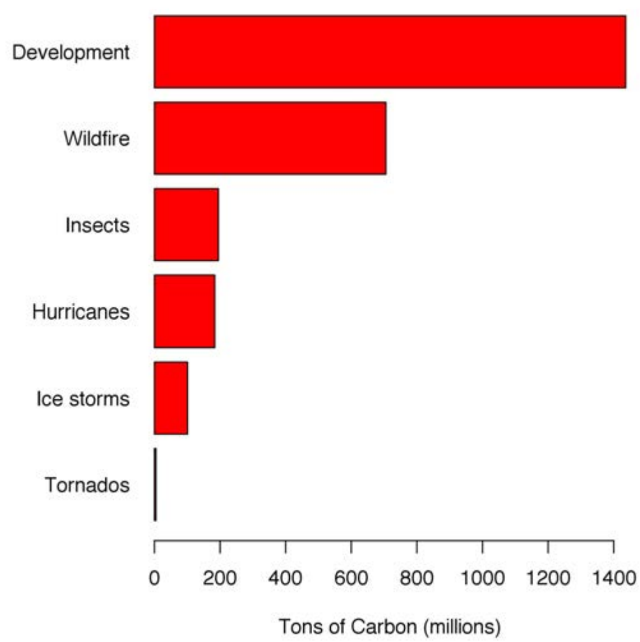

Figure 76. Tons of carbon on threatened family forestland by threat.

4.4.3.3 Threats to Wildlife Habitat

Along with development, fragmentation, insect and disease infestation, wildfire, and natural disasters all have the potential to diminish or drastically alter the quality of wildlife habitat as these processes change the structure and composition of the forest.

However, it is problematic to speak in absolute terms about how these phenomena affect habitat because so much is dependent on the severity of the threat, and the habitat needs of individual species. In some cases fragmentation will benefit animal species that make use of both internal forest habitat and open areas. Or, for example, ice storms can create damage to trees causing them to form cavities that provide excellent den sites for particular species. That said, it is our belief that the threats listed above and illustrated below have the potential to significantly alter the benefit of wildlife habitat that family forests provide.

4.4.3.3.1 Threats to Core Forest

Core forest is most valuable to species requiring large tracts of forest. Depending on the individual wildlife species certain threats may be more problematic than others. While development, by definition would change forest to non-forest, something like damage from insects and diseases could do very little to significantly impact wildlife that use core habitat primarily for den sites, while it could significantly reduce the forage and perching requirements for interior-dwelling neo-tropical migrant birds.

4.4.3.3.1.1 Development

As has been the case with all other benefits threatened by development, we see a primary concentration of highly threatened watersheds in the eastern region of the U.S. (Figure 77). Development threatens a total of 7,452,000 acres of core forest wildlife habitat on family forests, with an average of 5,380 acres per watershed.

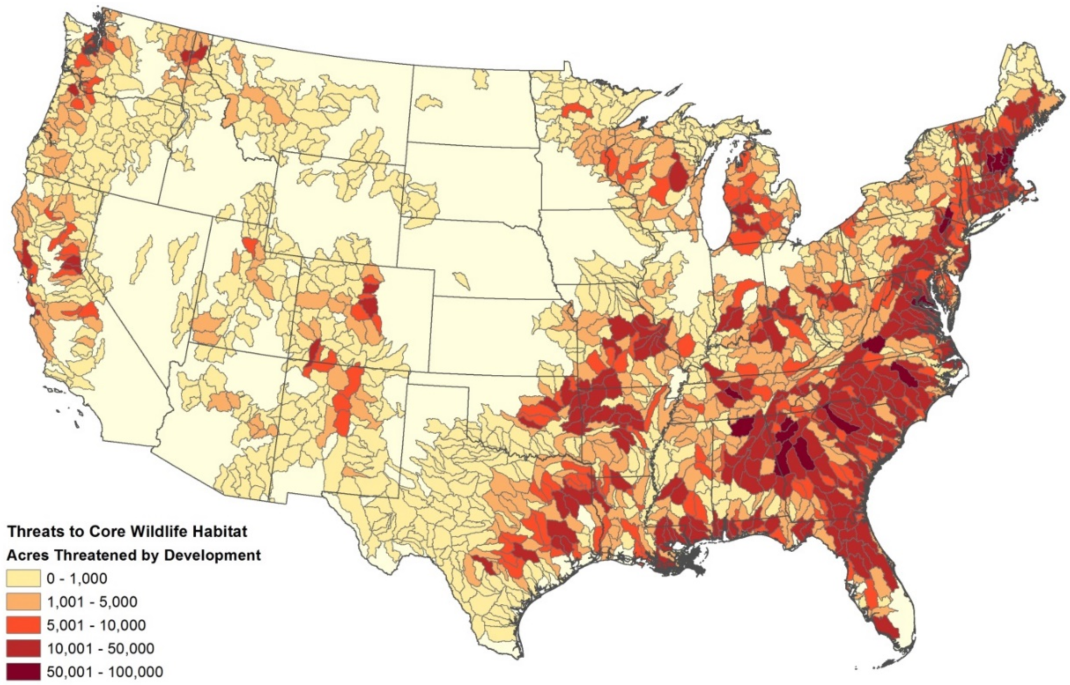

Figure 77. Area of core wildlife habitat on family forestland that is threatened by development.

4.4.3.3.1.2 Forest Fragmentation

Fragmentation is much more widespread, and covers a greater area than the threat of development. As was mentioned previously, it is less than optimal that our measure of fragmentation is a single snapshot in time. It would be much more valuable to know where fragmentation is likely to occur over time, in order to have a sense of where core forest habitat is likely to become fragmented.

Complicating the analysis of the threat of fragmentation on core forest is the close relationship between the two source datasets. Using the same datasets, core forest is defined as forest at least 120 meters from a non-forest edge, while fragmented forest is defined as forest less than 30 meters from a non-forest edge.

Fragmentation threatens roughly 15,300,000 acres of core forest on family forestland, with an average of 11,000 acres per watershed (Figure 78).

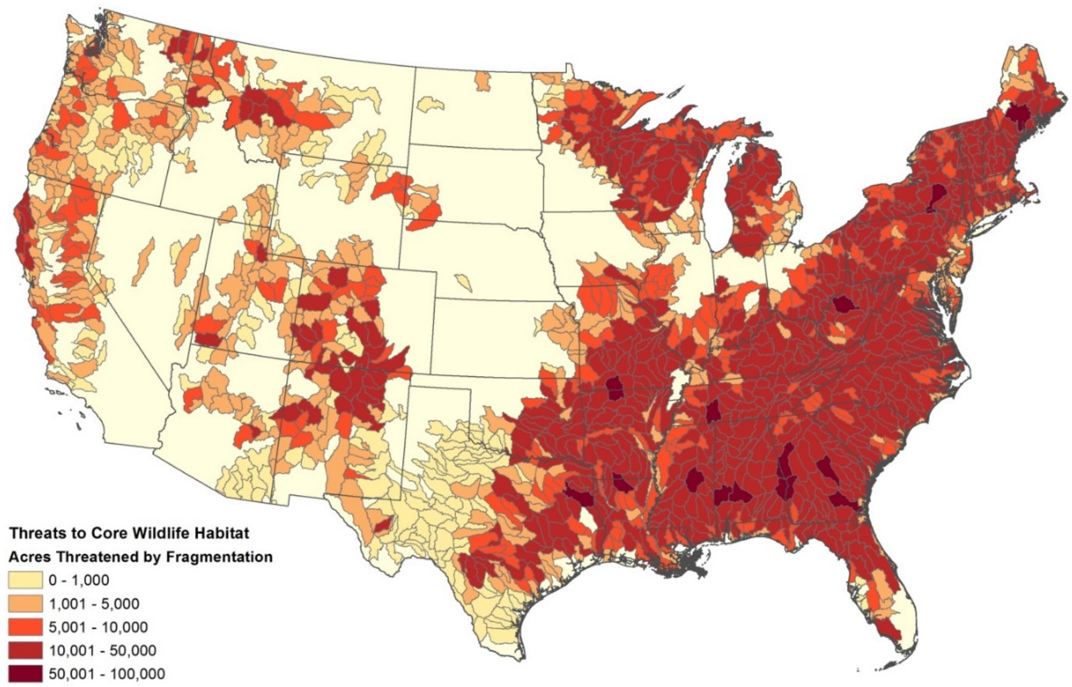

Figure 78. Area of core forest habitat on family forestland that is threatened by fragmentation.

4.4.3.3.1.3 Insects & Diseases

For the most part, insect and disease threats to core forest habitat are not as severe as are fragmentation or development. Hot spots for core habitat threatened by insects and diseases occur where the greatest density of core habitat meets the greatest risk of damage from insects and diseases. In total we estimate over 3,000,000 acres of core habitat threatened due to insects and disease, with an average 2,210 acres per watershed (Figure 79).

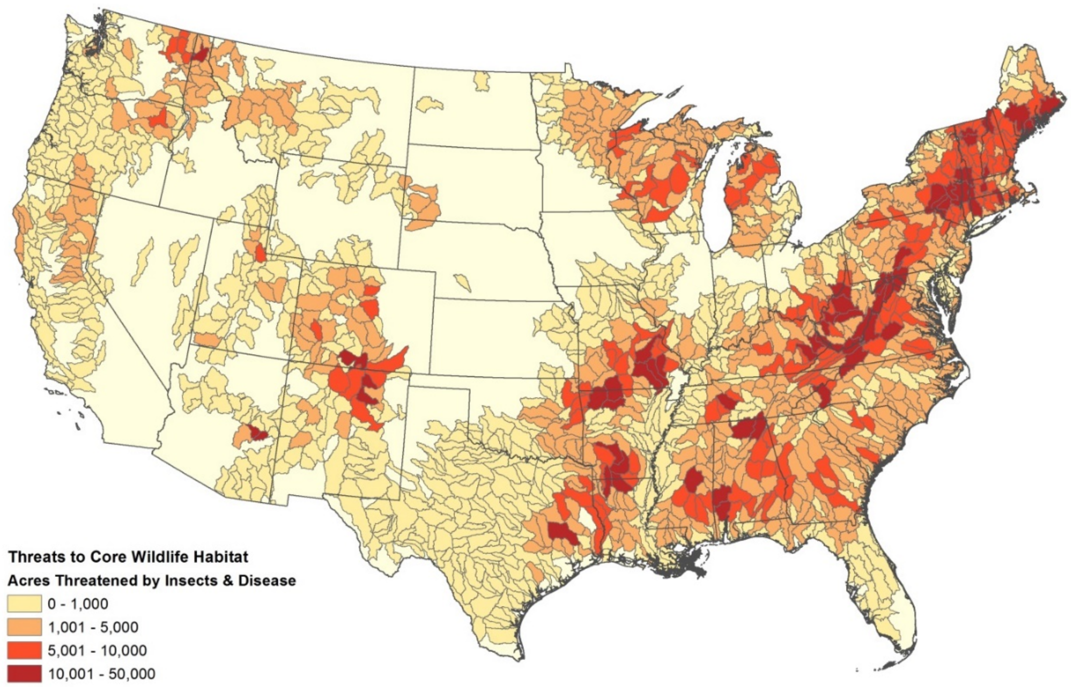

Figure 79. Area of core forest habitat on family forestland that is threatened by insects and diseases.

4.4.3.3.1.4 Wildfire

Wildfire has the potential to have the greatest impact to core habitat in the Southeast, Rocky Mountain region, and along coastal California. In total, wildfire threatens 1,765,000 acres of core habitat, with an average of 1,270 acres per watershed (Figure 80).

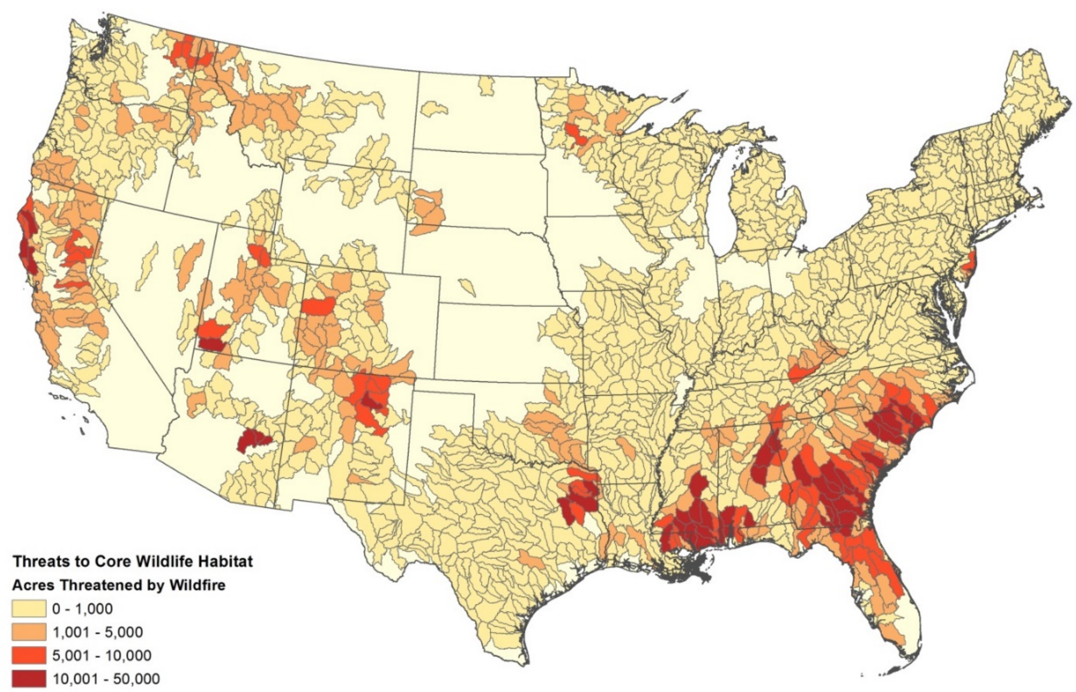

Figure 80. Area of core forest habitat on family forest that is threatened by wildfire.

4.4.3.3.1.5 Natural Disasters

Natural disasters have the potential to disturb a wide area of core habitat, though where they do strike it can be highly variable in terms of the damage incurred. We estimate a total of 5,630,000 acres threatened by hurricanes, and 133,000 acres by damage from tornados (Figure 81 - Figure 82). On average 4,062 acres per watershed are threatened by hurricanes, and 96 acres by tornados.

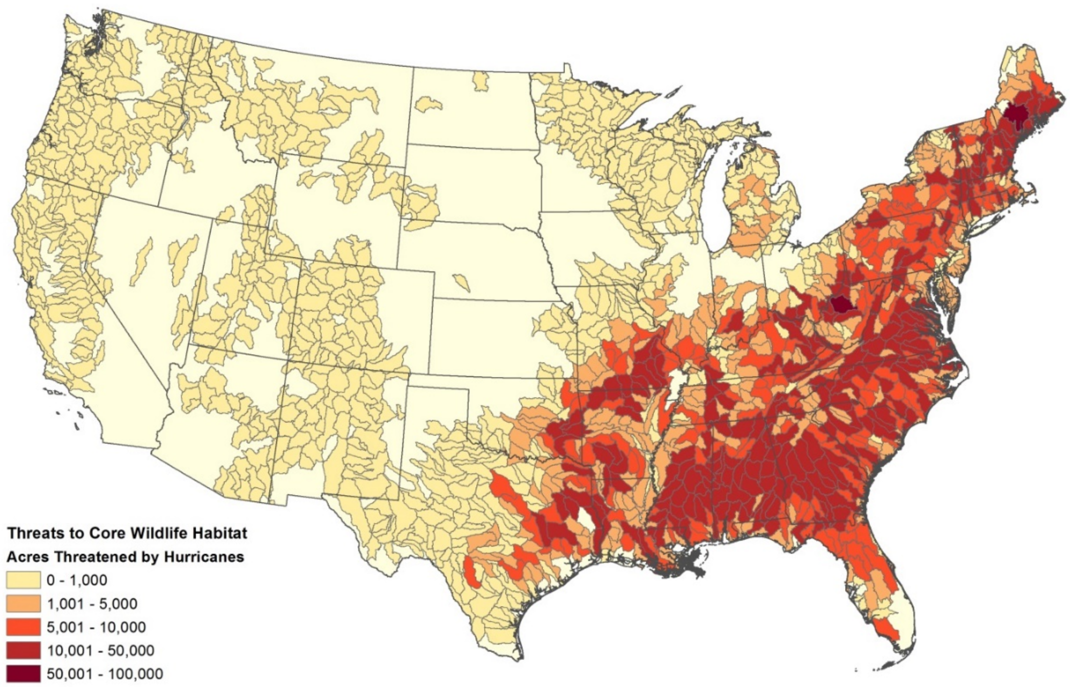

Figure 81. Area of core forest habitat on family forest that is threatened by hurricanes.

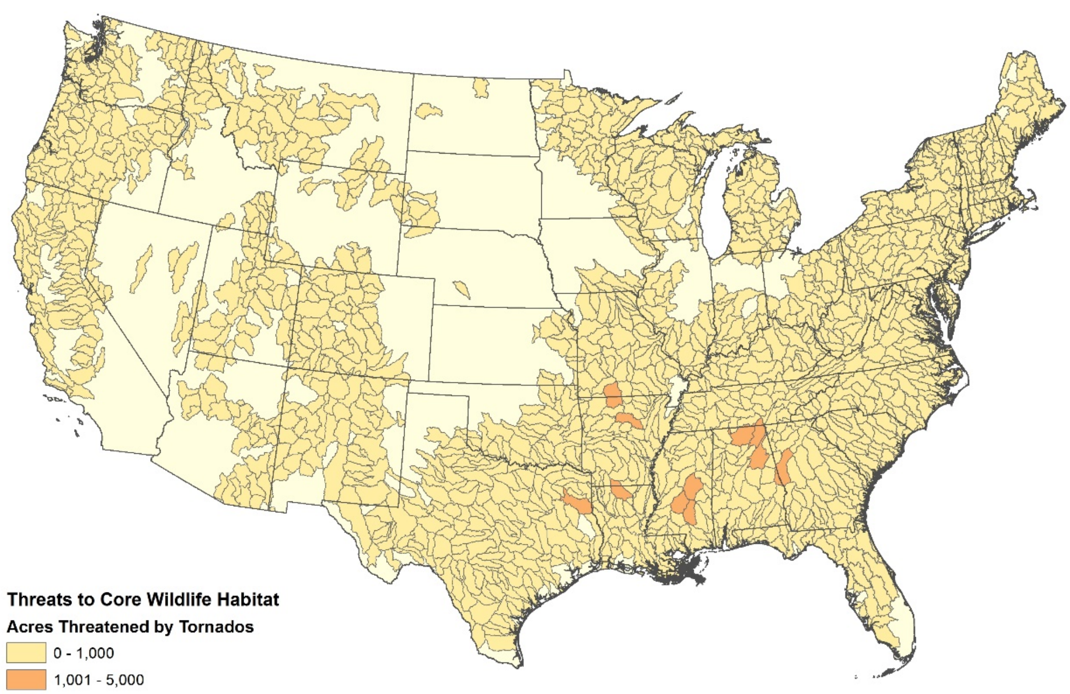

Figure 82. Area of core forest habitat on family forest that is threatened by tornados.

4.4.3.3.1.6 All Threats Combined

In total 33,300,000 acres of core habitat are threatened by the individual threats above (Figure 83). Of these, fragmentation and development represent the greatest potential threats (Figure 84).

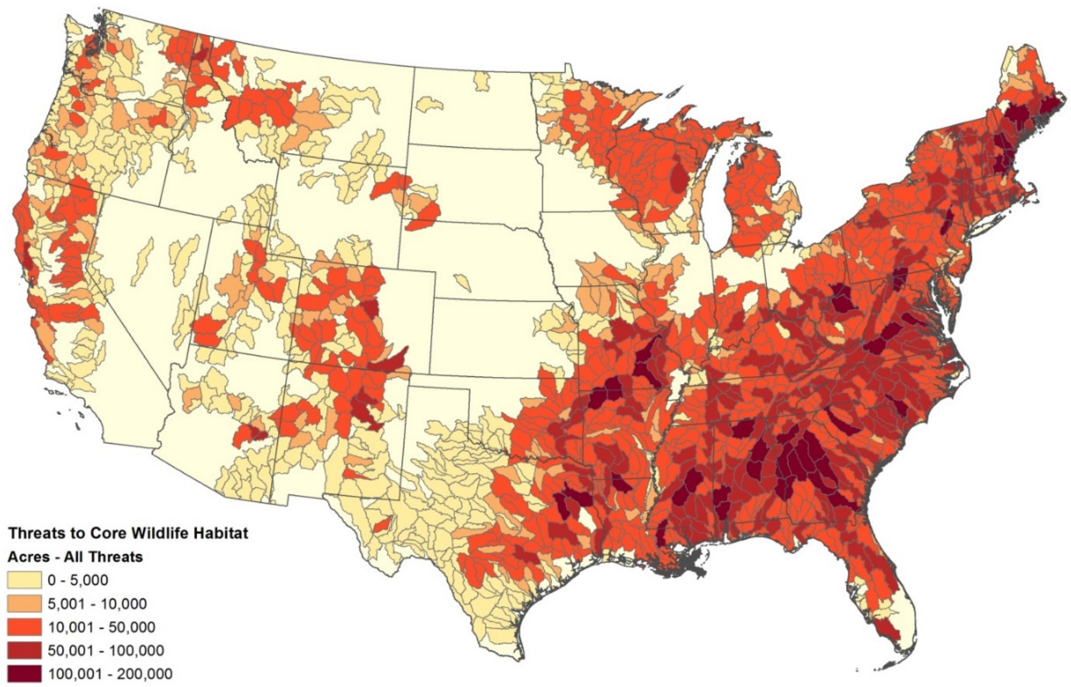

Figure 83. Total core forest wildlife habitat area that is threatened on family forestland.

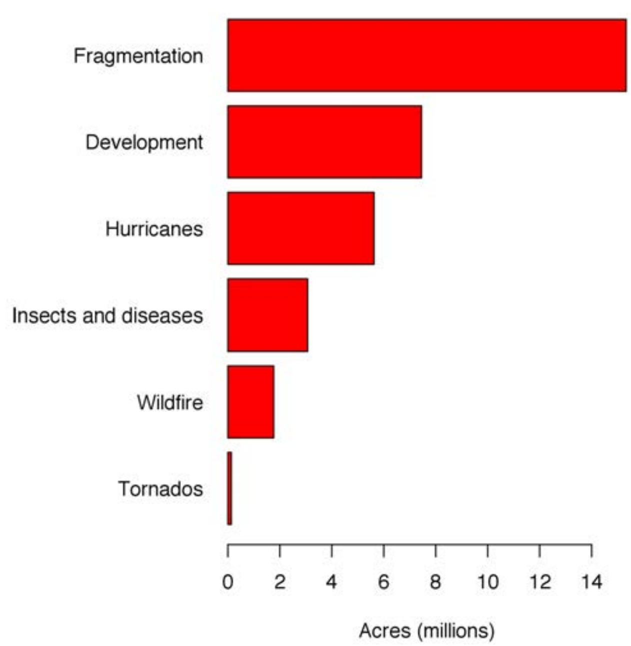

Figure 84. Area of core forest wildlife habitat threatened on family forestland by threat.

4.4.3.3.2 Threats to Threatened & Endangered Species

It is difficult to speak broadly about threats to threatened and endangered species given the data available to us. We don't know what the specific species are or what their habitat requirements are, we know only that they are designated as threatened and endangered and have been found on land predicted to be in family ownership.

4.4.3.3.2.1 Development

The intensity of development coupled with what species are affected, will result in a wide array of outcomes. In some instances, alterations to habitat will devastating for particular species, while types of wildlife may actually benefit from the creation of additional edge habitat along the newly developed areas.

As calculated here, development threatens over 2,000 species occurrences on family forestlands, with an average of 1.5 species threatened per watershed (Figure 85).

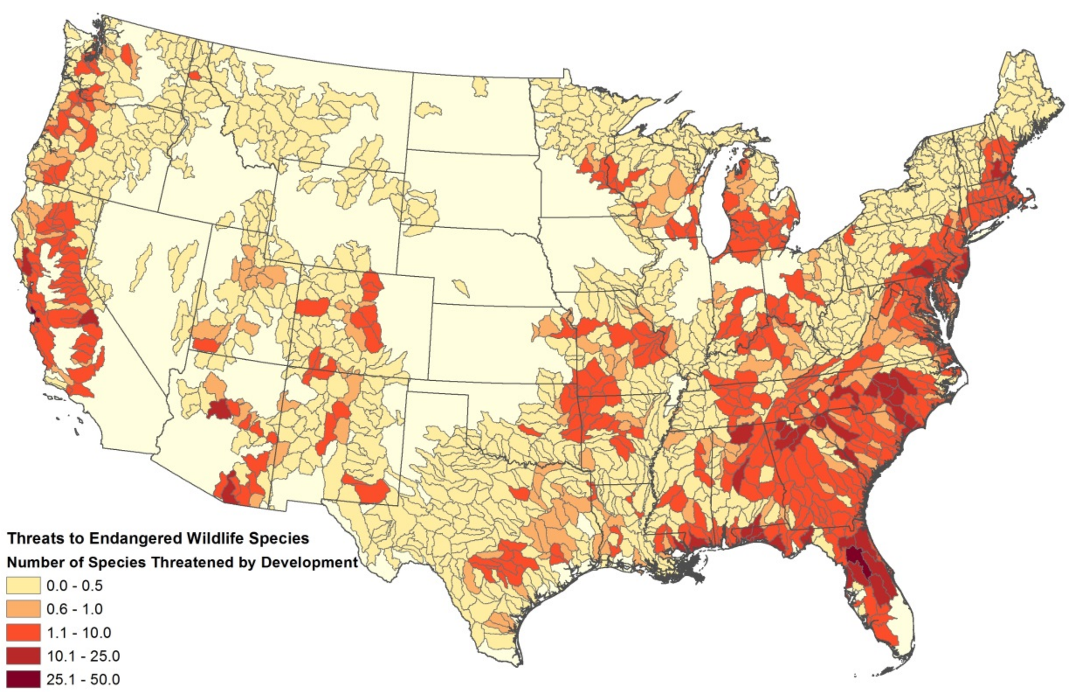

Figure 85. Number of species threatened by development

4.4.3.3.2.2 Forest Fragmentation

As mentioned previously, fragmentation effects on particular species is apt to be highly variable. On the whole, fragmentation threatens 3,480 species occurrences on family forestlands, with an average of 2.5 species per watershed (Figure 86).

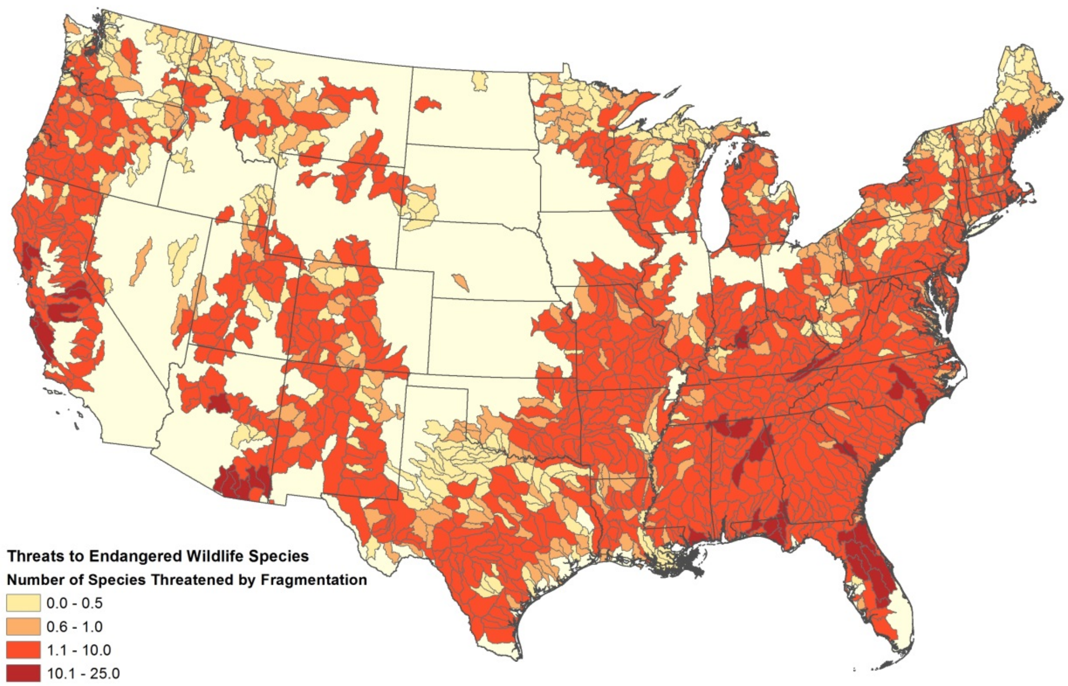

Figure 86. Number of species threatened by fragmentation

4.4.3.3.2.3 Insects & Disease

Again, the effects of forest insects and diseases on threatened and endangered species will depend on the severity of the damage incurred, and the needs of the individual species. We estimate insect and disease threats could impact 468 species occurrences, with an average of 0.34 per watershed (Figure 87).

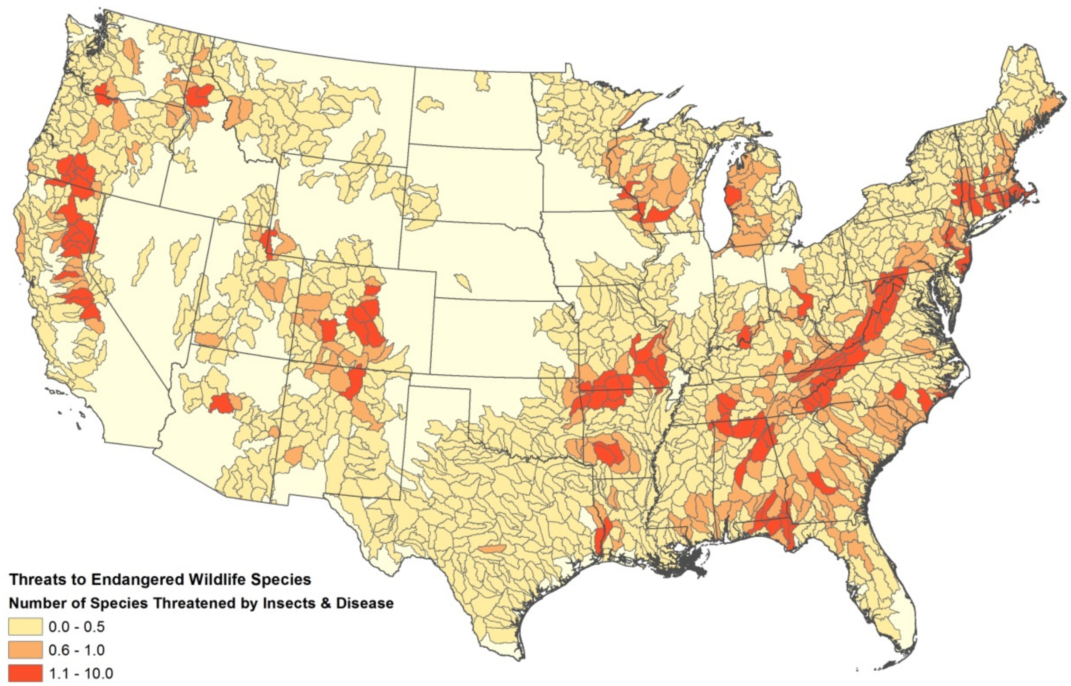

Figure 87. Number of species threatened by insects & disease.

4.4.3.3.2.4 Wildfire

While wildfire may alter habitat in such a way to make it more beneficial for certain threatened and endangered species, not knowing what species we are dealing with, and that many may be negatively impacted, we estimate that wildfire could impact 629 species occurrences, with an average 0.45 per watershed (Figure 88).

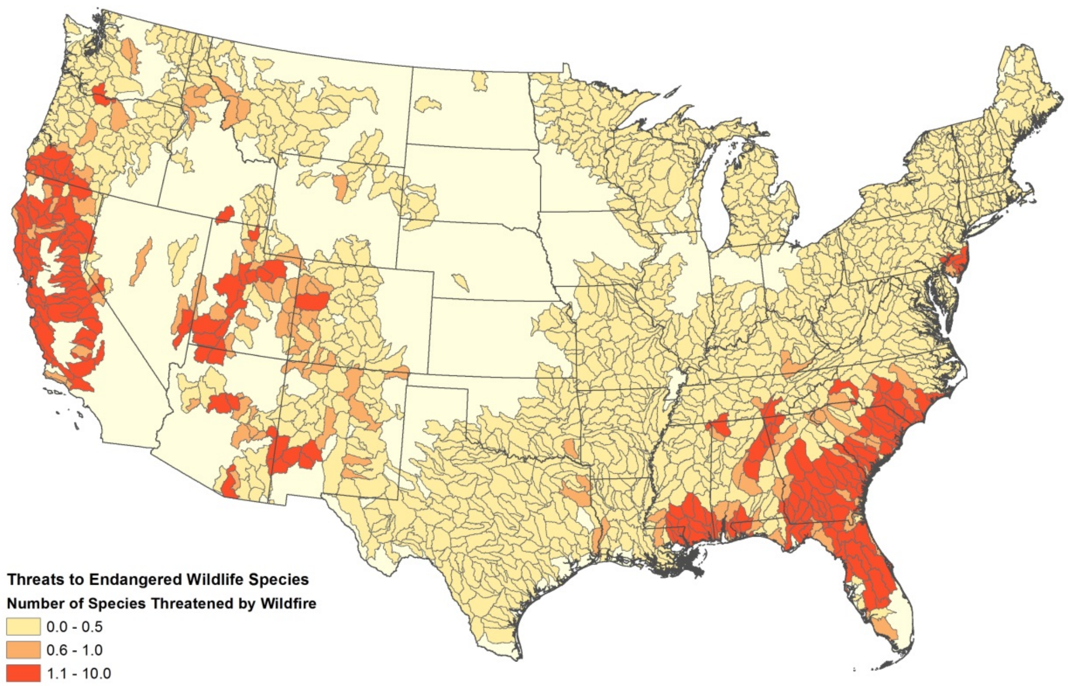

Figure 88. Number of species threatened by wildfire.

4.4.3.3.2.5 Natural Disasters

Emphasizing again that the severity of natural disasters and the habitat needs of individual species will determine outcomes in the field, we estimate that hurricanes could impact a total of 950 species occurrences, with an average of 0.69 per watershed, and tornados could impact a total of 22 species occurrences with an average of 0.02 species per watershed (Figure 89 - Figure 90).

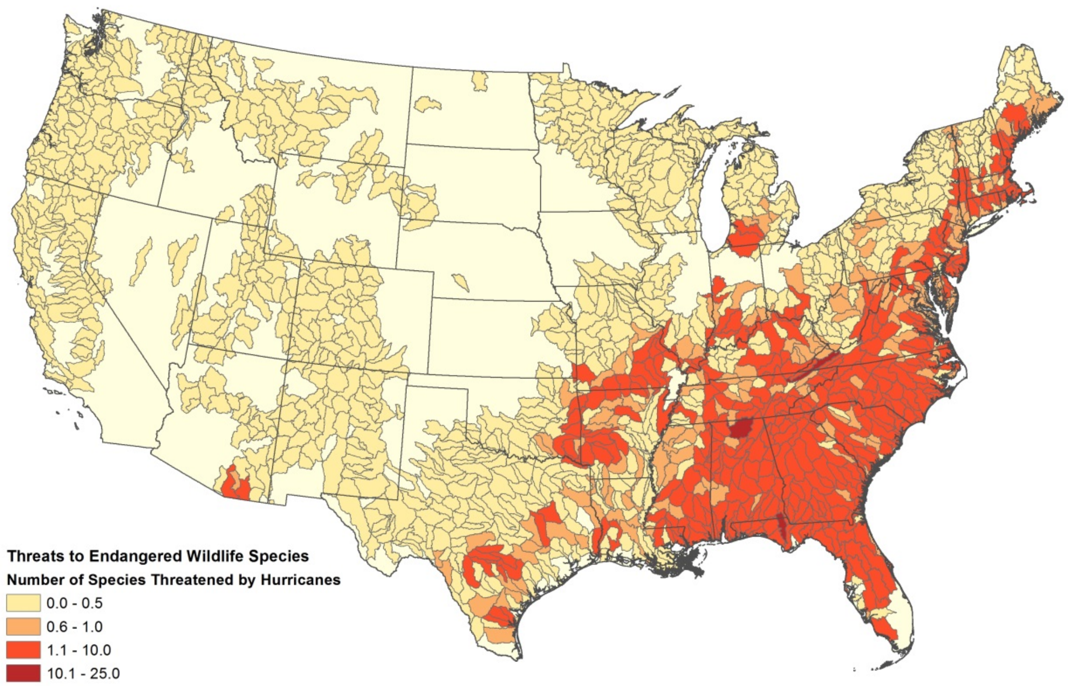

Figure 89. Number of species threatened by hurricanes.

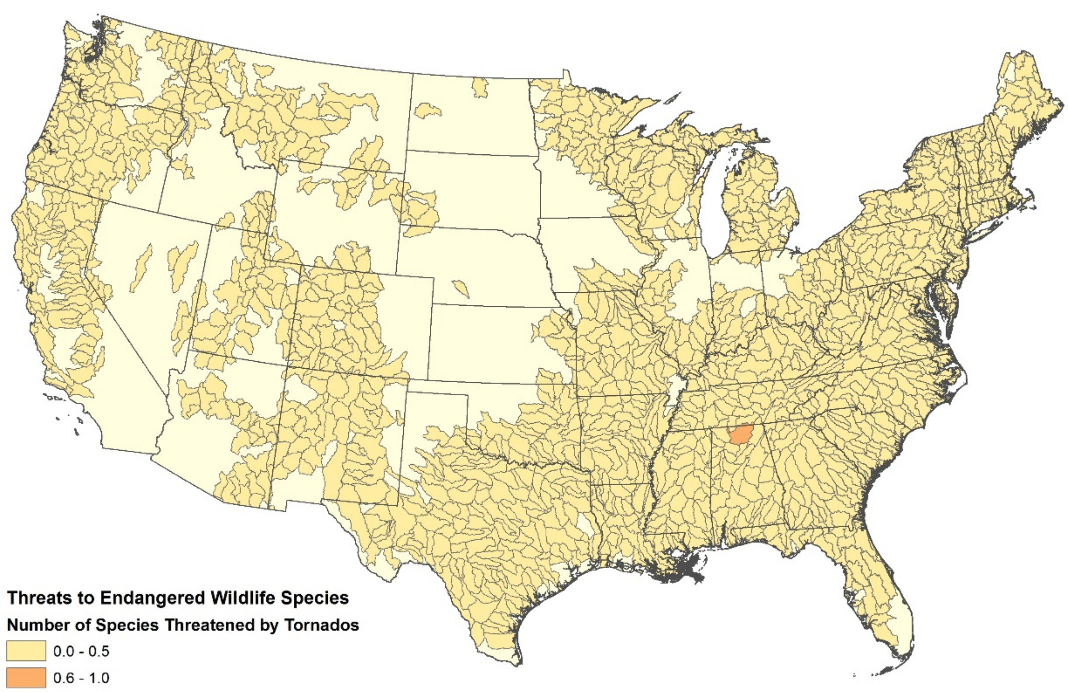

Figure 90. Number of species threatened by tornados.

4.4.3.3.2.6 All Threats Combined

All together the threats to wildlife species identified as threatened or endangered are poised to impact 7,520 species occurrences with an average of 5.43 per watershed (Figure 91). Like core forest habitat, the greatest threats to threatened and endangered species are Fragmentation and development (Figure 92).

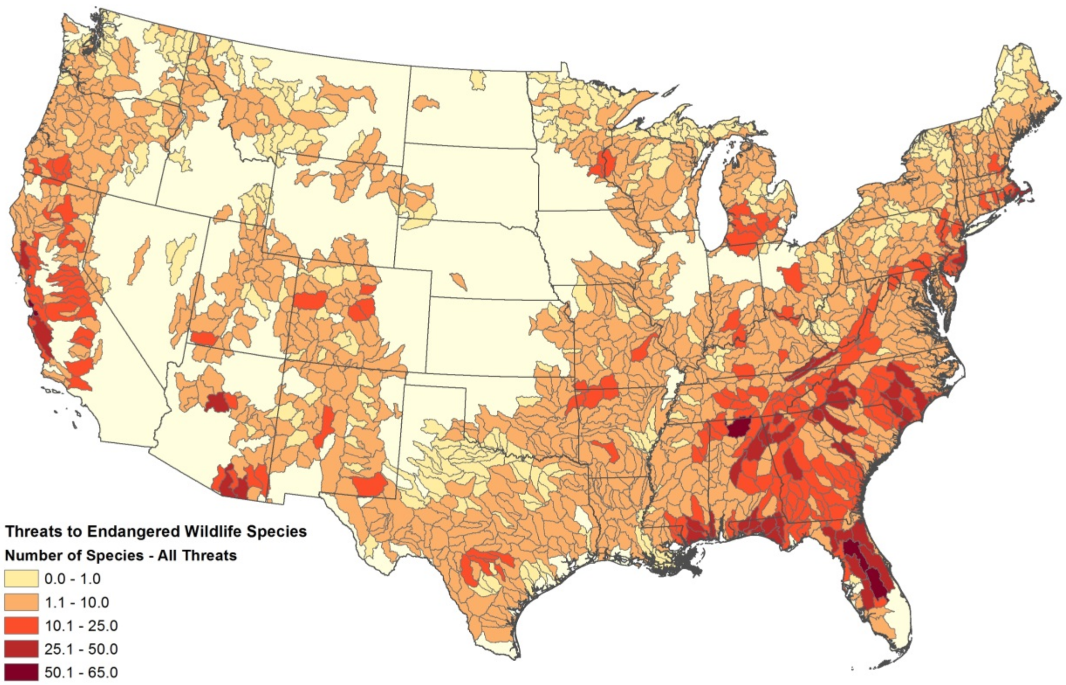

Figure 91. Total number of species threatened on family forestland.

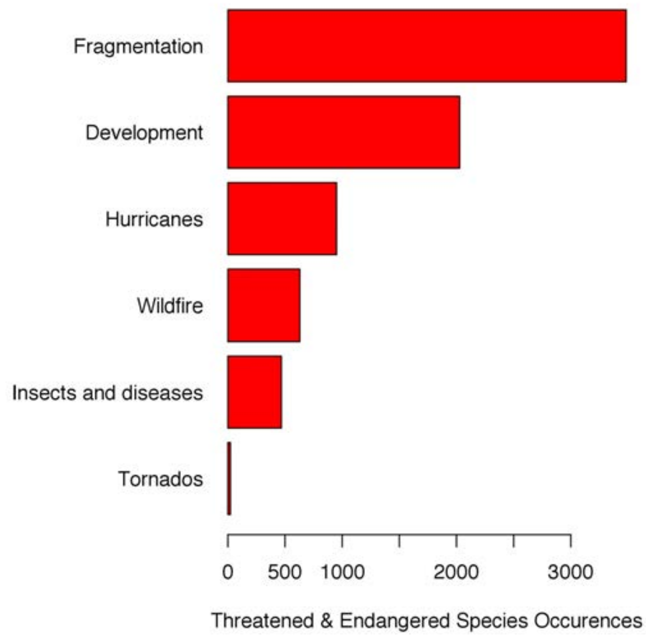

Figure 92. Number of occurrences of threatened and endangered species on family forestland by threat.

4.4.3.4 Threats to Wood Supply

Threats to wood supply are numerous, and include the loss of forest (development), the breaking down of ownerships into smaller parcels where owners may have differing objectives (parcellation), degradation of the resource from insects and diseases so as to make it unmarketable, wildfire - also decreasing marketable volume, social unavailability where owners are unlikely to harvest, and natural disasters which, like insects and diseases, threaten to degrade the resource.

4.4.3.4.1 Development

Development threatens the long-term production of timber on family forests. In the near-term, more wood may become available as land is cleared and merchantable timber is taken to market. However, once converted to non-forestland, the likelihood that the land will come back into timber production is non-existent in a ten-year time frame.

We estimate development to threaten a total of 132 billion board feet of timber on family forestland within the study watersheds, with an average 94.5 million board feet per watershed (Figure 93).

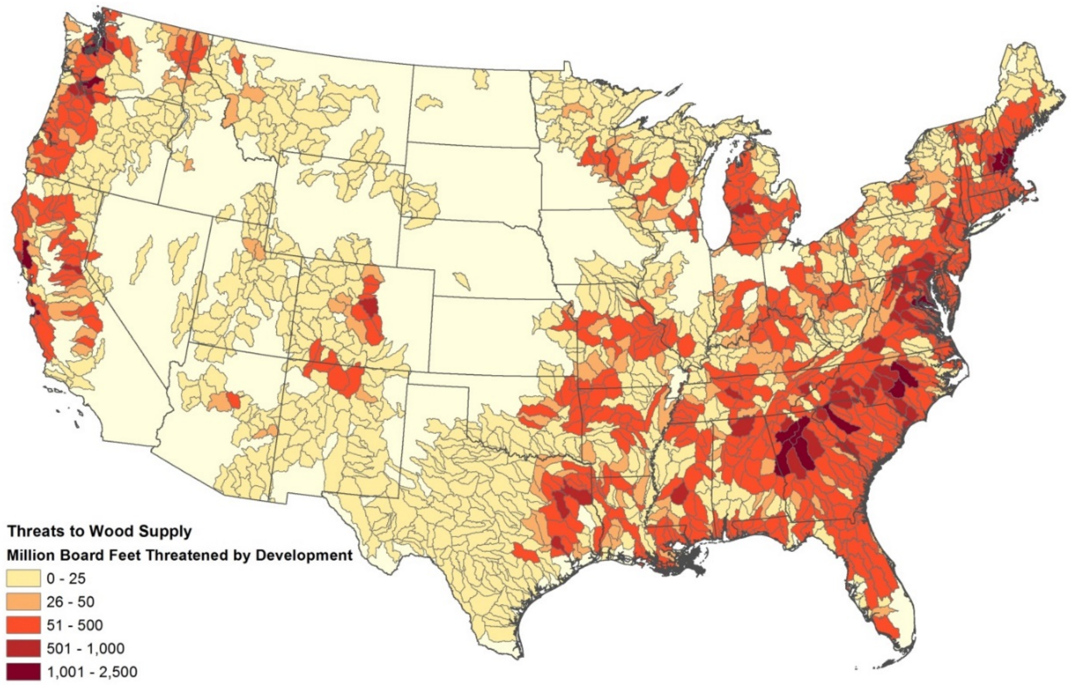

Figure 93. Volume of wood on family forestland threatened by development.

4.4.3.4.2 Forest Parcellation

Parcellation is a substantial threat to wood production on family forestland. While the volume of standing wood may continue to grow on subdivided land, the likelihood of harvest is drastically reduced when parcel size decreases, as it is no longer a financially viable endeavor for a logger once the size becomes too small.

We estimate parcellation to threaten a total of 197 billion board feet of wood across watersheds, and on average, 142 million board feet per watershed (Figure 94).

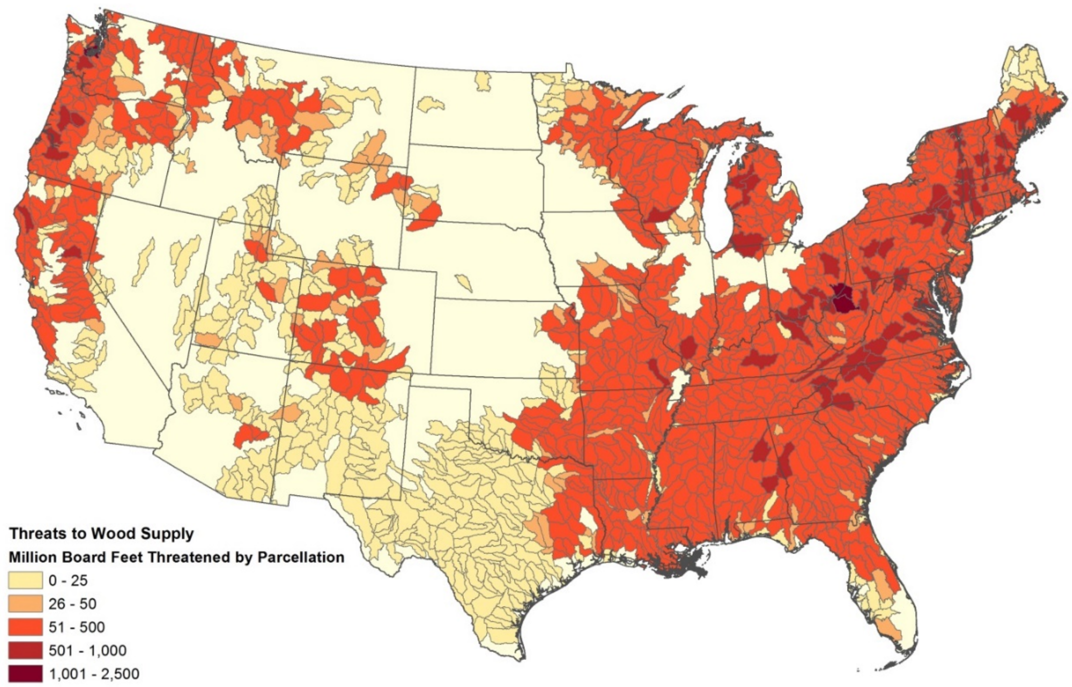

Figure 94. Volume of wood on family forestland threatened by parcellation.

4.4.3.4.3 Insects & Diseases

Insects and diseases can drastically alter the commercial value of timber. If tree damage is predominantly to the leaves, buds, and branches of trees, the damage will not be as detrimental as where damage to the bole occurs.

In total we estimate the threat of insects and diseases to standing wood on family forestlands to be 84.5 billion board feet of wood, with an average of 61 million board feet per watershed (Figure 95).

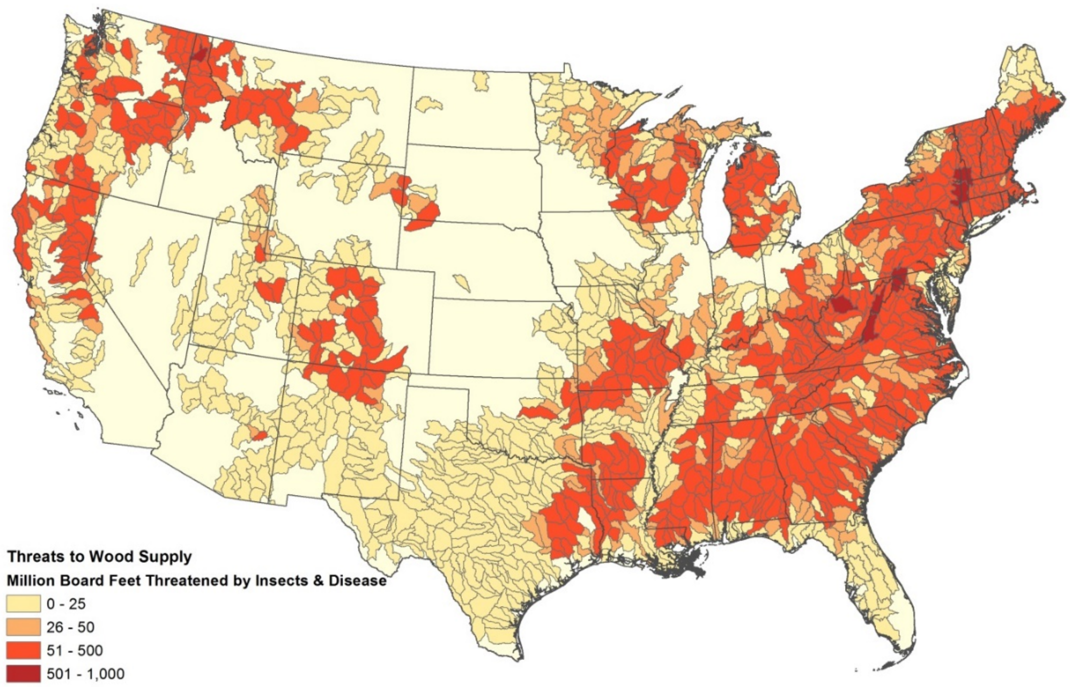

Figure 95. Volume of wood on family forestland threatened by insects and disease.

4.4.3.4.4 Wildfire

Damage of wildfire to timber is highly dependent on the fire severity as well as the tree species and ecosystem type. Many timber species are in fact fire dependent for regeneration or for keeping competing vegetation at bay.

In spite of this variability of effect, we estimate the damage of wildfire to wood supply to be roughly 68 billion board feet in total, and on average 49 million board feet per watershed (Figure 96).

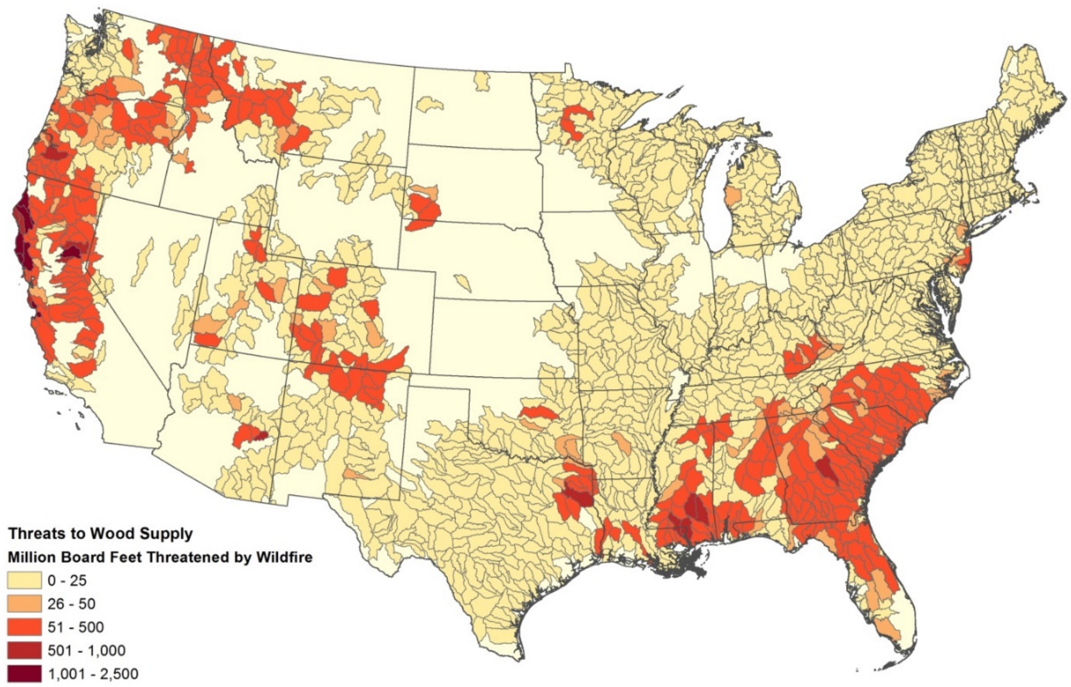

Figure 96. Volume of wood on family forestland threatened by wildfire.

4.4.3.4.5 Unavailability

Perhaps the single most critical threat to wood supply from family forestlands is landowner unwillingness to harvest trees from his or her land. Using data from the NWOS (Butler et al. 2014b) on landowner attitudes and behaviors, we estimate that as much as 316 billion board feet of timber may be unavailable due to unwillingness to harvest. On average 228 million board feet are estimated to be unavailable per watershed (Figure 97).

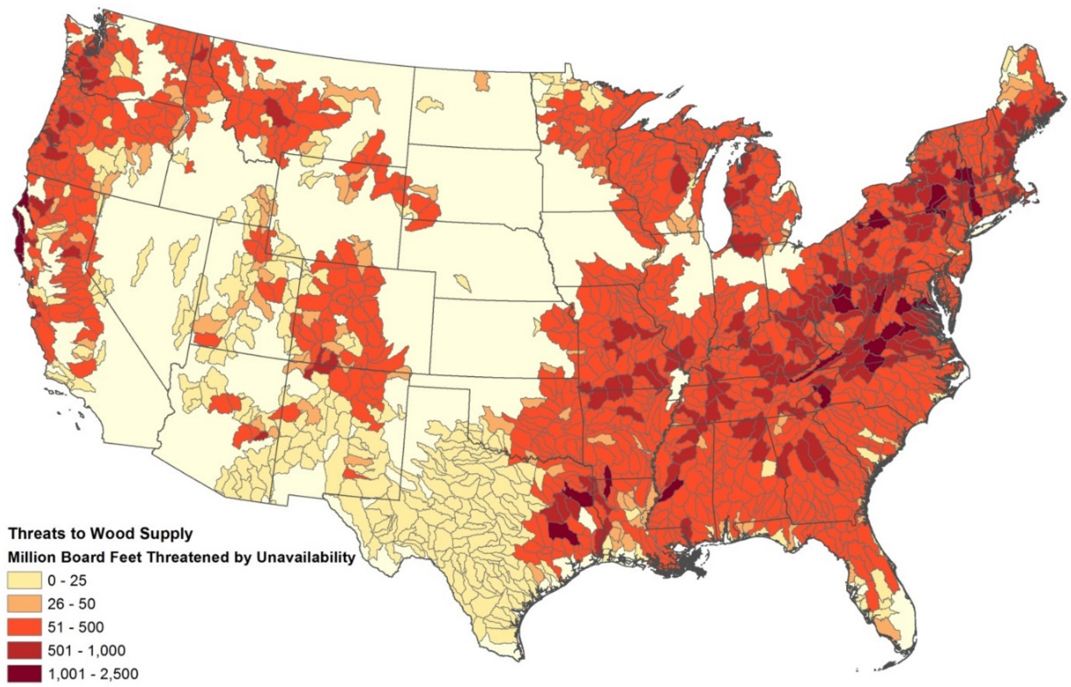

Figure 97. Volume of wood on family forestland that may be unavailable due to landowners' reluctance to harvest.

4.4.3.4.6 Natural Disasters

As in the case where natural disasters threaten other forest benefits, the magnitude of the damage is dependent on the area affected and the intensity or severity of the destruction.

According to our calculations, we estimate that a total of 75 billion board feet of wood are threatened by hurricanes, with an average of 54 million per watershed; a total of 3.6 billion board feet threatened by tornados, with an average of 2.6 million per watershed; and a total of 20 billion feet threatened by ice storms, with an average of 15 million per watershed (Figure 98 - Figure 100).

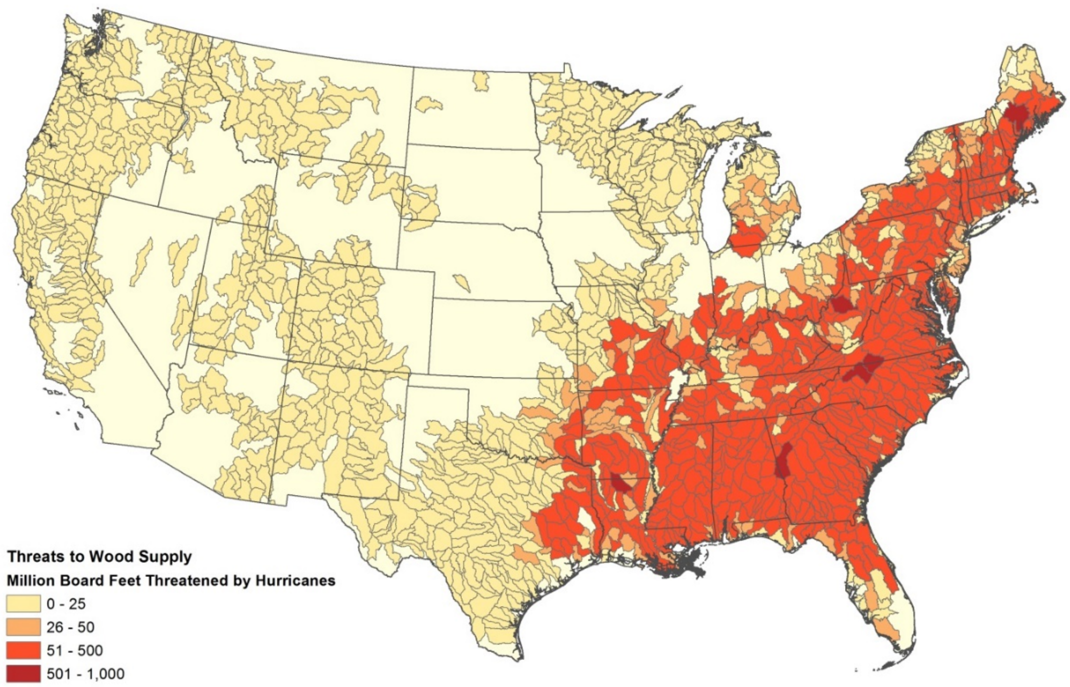

Figure 98. Volume of wood on family forestland that is threatened by hurricanes.

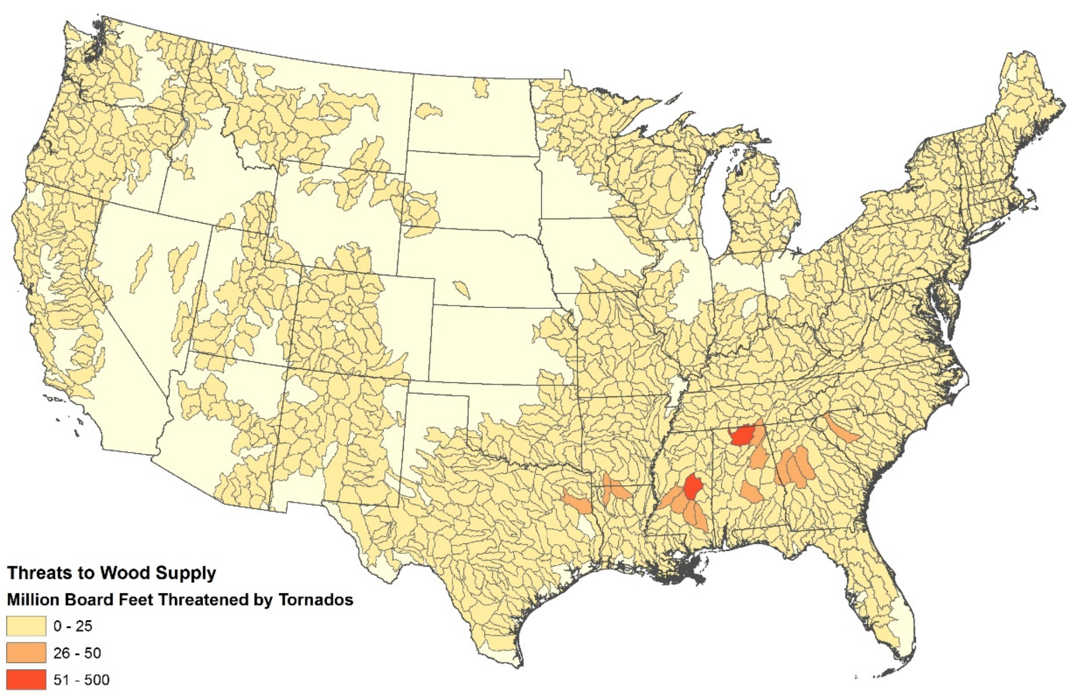

Figure 99. Volume of wood on family forestland that is threatened by tornados.

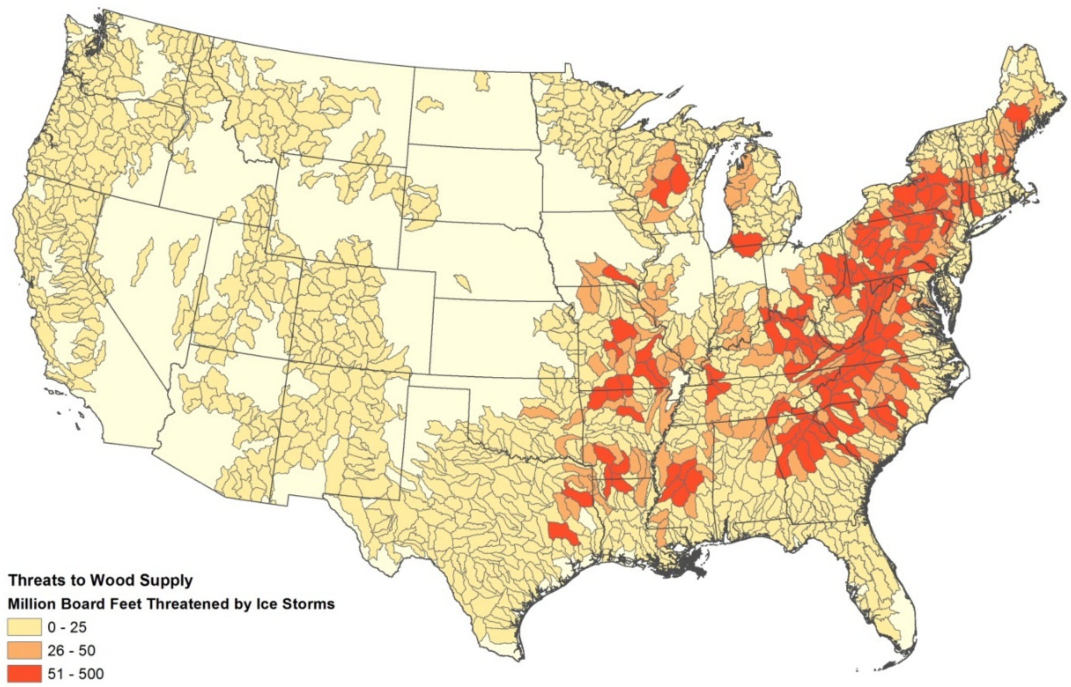

Figure 100. Volume of wood on family forestland that is threatened by ice storms.

4.4.3.4.7 All Threats Combined

In total we estimate that all threats to wood supply on family forestland exceed 855 billion board feet, with an average of 617 million board feet per watershed (Figure 101). Of these, timber unavailability and parcellation represent the greatest potential threats (Figure 102).

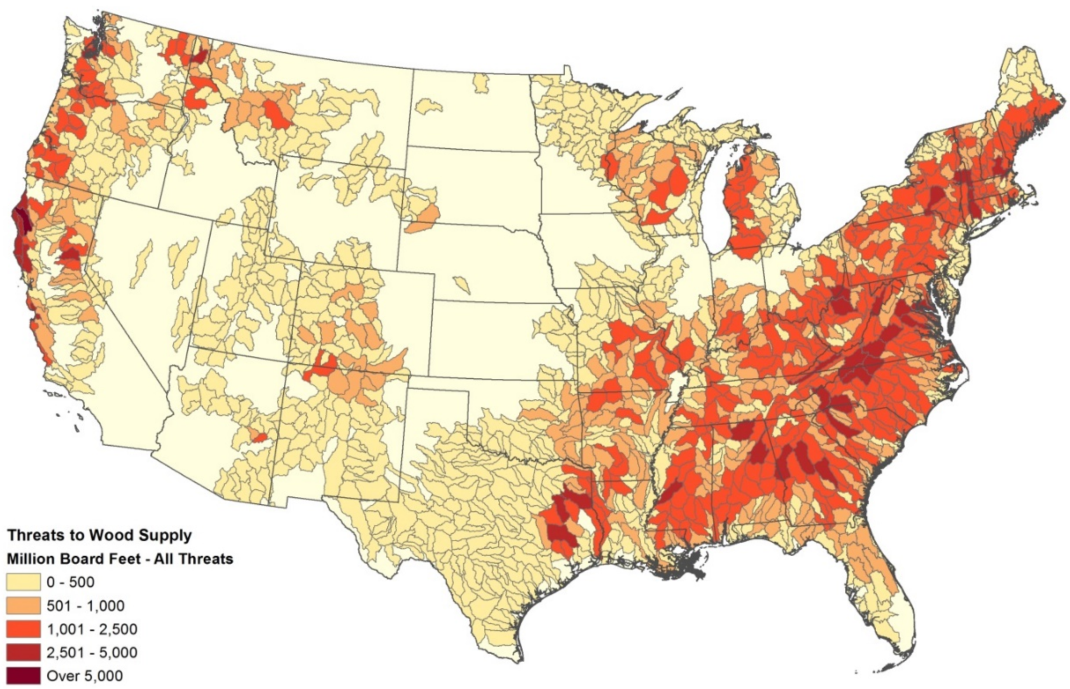

Figure 101. Total volume of wood threatened on family forestland.

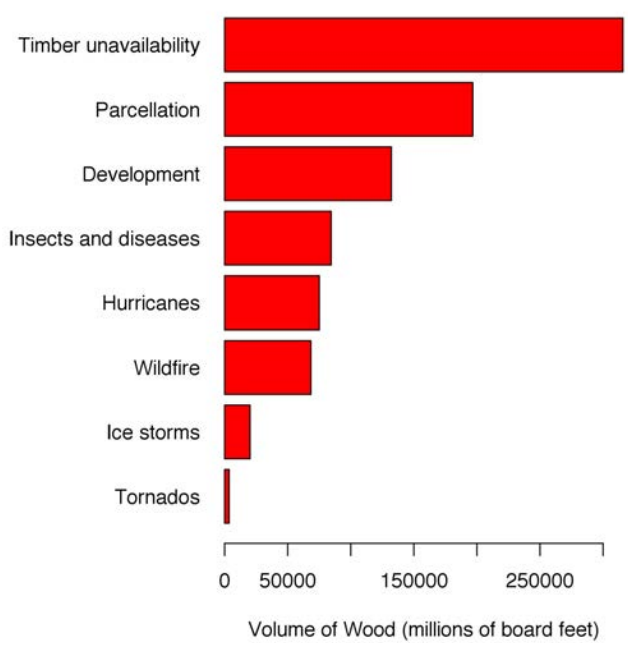

Figure 102. Volume of wood threatened on family forestland by threat.

4.4.3.5 Threats to Biomass Supply

Threats to biomass supply mimic those to wood supply, and include the loss of forest (development), the breaking down of ownerships into smaller parcels where owners may have differing objectives (parcellation), degradation of the resource from insects and disease so as to make it unmarketable, wildfire - also decreasing marketable volume, social unavailability where owners are unlikely to harvest and market biomass material, and natural disasters which, like insects and diseases threaten to degrade the resource.

4.4.3.5.1 Development

As with wood supply, development threatens the continued provision of biomass from family forests as they change to non-forested use. Again, it is possible that initially that biomass may enter the marketplace.

We calculate impacts from development on biomass to be 40 billion cubic feet of wood in total across study watersheds, with an average of 29 million cubic feet per watershed (Figure 103).

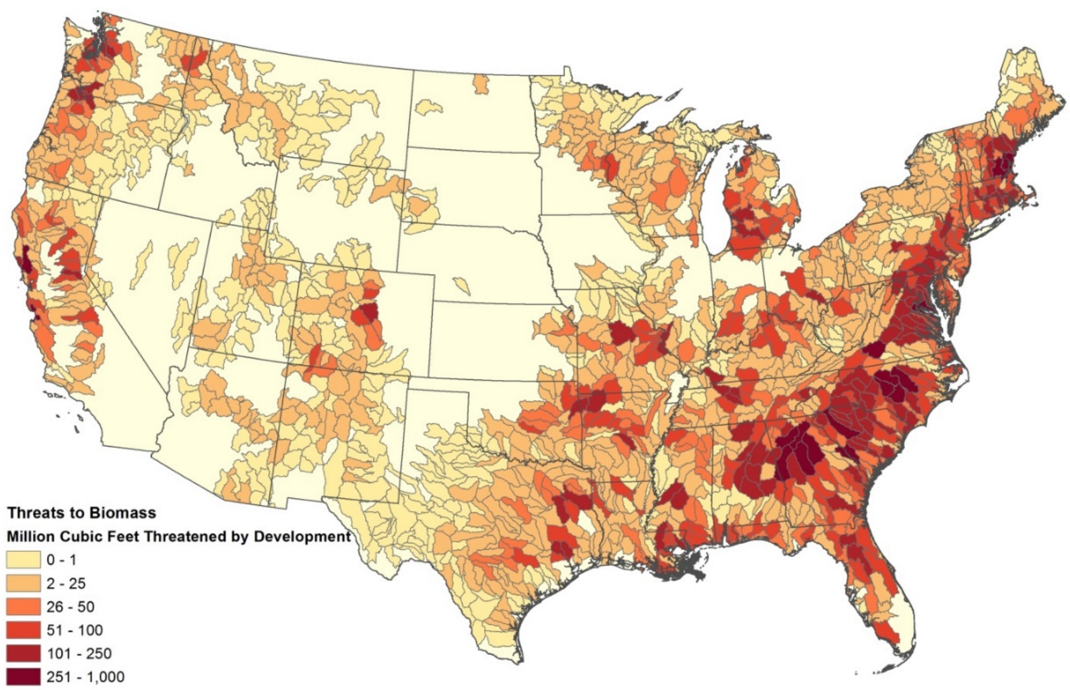

Figure 103. Volume of biomass on family forestland that is threatened by development.

4.4.3.5.2 Forest Parcellation

The smaller the ownership, the less likely a harvest operation is going to be financially viable for a logger, as well as lucrative for the owner.

Parcellation threatens to impact 63 billion cubic feet across family forestlands in our study watersheds, with an average of 45 million cubic feet per watershed (Figure 104).

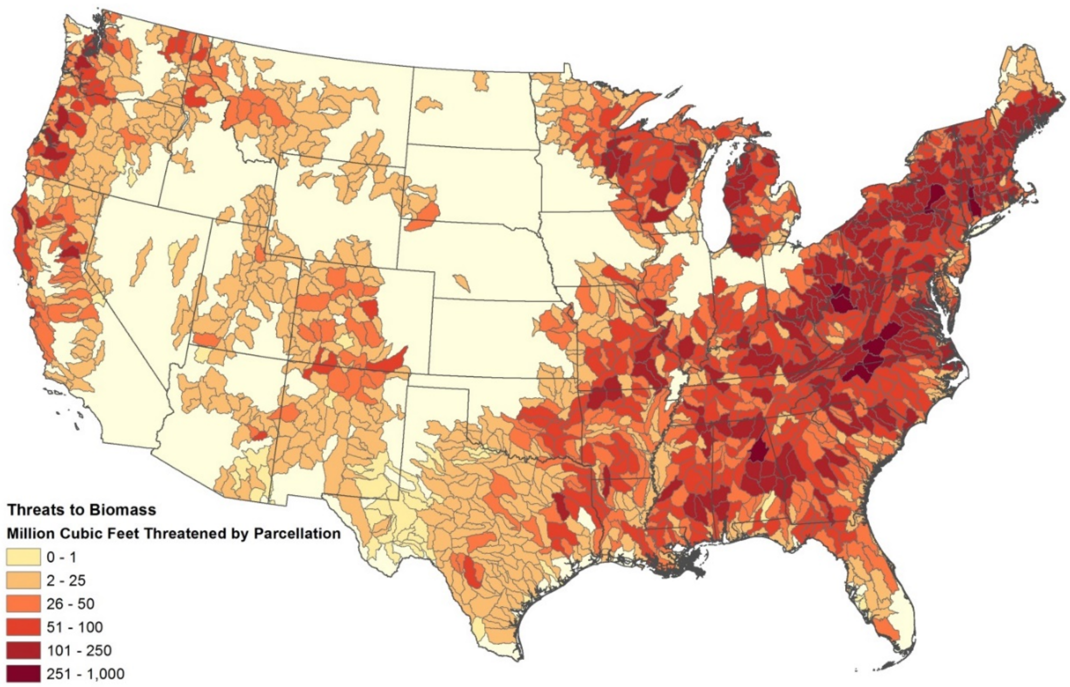

Figure 104. Volume of biomass on family forestland that is threatened by parcellation.

4.4.3.5.3 Insects & Diseases

Insects and diseases may not have as negative an impact on the value of biomass, but rules restricting the movement of infested wood may prohibit products from entering the marketplace.

We estimate insect and disease threats to impact 26 billion cubic feet of biomass, with an average of 19 million cubic feet per watershed (Figure 105).

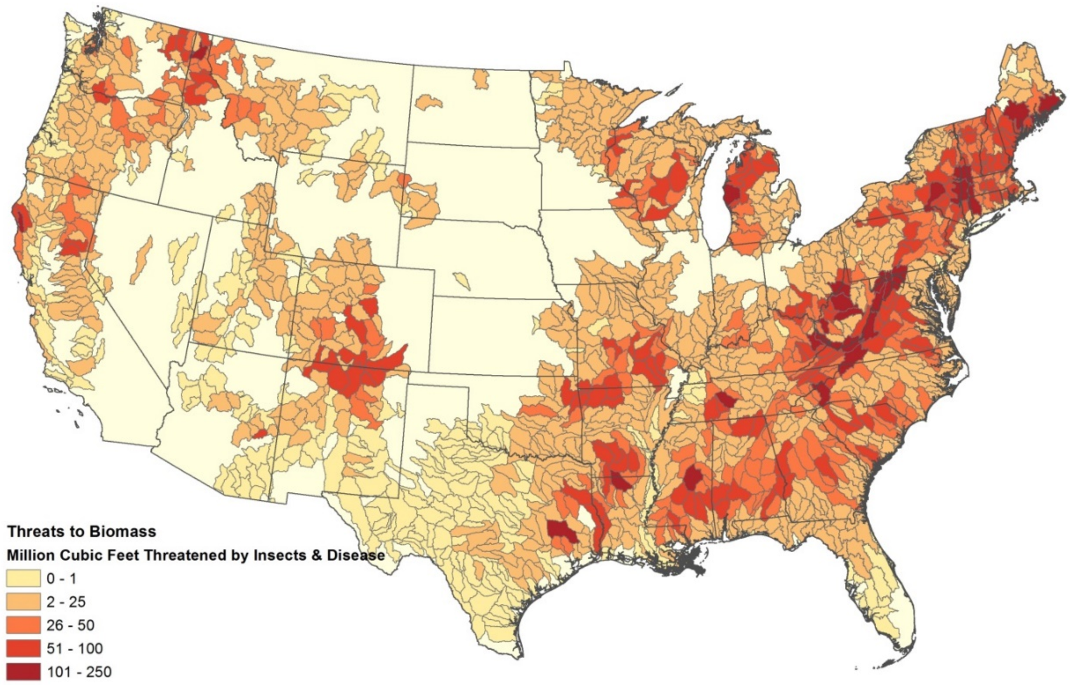

Figure 105. Volume of biomass on family forestland that is threatened by insects and disease.

4.4.3.5.4 Wildfire

As with wood supply, the impact of wildfire on biomass depends on fire intensity and other factors.

We estimate wildfire to threaten a total of 19 billion cubic feet, and an average of 14 million cubic feet per watershed (Figure 106).

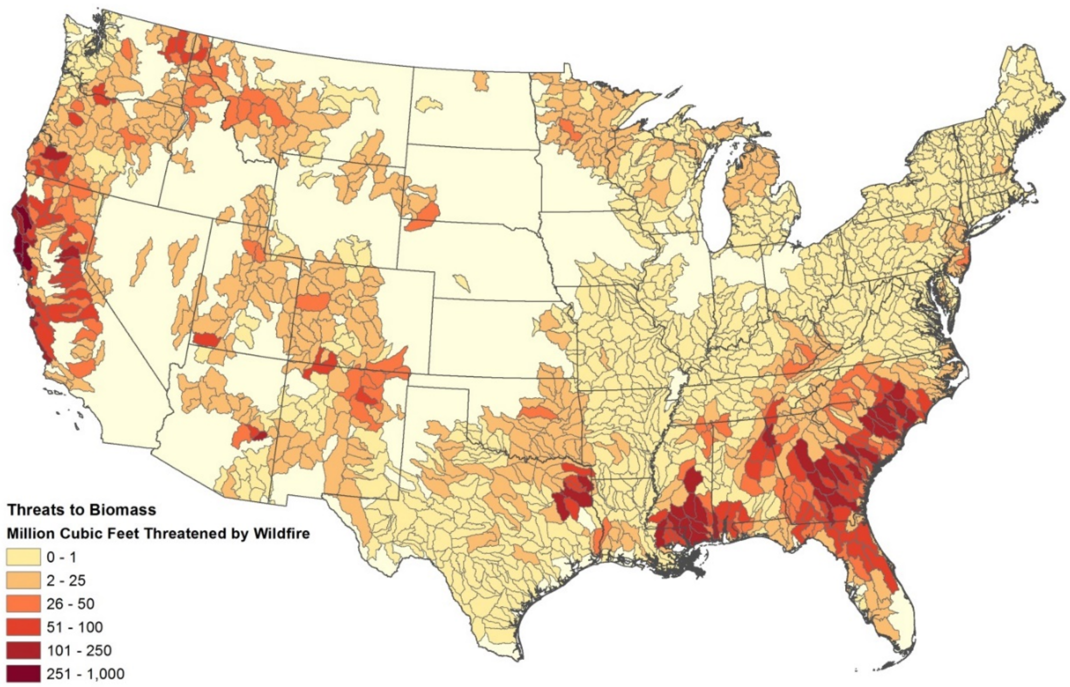

Figure 106. Volume of biomass on family forestland threatened by wildfire.

4.4.3.5.5 Unavailability

Family forest owners' decisions regarding what they choose to do with their lands are paramount in importance in terms of what does (or doesn't) go on in terms of forest products harvesting.

Based on survey responses indicating they have never sold wood products in the past, don't intend to do so in the future, and don't have timber management as a primary ownership objective, we estimate that 104 billion cubic feet of biomass are likely off limits to harvesting (Figure 107). On average, this equates to 75 million cubic feet per watershed.

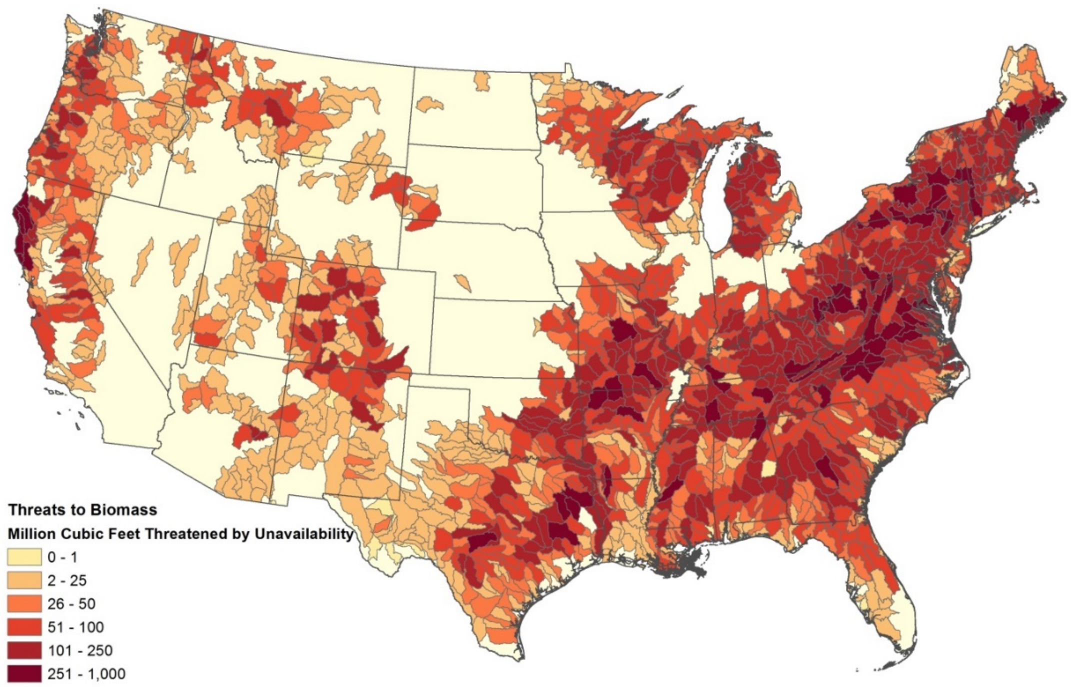

Figure 107. Volume of biomass on family forestland that may be unavailable due to landowners' reluctance to harvest.

4.4.3.5.6 Natural Disasters

The effects from natural disasters are highly variable and depend on severity and area over which they occur. They may have the effect of increasing biomass supply more than timber as there are not such stringent demands on quality of form for biomass.

None the less, we estimate potential damage from hurricanes to threaten 25 billion cubic feet of biomass, with an average of 18 million cubic feet per watershed; damage from tornados to threaten 1.2 billion cubic feet, with an average of 870,000 cubic feet per watershed; and damage from ice storms to threaten 6.7 billion cubic feet of biomass on family forestland, with an average of 4.8 million cubic feet per watershed (Figure 108 - Figure 110).

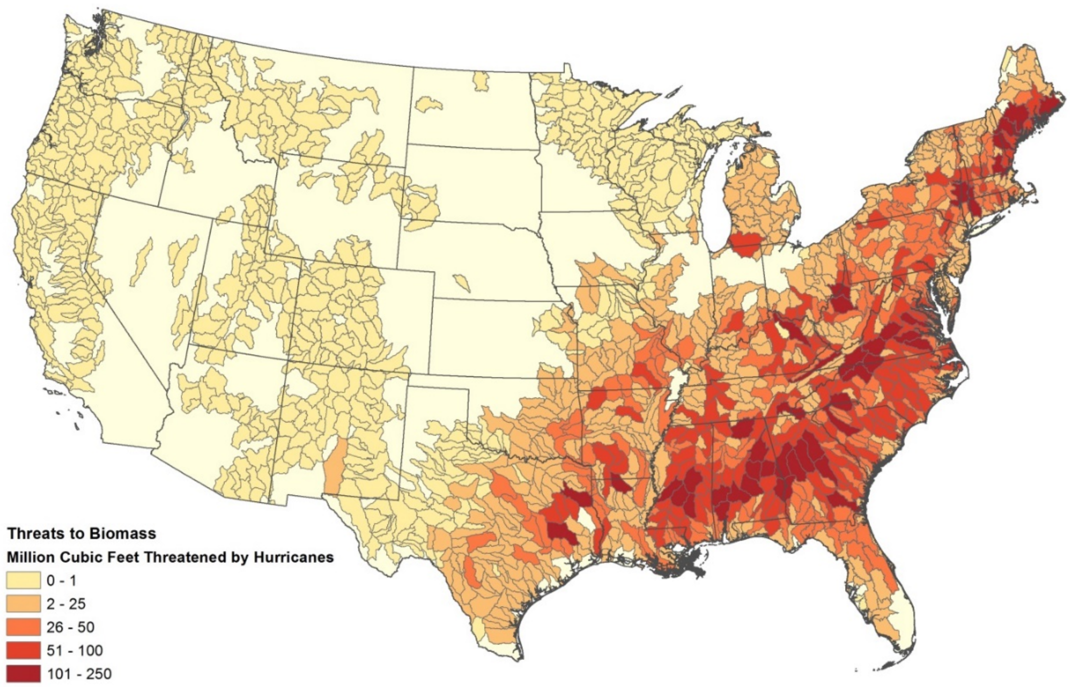

Figure 108. Volume of biomass on family forestland that is threatened by hurricanes.

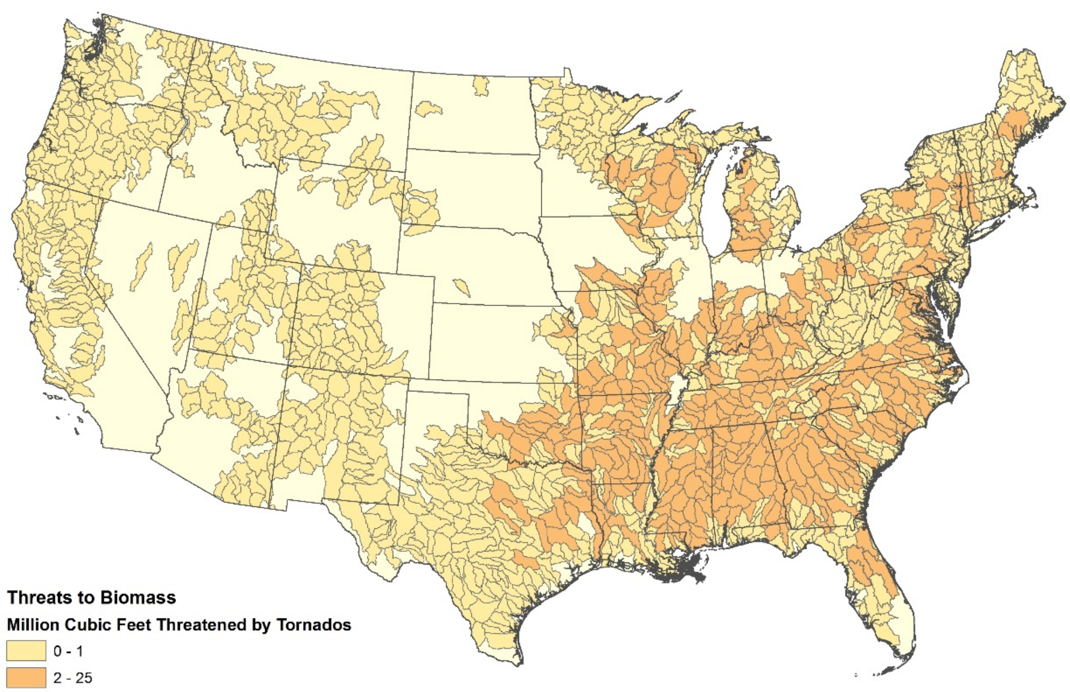

Figure 109. Volume of biomass on family forestland threatened by tornados.

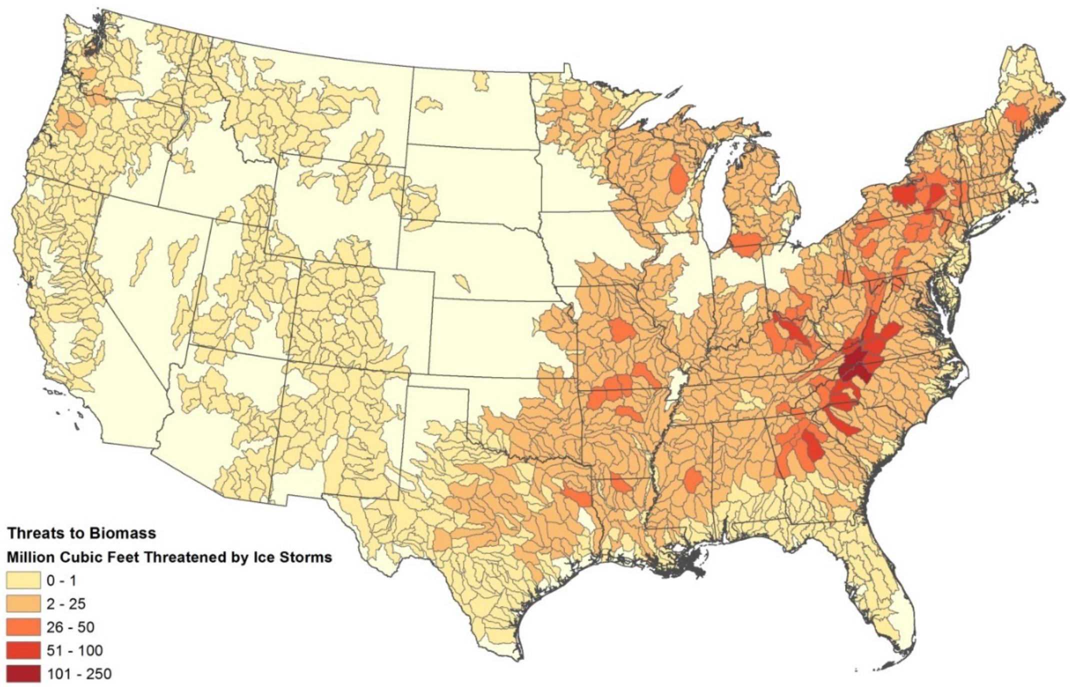

Figure 110. Volume of biomass on family forests threatened by ice storms

4.4.3.5.7 All Threats Combined

All together more than 272 billion cubic feet of biomass are threatened by the suite of threats delineated above, with an average watershed seeing 197 million cubic feet of biomass threatened (Figure 111). Like wood supply, timber unavailability and parcellation represent the greatest potential threats to biomass supply (Figure 112).

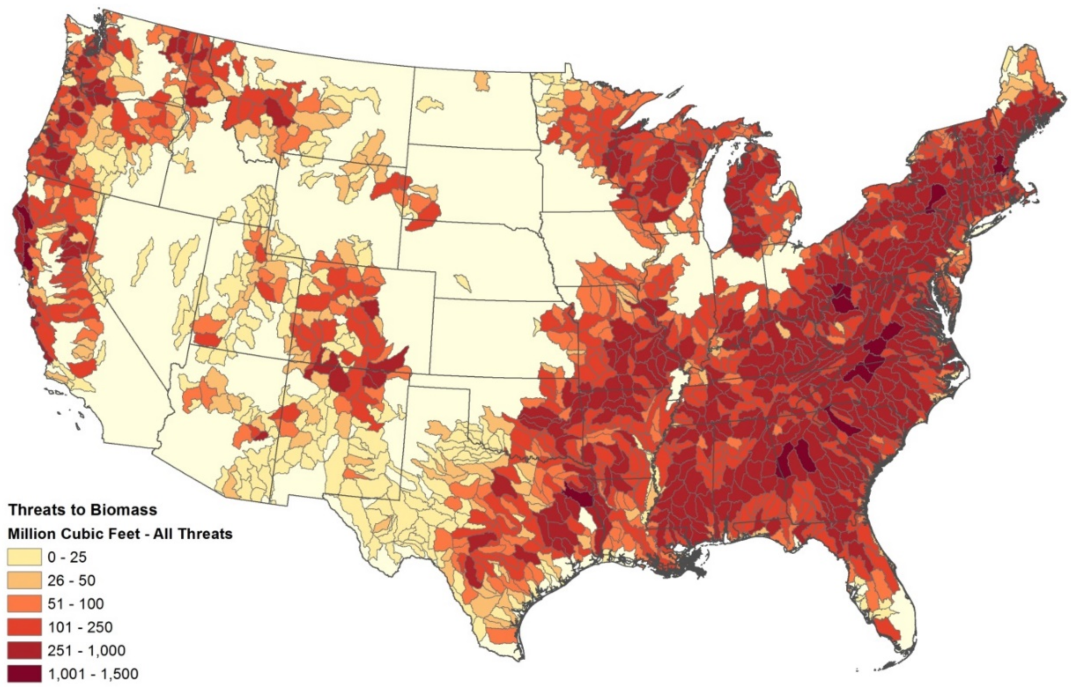

Figure 111. Total volume of biomass threatened on family forestland.

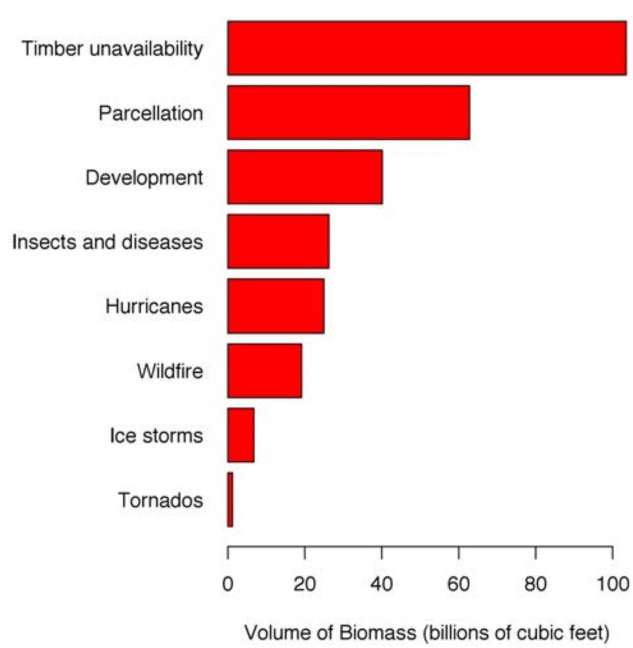

Figure 112. Volume of biomass threatened on family forestland by threat.

4.4.3.6 Threats to Recreation

Recreation on family forestland offers the public not only benefits to their own well-being, but can also enrich their connection to and valuing of these lands, potentially engendering more support for family forest owners.

Threats to recreational opportunities on public land range from more wide-spread and persistent threats such as development and parcellation, to less common and easier to recover from events like wildfire and natural disasters.

4.4.3.6.1 Development

As forestland is developed and becomes non-forested, fewer opportunities exist for recreation by the public.

We estimate that roughly 2.7 million acres of family forest open to public recreation are threatened by the risk of development, with an average watershed at risk of losing 1,970 acres of recreation open to the public (Figure 113).

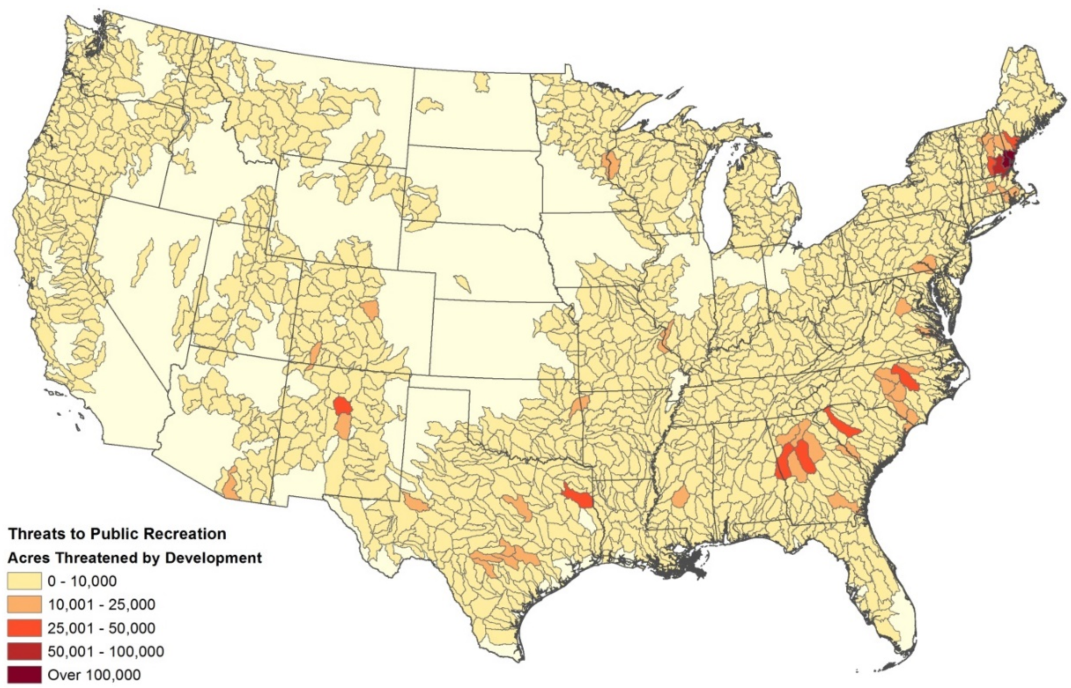

Figure 113. Area of family forestland open to public recreation that is threatened by development.

4.4.3.6.2 Forest Parcellation

Where land is divided into smaller holdings, resulting in more landowners and more decision making entities, the likelihood that some of that land will no longer be open to recreation increases.

Our calculations suggest that 2.7 million acres of land currently open to the public is threatened by parcellation, with an average of 1,970 acres per watershed (Figure 114).

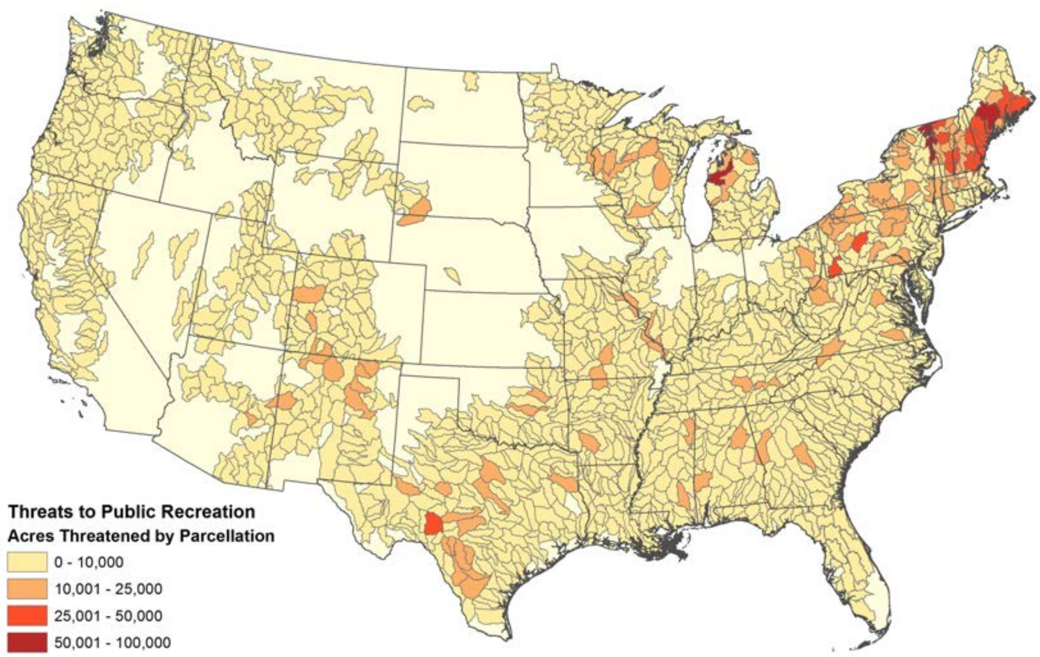

Figure 114. Area of family forestland open to public recreation that is threatened by parcellation.

4.4.3.6.3 Wildfire

Wildfire occurrence on family forest land may negatively impact recreational opportunities for the public as existing trails may become inaccessible due to damage, or aesthetics sufficiently impacted to make recreation uninviting. We estimate that wildfire threatens over 321 thousand acres of family forest that is open to public recreation, with an average of 232 acres threatened at the watershed level.

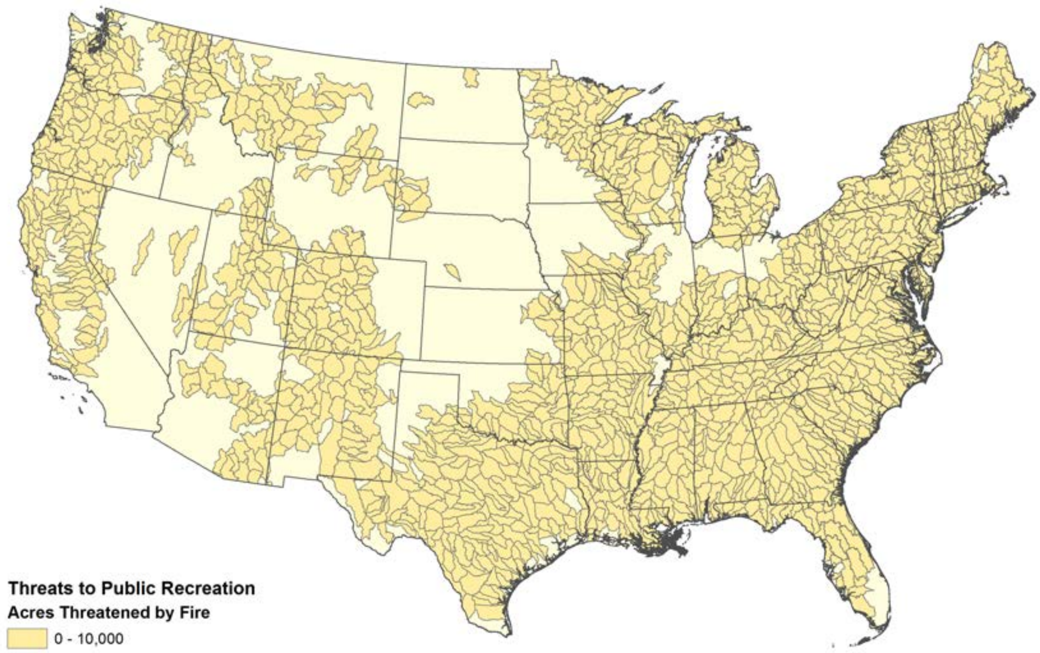

Figure 115. Area of family forestland open to public recreation that is threatened by wildfire.

4.4.3.6.4 Natural Disasters

When storms such as hurricanes, tornados, and ice storms occur, forests are often made dangerous and impassible due to downed trees and limbs. Given historic storm patterns, we estimate that hurricanes threaten a total of 391 thousand acres of family forest land open to recreation, tornados threaten over nine thousand acres, and ice storms threaten upwards of 190 thousand acres (Figure 116 - Figure 118). While storm damage doesn't necessarily mean that family forest land will be inaccessible for public recreational purposes, landowners who fear liability issues may decide to close off their lands to the public following severe storm damage.

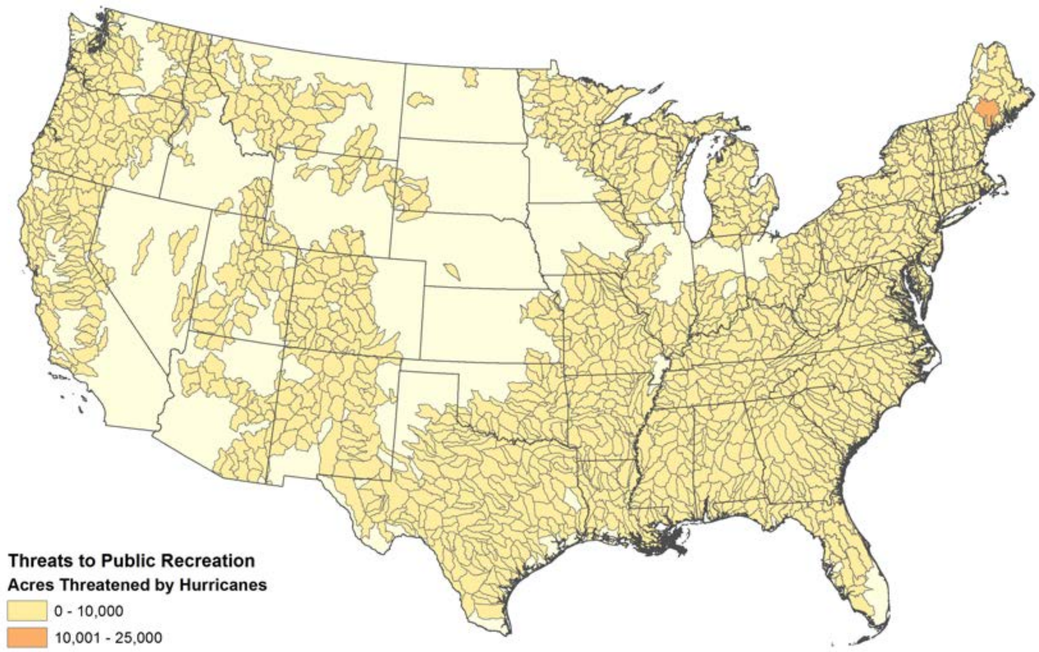

Figure 116. Area of family forestland open to public recreation that is threatened by hurricanes.

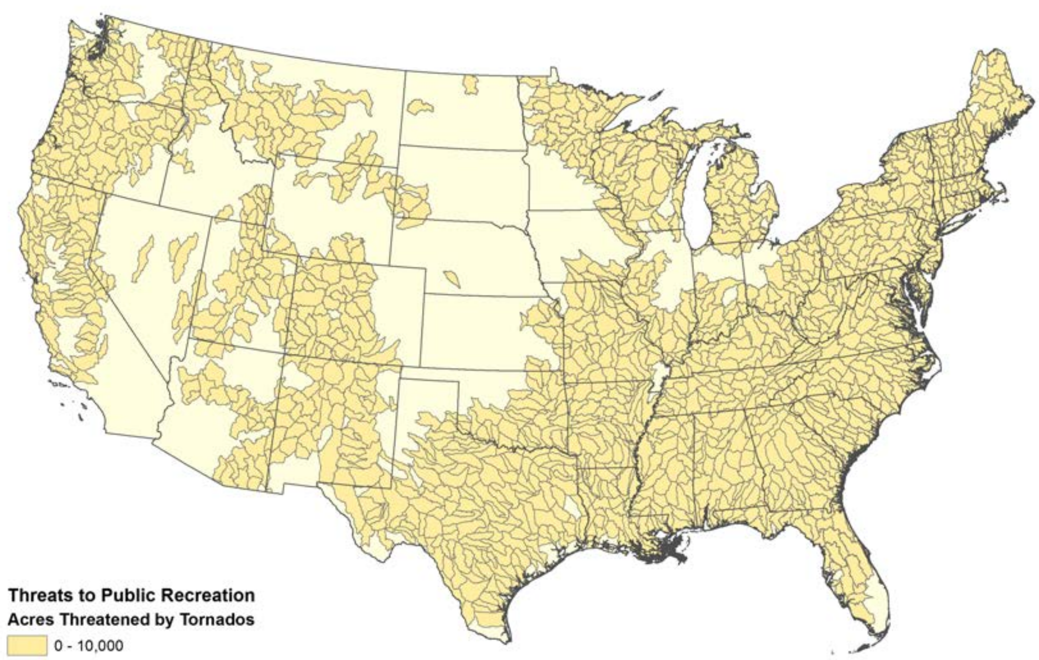

Figure 117. Area of family forestland open to public recreation that is threatened by tornados.

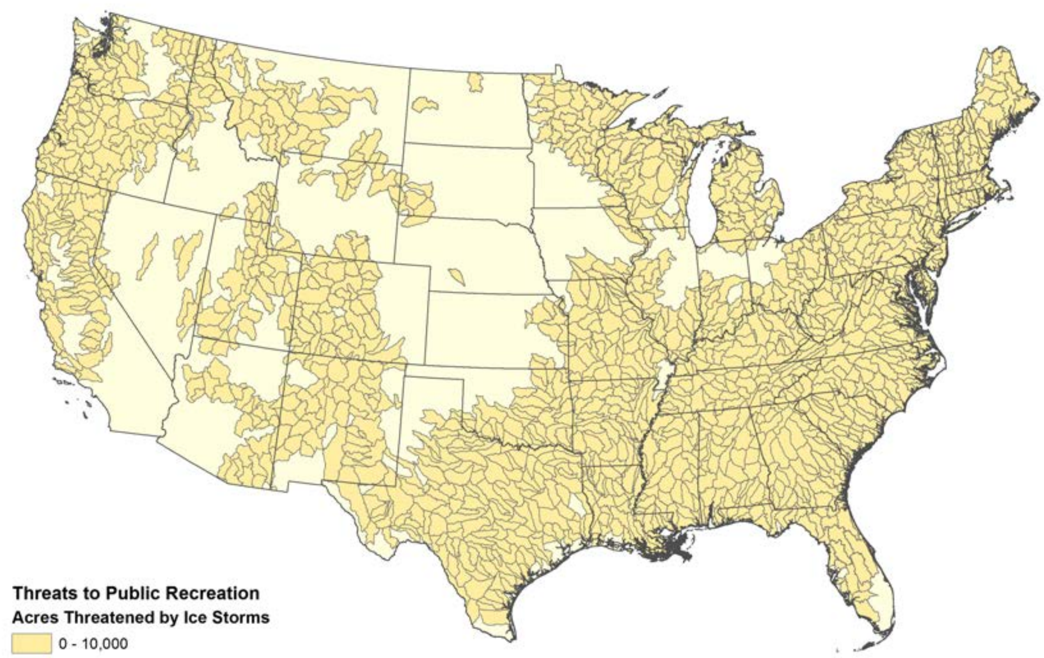

Figure 118. Area of family forestland open to public recreation that is threatened by ice storms.

4.4.3.6.5 All Threats Combined

All together the threats to recreation are poised to impact nearly 6.5 million acres of family forestland within the study watersheds, with an average of 4,690 acres of family land affected per watershed (Figure 119). Development and parcellation are of nearly equal significance as threats, while natural disasters pose far less of a threat(Figure 120).

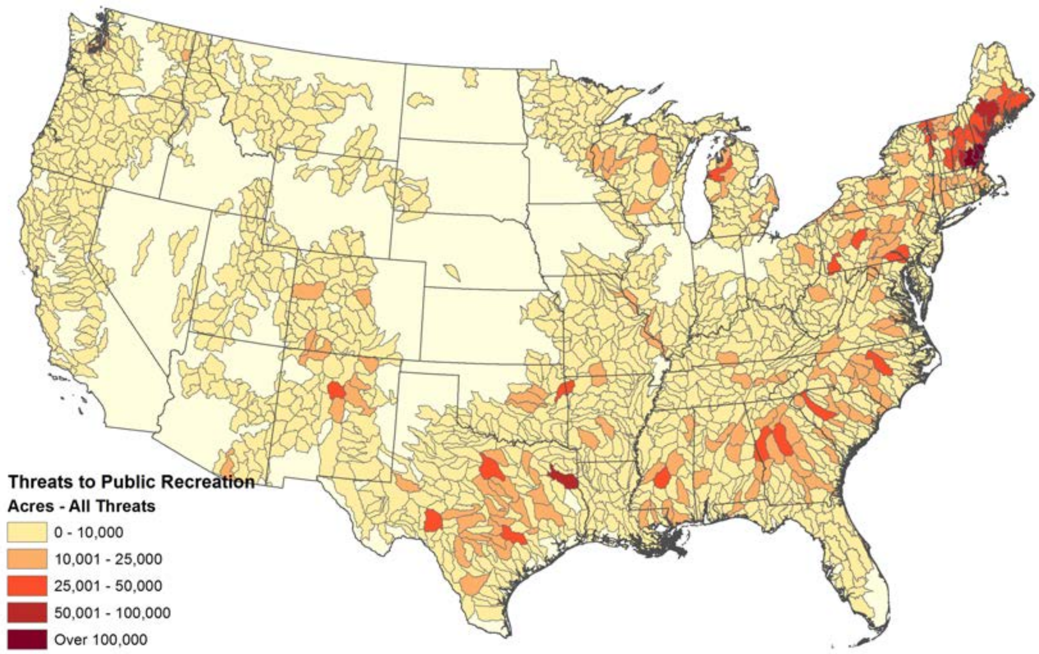

Figure 119. Total area open to public recreation threatened that on family forestland.

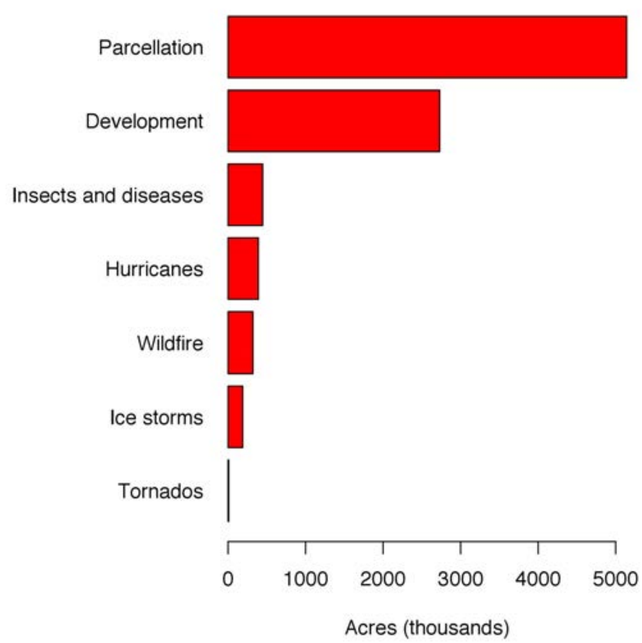

Figure 120. Threatened acres of family forestland open to public recreational access by threat.

4.4.4 Composite Rankings

It is not possible to directly compare benefits from family forests. What is more important - water, wood, or wildlife? And by how much? A common approach for comparing disparate metrics is the Borda count method (Ho et al. 1994). Although most commonly used in tallying election votes, it has also been applied to conservation efforts, such as *Forests on the Edge* (Stein et al. 2010b). The Borda method relies on rankings. For each family forest benefit, the relative ranking was determined by ordering the watersheds from the one that provided the least amount of the benefit to the one that provided the most. An inherent problem with this approach is that it is not capable of differentiating based on the degree of separation between rankings, but there are no superior methods for accomplishing this objective. After each benefit is ranked, the rankings are summed for each watershed and the resulting values are re-ranked with the "most beneficial" watersheds having the highest values.

To allow for differentiation among benefits, a weighting was applied when combining the rankings. The weightings used here were taken from an exercise conducted with members of the American Forest Foundation staff and committee members (see Section 3.2). The weightings assigned, based on the averages of all participants, for the available data layers are shown in Figure 121. In other words, water was rated as roughly twice as important as biomass. Applying the AFF weights results in the benefits ranking depicted in Figure 122. The ten watersheds with the highest combined rankings are outlined in white.

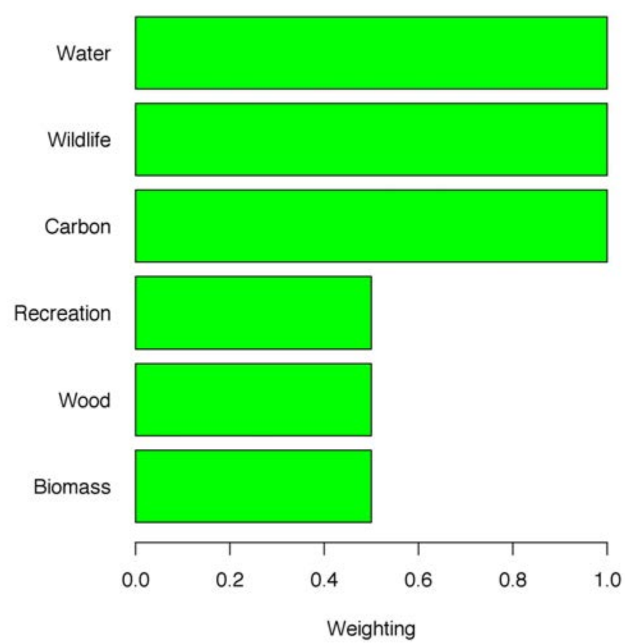

Figure 121. Ratings of benefits from family forests as estimated by the report authors.

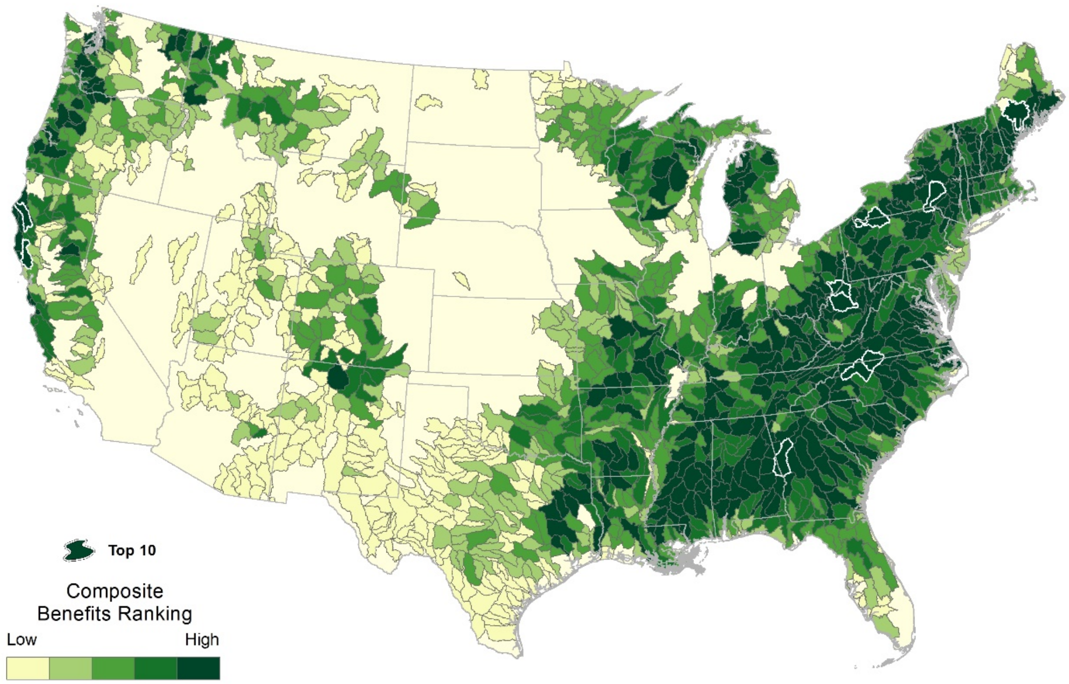

Figure 122. Total benefits from family forests as determined by the Borda count method.

As with the benefits, the Borda count method was used to combine the threats. Again, relative weights were taken from the exercise done with the AFF staff and committee members (Figure 123). Applying the AFF weights results in the threats ranking depicted in Figure 124. Again, the ten watersheds with the highest combined rankings are outlined in white.

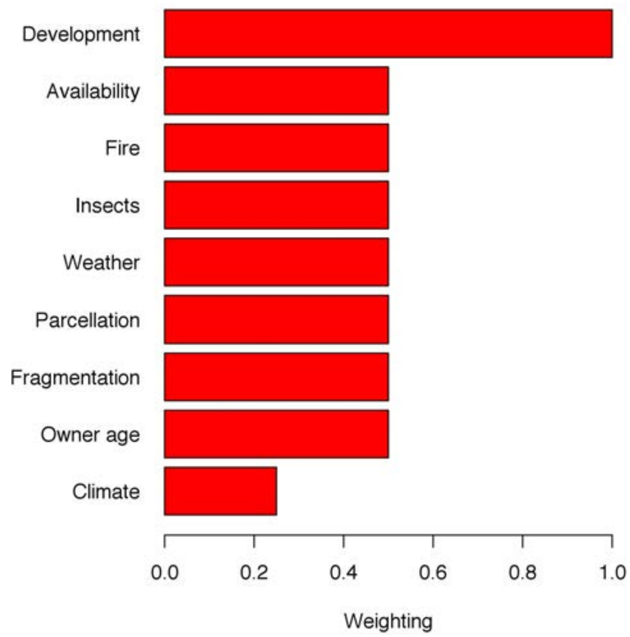

Figure 123. Ratings of threats to family forests as estimated by the report authors.

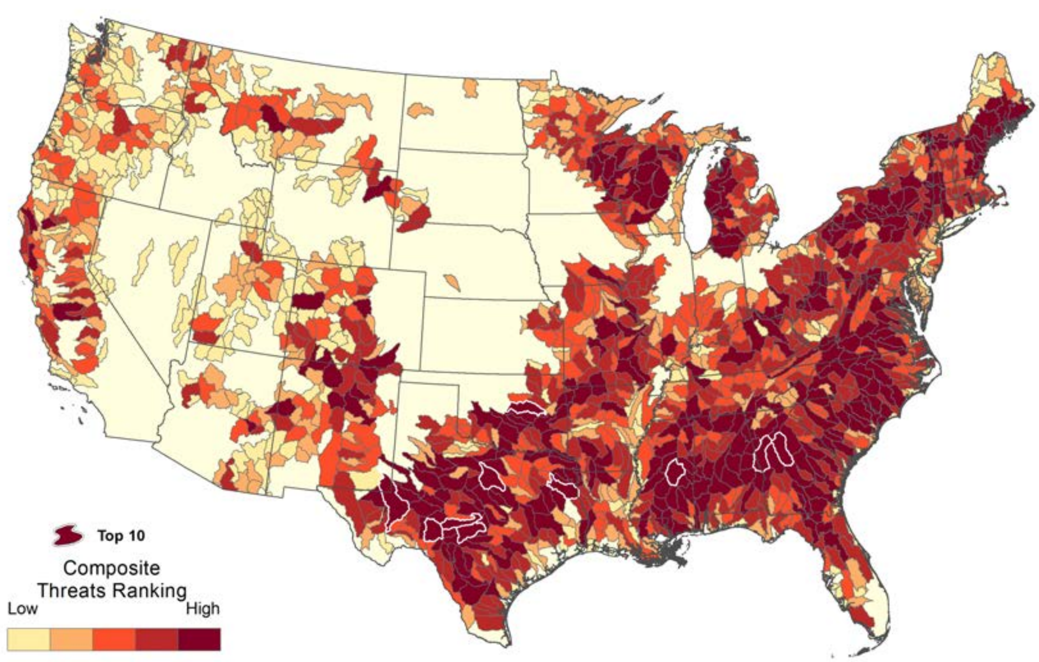

Figure 124. Total threats to family forests as determined by the Borda count method.

Combining the composite benefits and threats values provides an indication of those watersheds that have high benefits and high threats (Figure 125). These highly ranked watersheds present significant opportunities for forest conservation. But the identification of the optimal watersheds to focus conservation efforts needs to also consider if the threats can be addressed by the current tools and resources and where there is sufficient political and organizational support which are necessary for successful efforts.

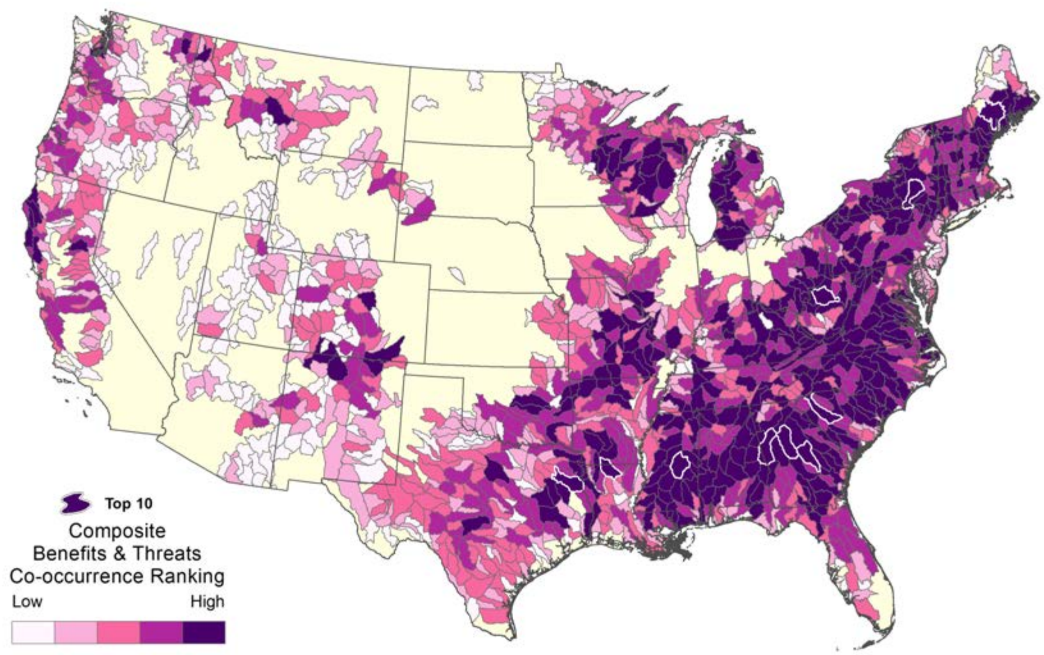

Figure 125. Intersection of total benefits from and total threats to family forests as determined by the Borda count method.

4.5 Other Benefits & Threats Not Used in Analyses

4.5.1 Forest Loss

How much family forestland is being lost and gained and where? A seemingly simple question that one would assume the forest research community should be able to definitely answer. Unfortunately, there are conflicting answers depending on the source. The primary data sources for forestland area statistics in the U.S. are:

- U.S. Forest Service, Forest Inventory & Analysis (FIA; www.fia.fs.fed.us)
- U.S. Natural Resources Conservation Service, National Resources Inventory (NRI; www.nrcs.usda.gov/technical/NRI)

- U.S. Geological Survey, National Land Cover Database (NLCD; www.mrlc.gov)

FIA is a ground-based sample, with one plot per 6,000 acres, covering all ownerships in the U.S., and uses a land use classification system. NRI relies mainly on aerial photography at selected sample sites, covers all non-Federal lands, and uses a primarily land use classification system. NLCD uses satellite imagery and covers all ownerships in the conterminous U.S. and uses a land cover definition. Land cover definitions classify any lands that have a minimum amount of tree cover as forest. Land use definitions define forest based on whether the dominant growth form is trees, if there is a sufficient number of trees, and if natural regeneration is permitted. So trees that overtop a house would be called a forest in the land cover definition but not the land use definition. And a clearcut that is likely to revert to forest would be classified as forest by the land use definition but not the land cover definition. A new product, the North American Forest Dynamics (NAFD) Project coordinated by NASA, Oak Ridge National Laboratory, and others (http://daac.ornl.gov/NACP/guides/NAFD_Disturbance_guide.html), promises to provide both the higher spatial resolution of the NLCD types of products with the more precise classification of the ground based systems. While NAFD has been completed for selected sites, it is unclear when it will be nationally available.

The trends in forest area vary enormously across these sources (Table 2). FIA has reported a large increase in forest area, over 20 million acres, over the last couple of decades. NRI reported a more modest 3 million acres increase over a slightly longer time period. In contrast, NLCD reported net *losses* of over 20 million acres over a slightly shorter time period.

Table 2. Forest area change by data source.

Source	Time Span	Net Forest Area Change (millions of acres)
FIA	1987 - 2007	20.9
NRI*	1982 - 2007	3.0
NLCD**	1992 - 2001	-15.3
NLCD**	2001 - 2006	-6.5
NAFD	1985 - 2010	??

* Non-federal only

** Conterminous US only

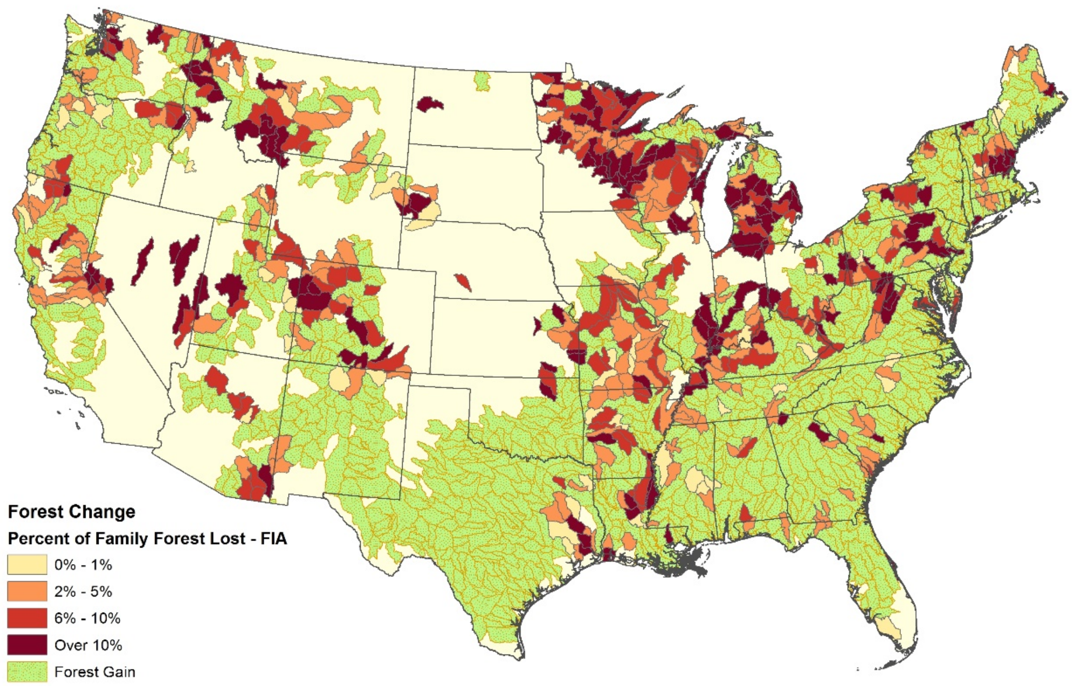

Figure 126. Percent of forest change on family lands according to FIA estimates 2006 – 2012.

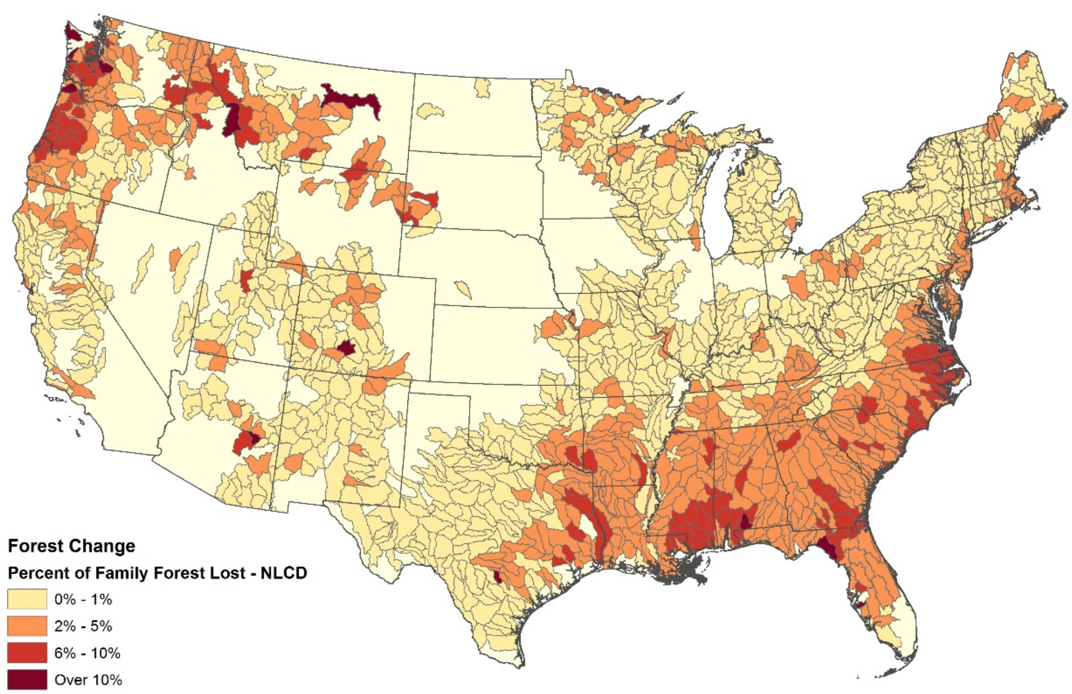

Figure 127. Percent of forest change on family lands according to NLCD 2001 – 2006.

5 Conclusions

In this final section of the report, we bring together results from the other sections to make comparisons in terms of benefits, threats, and solutions. These discussions are augmented by data from other sources, such as the NWOS Butler et al. 2014b, where applicable. The implications of this research for determining metrics for forest conservation are then discussed, and we end with thoughts on next steps.

5.1 Benefits

There are numerous benefits that family forests provide, but they are not often quantified. Based on the data presented in Chapter 4, quantification of some the benefits are:

- 14 billion tons of carbon
- 359 billion tons of biomass
- 79 million acres of core forest habitat
- 34 million acres open to public recreation
- 14,000 occurrences of threatened and endangered species
- 1,100 billion board feet of wood

As stated in the preface to Section 4.4.4, it is not possible to directly add or compare benefits. The importance is based on the perspective being taken, e.g., society versus landowner and the opinion of the group/individual providing the input. There is no published literature that provides the relative importance of various benefits.

The relative ratings of the benefits from the American Forest Foundation staff and committee members (AFF; see Chapter 3), the Family Forest Research Center authors of this report (FFRC), the extension forester survey (Chapter 3), the published literature (Chapter 2), and the U.S. Forest Service, National Woodland Owner Survey (NWOS; Butler et al. 2014b) are shown in Figure 121. Ratings of zero, i.e., carbon for NWOS, imply the requisite information was not available. As stated earlier, it is important to recognize that there is no literature that explicitly rates the benefits from, threats to, and solutions for family forests. These literature values represent the relative number of articles that discussed the specific topic. The NWOS values represent the landowners' perspective and are taken from preliminary results from the 2011-2013 iteration of the NWOS (Butler et al. 2014b).

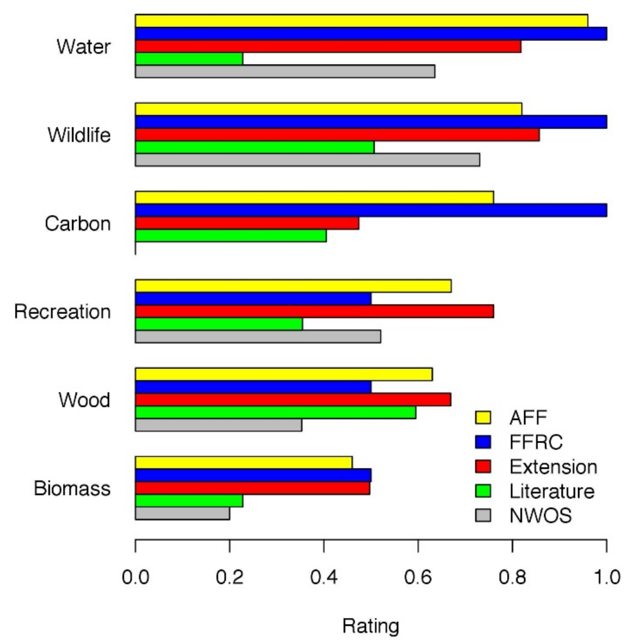

Figure 128. Relative ratings of benefits from family forests.

The FFRC values are based on the opinions of the authors of this report and were developed using the concept of the Forest Benefits Pyramid (Figure 129). This pyramid, adapted from the Forest Conservation Pyramid proposed by David Kittredge and Paula Catanzaro (University of Massachusetts, Amherst), assigns benefits according to the relative value of benefits provided by family forests to society. Using the framework of the Millennium Ecosystem Assessment (2005), benefits, or services to use their parlance, can be divided into supporting, regulating, provisioning, and cultural categories. Supporting benefits include primary production and nutrient cycling. The regulating category includes climate regulation and water purification. The provisioning category includes the goods we extract, such as wood. The cultural category includes aesthetic, spiritual, and recreational values. This framework of the Millennium Ecosystem Assessment was used to assign benefits to levels of the pyramid with the order of importance going from supporting/regulating to provisioning to cultural. The exact order of benefits is not possible to determine, so the FFRC ratings are 1.0 for the benefits with the greatest values, 0.5 for intermediate values, and 0.25 for the lowest values, from the societal perspective.

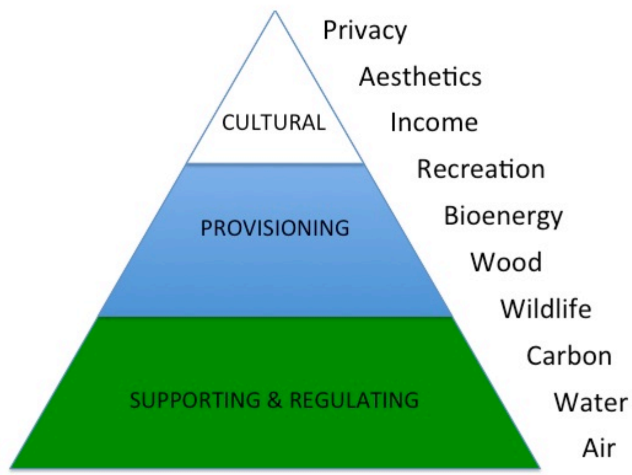

Figure 129. Forest benefits pyramid.

Across the sources (Figure 128) there is some agreement and some disagreement as to the relative order of the benefits. The AFF and FFRC ratings are in relative agreement. The extension ratings are largely in agreement with the AFF and FFRC ratings with the exception of a lower ranking for Carbon. Compared to the AFF and FFRC ratings, the NWOS ratings put wildlife slightly above water, but this makes sense from an owner's perspective. The biggest differences are from the literature ratings, but this is not surprising given what those numbers actually represent – the number of sources that discuss the issue.

5.2 Threats

As discussed in Chapter 4, the threats depend on the benefit. The relative ratings of the threats from AFF, FFRC, Extension, Literature, NWOS, and a survey of American Tree Farm System members (ATFS; Rita Hite, American Forest Foundation, personal communication) are shown in Figure 123. Due to the ATFS survey asking respondents to indicate the one greatest threat, the values were relativized by dividing them all by the value of the most commonly selected threat, insects and diseases.

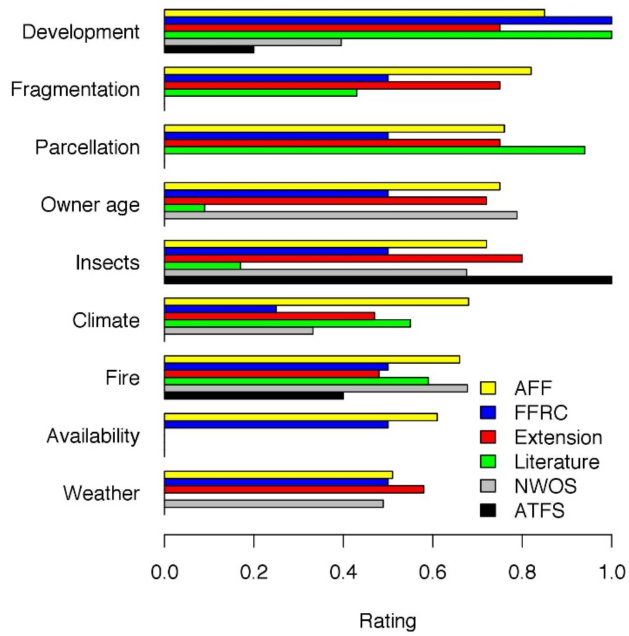

Figure 130. Relative ratings of threats to family forests.

With the exception of climate change, there is still good agreement between the AFF and FFRC ratings. The difference with climate change may be due to time scales being considered. For FFRC this was explicitly 10 years, but it is uncertain how AFF respondents interpreted the time scale. The Literature is again, overall, the most dissimilar.

5.3 Solutions

After determining which benefit(s) and associated threat(s) are being targeted, the next question becomes what are the most effective solutions. There are many potential solutions discussed in the literature, but there is woefully little empirical evidence on the effectiveness of the solutions and under what circumstances they would be most applicable. In lieu of a definitive answer, we provide relative ratings of solutions as provided by AFF, Extension, and Literature (Figure 131). Although questions were not framed quite the same, data from the NWOS on owners' opinions on solutions are also provided (Figure 132). Extension foresters and AFF staff and committee members all thought that there were many actions that can help family forest owners. The Literature primarily focuses on financial options. Family forest owners state they would most prefer improved tax policies and more advice and information.

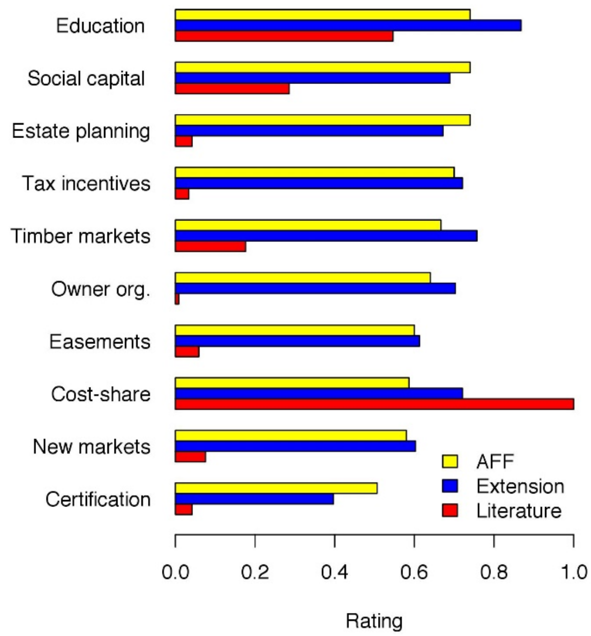

Figure 131. Relative rating of solutions to threats to family forests.

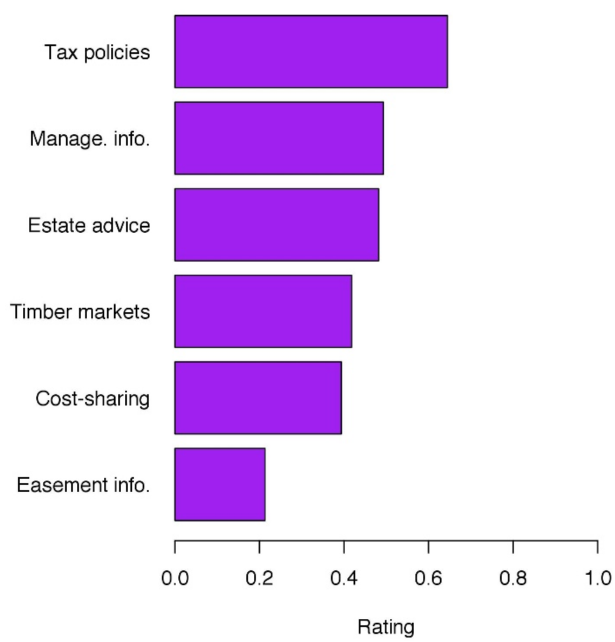

Figure 132. Rating of solutions to threats to family forests from family forest owners' perspective (Butler et al. 2014b).

5.4 Metrics

In order to empirically evaluate the effectiveness of an action, it is necessary to determine metrics. Ideally, these metrics are: closely aligned with the project goals, objective and repeatable, transparent and simple/straightforward, and ideally, utilize data that are already being collected for other purposes or as at least, inexpensive and easy to collect.

As was seen in earlier portions of this report, the solutions and threats vary significantly depending on what benefits are being sought. Likewise, the metrics need to be appropriately aligned with the desired outcomes. For many forestry activities, this will necessitate both short-term and long-term metrics. A confounding problem, particularly with the long-term metrics, is that there are often other factors impacting the desired behavior. When feasible, establishing a control group where everything is the same except the treatment, with which to compare, will alleviate this problem.

As an example, we present some potential metrics for an effort that is aimed at increasing timber supply from family forests. Threats to timber supply include unavailability due landowners' attitudes, natural disasters, insects and diseases, fire, development, and parcellation. The first of these threats is one of the largest and one that the forest conservation community can conceivably address. One way to do so is to overcome the barriers owner perceive regarding harvesting, namely trust of those who are doing the harvesting and awareness of the value of their wood and their harvesting options. In the short-term, surveys can be conducted to measure owners' attitudes towards harvesting. In the long-term, we would want to monitor the amount of wood being harvested, but this will be complicated by factors such as demand for timber.

Unfortunately there is not conclusive evidence from the literature on what are the specific threats to each benefit or on the effectiveness of specific solutions. By taking an approach such at that proposed by Evidenced Based Practices (Kitson et al. 1987), groups can overcome this problem by assessing the available information and combining it with expert opinions and the goals and values of the project. An important component of this, and all efforts, is evaluation or self-learning.

5.5 Next Steps

While this report provides a synthesis across many data sources, it has generated more questions than answers. The gap between what forest conservation groups are seeking and what the literature provides is immense. There needs to be a renewed concentration on empirically assessing the effectiveness of solutions to the threats facing family forests.

To solidify and move forward on a new research agenda, it would be beneficial to convene the primary family forest researchers and users of the research through a workshop, symposium, or other mechanism. They would be able to further refine the conclusions from this report and decide on how to proceed. It would be important to ensure such an endeavor is well facilitated and has specified deliverables that will ensure the participants stay on target.

The analyses presented in Chapter 4, Spatial Analysis, are limited by data availability. There were some benefits and threats for which no data were available and for other topics, the available data were only a rough proxy of the underlying phenomenon. Requiring national level data is constraining and practically necessitates the use of pre-existing data. By focusing further efforts on specific landscapes, richer data could be assembled and new data could be more easily generated.

There is a continual need for information amassed in the peer-reviewed literature to be made available to those in the conservation community. Ideally, there would be a searchable database of this knowledge. It could also include mechanisms for including non-peer reviewed literature and for practitioners and others to import their own experiences.

The data assembled and analyses conducted as part of this project are richer and more complex than just what is presented in this report. The research team will be working on journal articles and other publications to further refine the findings and distribute the results to a broader audience.

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The included CD contains the following materials:

- Stem report
- Appendix 2-A: Literature review references
- Appendix 3-A: Extension forester survey phase 1 survey results
- Appendix 3-B: Extension forester survey phase 1 illustrative examples
- Appendix 3-C: Extension forester survey phase 2 survey results
- Appendix 3-D: American Forest Foundation survey results
- Appendix 4-A: Spatial analysis HUC8 watershed details