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# A land systems science approach to assessing forest governance and characterizing the emergence of social forestry in the Western Cascades of Oregon

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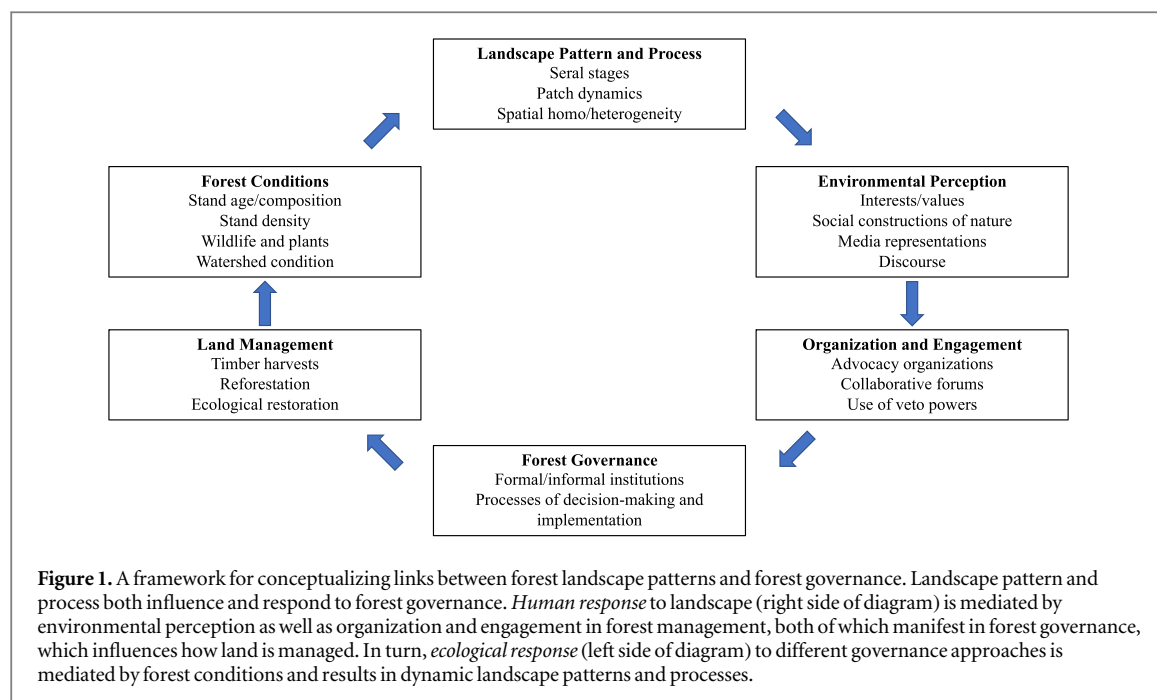
## Abstract

National forests in the United States are undergoing a spatially and temporally uneven governance transition in response to Congressional policies, agency mandates, and social and economic pressures, with many moving from a wholly state-led ‘dominant federal’ model to a more collaborative networked governance model which we refer to as ‘social forestry’. While the broad contours of this transition have been observed and studied previously, there have been few attempts to characterize it using quantitative, qualitative, or geospatial methods. Here, we combine a novel remote sensing-based method with qualitative social science research to understand the emergence of social forestry and its implications for land use/land cover change associated with implementation of the Northwest Forest Plan (NWFP) in the Western Cascades of Oregon. We linked time-series satellite data with forest inventory data to track patterns of timber harvest at scales commensurate with timber management decision-making. We then compared these patterns to policy-based expectations. We found a significant disconnect between NWFP policy and actual timber harvest patterns, raising questions about the effectiveness of the NWFP land use allocation system and the ‘land sparing’ approach to managing tensions between conservation and production. Qualitative research, including semi-structured interviews with federal agency personnel and local stakeholders, shed light on the causal mechanisms and reciprocal relationships driving spatial patterns of timber harvesting, which we discuss in terms of the emergence of social forestry involving complex, place-based negotiations between the federal government and local veto actors advocating for conservation. Findings have implications for US Forest Service public engagement strategies and efforts to establish zones of agreement regarding timber harvesting, as well as broader discussions about the agency’s future.

## 1. Introduction

In a world dominated by humans, landscape patterns can be thought of as artifacts or reflections of social, political, and economic driving forces. Remotely sensed patterns on forest landscapes, for example, can provide important insights into policy effectiveness (or ineffectiveness) and the realities of forest governance, but they can be challenging to decipher (Munroe *et al* 2019). A land system science (LSS) approach that combines remote sensing and geospatial analysis with

social science research can improve understanding of complex feedbacks between the societal and environmental components of the integrated land system and help elucidate cross-scale interactions and interdependencies between local, regional, national, and global phenomena that influence land use decision-making processes at different scales (Rounsevell *et al* 2012, Munroe *et al* 2019). LSS that includes attention to environmental history sheds light on the impacts of land use decisions on ecosystem services and human well-being as well as causal mechanisms that may be



influencing patterns and creating path dependencies (Foster *et al* 2003, Verburg *et al* 2015). As Roy Chowdhury and Turner (2019) note, understanding the ‘social, economic, and political drivers of land use change, the values and preferences attached to landscapes and ecosystem services, and the role of institutions and decision-making on land uses’ is necessary for improving land-change projections for the future of the biosphere.

Focusing on federal forestland in the Western Cascades of Oregon, we use LSS to analyze the discrepancies between national forest policy as stated and as implemented. After describing our conceptual framework, we provide a brief overview of federal forest governance in the Pacific Northwest, including its centerpiece, the Northwest Forest Plan, focusing on those aspects that were designed to influence timber harvest decision-making. We present a novel methodology for quantifying timber harvest patterns using geospatial analysis, and then demonstrate its utility for providing insights into how current governance dynamics surrounding timber harvesting on federal lands in the Northwest Forest Plan Area have evolved since implementation in 1994. We explain federal forest landscape patterns by linking them to the emergence of *social forestry*, a socio-political and cultural phenomenon that has had a significant imprint on forest landscapes in the Pacific Northwest. Qualitative research provides insights into emerging processes and dynamics that may signify an inflection point in forest governance dynamics in this region characterized by new approaches to addressing tensions between conservation and development across landscapes. We conclude with a discussion of the implications of our findings for future US Forest Service (USFS) planning and management.

## 2. Conceptual framework

This paper concerns itself with the links between forest governance—the set of formal and informal processes, mechanisms, and institutions through which actors influence decisions (Lemos and Agrawal 2006)—and landscape pattern and process (figure 1). Forest governance determines the extent to which forest policy (e.g. annual timber targets), forest science (e.g. disturbance ecology, early seral habitat, stream shading), and societal values (e.g. the value of old growth forests and the acceptability of different silvicultural treatments) are reflected in forest management. The relative influence of forest policy, forest science, and societal values in forest governance has changed over time in response to a variety of cross-scale influences (Shindler and Mallon 2006, Moseley and Winkel 2014, Inman *et al* 2018).

Recent LSS scholarship has called for more attention to the ways in which changing landscape conditions mediate land use changes through ‘reciprocal relationships’ and the mechanisms by which regional context enables or constrains decisions (Munroe *et al* 2019). Interpreting regional context requires greater attention to ‘the cultural aspects of landscape patterns’ and their effect on ‘decision-making processes as well as the institutions and governance structures involved in land management’ (Rounsevell *et al* 2012). Our approach is founded on existing scholarship that examines how environmental signals (feedback from the environment) are incorporated into decision-making through perception, interpretation and valuation (Verburg 2006, Lambin and Meyfroidt 2010, Meyfroidt 2013, Meyfroidt *et al* 2018).

We suggest that the dynamics on the right side of figure 1—the ways in which feedbacks from landscape

pattern and process influence forest governance via environmental perceptions and stakeholder participation in influential organizations such as local forest collaboratives—are in need of better understanding, since decision-making regarding timber management on federal lands has important implications for future landscape patterns and processes that support biodiversity and other ecosystem services across the western US. They also influence social dynamics and determine future economic possibilities in rural communities adjacent to federal lands.

Our analysis highlights and explains landscape patterns on national forest lands in the Pacific Northwest that have significant implications for the future of US western forests as well as relevance to current scholarly debates about ‘land sparing’ versus ‘land sharing’ (Muller and Munroe 2014). Our goal is to both address the LSS challenge to better integrate social theory with geospatial analysis (Roy Chowdhury and Turner 2019) and inform discussion of the social-ecological future of this region.

### 2.1. Forest governance in the Pacific Northwest

In the Pacific Northwest (PNW) region of the United States, a large proportion of forest lands—roughly 60% in Oregon and 44% in Washington—is managed by federal agencies, primarily the USFS. For decades after the establishment of the USFS in the early twentieth century, forest management decisions were largely made by USFS rangers empowered to manage according to their understanding of a generalized ‘greatest good’ (Bullis and Tompkins 1989). As an example of what has been termed a ‘dominant federal’ (Babcock 1996) approach to administration, federal foresters typically decided which stands were ready for harvesting and offered them for sale to timber harvesters with only limited avenues for public involvement. The goal was the establishment of a ‘regulated forest’ rationally producing optimal levels of resource outputs (Sample and Sedjo 1996). The resulting patchwork of harvest blocks across the landscape was both planned and anticipated.

The regulated forest vision was complicated by diverse and often dynamic social demands for greater public participation in decision-making and consideration of a wider range of values on federal forestlands, including old-growth forest preservation (Sample and Sedjo 1996). Although laws passed in the 1970s mandated greater public participation and provided new levers for nonfederal actors to contest official decisions, the dominant federal model persisted until the end of the 1980s. It was at this point that national forest managers in the PNW could no longer reconcile an aggressive timber production program with conservation of the northern spotted owl (*Strix occidentalis*, NSO) and other old growth-dependent species, leading to a series of legal and social crises that greatly undermined the agency’s legitimacy as well as

its autonomy (Abrams 2019). Officially, these crises were resolved through the creation of the Northwest Forest Plan (NWFP), a zoning-oriented, ‘land sparing’ approach that established extensive reserve networks on Northwestern federal forestlands but also identified lands where timber production (including via harvest of some old-growth stands) would continue.

Unofficially, these changes also helped to catalyze the emergence, at least in some geographies, of what has been termed ‘social forestry’ (Johnson 2007, Winkel 2014, Maier and Abrams 2018, Abrams *et al* 2019): a networked model of governance in which non-government actors have greater influence and authority as both potential contributors and obstacles to the achievement of agency objectives. Unlike community forestry in the conventional sense, in which some degree of formal authority is vested in local communities (Davis *et al* 2020), social forestry in the United States context refers to a more complex and ambiguous set of institutional pressures that create space for non-USFS actors at various scales to influence the management of federal forestlands. As Abrams (2019) explains, this outcome is the result of the growing reliance of the USFS on external entities for the legitimacy, capacity, and ability to engage in institutional innovation that were once largely monopolized by the agency. As the USFS has lost its traditional autonomy, it has been compelled to engage more substantively with the non-agency actors capable of using various ‘veto powers’ (administrative or legal levers that can stall or block proposed management actions) or, alternatively, of supporting agency activities through the contributions of resources such as funding and political support. Social forestry dynamics have resulted in more partnerships between the USFS and outside entities, often in the form of innovative institutional arrangements such as stewardship contracting to accomplish management goals in a more integrated way (Maier and Abrams 2018, Abrams *et al* 2019, Abrams 2019), yet they also underscore the extent to which non-federal entities can shape forest management through actual or threatened legal and administrative challenges to federal decisions.

### 2.2. The Northwest Forest Plan

The crises brought on by social and legal challenges to prevailing national forest management forced the USFS to make ‘the largest shift in management focus since its creation’ through the adoption of the 1994 Northwest Forest Plan (NWFP or Plan; Thomas *et al* 2006). Described in detail elsewhere (e.g. Steen 2004, Williams 2005), the story of the NWFP is long and complex. Here we describe the Plan briefly and put it into historical context, framing its implementation history as a manifestation of a larger transition from a ‘dominant federal’ model to a social forestry model.

The NWFP is a series of federal policies and guidelines that amended the resource management plans of

**Table 1.** Management expectations for NWFP land use allocations discussed in this paper. Other LUAs include Riparian Reserves (protective buffers along streams, lakes and wetlands); Congressionally Reserved Areas (e.g. wilderness areas, wild and scenic rivers); and Administrative Withdrawn Areas (e.g. for recreation or visual aesthetics).

LUA (% of study area)	Purpose	Management expectations
Matrix (55%)	Allow for production of timber from all types of forest, including older, high-volume stands	<ul style="list-style-type: none"> <li>• Will yield the highest proportion of timber volume</li> <li>• Most of this volume will come from older, high-volume stands</li> <li>• The dominant harvest method will be regeneration harvest (i.e. clearcutting)</li> </ul>
Late Successional Reserve (30%)	Protect and enhance conditions of late-successional and old-growth ecosystems	<ul style="list-style-type: none"> <li>• Will yield a low proportion of timber volume compared to matrix</li> <li>• Most of this volume will come from younger (&lt;80yo), relatively low-volume stands</li> <li>• When harvests do occur, the dominant harvest method will be low-intensity thinning or partial harvest</li> </ul>
Adaptive Management Area (7%)	Develop and test management approaches that integrate ecological and economic goals	<ul style="list-style-type: none"> <li>• A relatively small proportion of timber volume will be produced</li> <li>• This volume will be produced by a mix of both regeneration and partial harvests</li> </ul>

19 national forests and 7 Bureau of Land Management (BLM) districts within the range of the NSO (24.5 million acres in total). Its goal was to initiate a shift in management priorities on federally administered forests from the provision of a predictable and sustainable volume of timber to the protection of late-successional and old-growth forests, and to the maintenance of biodiversity associated with native species and ecosystems, all based in contemporary scientific understandings (Thomas *et al* 2006). It was one of the first government-led efforts to experiment with landscape-scale ecosystem management, seeking to establish a balance between (1) protection of old growth forests and NSO habitat, (2) restoration using active management, and (3) sustainable timber harvest to support local rural economies.

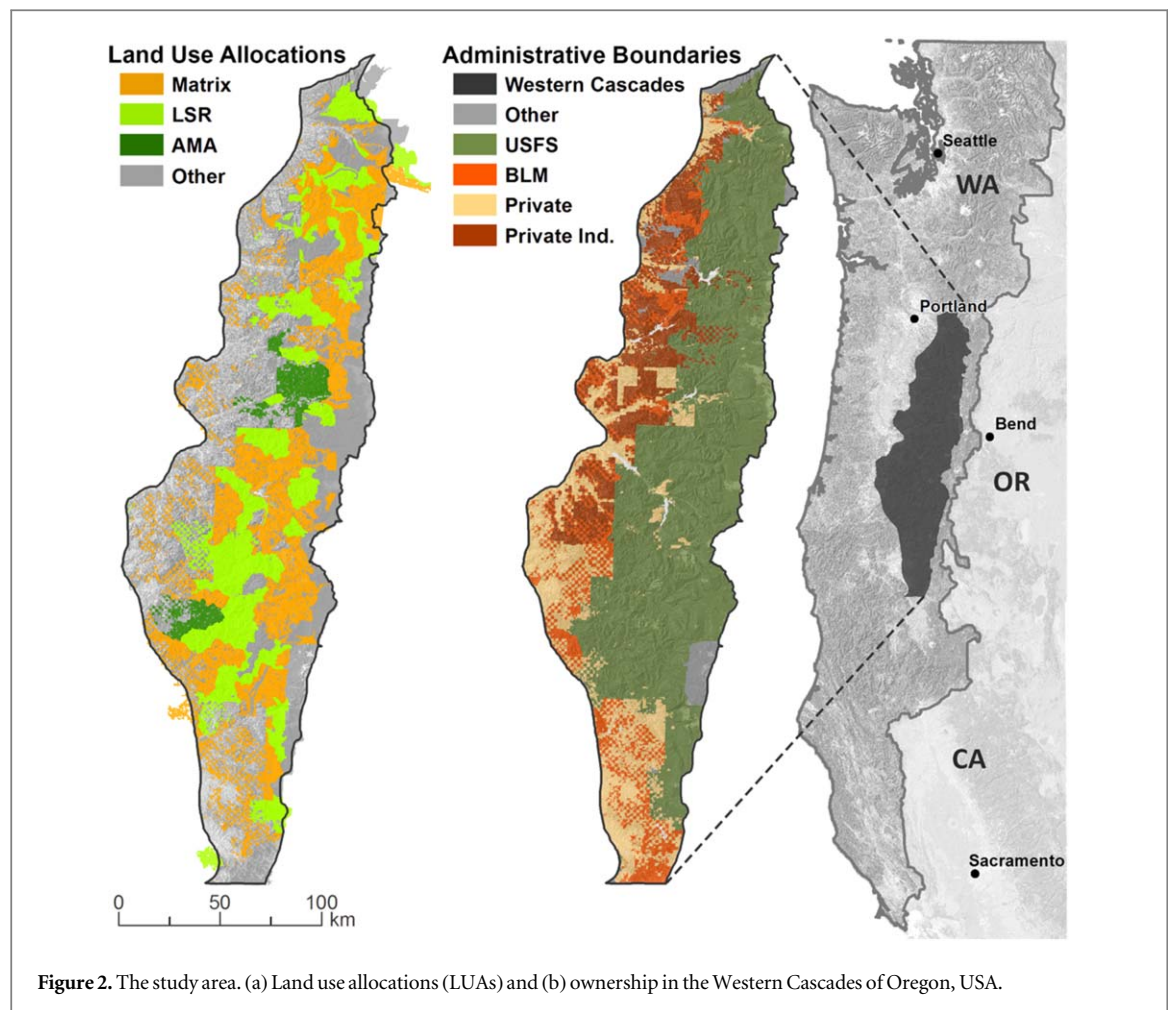
To establish that balance, the NWFP designates a system of land use allocations (LUAs) whose management priorities are described in an attachment to the Record of Decision known as the ‘Standards and Guidelines’ (USFS 1994b, table 1). LUAs are a type of spatially explicit zoning of the forest into geographic areas where single or dominant uses prevail. All national forest and BLM lands within the range of the NSO are assigned to one of seven LUAs. Preservation and restoration of old-growth habitat prevails in Late Successional Reserves (LSRs), while timber production dominates the LUA known as ‘Matrix.’ In a nod to ecosystem management, ten so-called Adaptive Management Areas (AMAs) were established to provide

space to experiment with novel silvicultural techniques that would advance the science of sustainable forest use and integrate ecological and economic objectives.

Twenty-five years after the NWFP’s inception, it is clear that it has not been implemented as expected (Spies *et al* 2018). The most notable departures from policy have to do with the amount of timber harvested on Matrix lands, which comprise 20% of the NWFP area and which include old-growth forest. Of the 1.1 billion board-feet expected to be harvested annually during the first decade following NWFP implementation, only 54% was ever cut (Charnley *et al* 2006) and less than 2% of existing old-growth forest on federal lands at the time of NWFP implementation has been lost to timber harvest (Davis *et al* 2015). Expectations regarding adaptive management have also been mostly unmet, largely due to unanticipated resistance from powerful actors who are skeptical of experiments in highly valued public forests (Stankey *et al* 2003, Moseley and Winkel, 2014).

This disconnect between policy and management can be attributed to the emergence and evolution of social forestry, described above. Links between forest governance and landscape pattern (figure 1) are less predictable now than in the ‘regulated forest’ era, subject to complex social interactions that vary over space and time. Indeed, a recent synthesis of research related to the NWFP’s effects over the past 25 years (Spies *et al* 2018) concludes that implementation of the Plan has





varied across the broad and diverse geography to which it applies. This can be attributed to variation in how NWFP details have been interpreted by different forests, districts, and changing personnel over time, as well as to variation in social consent for various types of harvesting strategies across the region.

While the emergence of social forestry has been described qualitatively (Maier and Abrams 2018) and in terms of indicators (Abrams *et al* 2019), its spatial and temporal dimensions are not well understood. Measured with a consistent tool, spatial variation in NWFP implementation may provide clues into the mechanisms of social forestry and forest governance more broadly (Harris 2018). With its synoptic view and long temporal reach, satellite remote sensing may offer such a consistent measurement tool. When combined with social science methods, causal mechanisms of forest governance may become apparent.

This study builds on current understandings of social forestry with quantitative and geospatial analyses to more clearly elucidate the links, connections, and feedbacks between forest governance and forest landscape pattern and process in the Pacific Northwest (figure 1). Our method uses a blend of remote sensing and qualitative social science to analyze alignments and disconnects between forest policy and forest management in order to examine what social forestry

‘looks like’ on the ground. By tracking and characterizing change over time on federal forest landscapes, our method serves two purposes: it provides clues about the cultural and societal values it reflects, and it provides important landscape scale feedback as to how those values are manifesting in the material world.

### 3. Methods

#### 3.1. Study area

We focused on the Western Cascades of Oregon, one of 12 ‘physiographic provinces’ defined in the NWFP based on common biophysical characteristics. It encompasses  $\sim 30\,000\text{ km}^2$  of mountainous terrain that is 96% forested and 75% federally managed (primarily by the USFS; figure 2). This region contains some of the most productive conifer-dominated forests in the world (Waring and Franklin 1979), and has a high proportion of the remaining old-growth forests within the NWFP area (Davis *et al* 2015). National Forests (NFs) within the Western Cascades include Mt. Hood, Willamette, Umpqua, and the eastern portion of Rogue River-Siskiyou. Historically, the Willamette and Umpqua NF produced high volumes of timber relative to other forests in the NF system and continue to do so today (Rakestraw 1991,

Winkel 2014). The Western Cascades is also a site of research that contributed to the development of the NWFP during the ‘timber wars’ era<sup>4</sup> and continues to inform NWFP implementation (e.g. Forsman 1980, Forsman *et al* 1984, Meslow *et al* 1992, Cissel *et al* 1998, Franklin *et al* 2002, Ackers 2004, Healey *et al* 2008).

### 3.2. Establishing expected patterns of harvest

Based on review of NWFP documentation pertinent to the LUA system—the ROD and accompanying Standards and Guidelines (USFS 1994a, 1994b)—we established expectations for the relative proportions and types of harvest volume if timber management practices were performed strictly according to the priorities prescribed within each LUA (table 1). Expectations were developed only for allocations that allow for timber management: Matrix, Late-Successional Reserves (LSR), and AMA. It is important to note that another LUA—Riparian Reserves—was not included in this study due to inconsistencies in defining and delineating the stream network on which Riparian Reserves are based and varying site-specific definitions (Moeur *et al* 2005).

### 3.3. Mapping actual patterns of timber harvest

Our geospatial analysis linked time-series satellite data with forest inventory data to track patterns of timber harvest at scales commensurate with timber management decision-making. Methods to build the maps used here are described in detail in Kennedy *et al* (2018) and are briefly summarized in the appendix<sup>5</sup>.

### 3.4. Assessing narratives and mechanisms

To explain dominant patterns detected, we used qualitative methods including semi-structured interviews with USFS agency personnel (FS), environmental advocacy group personnel (EA), and scientists (S) active in the Western Cascades. Interviews were transcribed, coded, and analyzed to identify emergent themes related to the causal mechanisms driving spatial patterns of timber harvesting. Methods also included participant observation (e.g. USFS-led field trips, forest collaborative meetings) and document analysis (e.g. National Environmental Policy Act (NEPA) documents, meeting minutes). Our analysis also includes excerpts from oral histories (OH) with members of the Forest Ecosystem Management Assessment Team (FEMAT) conducted as part of the Northwest Forest Plan Oral History Project associated with the Andrews Forest Long Term Ecological Research Program.

<sup>4</sup> During the 1980s and 1990s logging interests and environmental interests fought over the fate of federally managed old growth forests, which comprised critical habitat for the threatened northern spotted owl, in both the courts and the popular press.

<sup>5</sup> Note that appendix includes figures A1–A3.

## 4. Results and discussion: patterns and discrepancies in post-NWFP timber harvesting

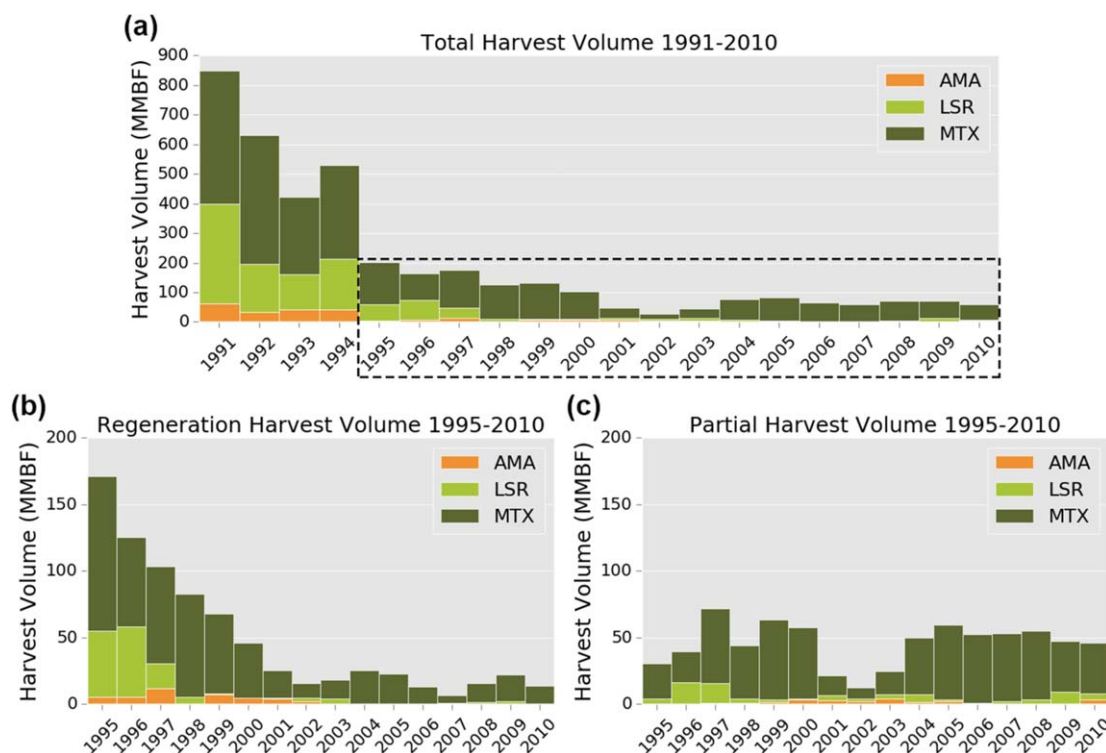
The disconnect between USFS assumptions and expectations and the amount of timber actually harvested during the post-NWFP period is notable and has been analyzed at length elsewhere (Stankey *et al* 2003, Thomas *et al* 2006, Molina *et al* 2006, Shindler and Mallon 2006, Bormann *et al* 2007, Winkel 2014, Maier and Abrams 2018). Our analysis, which builds on these observations with a quantitative analysis, focuses on timber harvest patterns by both LUA and harvest type, distinguishing between regeneration harvest and partial harvest.<sup>6</sup> This approach allows us to evaluate our observations against the expectations established above.

Of the total ~1.5 billion board feet harvested in the Western Cascades in the post-NWFP period of observation (1995–2010), Matrix lands contributed 81%, which meets our expectation that most timber volume would come from this LUA (figure 3(a)). The expectation laid out by the NWFP regarding harvest method on Matrix lands was partially met, in that a majority of timber volume was extracted by regeneration harvest, but only for the first 9–10 years of NWFP implementation (figures 3(b) and 4); by 2002, timber management practices began to shift toward partial harvest, and annual harvest volume remained below 90 million board feet through the rest of the observation period (figures 3(b) and (c)). From 2002 to 2010, partial harvests on Matrix lands accounted for 68% of the ~700 million board feet total, highlighting that timber resources on Matrix lands have not been extracted to the extent allowed by the NWFP, nor by the expected harvest method. Regarding LSRs, our expectations for overall harvest volume were met in that they yielded much less than Matrix lands. However, given that LSRs occupy over 30% of the Western Cascades, the proportion of volume yielded is surprisingly low.

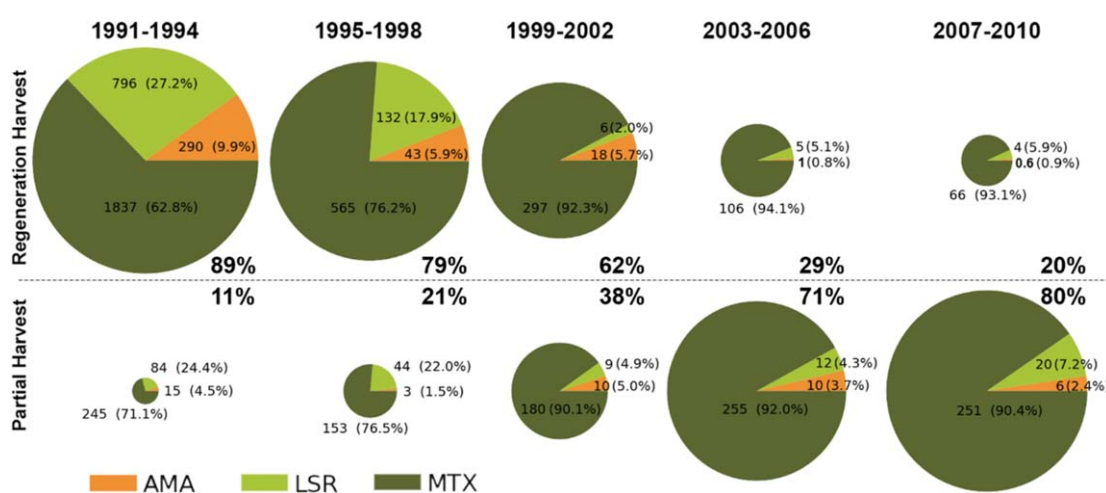
Somewhat more striking patterns emerge if timber volumes are aggregated into four-year periods (figure 4). Interestingly, despite their significant difference in total area, volumes extracted from AMAs and LSRs by partial harvests were nearly on par for the 1999–2002, 2003–2006 and 2007–2010 aggregate periods.

Our observations for AMAs show very low timber volume extraction, which was expected given their low proportional area. Harvesting on AMAs seems to have been prevalent in the first decade following NWFP implementation, but no regeneration harvests occurred after 2002 (figures 3(b), (c); 4). This may be a

<sup>6</sup> ‘Regeneration harvest’ as used in this paper refers to silvicultural treatments that remove all or nearly all trees in a given patch. ‘Partial harvest’ can be thought of as synonymous with thinning in plantations or previously harvested stands.



**Figure 3.** Annual proportions of timber harvest volume in million board-feet (MMBF) for land use allocations where timber management is typically permitted: adaptive Management Areas (AMA), Late-Successional Reserves (LSR), Matrix lands (MTX). (a) Total harvest volume for the full 1991–2010 period, (b) volume from regeneration harvest only in the post-NWFP period, (c) volume from partial harvest only in the post-NWFP period. Note that (b) and (c) are subsets indicated by the dashed rectangle, which facilitates comparison between regeneration harvest and partial harvest volumes in the post-NWFP period.



**Figure 4.** Harvest volumes on USFS lands in the Western Cascades aggregated in four-year periods, separated by harvest type (regeneration harvest (top), partial harvest (bottom)) and NWFP land use allocations (LUAs), which include Adaptive Management Areas (AMA), Late Successional Reserves (LSR) and Matrix (MTX). Values in pie chart slices indicate the total volume of harvest (MMBF) and the proportion of the total for that period represented by that LUA. Note that pie charts are scaled according to the proportion of total harvest volume extracted by each harvest type in a given period. Overall total volume of harvest in partial harvest is substantially less than in the regeneration harvest.

reflection of the widely perceived failure of the AMA concept in the NWFP (Stankey *et al* 2003).

In sum, our geospatial analysis shows that some expectations of the NWFP *have* been met: timber harvesting methods in LSRs were primarily partial harvests, and total harvest volume declined steeply across

all land use allocations compared to the pre-NWFP time period. Other expectations *have not* been met: overall timber harvest volume was significantly lower than expected, especially in Matrix lands where timber production is an intended management priority; and there was far less regeneration harvest across all LUAs



than anticipated. Over the course of the 1991–2010 study period, we observe a near reversal of timber harvest method from regeneration harvest to partial harvest.

These findings reflect the ways in which the USFS eventually came to terms with the new political reality under social forestry, where segments of the public and the litigators that represented their interests wielded unprecedented power. Because the law prevented them from going into older stands until they complied with Survey and Manage protocols established after the NWFP was adopted,<sup>7</sup> the agency, by necessity, had to explore other areas to harvest. Science conducted at the HJ Andrews Experimental Forest in the 1990s informed a new approach to producing timber volume without using regeneration harvest techniques in older stands. The Young Stand Thinning and Diversity Study examined the effects of alternative intensities and patterns of thinning of young, even-aged plantations on ecological, social, and economic responses (Cascade Center for Ecosystem Management 1996, Davis *et al* 2007).

Environmental advocates, accustomed to opposing any timber sale, eventually came to support this new approach in the early 2000s, with some calling it ‘a win-win opportunity’ (EA4). They described their strategy as distracting the USFS from older stands by being amenable to thinning in plantations.

It started out as debate within the environmental community, like are we really okay with commercial logging of our public lands? Some of us were arguing, ‘Yeah. These are tree farms that are not natural, and we could put them on a trajectory [toward old growth conditions].’ And so I was kind of making the case to my fellow conservationists, ‘Let’s embrace this opportunity, and we can keep the agencies distracted from the old growth logging by thinning the plantations.’ (EA4)

Over time, the USFS began to interpret the NWFP as a mandate for preservation of old growth and restoration of previously manipulated forests to a more

natural state. Any logging would have to be justified in terms of such restoration, not merely in terms of timber production. With consistent pressure from environmental groups, the USFS came to see their timber program as one of thinning in plantations younger than 80 years old. Speculating on the origins of the unwritten rule that stands older than 80 years would generally be off-limits for harvesting, one USFS employee explained,

I think that 80 really comes from a sense of not only the biology, but it’s also a time before there was active management on federal lands. So they [environmentalists] were trying to capture if people have monkeyed around with it once—ok you can go back and continue to influence that stand, but if you have not [managed it previously], do not [manage it now]. (FS5)

As this quote suggests, by about 2002 (after a series of Survey and Manage lawsuits) thinning in young plantations became the new normal, the beginning of a ‘truce’ with the environmental groups, who called this unwritten arrangement their ‘happy place’ (EA3). Social license for clearcuts or regeneration harvest has been largely non-existent for the past two decades and the USFS has largely stopped attempting regeneration harvesting in older stands due to the social forestry dynamics described above. As one USFS employee stated, the threat of litigation keeps them from venturing out of that space.

I think right now most of our projects are designed to get through without litigation. I mean we set it up, because we do not want to waste your money. If I went out and said let’s do three clearcuts because it’s the best thing for this watershed, then it is just going to get sued. Why should I waste your tax dollars? (FS5)

What these dynamics reveal is that the LUAs are not serving the purpose imagined, which was to provide a zoning system that would determine what kind of harvesting would be done in various zones and forest types. Instead, partial harvest of younger stands is the dominant and consistent approach across Matrix, LSR and AMAs.

There’s a bunch of plantations in Matrix, and there’s a bunch of plantations in LSRs, and they’re all getting thinned. So in the short term, we’re managing somewhat similarly in all the land allocations. (EA4)

<sup>7</sup> While actors associated with environmental advocacy organizations already had a large number of potential veto levers to pull given the various issues involved (e.g. owls, salmon) and the network of laws and regulations including NEPA, the viability clause in regulations for the National Forest Management Act, and the ESA, the NWFP unexpectedly gave them an even more effective lever in its ‘Survey and Manage’ provisions. After the scientists in charge of developing the NWFP put the finishing touches on their landscape scale, ecosystem-based plan for integrated conservation and development, they handed it off to another team of scientists who were tasked with developing implementation guidelines that fundamentally changed the NWFP from a ‘coarse filter’ approach to a ‘fine filter’ approach and ‘made it difficult to achieve some of the Forest Plan’s main goals’ (OH-Franklin).

Basically, the zoning, all parts of it, are imperfect, and the national forests are being managed without the distinctions between the different zones that were envisioned, especially those three. (OH-Johnson)

In sum, today's landscape pattern is a reflection of the 'truce' or 'happy place' that USFS and non-government veto actors have reached; an unwritten zone of agreement.

But the national forests, realizing they could not implement the harvest schedule with [the NWFP], they shifted mainly to thinning in plantations. The national forests have, depending on where you are, another 20–30 years of that. They do not have the notion of [the NWFP] that you would have sustainable timber harvest levels forever, long-term sustained-yield. That idea is pretty much gone. (OH-Johnson)

As the quote above suggests there is growing recognition that the current strategy is not sustainable in the long run, since there is a finite supply of previously logged plantations to thin. USFS employees refer to the coming 'thinning cliff' where harvest rates will drop off significantly when the last plantation is thinned and social license to go into older stands is still lacking (FS2, FS3, FS4, FS6). This raises fundamental and even existential questions about the future of national forests in this region. Our conceptual framework (figure 1) suggests that the new landscape patterns resulting from the approach to NWFP implementation described here combined with a rapidly changing social context and new organizational dynamics are currently creating the conditions for the emergence of new forms of forest governance involving novel manifestations of social forestry.

From an ecological standpoint, perceptions of an increasingly homogeneous landscape and a declining inventory of early seral habitat have led some scientists to call for a new type of regeneration harvesting associated with ecological forestry and managing for complexity and resilience in the context of a changing climate (Franklin and Johnson 2012, Puettmann *et al* 2009). National politics may be aligning with such calls, as the past year has seen increasing pressure from Congress and the White House to increase timber production on federal forestlands while streamlining environmental permitting processes, which may reduce veto opportunities and with it the influence of non-federal stakeholders (Abrams 2019). USFS planners are newly emboldened to 'get the cut out,' gearing up to address the 20 year 'backlog' of deferred harvesting on Matrix lands (FS6). This will involve offering sales in older stands with prescriptions for the kind of

regeneration harvests originally imagined in the NWFP (EA4, FS6). These dynamics may result in a new wave of resistance and litigation from the environmental community focused on old-growth forest preservation, i.e. a continuation of the 'land sparing' approach; but some, including a FEMAT team member, question the effectiveness of that approach.

In retrospect, we made the mistake of continuing the same kind of division people have done forever...you cannot divide up the world into reserves and timber production areas, it does not work anymore on federal lands. It just does not. [The NWFP was] flawed in that the 'reserves' needed a lot of harvest in the plantations, and to contribute a fair amount of harvest as of this day, but we never counted it. And the 'Matrix,' federal lands just do not have timber production areas anymore. There [are] so many considerations on every acre, you just do not have those areas that we imagine where you just can schedule an allowable cut and be sure of it. So, that's a change in my thinking, that really is... [the idea that] economic considerations were sufficient to justify harvests. Unless you provide an ecological benefit, you're not going to have a stable timber harvest program. (OH-Johnson)

Reflecting an alternative approach, the region is seeing growing interest in collaborative, community-based planning involving integrated, landscape scale strategies in which restoration and production are co-located, i.e. 'land sharing' (Grau *et al* 2013, Nagendra *et al* 2013, Muller and Munroe 2014, Charnley *et al* 2014, Abrams *et al* 2019). The USFS, and Region 6 (Oregon and Washington) in particular, has been investing in improving community relationships, e.g. through regular participation in local, place-based forest collaboratives (Davis *et al* 2017). Better working relations between the USFS and environmental organizations have created space for small-scale experiments with regeneration harvesting in younger stands, and even some ecological forestry (Franklin and Johnson 2012) in older stands that could lead to a redefined 'happy place' and expanded zones of agreement in some contexts. Trust-building activities including third-party monitoring of the ecological effects of different harvesting strategies with a promise that ecological and social learning will result may produce a new wave of social forestry dynamics (Nelson *et al* 2017).

Forest governance in the region seems poised at a juncture with the potential for radically different future scenarios. In one scenario, the USFS continues

to thin remaining plantations and then transitions into more of a preserve model, focused on maintenance, recreation, and firefighting (FS2, FS6). In another, a combination of legal reform that makes environmental litigation more difficult and better relations between the USFS and potential veto actors results in a revitalized timber-producing agency and, perhaps, an integrated landscape-scale approach to conservation.

## 5. Conclusion

This paper demonstrates that a remote sensing-based approach can provide new insights into trends in change over time in forest landscape pattern and process as well as links and disconnects between forest policy and forest management. We used this new approach to identify and characterize spatial patterns of timber harvesting over the 20 year period since the NWFP was implemented. We used qualitative data to provide context for the quantitative data and shed light on causal mechanisms and links between forest governance and forest landscape pattern and process; not only how governance plays out on the land, but how the changing landscape (e.g. intact forest to a mosaic of clearcuts; clearcuts to young plantations) influences governance via environmental perceptions, and structures and networks associated with social forestry (collaboratives, NEPA processes, USFS planning processes). Interviews provide insights into how veto actors understood and responded to landscapes resulting from perceived excesses of clearcutting, and how they organized to prevent such land management from occurring again.

We frame the geospatial analysis of landscape change as evidence on the ground of the emergence of social forestry involving place-based negotiations between the federal government and local veto actors. Our results suggest that the acceptability to veto actors of particular practices in particular forest types—rather than the LUAs and direction contained in the NWFP—were the drivers of forest management and subsequent landscape pattern and process in the study area. The concept of ‘social forestry,’ which reflects the heightened role of social consent in federal forest management, helps explain why the NWFP has not been implemented as planned, as evidenced by geospatial analysis of expected and actual harvest patterns in different LUAs.

This mixed methods approach contributes to scholarship in LSS by elucidating links between social and ecological phenomena and cross-scale interactions between local, regional, national, and global phenomena that influence land use decision-making. USFS actors working at the district level are making decisions regarding timber harvesting with pressure from leaders above to achieve targets, as well as from

local veto actors who want to prolong the ‘truce’ where thinning in young stands is the main activity.

Future research should experiment with new approaches to engaging practitioners and stakeholders in the co-design of participatory futures scenario analysis involving environmental and social sciences ‘to (re)frame scientific problems and implement user- as well as science-based solutions’ (Roy Chowdhury and Turner 2019). Such research could integrate explorative scenarios that reflect possible outcomes with normative visions that identify desired outcomes in order to co-produce new knowledge regarding locally appropriate zones of agreement. There is a need to co-design and pilot new land systems that incorporate collaborative monitoring and ongoing social learning into timber harvesting—to better fit local interests and demand for ecosystem services. Such an approach has the potential to facilitate social learning and the emergence of adaptive governance for more resilient forest landscapes in the future.

## Acknowledgments

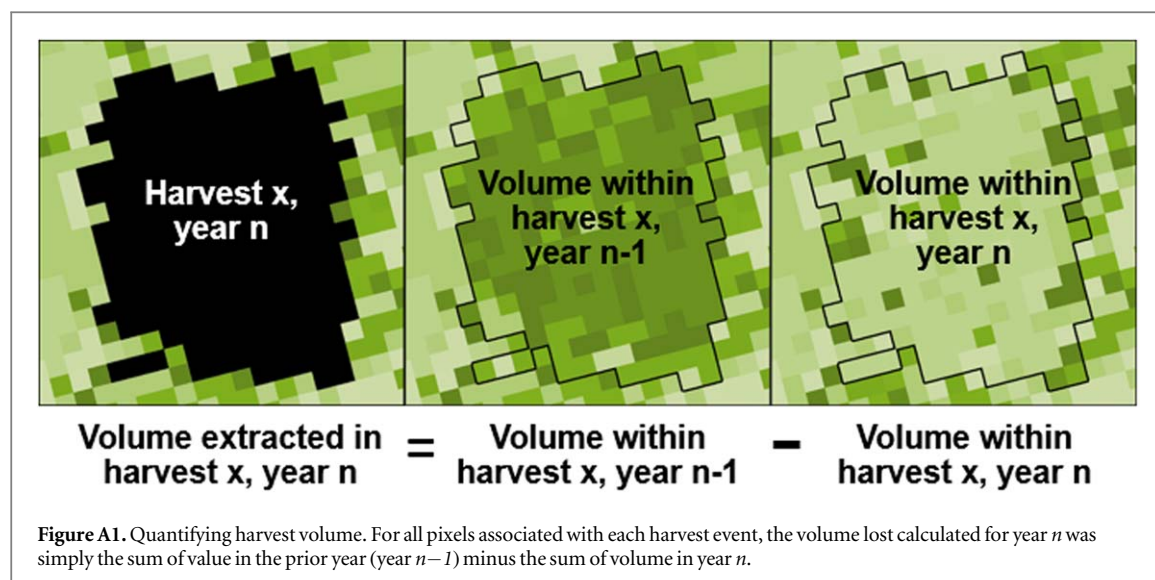
This work was funded in part by the National Science Foundation Long Term Ecological Research Program, Grant # DEB1440409. Special thanks to LTER colleagues whose ideas and research informed much of this work, and to Willamette National Forest collaborators and stakeholders associated with the McKenzie Watershed Stewardship Group, whose participation enabled this research.

## Appendix. Supplement to Methods section

### Mapping actual patterns of timber harvest

Our geospatial analysis linked time-series satellite data with forest inventory data to track patterns of timber harvest at scales commensurate with timber management decision-making. Methods to build the maps used here are described in detail in Kennedy *et al* (2018) and are briefly summarized here.

*Remote sensing.* The core of the remote sensing method is temporal segmentation of the Landsat satellite image archive using the LandTrendr algorithms (Kennedy *et al* 2010). Temporal segmentation allows both the capture of change and the stabilization of noisy data across time. The latter provides imagery used in statistical modeling to create consistent maps over time. The former allows mapping of forest disturbance (Kennedy *et al* 2012), which can then be matched with expert interpretation and machine learning to ascribe labels to each forest disturbance (Kennedy *et al* 2015, 2018). For this study, we focused on disturbances labeled as ‘clearcuts,’ here defined as full removal of all trees from a site, and ‘partial harvest,’ here defined as any incomplete removal of trees from a site. All maps



derived from these remote sensing data had grid cells with a spatial resolution of 30 by 30 m.

**Linkage with forest inventory plots.** Remotely sensed images simply measure reflected light, and must be linked with actual observations to be converted into meaningful measurements. We used the Gradient Nearest Neighbor (GNN) approach to make this conversion, which was developed and is heavily utilized in the region of study (Ohmann and Gregory 2002, Ohmann *et al* 2012, Bell *et al* 2015). GNN matches stabilized satellite imagery with other spatial data layers in a multivariate dataspace, then co-locates USDA Forest Inventory and Analysis (FIA) plot data in that same dataspace, and imputes to each pixel an FIA plot measurement set based on that pixel's similarity to the plot. It allows flexible mapping of any metric that can be calculated from FIA plot measurements. Here we calculated aboveground forest biomass per cubic meter as per Kennedy *et al* (2018), then converted to board feet by dividing by 423.776. We created maps of standing forest volume for every year between 1991 and 2010.

**Mapping harvest volume.** To quantify the volume lost during harvest, we simply identified pixels mapped as harvest (by clearcut or partial harvest type), and subtracted the mapped forest volume before and after the harvest (figure A1).

### Comparing observed and expected harvest patterns

**Forest scale.** To assess whether Landsat-based mapping can reliably characterize landscape outcomes, we needed to confirm that estimates of forest harvest volume mapped from space were commensurate with harvest estimates derived from on-the-ground records. Although our overall study area covered the entire Western Cascades region, the only national forest fully contained in that region was the Willamette NF (WNF). Thus, we obtained estimates of forest volume at the

WNF level. Separately, we summarized all of our mapped harvests within the spatial bounds of the WNF by year. Tracking each by year allowed us to evaluate whether our estimates were of similar magnitude and whether they rose and fell over time in a manner consistent with the paper records.

To understand how observed harvest volumes related to expectations set forth in the NWFP, we downscaled the expected harvest volumes for the whole NWFP, laid out in the Record of Decision as *probable sale quantities* or PSQ, to the area specifically within the WNF and compared them to our observed harvest volumes for the whole WNF.

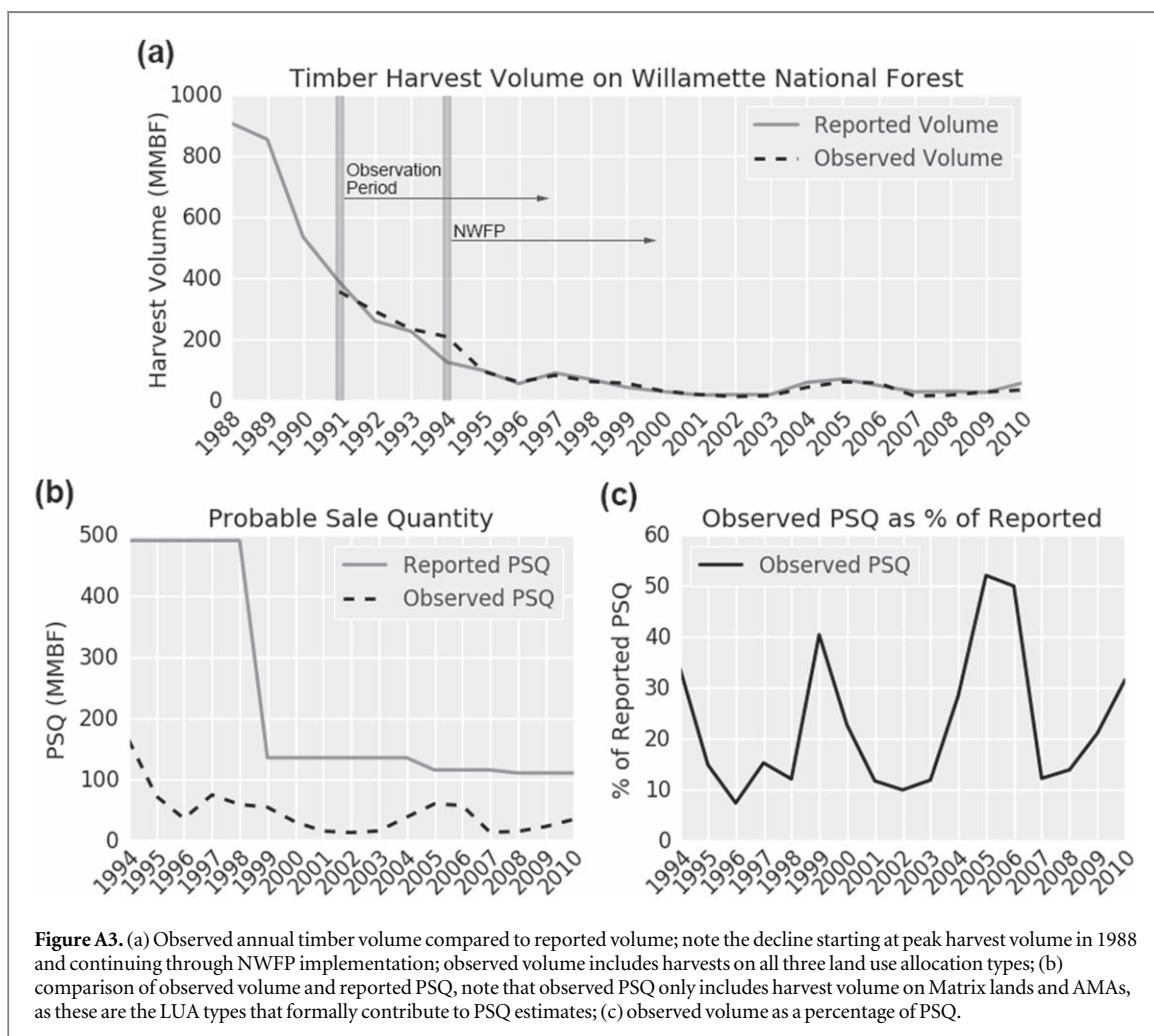
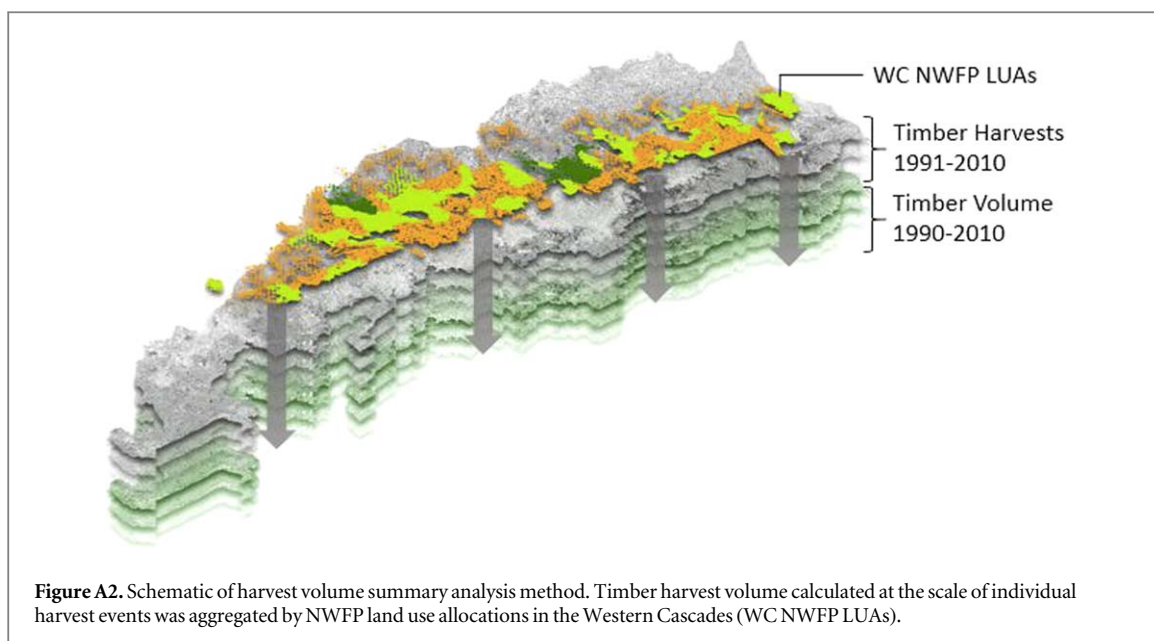
**LUA scale.** To evaluate our expectations of relative roles of harvest across LUAs (table 1) we summed harvest volume by LUA and forest harvest type (clearcut versus partial harvest, as predicted by remote sensing) by year across the entire Western Cascades study area (figure A2) and summarized across years and types graphically.

### Assessing the effectiveness of this approach

Our method of calculating timber harvest volume produced results that track well with reporting by WNF for the 1991–2010 observation period (figure A3(a)). Following several decades of high timber volume production, a steep decline began in 1988 that was attributable to a series of lawsuits brought against federal agencies over inadequate protection of the northern spotted owl (NSO) and its habitat, the 1990 listing of the NSO as threatened under the Endangered Species Act (ESA), and the ensuing injunction by US District Judge William Dwyer in 1991, which effectively halted timber harvest on federal lands in the region. Exogenous factors related to technology and globalization occurring at regional and global scales also contributed to the decline (Robbins and Barber 2011, Winkel 2014).

Following implementation of the NWFP in 1994, timber harvest volumes were expected to differ from





PSQ because federal agencies needed time to complete required surveys and assessments in order to prepare timber sales consistent with the NWFP standards and guidelines. In 1995, agencies were expected to offer timber sales amounting to 60% of PSQ; 80% of PSQ in

1996; and volumes equivalent to PSQ thereafter (Grin- spoon *et al* 2016).

On the WNF, the volume harvested from Matrix lands and AMAs reached a peak of only 52% of PSQ over the post-NWFP period (figure A3(c), year 2005).



The discrepancy between PSQ and the observed volume harvested reflects some of the assumptions on which PSQ estimates were based: (1) during the first decade, the USFS anticipated that about half of the total harvest would come from forests greater than 200 years old (generally considered old-growth); (2) the main harvest method would be regeneration harvest (USFS 1994a).

## Data availability statement

The data that support the findings of this study are available upon request from the authors.

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