Forest Ecology and Management 529 (2023) 120738

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Perspectives: Ethnoforestry, ecosystem wellbeing, and collaborative learning in the Pacific Northwest

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A R T I C L E I N F O

Keywords:
Adaptive management
Community engagement
Early seral habitat
T3 Watershed Experiment

A B S T R A C T

The field of forestry has changed substantially in the last 100 years as scientists and managers have grappled with ways to best manage forests and adapt to changing knowledge, needs, and climates. We believe a path forward may be through using an ecosystem wellbeing framework where both community and environment wellbeing must be achieved to meet ecosystem wellbeing goals. To achieve this, we used a collaborative learning process where managers, researchers, tribes, and stakeholders engage with one another to ask and answer questions about options and effects of management choices. We also propose the use of the field of ethnoforestry, or a people-focused forest management, as the necessary way to apply the input, knowledge, and feedback gained through the collaborative learning process. We offer two examples of ways ethnoforestry is being tested on the Olympic Peninsula through an operational-scale experiment that seeks to meet the needs of communities and the environment, while producing revenue for trust land beneficiaries and meeting late seral habitat requirements.

1. Introduction

Forest management over the last 100 years has seen significant changes, from operational equipment to philosophy. In the last few decades, there have been many meaningful attempts to change and update practices, such as the steady development of new milling, harvesting, and other technologies. Furthermore, some additional set-aside reserves have been added to public lands, and agencies have continued with projects to respond to widespread and intense wildfires in dry forests. However, what has been lacking are important changes in operational-scale prescriptions across ownership types. On public lands, from standard National Environmental Policy Act (NEPA) reviews to stakeholder engagement, societal involvement has been changing rapidly to include different forms of adaptive management (Walters 1986) and collaborative learning (Daniels and Walker 2001).

As forestry is thrust into the global limelight around climate adaptation, and with major climate and social changes afoot, increasing collective capacity to adapt forestry to meet these challenges is necessary. Therefore, creating frameworks focused on building and applying adaptive capacity quickly is imperative.

In this paper, we explore an ecosystem wellbeing framework that considers both community and environmental wellbeing as integrated and integral to the wellbeing of the forest ecosystem.

To understand what contributes to the livelihood and wellbeing of communities, we are using a form of collaborative learning where managers, researchers, tribes, and stakeholders are all involved in the development and implementation of management as described by Daniels and Walker (1996, 2001).

Finally, we explore how the emerging concept of ethnoforestry might be applied to smooth forestry's evolution going forward. Specifically, we focus on the intersection of the ongoing revolution of stakeholder engagement connected to needed innovation in land management practices. We apply our variant of ethnoforestry by seeking to integrate and apply concepts of sustainable development, adaptive management, and collaborative learning to the Washington Department of Natural Resources (DNR) trust lands on the Olympic Peninsula, WA through an operational-scale study called the Type 3 Watershed Experiment. This ownership and its legal, environmental, and social setting provide a new perspective that allowed us to develop an innovative approach that we believe may have value especially for other state and federal lands.

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https://doi.org/10.1016/j.foreco.2022.120738
Received 11 August 2022; Received in revised form 18 November 2022; Accepted 12 December 2022

2. Background

2.1. Forest management in the Pacific Northwest

In the Pacific Northwest, the ways in which federal and state lands are managed and operated changed significantly about 30 years ago with the listing of the northern spotted owl (*Strix occidentalis caurina*) and marbled murrelet (*Brachyramphus marmoratus*) as endangered species. The listing contributed to an injunction on federal lands in the early 1990s and the path forward emerged as the Northwest Forest Plan (the Plan), impacting management of nearly 25 million acres of federal lands. Other forest management plans were generated for state lands, with the similar goal to protect threatened and endangered species and their associated old-growth or late seral and riparian species and habitat, with variably reduced timber production. Additionally, other resource management plans have been created for tribal lands held in trust by the federal government and evaluated by the Indian Forest Management Assessment Team (Gordon et al. 2013b).

During this period, there has been a continued unfolding of more extreme weather events, greater intensity of disturbance, diseases, and wildfire, and changes in our understanding of how forests and rural communities work—all calling out for policy changes. Adaptive management has often been seen as a way to overcome these uncertainties, where new and innovative prescriptions can be created, implemented, and studied, and where learning is a main objective, and the outcomes address key uncertainties (Walters 1986).

Adaptive management was a key tenet of the Plan and was envisioned as a way for policies and practices to evolve to changing conditions through structured learning (USDA Forest Service 1994, Spies et al. 2018). Few applications, however, ended up testing major policy alternatives (Bormann et al. 2007) due to: 1.) limited resources or inclination to implement these types of experiments (Stankey et al. 2003); 2.) limited capacity to create an organizational learning culture (Brown and Squirrell 2010); and 3.) a lack of adoption of the study results into management policies and prescriptions. Although several refinements and alternatives to adaptive management have been proposed to address these issues, including active adaptative management (Larson et al. 2013), options forestry (Bormann and Kiester 2004), and collaborative adaptive management (Colfer 2010, Barrett et al. 2021), there is still limited operational-scale research that addresses uncertainty. In 24 years under the Plan, Spies et al. (2018, 2019), concluded that adaptive management has been slow to respond to specific challenges, including climate change (and its effects on wildfire regimes), loss of habitat diversity, degradation of habitat quality for vulnerable species, and greater recognition of diverse public values. A decline in early seral habitat is a notable example.

There have been difficulties addressing the sharp declines in early seral habitat on both public and private lands in the Pacific Northwest (Phalan et al. 2019). The Plan's focus on late seral reserves and the forest industry's effectiveness in limiting competing vegetation in short-rotation conifer stands led to a decline in early seral vegetation, a stage that is typically dominated by sun-tolerant graminoids, forbs, shrubs, and hardwoods, critical for the health and population growth of ungulates and other wildlife (Cook et al. 2013, Ulappa et al. 2020). Declines in the early seral stage has had ripple effects for all aspects of ecosystem wellbeing, limiting the amount of available forage and plant material for wildlife, and tribal and rural communities.

2.2. Collaboration

Throughout this time period, there has been an explosion of ideas, frameworks, and practical applications surrounding improving forest management in the United States and elsewhere through collaboration. While this paper is not intended to present an exhaustive list, we would like to highlight some notable examples.

First, the concept of social learning emerged several decades ago and had been used in a myriad of fields, including natural resource management. As with many widely used terms, there are multiple definitions applied, but some commonality between these includes stakeholder participation where learning is occurring (Reed et al. 2010). Social learning has been used in the collaboration and natural resource context, intersecting with collaborative management, adaptive management, adaptive co-management, and others (Cundill and Rodela 2012). Starting in the early to mid 1990s, collaborative learning provided an innovative framework for collaboration in natural resource management that built off principles within social learning. It emphasizes systems thinking, conflict resolution, and learning from one another (Daniels and Walker 1996, Walker and Daniels 2019). Collaborative learning has been used extensively as a framework to guide collaboration efforts (e.g., Blatner et al. 2001).

One example of the principles of collaboration being applied to natural resources would be the creation of the Collaborative Forest Landscape Restoration Program (CFLRP) in 2009. The CFLRP funds landscape-scale collaborative projects that work on a broad range of sustainability and restoration goals (Schultz et al. 2012). Oftentimes, this is centered around wildfire mitigation, a topic that has united collaborative groups due to the pressing and tangible nature of the issue. An assessment of the 2020 fiscal year projects showed high demand to participate in this program, with many proposals in regions that had never applied for this funding before (Kooistra et al. 2022). These projects are restoration focused and do not typically include formal research projects.

In addition to CFLRP, there have been numerous other examples of formal and informal collaboration occurring on a range of spatial and temporal scales that address natural resource issues through the participation of engaged stakeholders (Margerum 2007). Examples include public agencies engaging in collaboration including between tribes (Charnley et al. 2007, Donoghue et al. 2010) and through collaborative groups that advise and build consensus around management in National Forests (Davis et al. 2017). Most often, stakeholders are not the final decision makers, but rather give input (Butler 2013). The Forest Service planning rule of 2012 opened the door to trying more collaborative approaches that includes additional public involvement (Ryan et al. 2018). Participants in National Forest collaboratives are convinced that this has reduced lawsuits, but some wonder if their de facto consensus model gives individuals within the collaboratives veto rights over significant changes, forcing everyone to fully agree on each part before anything can be initiated (Flitcroft et al. 2017, Urgenson et al. 2017).

Though there has been collaboration, lawsuits against state and federal agencies that manage forests are still common (Keele et al. 2006). Inconsistencies between environmental laws, precedents based on limited perspectives, and disillusionment with public input has seemingly led to lawsuits as the main change mechanism (e.g., the Plan). Courts, however, are not well suited, nor have much capacity, to manage forests. In some cases, litigants can reduce economic viability of management by slowing decisions, and on federal lands can even collect large legal fees by winning narrow lawsuits that sustain their staff. By design or accident, this often appears to intimidate decisionmakers. With increased collaboration and buy-in from the beginning of a project, there is a potential to reduce the number of lawsuits and satisfy a diverse array of stakeholders.

2.3. Ethnoforestry

The concept of ethnoforestry is largely one that has been used in research in India and other parts of Asia, and often centered around agroforestry. Limited work has been published in North America. However, this concept certainly has implications and usefulness in Pacific Northwest forestry. Ethnoforestry has previously been defined as "the creation, conservation, management, and use of forest resources, through continued practice of customary ways by local communities" by

Fig. 1. The ecosystem wellbeing framework that gives equal consideration to both community and environment wellbeing, focusing on the inherent interactions between these two elements where learning occurs.

Dr. Deep Pandey, one of the first scholars to write and publish on this topic in the late 1990 s (Pandey 1998). Many other researchers have applied ethnoforestry to their research and work, focusing on using input and knowledge from local communities in forests and resource management (da Silva et al., 2011, Prabakaran et al. 2013). In our context in the Pacific Northwest, we see ethnoforestry as not exclusively using 'customary ways' but also new and innovative approaches that have not been attempted.

The application of a people-oriented forestry is not new. Indigenous communities have been actively managing land since time immemorial to produce food, plant material for crafts such as basket weaving, for timber production, and for a wide range of cultural values using their expert and traditional ecological knowledge, for example using fire to maintain early seral and open conditions to promote culturally important species such as camas (*Camassia quamash* (Pursh) Greene) or beargrass (*Xerophyllum tenax* (Pursh) Nutt.) (Turner et al. 2000, 2009, Shebitz 2005, Charnley et al. 2008, Gordon et al. 2013b). Many indigenous communities use a holistic approach to management that avoids creating conservation or cultural area preserves. Instead, their prescriptions actively manage their lands for cultural resources and other values (Gordon et al. 2013a). Gifford Pinchot's vision for the U.S. National Forests of "the greatest good for the greatest number, in the long run" is another reflection of a strong people-oriented goal.

3. Looking forward to the future of forest management

In this paper we ask, what if increased collaboration, engagement, and structured learning could be applied to forestry to enhance our adaptive capacity into the future? As we consider a future for forestry that is more collaborative, inclusive, and adaptive, we believe one solution lies in implementing the following framework and process, that serve as a foundation for a field that reorients collaboration and learning to be central to sustainable forest management.

3.1. Ecosystem wellbeing framework

There are many different social-ecological models and frameworks that have been used to address natural resource and forestry issues that this research builds upon. The two that most inspired our work are: 1.) the human-forest ecosystem model by Olson et al. (2017) that advocates for management prescriptions incorporating both scientific insight and social and economic viewpoints; and 2.) the human-ecosystem model by Burch et al. (2017) that highlights specific critical resources necessary to support a social system. Although we find great value in these frameworks and understand that there are numerous other published models and frameworks that address wellbeing in some capacity (e.g., Millennium Ecosystem Assessment 2005, Villamagna and Giesecke 2014, Breslow et al. 2016), we propose a simple ecosystem wellbeing framework that is holistic yet easy to visualize and apply (Fig. 1).

Our ecosystem wellbeing framework gives equal consideration to both community and environment wellbeing, understanding that they are inherently linked and interact with one another. Similar to the other foundational models, people are a part of the ecosystem. In order to truly achieve ecosystem wellbeing, both community and environmental wellbeing need to be considered simultaneously and with equal seriousness. This stands in contrast with some other frameworks that consider an ecosystem detached from nearby people and communities, or that demand environmental wellbeing be achieved before community wellbeing can be fully addressed (or vice versa). When the components of this model are interactive, a focus on formal, structured learning becomes the key to success. Achieving community wellbeing, and by extension ecosystem wellbeing, starts with a process of engaging people.

3.2. Harnessing collaborative learning

There are certainly numerous approaches to collaboration in areas of the Pacific Northwest and beyond. However, we are focused on the west side of the Olympic Peninsula where formal collaboration has not been done on state lands. This area differs from the rest of the state in many ways, both ecologically and socially. The west side of the Olympic Peninsula is situated in a temperate rainforest, where the region receives well over 100 in. of rain per year and the main disturbance agent is windthrow. Additionally, rural communities in this area suffered tremendously with the rise and fall of the timber industry in the 1990s and are still recovering. Many tribal communities have reservation lands in this region that are remote and have different needs from public lands management than tribes near urban areas. These factors led us to use a form of collaborative learning to engage managers, researchers, stakeholders, and tribes (Daniels and Walker 1996, 2001).

We believe that a collaborative learning process is well suited to successfully achieve ecosystem wellbeing in our setting. This term has been defined many ways by researchers in the last 30 years. In our context we see collaborative learning as an iterative process in which (a) natural resource managers including tribal and other leaders; (b) natural, social, and policy researchers; and (c) other collaborators engage with one another, focusing on asking and answering questions about options and effects of management choices through scientifically valid comparisons. Through participatory research design and co-production of research questions, monitoring, and study objectives from the outset of a project, studies can better incorporate the values and needs of stakeholders (Fernandez-Gimenez et al. 2008, Ballard and Belsky 2010). This emphasizes that learning should be focused on the key questions as well as on the learning process itself to inform future work.

This collaborative process is focused on putting structured learning first ahead of negotiating, seeking to create an environment of trust, respect, and curiosity, where people can raise or consider novel and innovative approaches that are currently missing, creating a safe space for nurturing creative solutions. We believe this increases the likelihood of different perspectives coalescing around new ideas and out-of-the-box thinking that can be adopted into emerging practices. This approach to collaboration, which situates learning as central to its success and brings diverse, often opposing viewpoints together to test their range of ideas and feedback, can bring success and can further our adaptive capacity. This can ensure the process to produce work is more equitable by facilitating stakeholder engagement from the beginning of a given project including research development, design, and monitoring. The input gained from this bottom-up approach can be directly fed into management prescriptions that meet the needs of the entire ecosystem, people and the environment. We propose the field of ethnoforestry as the necessary context for implementing ideas and knowledge generated from the collaborative learning process.

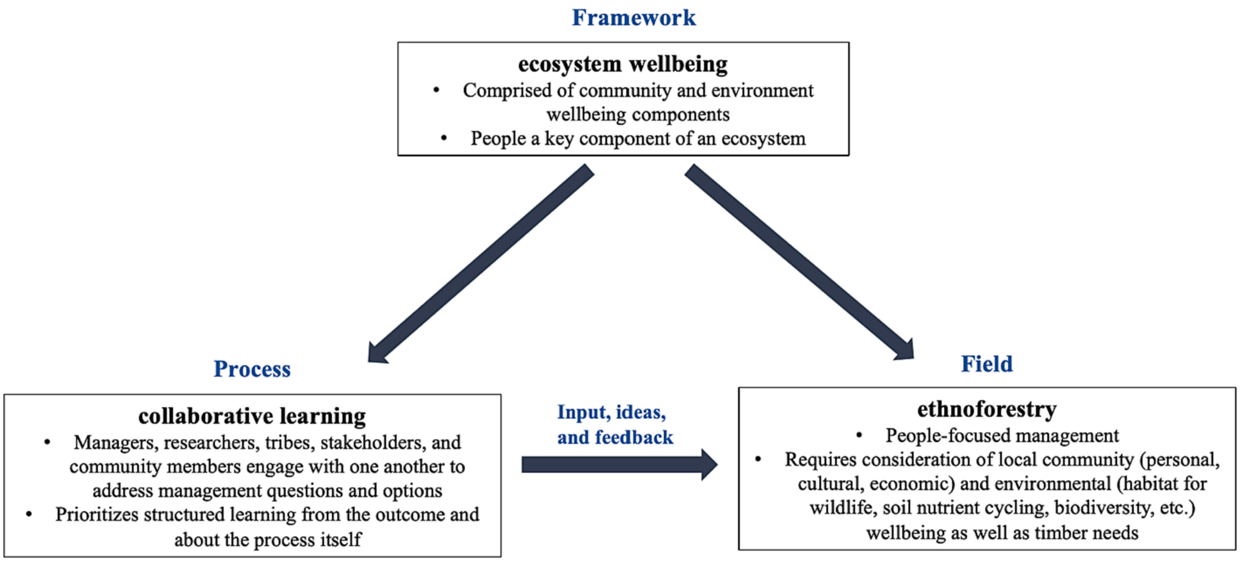

Fig. 2. The interaction of the ecosystem wellbeing framework, collaborative learning, and ethnoforestry.

3.3. *Ethnoforestry: Our variant*

We believe ethnoforestry can be used to better meet forest management goals. We build off the previous work and, in our context, define the field of ethnoforestry as people-focused forest management. *Ethno* comes from the Ancient Greek *εθnνs* meaning 'nation' or 'folk'. In the forest management context, ethnoforestry requires the study of all constituencies (managers, tribal peoples and nations, and stakeholders) who shape, are affected by, and inform forest policy. This entails people's affect, behavior, knowledge, feelings, preferences, and values, in so far as it is associated with a forest ecosystem. This differs from forestry, which inherently includes certain groups of people such as managers, operators, loggers, and more. Ethnoforestry also requires the inclusion of those that are affected (economically, culturally, socially, etc.) by forest management but that often do not get a seat at the decision-making table. In many cases this includes rural community members and tribes.

The science of ethnoforestry draws from diverse and interconnected disciplines including cultural anthropology, human geography, forestry, ecology, history, and public policy and governance. Similar to ethnobotany, ethnozoology, or ethnoecology, ethnoforestry can also be situated as under the umbrella of ethnoscience (Sturtevant 1964).

Although ethnoforestry certainly advocates for the involvement of all local communities, including tribal communities, it should not be thought of as exclusively indigenous. Ethnoforestry seeks to ensure that people, especially those who are invested (socially, culturally, economically, spiritually, etc.) in the outcome of public lands management, be included in forest management. We advocate for the consideration of expert, local, scientific, and traditional ecological knowledge into this process to ensure it is meeting the needs of all constituencies (Grant and Miller 2004).

3.4. *Interactions*

A key tenet of ethnoforestry is that people are central to the process. As such, ethnoforestry can only be successfully achieved through the lens of the ecosystem wellbeing framework that requires both communities and the environment to be considered simultaneously. Ethnoforestry also requires collaborative learning for its success, where three distinct groups must be engaged including 1.) forest managers; 2.) researchers; and 3.) tribes and stakeholders. These groups must all be part of the research design and implementation as they each bring important perspectives and expertise to the table (e.g., researchers bringing study design or statistical frameworks; tribes and stakeholders bringing their unique needs and knowledge). Through this, results may have a better chance of connecting back to management due to the involvement and buy-in from key players from the outset, the development of tangible and specific ecological and/or forest management problems being addressed, and a clear emphasis on learning (Bormann et al. 2007, Greig et al. 2013). We believe that this framework, process, and field presented (Fig. 2) was central to the success of our work. This large operational-scale research provides an example of how these elements can come together.

4. Ethnoforestry in Practice: Case study from the Olympic Peninsula, WA

4.1. *Study background*

A 20,000-acre adaptive management project called the Type 3 (T3) Watershed Experiment (Chauvin et al. 2021) provides a case study on state trust lands in the Olympic Experimental State Forest (OESF) managed by Washington Department of Natural Resources (DNR). This forest lies on the outer Olympic Peninsula, known for fast-growing forests, very infrequent wildfire, and occasional windstorms. This project seeks to build institutional and societal capacity to learn and adapt at a fast enough pace to address critical needs of forests and communities on the Olympic Peninsula in the face of climate and other changes. The scarcity of new solutions in Pacific Northwest forestry over the last 30 years suggested limited capacity and motivated this strategic application of ethnoforestry.

Through its policy for sustainable forests, DNR manages 850,000 ha (2.1 million acres) of state forested trust lands "…to produce long-term, sustainable trust income and environmental and other benefits for the people of Washington" (Washington Department of Natural Resources 2006). The fiduciary responsibility has pushed DNR to maximize net present value through 40- to 50-year conifer rotations on operable areas not included in reserves. Driven by available funding, administrative efficiencies, and legal strategies by stakeholders on different sides, DNR's array of management options (its toolbox) became very limited. The T3 Watershed Experiment was designed to explore whether the DNR management toolbox could be expanded by applying ethnoforestry. The ecosystem wellbeing framework helped broaden the potential goals beyond standard conifer rotations and late seral habitat to include emerging environmental concerns, and more specific social and economic concerns associated with community wellbeing. The

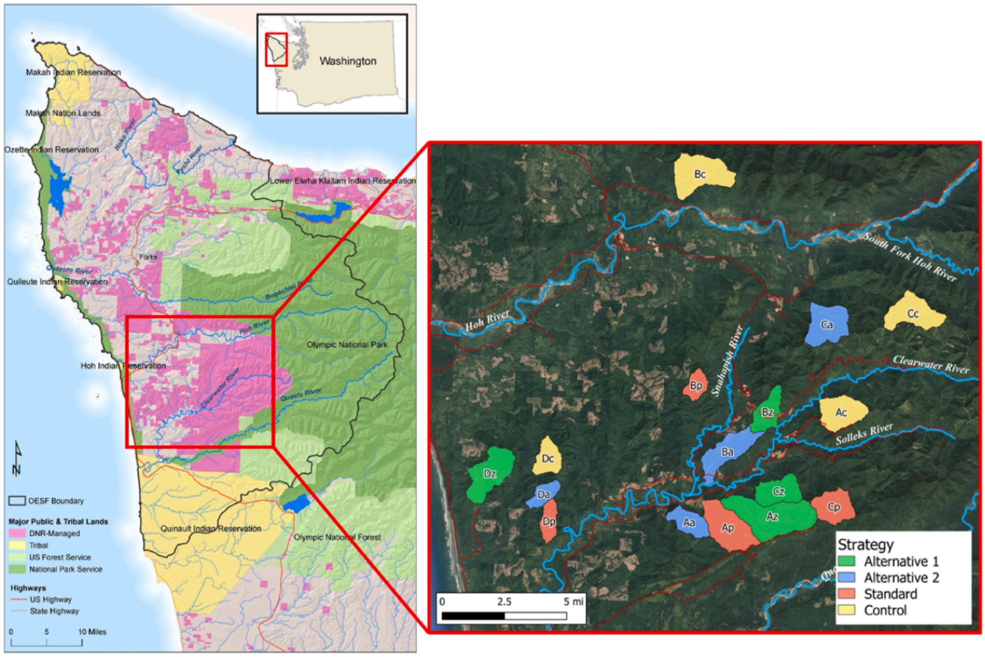

Fig. 3. The location of the T3 Watershed Experiment, taking place on the westside of the Olympic Peninsula within the Washington DNR's Olympic Experimental State Forest.

collaborative learning process was applied to bring in knowledge and ideas from participating researchers, managers, tribes, and stakeholders, and several possible innovations and solution spaces emerged, some that appear to better reflect what people want without reducing net present value[1]. This approach has real potential to build the social and scientific mandates behind active management on state forest lands.

The people focus of ethnoforestry led to increased attention on both tribal and non-tribal forest users. The Olympic Peninsula tribes have rights to hunt, fish, and harvest plant material on reservation, ceded, and Usual and Accustomed lands, many of which are now managed by DNR and the USDA Forest Service. Species such as beargrass, cedar bark (*Thuja plicata* Donn ex D. Don), and red huckleberry (*Vaccinium parvifolium* Sm) are frequently harvested to make anything from baskets to teas (Arnett and Crawford 2007, Shebitz et al. 2009, Hummel et al. 2012, Hummel and Lake 2015). Additionally, some residents on the Olympic Peninsula work in an informal market harvesting non-timber forest products (NTFP) from public lands such as salal (*Gaultheria shallon* Pursh), Oregon grape (*Mahonia nervosa* (Pursh) Nutt.), and evergreen boughs (Hansis 1998, Lynch and McLain 2003). The number of jobs and profits from NTFP industry is difficult to quantify, but certainly contributes to local, state, tribal, and federal economies (Vaughan et al. 2013, Frey et al. 2019).

4.2. Community engagement

To successfully create new ethnoforestry prescriptions, we engaged managers, tribes, stakeholders, and local communities through collaborative learning. This provided the necessary information and input to create ethnoforestry prescriptions, and by extension contribute to community wellbeing. In order to understand the ways in which current management could change to have a positive impact on their wellbeing, we used mixed qualitative methods to conduct semi-structured interviews with local people on the westside of the Olympic Peninsula (Dexter 1970, Terkel, 1974). Through these interviews, key themes emerged around the changes and reduction in abundance of particular plant species (with beargrass and cedar being a common response) and a decline in the population of ungulates over the last several decades, with a lack of appropriate forage material cited as a contributing factor (Shebitz 2005, Cook et al. 2013, Ulappa et al. 2020). These changes to the local environment have direct personal, cultural, economic, and social impacts on the livelihoods of both tribal and non-tribal residents.

Through the collaborative learning process, our research team also hosted numerous engagement meetings where principal investigators presented the T3 Watershed Experiment novel treatments. This included two 8-hour conferences, three 2-hour sessions focused on individual prescriptions, presentations at various meetings, and countless one-on-one or small group meetings with stakeholders to gain additional insight. These engagement efforts were opportunities for anyone to listen, comment, or offer feedback. In addition, the team hosted a field tour that brought together nearly 40 people representing researchers, managers, tribes, forest industry, business development, environmental groups, and engaged community members. The feedback from all of these outreach events was critical to ensuring the study met the needs of local people. The input and conclusions drawn from the community interviews and outreach efforts were used to directly inform the experimental study plan and generate ethnoforestry prescriptions. Eight different learning groups made up of researchers, managers, tribes, and stakeholders have been formed around particular topics (e.g., invasive species, tribal needs, remote sensing, cedar browse, economics, and history) that will continue to inform research questions, implementation, and monitoring efforts into the future (Bliss et al. 2001). These groups allow anyone who has interest or expertise in a particular topic to be engaged. This allows for continued relationship building, collaboration, and learning. While some groups are focused on staying informed about particular aspects of the study, others are putting together sub-studies to inform future management (e.g., cedar browse learning group).

[1] Project scientists are exploring large uncertainties in existing growth and yield models for projecting future revenue of ethnoforestry prescriptions and how this might change broad-scale planning. Projections will form hypotheses to be evaluated through time.

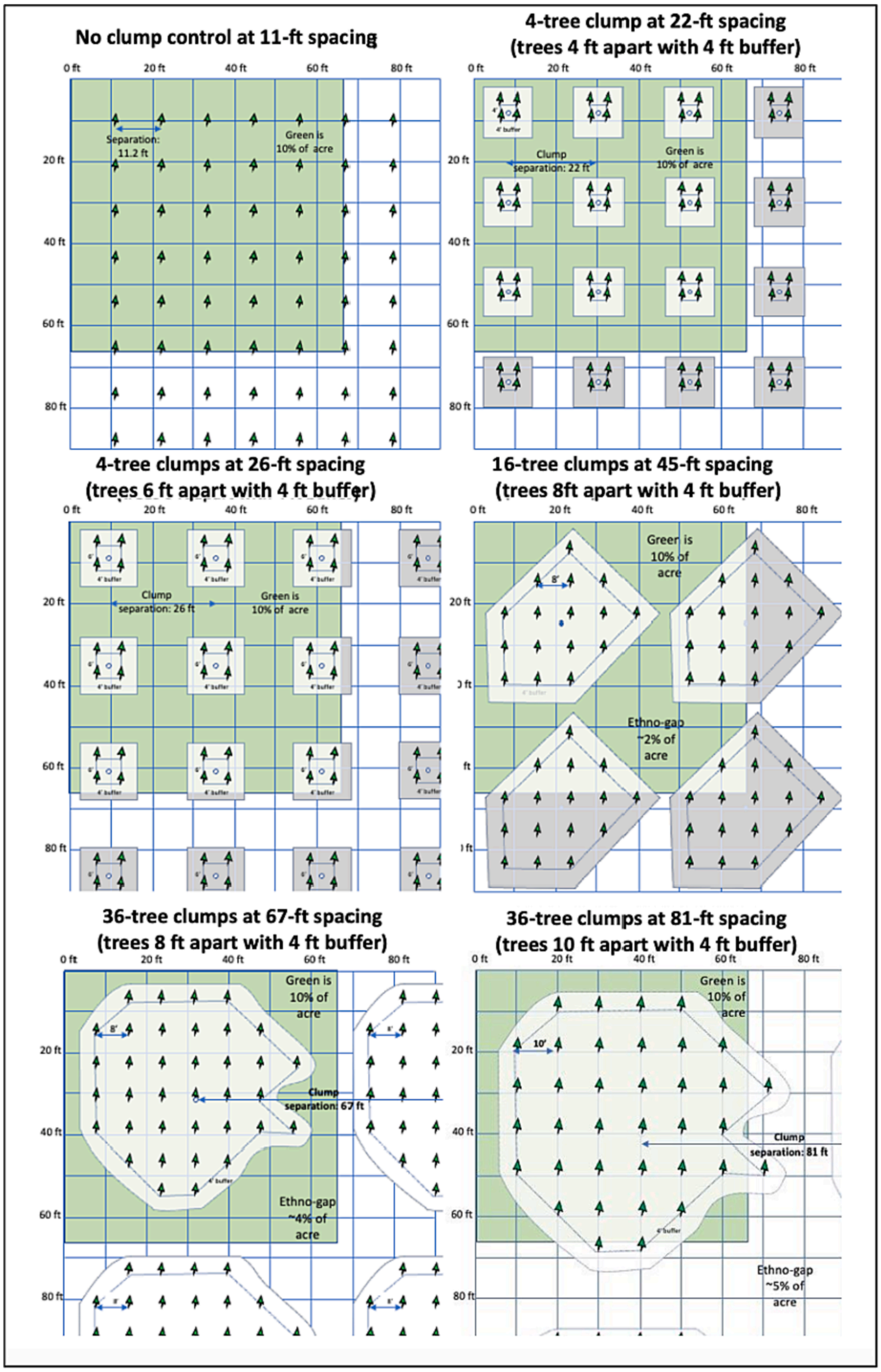

Fig. 4. Conifer clumping and interstitial arrangements in the variable-density planting treatment. Options include no-clump controls, 4, 16, and 36 tree clumps with varying spacing, and interstitial space open in between for recruitment of valuable understory species.

4.3. *Expanding the management toolbox*

Possible solution spaces in the T3 Watershed Experiment have taken the form of new management tools to be tried out for possible broader use in the future. New directions include increasing ways to diversify stands and landscapes that build resilience to climate and other uncertainties, speed late seral development, support wildlife (e.g., insects, birds, elk), diversify forest products (e.g., red alder (*Alnus rubra* Bong.), cedar, culturally important species), and build back early seral habitat actively and passively. Key to our approach to adaptation is trying new forest management ideas at an operational-scale where true costs and benefits are easier for all to see. The T3 Watershed Experiment is comparing 7 upland and 5 riparian operational-scale (>30 acre) prescriptions (4 novel upland and 3 novel riparian) placed on 16 watersheds (Fig. 3). Prescriptions, initially totaling about 2000 acres, were developed to be applied as part of 4 landscape-scale strategies:

Control (no-action): The only possible strategy for the Control watersheds is to maximize carbon sequestration, but this is not possible on a widespread basis given the Trust mandate. The Control serves to provide evidence of background changes critical to interpreting the other strategies. DNR has committed to one decade of no-action at this point.

Standard Practice: Continue the current best practice and plan as set forth in the OESF forest land plan (Washington Department of Natural Resources 2016) including harvesting for revenue and management for various upland and stream habitats.

Alternative-1 Integration: Seeks greater integration of additional ecological concerns (early seral habitat, riparian function, and fish populations mainly) with continued revenue generation and habitat mandates—by applying the latest environmental science knowledge.

Alternative-2 Integration: Seeks greater integration of community wellbeing concerns by applying perspectives and knowledge from diverse collaborators, along with social and environmental science developments, including increasing cultural understory species, ungulates, red alder, western red cedar, fish populations, and stakeholder and tribal engagement. This is accomplished through ethnoforestry prescriptions.

Here, we describe the two upland ethnoforestry prescriptions developed with community outreach being applied in the four replicate Alternative-2 Integration watersheds.

4.3.1. *Ethnoforestry with variable-density planting*

In a typical westside Olympic Peninsula forest, the first two decades following a timber harvest or major disturbance results in a pulse of available nutrients, space, and sunlight reaching the forest floor. This can result in a reestablishment of sun-tolerant graminoids, forbs, and fast-growing shrubs and hardwood trees (e.g., red alder) and add structural complexity (Swanson et al. 2011). Most often, broadcast herbicide mixtures are used prior to planting to control species that compete with the evenly spaced, planted Douglas-fir. Typically, competition from naturally regenerating and overly abundant species such as western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is not controlled and is instead reduced during precommercial thinning around age 15, but usually not before shading out most understory plants. This herbicide and evenly distributed planting approach truncates the time and space for early seral species that would have persisted much longer under natural succession (Donato et al. 2012, Bormann et al. 2015).

Many managers see all competing understory species as "brush", which stands in contrast to the view of many community members and some researchers who find ecological and social value in these species. Through the collaborative learning process, we learned that stakeholders and tribes are clearly interested in ungulates that use and depend on understory as forage and in plant harvesting for their cultural, economic, or personal use. Researchers were interested in the regional diminishment of species and ecological processes associated with declining early seral forest, especially in the coastal Pacific Northwest (Phalan et al. 2019).

Instead of viewing this as a simple choice or trade-off, we sought innovative solutions to better integrate conifer production and early seral habitat by applying an ethnoforestry prescription based on the feedback and outcomes of the collaborative learning process. To achieve this, the variable-density planting prescription will include planting conifers in varying sized clumps (ranging from 4-tree to 36-tree clumps), leaving interstitial space between clumps to actively promote understory species that are valuable for ecosystem wellbeing and exclude excessive ingrowth of seedlings and non-favorable understory species. Growth of evenly distributed conifers versus clumps is poorly understood and generally not accounted for in standard growth and yield models. Means of controlling species in the interstitial area to economically favor ungulates, insects, or cultural species is also poorly known. Due to the remote location and steep slopes in treatment areas, it is an undesirable location for personal harvesting. Instead of focusing on plant material for people, we will promote development of desirable understory plants that are beneficial to ungulates, a key concern of local communities and tribes. This will be accomplished through one or more re-entries after planting to manually remove dominant or recalcitrant understory species and seedlings (e.g., scotch broom (*Cytisus scoparius* (L.) Link), salal, or western hemlock seedlings).

These uncertainties were used to build this prescription that includes a sub-study to examine relative effectiveness of different clumping patterns (Fig. 4). The prescription increases heterogeneity at multiple scales and focuses on learning why variable-density planting might be successful. If this approach works, doors could open to a myriad of planting arrangements and understory management that could be tailored for varying ecosystems and community needs (Halpern and Spies 1995).

4.3.2. *Ethnoforestry with variable-ratio polyculture*

On the Olympic Peninsula, Douglas-fir is predominately planted after harvest, with other conifers planted historically less than 10 % of the time; recently this jumped to 40 % (M. Perry Pers. Comm.). Combined with natural regeneration of hemlock, these two species are favored because they are well-suited for short-rotation, dimensional-lumber production. Benefits from increasing the diversity of tree species, mainly cedar and alder, and concerns over reduced heterogeneity were raised by tribes, stakeholders, and researchers in the collaborative learning process.

The abundance of western red cedar has declined substantially in the last 75 years, resulting from demand, difficulty in re-establishment, and lower compatibility with short-rotation culture. Cedar manufacturing has also plummeted from its heyday in the mid-late 1900s. Cedar's cultural and ecological value cannot be overstated. Uses for housing, basketry, clothing, canoes, and totems are well known (Johnson et al. 2021). Many indigenous peoples have historically and currently strip cedar bark annually (Zahn et al. 2018) and have noted the difficulty in finding cedar trees in accessible locations for these ceremonies. Cedar is also one of the longest living and largest trees of special importance to late seral conditions, such as nesting and roosting for Northern spotted owls and marbled murrelets.

Abundance of harvestable red alder on the Peninsula has also declined to the point that local alder mills are importing logs from Canada to remain in business (Sweitzer Pers. Comm.). Much effort has been given in effectively controlling alder in young stands, with almost no effort given to learning to plant and grow alder for profit, even though it often has higher stumpage value than Douglas-fir. Alder's ecological value is well established as the predominant N_2 fixing species in the Pacific Northwest that can also build available nutrients and organic matter in the mineral soil and speed weathering release of nutrients from minerals (Binkley et al. 1992, Bormann et al. 1994, Edmonds and Tuttle 2010). Other benefits include higher understory biodiversity (Deal 2007) and greater understory biomass (Hanley et al. 2006). Rapid early growth has the potential to capture carbon more effectively than conifers, at least for the first 20 to 30 years (Binns et al. 2021).

Concern over declining heterogeneity on the "vast tree-farm landscape" was a concern of some stakeholders and researchers who preferred more natural looking stands. Others worried about future, more extreme pest and pathogen outbreaks on landscapes lacking heterogeneity. An example of the latter is planting of Douglas-fir near the Pacific Ocean, where its pathogen, Swiss needle cast, has already been increasing (Ritóková et al. 2016). Other diseases and their interactions under a changing climate are of concern as well (Agne et al. 2018).

The collaborative learning process allowed for potential innovations to flourish in this prescription as well. The idea of growing alder and cedar together emerged as a way to connect to community wellbeing and at the same time address ecological concerns. This operational-scale, ethnoforestry prescription allows for 2 alder rotations at 30–35 years with a single cedar rotation of 60–70 years allowing it to achieve much higher value. How to grow alder and cedar intentionally and together is uncertain so a variable-ratio approach will be used to explore

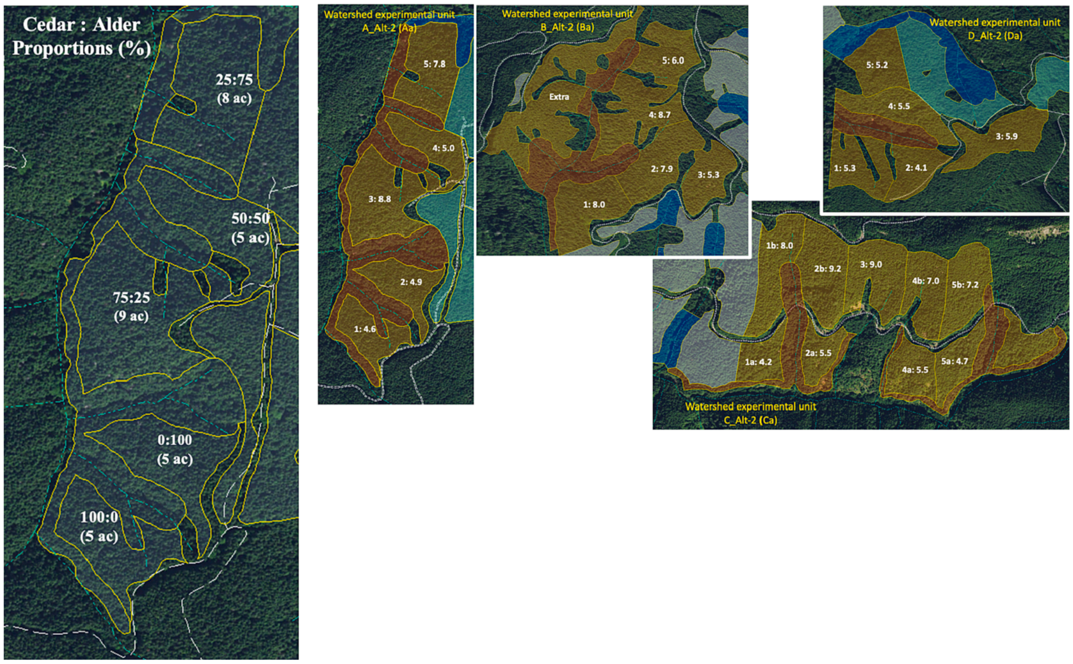

Fig. 5. The variable-ratio polyculture treatment arrangement with varying proportions of western red cedar and red alder planted in subunits across the four watersheds (Aa, Ba, Ca, and Da) with associated riparian prescriptions (dark orange). Subunits range from approximately five to ten acres (right). The proportions of western red cedar and red alder include 0:100, 25:75, 50:50, 75:25, and 100:0 respectively (left).

options and, like variable-density planting, includes a sub-study to explore how well individual ratios work. In the variable-ratio polyculture prescription, 5 stands will be planted with red alder and western red cedar at varying ratios, (100:0, 50:50, 0:100, 25:75, and 75:25; Fig. 5). These mixes will be planted in 5- to 10-acre patches within operational-sized units of 30 + acres. The primary purposes are to produce net revenue from rotations of high-value western red cedar and red alder, while also producing additional benefits such as increased local jobs through value-added manufacturing, adding heterogeneity, increasing soil productivity, and generating future options for late seral habitat or tribal uses associated with larger trees.

4.4. Learning about wellbeing and collaborative learning

Through the development and implementation of this experiment, collaborative learning was used to generate the input, knowledge, and feedback that made the ethnoforestry prescriptions possible. This allowed the study plans, research questions, and treatments themselves to be shaped by the communities who will be most affected by this research and its outcomes. By creating space for ideas and questions from managers, researchers, tribes, stakeholders, and local people, we hoped to generate research with widespread buy-in that could be directly connected to future management decision making. The wellbeing framework eased tribal and stakeholder engagement and facilitated new prescriptions that reflect their ideas and needs, which in turn helped gain support from researchers and managers.

Our experience suggests that this case would have failed if it had not been designed and applied at the operational-scale. Research, historically done at small scales, rarely translates easily to management. We suggest that an operational-scale, along with research participation, has also helped tribes and stakeholders perceive manager's commitment to learning and trying new ideas with more seriousness. Study of the economics and application issues will provide for a more informed debate about prescription preferences. Finally, we postulate that the extent and speed of adaptation depends on a working collaboration of researchers, managers, and tribes and stakeholders—all are necessary.

5. Conclusions

The three elements described in this paper–the ecosystem wellbeing framework, collaborative learning, and the field of ethnoforestry–are intended to expand the forestry toolbox by bringing in new perspectives and innovations when developing management strategies and prescriptions. This facilitates adaptation by embracing collaborative learning and having a greater consideration of new and emerging needs of local people. Experimental studies will allow managers to make informed decisions on potential changes to forest management in the future. As we look ahead to the next phase on forest management in the Pacific Northwest, we think innovation, collaboration, and structured learning will allow us to adapt to the changing needs of our climate, communities, and the environment that we all cherish and depend on.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

This research was funded by the Washington State Legislature through the Olympic Natural Resources Center (administered by the School of Environmental and Forest Sciences, College of the Environment, University of Washington). The authors would like to thank Teodora Minkova, Bill Wells, Angus Brodie, and Greg Ettl for their contributions and collaboration on creating and designing the Type 3 Watershed Experiment, without which this project would not have been possible. In addition, the authors would also like to thank Bill Burch for his wisdom, advice, and guidance that inspired our framework and approach. The authors also thank John Gordon and Tim Vredenburg for their expertise and input on engagement and relationship building. This paper is dedicated to Viola Penn Riebe, whose knowledge and input shaped our work from the very beginning.

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