Agroforest Syst
https://doi.org/10.1007/s10457-023-00905-4

Design and application of silvopasture in washington state

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Received: 17 June 2023 / Accepted: 7 September 2023

Abstract Few studies have been conducted on the extent and nature of silvopasture usage in Washington state. The goal of this research was to investigate the livestock, forages, and tree composition of the silvopasture systems currently being utilized and landowner goals for these systems. To accomplish this, we conducted a statewide survey administered via interviews of practitioners to determine the social, economic, and ecological drivers and demographics of farmers utilizing silvopasture. To identify landowners using silvopasture and gain insights into its perceived usage and impacts, we contacted and interviewed multiple state and federal agency representatives. The farms identified for the study ranged from 2 to 1100 acres in size and found on both sides of the Cascades. Of the 19 landowners utilizing silvopasture, 100% had goals of diversifying revenue streams and incorporating ecosystem services into their management systems. Benefits cited by practitioners included regular revenue streams from forest products and livestock sales. The challenges identified included limited regionally specific literature and a lack of trained professionals familiar with silvopasture and associated best management practices. This research provided evidence that landowners are utilizing and adapting silvopasture systems to a broad array of bioregions within Washington state to meet their objectives. The ecological adaptability of silvopasture is demonstrated by the variety of trees, forage, and livestock combinations found throughout the study sites. For silvopasture to advance as a land management practice in this region, our research showed the need for further studies to occur to determine the best practices, economic viability, and ecological effects of silvopasture.

Keywords Silvopasture · Agroforestry · Adoption · Forest management

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Introduction

Silvopasture is defined by the USDA as the deliberate integration and intentional management of trees, forages, and grazing livestock operations on the same

Published online: 16 September 2023

unit land. The intentional integration of these components is influenced by the economic and ecological goals of the landowner (Jose et al. 2019) and driven by the eco-physiological interactions that occur in a given ecosystem. Despite its inherent complexity, it is a common agroforestry system (Sharrow 1999). It is the complex design and management of silvopasture that directly increases ecosystem services and provides diverse economic streams (Smith et al. 2022). This complexity poses challenges as silvopasture is a difficult management system to study and communicate because the design of the system and its functional attributes must be uniquely tailored to the specific ecosystem in which it is implemented (Sharrow 1999 and Cubbage et al. 2012). A second challenge is the lack of comprehension of silvopasture as a practice. This is in part driven by the relatively recent divergence of terminology. *Forest grazing,* defined as utilizing open forests for livestock production with potential for increasing ecosystem services, was referred to as a type of agroforestry in peer reviewed literature as recently as the 1990s (Lawrence et al. 1992). Silvopasture has now supplanted forest grazing as the accepted agroforestry term and has been further defined by the USDA. A primary distinction between these two terms in Washington State lies in livestock management. The most common grazing method employed in silvopasture systems is rotational grazing as defined by Allen et al. (2011). Recent research confirms that rotational grazing and managed intensive grazing is a preferred grazing methodology of landowners who use silvopasture (Smith et al. 2022). In contrast, forest grazing refers to livestock grazing in timbered lands that lacks the intensive management of trees, forage and livestock associated with silvopasture. Because there is an overlap in the usage of these terms by landowners, state, and federal advisors and, to some extent, in the practical applications of forest grazing and silvopasture, more regionally specific research is required to observe and document the actual land management practices being employed. Systematic analysis of the social, economic, and ecological potential of silvopasture systems will depend upon consistent application of terminology (Brandtly 2014; Frey and Fike 2018).

A third challenge to conducting research and education about silvopasture practices in Washington state are the preexisting negative perceptions held by both forestry and agricultural advisors. Historic forest grazing has created multiple ecological problems including reduced biodiversity, decreased understory species density, decreased herbaceous plant density, and decreased herbaceous cover (Rummel 1951; Zimmerman and Neuenschwander 1984; Cole and Quigley 1997; Bakker and Moore 2007; Hessberg et al. 2015). Specific to Washington, there is evidence of the negative impact of cattle on survival, growth, and development of ponderosa pine and Douglas fir/ninebark plant communities (Rummel 1951; Kingery and Graham 1991). Historic grazing methods in the western United States have changed species composition more than climate variation (Huago et al. 2010). Research has shown that overgrazing has often resulted in the near total elimination of native herbaceous vegetation cover, destruction of woody seedlings, widespread soil compaction, and establishment of exotic annual weeds across large areas of the Pacific Northwest (Mack 1981).

These examples provide critical evidence of the need to improve livestock grazing occurring in forests in the western United States and the need to review potential solutions using improved management methods that are economically and ecologically viable for small and medium farms. Intensive management strategies that employ silvopasture techniques based on managed rotational grazing combined with modernized silvicultural methods show initial promise as a way of addressing some of the environmental problems noted above (Smith et al. 2022). Research in the southeastern United States demonstrates that cattle utilized the landscape more evenly in silvopasture versus open-pasture (Clason 1998) resulting in the potential for less soil compaction in comparison to non-silvopasture systems. More recent studies indicate that there is no significant difference between surface and subsurface infiltration in forests that have been converted to silvopasture and pastures (Stewart 2020). There has been preliminary research into the use of silvopasture systems as a method for reducing high severity wildfires (Ruiz-Mirazo 2011). Finally, the use of silvopasture can potentially diversify and enhance farmer income through the simultaneous production of livestock and forest products (Rigueiro-Rodriguez et al. 2009).

The lack of literature specific to silvopasture in Washington state may constrain the understanding and attitudes of professionals and landowners. This effect has been noted in the Northeast and

Midwestern regions of the United States (Mayerfeld et al. 2016; Orefice 2017). In addition, there are no well-known silvopasture examples in Washington that can provide professionals or practitioners with a model or a baseline of best management practices. The objectives of this research project were to focus on gathering data on the extent and types of silvopasture practices being implemented in the state in relation to current definitions of silvopasture as described by the National Agroforestry Center (NAC) and the Natural Resources Conservation Service (NRCS) and to identify opportunities for improving practices through research and education. This study investigated farmer/rancher demographics, land and livestock management practices, and the economic and ecological objectives of current silvopasture practitioners. Enhanced knowledge of current practices and land manager goals are used to assess opportunities for improving the social, economic, and ecological outcomes of silvopasture management practices in Washington State.

Materials and methods

Due to limited regionally-specific agroforestry literature or research, this study sought to fully investigate the extent, characteristics, management of, and reasons for use of silvopasture among existing practitioners in Washington state (Orefice et al. 2017). To enhance the validity of this study a three-tiered approach was employed with each tier involving a different source of data enabling triangulation through cross verification. The first tier of the analysis involved exploring Web of Science and Scopus using the search terms: silvopasture, forest grazing, rotational grazing, managed intensive grazing, agroforestry, and Washington. The second portion of this first tier involved the examination of published research and an exploration of multiple databases, including the National SARE database, the National Agricultural Library, the NRCS-EQIP, and the USDA-NIFA-CRIS database to assess salient research conducted on silvopasture in Washington state. The second tier of investigation consisted of inquiries and key informant interviews with professionals from multiple state. These agencies were selected based on their mandate as a non-regulatory organization address site specific resource concerns and landowner information needs. Agencies including the Washington State Conservation Commission, twenty-two conservation districts, NRCS staff, Department of Natural Resources staff, and Washington State University (WSU) Extension. Preliminary data analysis from this tier helped to explore the extent of silvopasture use and identify silvopasture practitioners. Based on the information obtained from key-informant interviews and existing producer databases including the Washington Farm and Food Finder, Tilth and Western SARE database, an initial list of 30 land managers who were potentially using silvopasture in Washington state was compiled. Additionally, this second tier of research used the key informant interviews to investigate motivating factors and barriers to adoption of silvopasture based on the experiences and observations of professionals who worked with landowners. The third tier of research was based on surveying landowners using a structured questionnaire. The intent of this survey was to comprehend management goals and practices and the resources available to land managers, as well as to explore the range of factors integral to the success of silvopasture as an effective agroforestry practice in this region.

The landowners were selected from the statewide list of potential practitioners developed during the first two tiers of research above. The following criteria were utilized to further screen and select the landowners to interview: willingness to offer an interview; ownership, or access to land; knowledge of silvopasture; number of years practicing silvopasture; timber stand structure and composition; and number of hectares in silvopasture. After initial screening based on these predetermined criteria, 19 landowners were determined to be practicing silvopasture and were contacted and invited to participate in an interview. One-hundred percent of the invited landowners agreed to voluntarily participate in the structured interviews. Interviews occurred by phone using a structured protocol with the scripted questions as guide for both closed and open responses.

Survey design

To aid in construction of the survey questions, silvopasture researchers at other academic institutions were consulted to determine the scope of the needs and resource assessments that were needed. This input was used to develop categorical questions that

could effectively document and analyze the characteristics of silvopasture systems in Washington state. The questions helped to identify landowner goals for practicing silvopasture, barriers to implementation, and to better understand the necessary skills and infrastructure for successful utilization of silvopasture in Washington state.

The resulting questionnaire was divided into four main categories (Annex 1): (1) Screening questions gathered farm characteristics including ownership, size and location, and farmer/rancher experience; and assessed intentional integration of livestock with forests/orchards; (2) Land management data was gathered on livestock grazing methods, forage and forest composition, structure and methods of management, and specific ecological goals and objectives; (3) Economic data was gathered on expenses including investment costs, yearly management costs, and indirect costs; and on sources of income specific to the silvopasture systems; and (4) Social data was gathered on resources such as education, funding, lessons learned, and networking with other practitioners. While extensive efforts were made to locate all the potential silvopasture practitioners in the state when building the list for this study, our list was likely incomplete. In communications with NRCS staff, they said they knew of some landowners who currently use silvopasture, but as a federal agency, personal information of landowners is protected. Instead, formal letters of invitation to participate in the research were sent to these landowners via NRCS staff, however, no additional landowners responded. It is likely that the 2020 National Agroforestry Survey conducted by the USDA will provide further insight on the actual number of silvopasture practitioners in Washington state.

Results

Our study found that silvopasture systems have not been well researched for their socioeconomic and environmental impacts whether negative or positive and, in particular, have not been investigated in Washington state. Our literature review determined that the extent of published literature was limited. Research was conducted by Washington State University that employed a statewide survey on the awareness and perceptions of agroforestry (Lawrence and Hardesty 1992). This study found a general awareness of agroforestry but a lack of technical knowledge and assistance. Further research conducted by Oregon State University examined silvopasture establishment and impacts on forage and soil quality and quantity (Sharrow 1999, 2004, 2007). This research was primarily restricted to Oregon state. A search of federal databases only found a Western SARE project titled "Silvopastoral Alternatives for Fruit Growers" that investigated the economic and ecological impacts of incorporating livestock into tree fruit production systems using silvopasture methods. A Freedom of Information Act Request showed that from 2012 to 2018, the NRCS processed 6 Environmental Quality Incentives Program (EQIP) grants for the purpose of establishing or supporting ongoing silvopasture systems on private property in four counties in Washington state.

Key informant interviews

From key informant interviews with representatives of partner organizations we learned that knowledge and perceptions of silvopasture varied among organizations. Of the twenty-two conservation districts contacted, six were actively working with or were aware of silvopasture practitioners. Among these six conservation districts, knowledge of best management practices (grazing density and optimized overstory and understory management) relied on multiple specialists (foresters and livestock specialists) for management input due to the integrated nature of silvopasture. Representatives of all six districts noted that the lack of literature available to professionals and practitioners discouraged widespread adoption of silvopasture. Among those interviewed, representatives of conservation districts had varied perceptions and awareness of silvopasture. For example, the person interviewed at the conservation district associated with the county that had received two NRCS EQIP grants for silvopasture in 2018 was unaware of any silvopasture systems in the county and stated: "This is a practice we recommend against, mainly because the damage to the forest stand far outweighs any benefits—there's little if any forage in western Washington forest stands. You would know far better than I, but I think grazing forest stands would have more benefits in eastern Washington." This perception may be due to the lack of understanding of the definition

and management practice of silvopasture as the term was not widely used among professionals.

Another conservation district representative was unsure whether silvopasture was being practiced due to the scale of the farm, stating "We have a couple of folks who are grazing their forest land, but it probably isn't silvopasture as they are mostly hobby scale." These perceptions likely serve as barriers to adoption (Orefice et al. 2017). The NRCS staff that we spoke with were aware of landowners using silvopasture. One representative noted that "we work with quite a few landowners who graze livestock in a silvopasture system and some we have funded via EQIP to do this type of work." In addition to the wide range of perspectives and experience, members of partner organizations noted that they relied on agroforestry literature that was not regionally or ecologically specific to Washington state. The challenge with relying on literature from other regions is that silvopastures tailored to their social, economic drivers and ecological regions United States (Plieninger and Huntsinger 2018, Brodt et al. 2020). Finally, it was noted in discussions with partner organizations that terminology and definitions of silvopasture varied greatly. The terms "forest grazing" and "silvopasture" were used interchangeably by many organizations. Other challenges arose because agencies have different goals for establishing silvopasture. In Washington NRCS goals focus more on resource concerns such as reducing soil erosion, improving water quality, and enhancing wildlife habitat. In contrast, the USDA National Agroforestry Center has goals that focus on diversifying incomes, forage production, and improved habitat for livestock. While these are not mutually exclusive objectives, the interpretation of these goals by partner organizations greatly influenced the perceived understanding of what silvopasture is, what the benefits could be, and how this management system could be funded and supported.

Landowner interviews

From interviews with landowners, Table 1 shows a bimodal split in the number of years of experience of the principal operators with 36% having less than 10 years of experience and 31% having more than 30 years of experience. In terms of utilizing silvopasture on their current farm/ranch, 42% had 1–10 years of experience using silvopasture on their current property. Two primary types of silvopasture systems were identified: livestock integration with orchards and livestock integration into a managed forest. In the second type, a pre-existing stand has been thinned and forage management occurs prior to livestock integration. Two of the landowners had both orchards and forests on the same property. In terms of acreage, 57% of farmers/ranchers operated on lands that were between 81 and 1100 acres and 42% operated on lands that were 80 acres or less. Interview participants were asked about their investments in silvopasture infrastructure such as fencing and irrigation, however, only four landowners were able to provide specific costs. The remaining landowners were not keeping financial records. Participants were asked to estimate yearly management costs and associated indirect costs. Only four landowners had estimates for yearly management costs ranging between

Table 1 Characteristics of silvopasture farms/ranches (N = 19)

Location	Number	Percent (%)
Western Washington	10	53
Eastern Washington	9	47
Silvopasture type		
Orchard	6	28
Forest	15	71
Years farming/ranching		
1–10 years	7	37
11–20 years	3	16
21–30 years	3	16
31–60 years	6	32
Years using silvopasture on current land		
1–10	8	42
11–20	2	11
21–30	3	16
31–60	6	32
Acres operated		
1–10 acres	3	16
11–80 acres	5	26
81–800 acres	5	26
800–1100 acres	6	32
Commodities produced		
Meat, Dairy, Wool	19	100
Firewood	7	37
Timber	5	26
Wood pulp	2	11
Fruit/Nut	6	32

$1500 and $10,000 per year. Only two landowners had estimates of indirect costs ranging between $100 and $2000 per year. An estimate of direct economic benefits from livestock (meat or wool sales) and forest/orchard (timber, fruit, and nut sales) was unavailable with only two landowners able to estimate yearly income. These landowners estimated that total annual sales of meat and/or wool were between $50,000 and $100,000. Landowners did not have data on other forest products.

The commodities produced by the respondents fell into five main categories with a majority producing more than one type of commodity. All landowners produced meat, wool, or dairy. Firewood was a common secondary product as a result of forest thinning, particularly for landowners who reported that their forest stands were composed of Ponderosa pine, Red alder, Garry oak, Big leaf maple, or Pacific madrone. Timber was reported as a commodity for landowners who had diverse forest stands of Douglas fir, Grand fir, Western larch, and Western cedar. Wood pulp was a commodity for landowners whose land was primarily composed of Ponderosa Pine. Asian pears, kiwis, chestnuts, cider apples, and hazelnuts comprise the scope of fruit and nuts grown in silvopasture systems.

Livestock species and composition fell into two main categories (Table 2): farms that utilized multiple species and farms that utilized single species. Multi-species farms followed a prescribed rotational grazing regime in which each species grazed separately in specific paddocks or grazed paddocks asynchronously. Landowners using multi-species and single species grazing determined the timing and duration of livestock rotation based on livestock species, herd size, forage residual height, vegetation status, and yearly precipitation. The number of yearly grazing events per paddock range from 1 to 7 times, with an average of two grazing events per paddock per year. Paddocks that were grazed more than three times in a year were irrigated. Paddock size varied and was dependent upon the number of livestock and farm size. The average number of paddocks on a given

Table 2 Livestock species and grazing management (N = 19)

	Number	Percent (%)
Farms utilizing multi-species	(5)	26
Livestock groupings		
Katahdin sheep, Kuni-Kuni and Berkshire pig	1	5
Finnish sheep, heritage turkey, broiler chicken, goat	2	10
Cow/calf, horse, goat	1	5
Cow/calf, bull stud, pig	1	5
Farms utilizing single-species	(14)	74
Livestock type		
Cow/calf	7	37
Cheviot sheep, Finn and Sally (wool) sheep	1	5
Katahdin sheep	3	16
Herford cow, old spots pig, Berkshire pig	1	5
Jersey (dairy) cow	1	5
Suffolk sheep	1	5
Herd size (number of head)		
10–20	2	11
21–50	7	37
51–100	2	11
101–200	7	37
201–500	1	5
Concerns about animal health in forest/orchard grazing		
Forage quality/quantity	13	68
Pine needle abortion	10	53
Parasite loads	2	10

farm was 20 with an average paddock size of approximately 6.74 acres and a range of 1.5 acres to 15 acres.

Concerns with livestock grazing in forest stands and orchards were driven primarily by tree species composition. For landowners who operated cow/calf operations and had forest stands with ponderosa pine there was a concern about induced abortion caused by ingestion of green pine needles. All landowners with a cow/calf operation and ponderosa pine stands reported having experienced this multiple times. Removing the lower limbs of trees and managing the timing of paddock grazing can reduce abortion rates however wind or tree/branch fall is unpredictable (Pfister et al. 2002). Quantity and quality of forage were also a concern as decreased light availability decreases the lbs./per acre of available forage (Sharrow 1991; Lindgren and Sullivan 2013; Mercier et al. 2020). Forage quality is also a management issue as shade tolerant species occurring in forest stands may be low in nutrients (Buergler 2006).

The amount of silvopasture on each farm/ranch ranged from 2 to 1000 acres with a median of 20 acres of silvopasture per site (Table 3). Silvopasture conversion was reported to occur through forest management practices such as pre-commercial or commercial thinning of existing stands that resulted in a median of 3 unique forest stands per property. Eleven landowners said they worked with a forester or were foresters themselves. Only two landowners who worked with a forester reported that the forester did not approve of livestock integration. In eastern Washington most participants stated that their silvopasture sites have even-age stand structure with primary species composition of Ponderosa pine, Douglas fir, and Grand fir. Outlier species included Western cedar, Lodgepole pine, and Western hemlock. Western Washington sites were reported to be more varied in forest structure and composition with uneven and even age stand management being the most common systems utilized. The most common forest species included Douglas fir, Red alder, Cottonwood, and Garry oak. Eleven of the 19 sites utilized natural stand regeneration with four sites using both natural regeneration and intentional planting.

Conversion of pastures to silvopasture only occurred at four sites and involved orchard establishment. Landowners stated their goals for forest stands as primarily ecosystem services that benefited from the integration of livestock grazing (shade, wildlife habitat, and soil moisture retention for forage). Merchantable timber and other forest products including firewood production was a strong secondary goal mentioned by all landowners with forests.

Table 3 Forest/orchard composition (N = 19)

Acres of silvopasture per property	Number	Percent (%)
1–10 acres	5	26
11–100 acres	7	37
101–800 acres	6	32
800–1100 acres	1	5
Acres of non-silvopasture per property		
1–10 acres	5	26
11–100 acres	6	32
101–800 acres	7	37
800–1100 acres	1	5
Converted pasture to forest/orchard		
Yes	4	21
No	15	79
Method of regeneration		
Natural regeneration	11	58
Plant seedlings (orchard only)	4	21
Both	4	21
Worked with a forester		
Yes	11	58
No	4	21
N/A (orchard establishment)	4	21
Dominant tree species (forest)		
Ponderosa pine	6	32
Red alder	4	21
Douglas fir	2	11
Grand fir	1	5
Garry oak	1	5
Cottonwood	1	5
Primary tree species (orchard)		
Hazelnuts	2	11
Asian pear	1	5
Chestnuts	1	5

Reported understory forage species selection and management varied greatly between western and eastern Washington due to the delineation of soil types, temperature, and precipitation regimes. Six eastern Washington landowners said they had introduced preferred forages by broadcasting seed by hand or using a no-till seed drill along the edges of forest stands or in recently thinned stands. Using these methods, seeding typically occurred in October or November after

the first autumn rains and after a paddock had been grazed by livestock. An additional method reported was broadcasting seed in areas where slash piles were burned or where hay bales were placed during winter. Using this method, seeding occurred in late winter or early spring. Four landowners in eastern Washington who reported using this method had determined that this was the only time that mineral soil was adequately exposed for successful forage propagation. Additional forage management techniques reported included removing undesirable plants; 4 out of 10 landowners named snowberry (*Symphoricarpos albus*), Common Mullein (*Verbascum thapus*) and Rose (*Rosa multiflora*) as plants that they removed.

Five out of the nine western Washington landowners said they introduced preferred forages after discing, grazing, or herbicide application. Timing of seeding varied among landowners, with those who had irrigated pastures seeding in early spring and those who rely on yearly precipitation seeding after the first autumn rains. Plants perceived as undesirable varied depending on livestock species. Blackberry (*Rubus armeniacus*) was reported as undesirable by landowners who had cattle and poultry. Landowners who had goats, pigs, and meat sheep preferred to have blackberry for forage. Scotch broom (*Cytisus scoparius*) was named by six out of the nine western Washington landowners as an undesirable plant (Table 4).

Landowners reported that they utilized silvopasture for a few specific reasons (Table 5). One-hundred percent of landowners indicated that diversification of income streams, predictable revenue, shade, and a perceived increase in interaction with their farm/ranch and livestock were reasons for silvopasture adoption. Seventy-eight percent of the landowners indicated that intentional integration of livestock and trees provided greater utilization of their existing forests. "The use of rotational grazing allowed flexibility" was a benefit cited by most of the landowners. When questioned further, landowners stated that rotational grazing allowed for rest periods between grazing events allowing forage to recover from grazing. In addition, rotational grazing allowed landowners to dictate when and where grazing events would occur. Sixty-three percent of landowners indicated that silvopasture utilization was associated with a perceived increase in ecosystem services (i.e., provisioning raw materials of fuel and timber; regulation of climate; controlling parasites; aesthetics of beauty and recreation; and supporting services such as increased biodiversity and nutrient cycling).

The time and cost of moving and managing rotationally grazed livestock as well as the costs of purchasing and maintaining permanent and portable electrical fences were the primary challenges reported with silvopasture. Nine landowners indicated that using rotational grazing required consistent and constant time allocation. Others noted that with the addition of trees comes a decrease in photosynthetically active radiation and thus less forage. This is recognized as a specific challenge among landowners whose property is primarily composed of forest or woodlands. The impact of livestock on tree regeneration was an additional complication reported by landowners. Fire was a concern for landowners who

Table 4 Common forage species managed for livestock

Grasses	Forbes
Italian rye (*Lolium* spp.)	Trefoil (*Lotus corniculatus*)
Triticale (×*Triticosecale*)	Plantain (*Plantago* spp.)
Smooth Brome (*Bromus inermis*)	Red Clover (*Trifolium pratense*)
Oatgrass (*Danthonia* spp.)	Chicory (*Cichorium intybus*)
Perennial ryegrass (*Lolium* spp.)	White clover (*Trifolium repens*)
Annual ryegrass (*Lolium* spp.)	Small Burnet (*Sanguisorba minor*)
Timothy (*Phleum pratense*)	Sub clover (*Trifolium subterraneum*)
Orchard Grass (*Dactylis* spp.)	Alsike clover (*Trifolium hybridum*)
Meadow Brome (*Bromus commutatus*)	
Mountain Brome (*Bromus carinatus*)	
Alfalfa (*Medicago sativa*)	
Kentucky blue grass (*Poa pratensis*)	

Table 5 Reasons for silvopasture establishment (n = 19)

	Number	Percent (%)
Diverse income streams	19	100
Predictable revenue	19	100
Shade for livestock	19	100
(Perceived) increase in interaction with landscape/livestock	19	100
Adaptability of rotational grazing	15	79
Comprehensive utilization of existing forests	15	79
(Perceived) increase in ecosystem services	12	63
Aesthetic values	10	53
Challenges of silvopasture		
Time and labor moving animals and electric fences	14	74
Less quality and quantity of forages	12	63
Impact of grazing on tree regeneration	6	32
(Perceived) threat of fire	6	32
Cost of permanent fencing	3	16

Table 6 Information needs identified by landowners (n = 19)

	Number	Percent (%)
Forage Management	10	53
Tree Protection/Regeneration	8	42
Preventing soil compaction	6	32
Management of invasive/noxious weeds	5	26
Opportunities for funding	4	21

lived in arid zones or whose property was adjacent to unmanaged private or public forests.

Of the 19 landowners who participated in this research project only one landowner knew of someone else practicing silvopasture. According to landowners this lack of awareness of other practitioners was in part due to a lack of forestry and agricultural agency staff who understand silvopasture in Washington state. Conversely, the landowners acknowledged that they felt confident in their own management systems and thus did not seek out specialists or other practitioners unless they encountered a specific issue. Landowners reported a reliance on out-of-state resources; including universities, professional organizations, conferences, or online resources; to determine best management practices for their silvopasture systems.

Topics that landowners desired to know more about were multidisciplinary (Table 6). When asked what research or information would support their operation a majority of the responses focused on site productivity. Ten landowners wanted to know more about which forages would be most productive on their land and which would have the most nutritional benefit for their livestock. Half of the landowners would like workshops or research on ensuring tree survival and protection from livestock. Preventing soil compaction caused by forest and livestock management was another topic of concern for many landowners, as was reduction of invasive species.

Discussion

Silvopasture in Washington state is unique in its design, driven in part by a wide range of climates and soil/water regimes causing landowners to adapt their silvopasture systems to a mosaic of forest or afforested landscapes. In conjunction with ecological drivers, the economic valuation of regional timber and forage species, forest/orchard products, and livestock products has led to the regionally adapted silvopasture management systems that are a unique blend of landowner goals, experience, and knowledge.

Using the USDA definition of silvopasture which is the deliberate integration of trees and grazing livestock operations on the same land, this survey has identified 19 small to medium-scale farms/ranches practicing silvopasture in Washington state. Our research sought to understand the extent to which these producers were seeking social, economic, and

ecological resiliency and adaptability through the use of silvopasture. Our research confirmed the challenge with the working definition of silvopasture as it is not a widely accepted term among landowners or professionals.

This survey concluded that 100% of the landowners utilized silvopasture with a goal to increase revenue streams and provide regular yearly income through the sales of livestock (Table 5). It is not clear whether landowners were meeting this goal as only 21% of those surveyed were formally tracking income and expenses. While there was not enough data to formally calculate revenues or added income from silvopasture operations, all landowners reported that they were receiving predictable income from the sales of livestock. Whether these sales consistently offset expenses associated with silvopasture practices needs further exploration. A second primary goal of landowners was to increase ecosystem services. Provisional and regulating benefits from silvopasture such as access to food, climate regulation via shade for livestock, and forage production are well documented in the literature. However, the extent to which these ecosystem services have increased due to silvopasture practice needs to be further quantified. While cultural services such as aesthetics and quality of life can be difficult to measure, it should be noted that 50% of the landowners who use silvopasture reported practicing this land management strategy for more than 10 years and expressed a high degree of satisfaction with their usage of silvopasture. This was evident in this subset of landowners as they spoke about the ease managing the various aspects of their land. These landowners had determined appropriate stocking rates for the livestock and established methods of rotating livestock that minimized livestock stress and associated labor. In addition, this subset of owners had well managed forest stands or mature orchards that provided economic valuation and minimal intervention as they had established a forest or orchard management plan.

In discussions with key informants from relevant organizations, regardless of the intensive management design of silvopasture, the incorporation of livestock grazing into existing forest stands in this region is interpreted by many professionals as forest grazing. This misperception is common in other regions as well (Smith et al. 2022). This may be in part due to the interdisciplinary nature of silvopasture which requires the use of and knowledge of rotational grazing to obtain maximum benefits and prevent soil compaction and tree damage (Gabriel 2018). Skill and knowledge of forage management under a treed canopy is required to ensure forage quality and quantity (Gabriel 2018; Frey and Fike 2018). Finally, knowledge and understanding of forest structure and composition is required. Comprehension of site variability, potential natural vegetation, slope, aspect, elevation, soil types, and precipitation regimes is necessary to ensure adequate tree growth, minimize disease and pathogens and maintain site productivity (Nyland 2016; Wilkens et al. 2021). In addition to foresters, landowners report that they have consulted conservation districts to discuss resource concerns, NRCS staff to discuss forage management, and livestock specialists from UC Davis to assist in grazing management to reduce parasite loads. Collectively the gaps in working knowledge of agroecosystems may inhibit professionals from seeking and/or recommending adoption and funding opportunities available to farmers/ranchers. Compounding this issue is a lack of regionally specific research or literature documenting the ecological, social, and economic impacts of silvopasture in Washington state or offering practical guidance. Finally, further research will be required to understand how the availability of cheap grazing on public lands in the Pacific Northwest may be a disincentive to establishing more management intensive grazing systems such as silvopasture on private lands, thereby contributing to the low adoption rates observed.

Despite the complexity of silvopasture and a lack of literature and resources, the landowners who were identified and surveyed reported that they have designed and invested in robust management systems. These early adopters said that they relied on previous forest management and/or grazing and farming experience to inform their land management. As one research participant stated, “You need to be hungry and be constantly looking for resources, look for passionate people who are interested in passing on their knowledge.”

There is evidence that the lack of understanding of silvopasture and a clear definition has negatively impacted landowners. Sixteen out of the 19 landowners stated that they experienced challenges caused by the lack of understanding of professionals who discouraged them from integrating livestock into forest/

orchards. As one respondent noted, "Any (professional) I talk to cannot tell me the number of trees I should have on my property to ensure I have good forage for my cows. The best they can do is point me to a rangeland specialist or an article written in another state." Clarifying the definition and identification of silvopasture systems in Washington state could be a primary step towards removing barriers, developing best management practices, building practitioner networks, and addressing potential social, economic, and ecological shortfalls. There is an opportunity for foresters, livestock, and agricultural specialists to learn from the success of state and federal organizations and universities in other parts of the United States.

Conclusion

This study identified silvopasture sites across the state and documented a remarkable variability in the application of this agroforestry practice. Numerous types of livestock and tree species are incorporated into these systems illustrating unique site-specific designs. Using the USDA definition of silvopasture, this study provides evidence that despite a lack of local research, technical assistance, or regionally specific literature; landowners are practicing silvopasture in regions of the state where suitable conditions exist. Most commonly grazing systems were being incorporated into forested lands or pastures were being converted into silvopasture orchards.

While all practitioners stated both economic and environmental objectives for their systems. Our study found a lack of economic data being collected by practitioners which is not unusual for agricultural producers. A follow-up study could consider developing an economic analysis tool to aid practitioners in understanding and improving the economic performance of their operations while optimizing ecosystem services. A regional study of both Washington and Oregon silvopasture systems could analyze their inputs and outputs in order to determine the best ways to integrate and optimize short and long term environmental and economic benefits. Specifically, both professionals and landowners identified a need for additional information regarding best management practices related to stocking density; stand composition and structure; soil health metrics; and methods for protecting trees from livestock. In-depth, site-based research on these topics would substantively inform future academic studies, practitioners, and NRCS EQIP and Conservation District assistance programs.

Author contribution Mark Batcheler wrote the manuscript and prepared tables and figures All authors reviewed the manuscript

Funding This research was partially funded by the Western Sustainable Agriculture Research Education (SARE) Graduate Student grant (Grant number: 138360–001). Funding included: (1) graduate student salary and travel expenses for Mark Batcheler; (2) funding for outreach and education event; (3) stipend for landowners who participated in this research project.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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