RESEARCH ARTICLE

J. For. 117(1):13–20
doi: 10.1093/jofore/fvy065

economics

Modeling the Financial Potential of Silvopasture Agroforestry in Eastern North Carolina and Northeastern Oregon

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Silvopasture is the planned and managed agroecosystem in which forage, livestock, and woody perennials are integrated "either simultaneously or sequentially on the same parcel of land." Silvopasture can help mitigate anthropogenic climate change through carbon sequestration in perennial vegetation. We examined silvopasture, forest, and pasture systems in eastern North Carolina and northeastern Oregon. In North Carolina, we evaluated forest and agroforestry systems using loblolly and longleaf pine species. In Oregon, we evaluated forest and agroforestry systems using ponderosa pine. We based the analyses on typical forest and cattle regimes, including yields, costs, and prices obtained from the literature, and consulted with experts in the respective subjects. The financial viability of land management investments was investigated using capital budgeting techniques. Cash flows were developed using 4 percent and 6 percent real discount rates. Analysis suggests loblolly pine timber management and cattle management are more profitable than silvopasture management in eastern North Carolina. Additionally, cattle management is more profitable than silvopasture in northeastern Oregon. Longleaf pine and ponderosa pine are not profitable when solely managed for timber and can benefit financially when combined with livestock.

Keywords: silvopasture, capital budgeting, loblolly pine (*Pinus taeda*), longleaf pine (*Pinus palustris*), ponderosa pine (*Pinus ponderosa*)

Current agricultural production contributes a significant amount of greenhouse gas to the atmosphere. Fermentation and respiration from ruminants produce methane, a greenhouse gas 30 times more potent than CO_2. Total emissions from global livestock contribute 7.1 gigatonnes of carbon dioxide equivalent per year, or about 14.5 percent of all anthropogenic greenhouse gas emissions annually (FAO 2018). Cattle raised for meat and milk products make up 65 percent of the livestock sector's emissions, as compared with chickens, pigs, and other animals raised for consumption (FAO 2018).

Silvopasture is one of the many potential solutions to mitigating climate change by enhancing carbon storage through the increased plantings of perennial vegetation. Silvopasture is a planned and managed agroecosystem in which forage, livestock, and trees or shrubs are integrated in order to enhance individual components (Sharrow 1997, Nair 2012). Trees can benefit livestock by slowing wind speeds and providing shade, while producing timber products, forage for livestock, and fruits or nuts. Livestock provide saleable meat or dairy, consume understory weeds in order to control tree-to-forage competition, and provide limited elements such as nitrogen, phosphorus, potassium, and sulfur through nutrient cycling in the form of manure (Sharrow 1997).

Multiple studies explore the potential for silvopasture to offset greenhouse gas emissions. Udawatta and Jose (2011) concluded that the potential for carbon sequestration under various agroforestry practices in the United States could help offset United

Received January 2, 2018; accepted October 30, 2018.

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Acknowledgments: *We would like to acknowledge the faculty and extension at North Carolina State University and North Carolina A&T, as well as the personnel at the Center for Environmental Farming Systems. Moreover, we would like to acknowledge the faculty and extension at Oregon State University for their insights and logistical input. Additionally, we would like to thank the landowners who graciously opened their farms to visitation in both North Carolina and Oregon.*

States greenhouse gas emissions by 33 percent. Sharrow and Ismail (2004) found that Douglas-fir silvopasture in Oregon sequestered 1.83 Mg C ac^{-1} yr^{-1} and 1.28 Mg C ac^{-1} yr^{-1} more than plantation and pasture in situ locations, respectively. Cubbage et al. (2012) compared silvopasture systems in eight regions of the world. They attest that with extreme weather events, silvopasture can offer diversity and resilience, as well as moderate returns comparable with latnerative production systems.

Greenhouse gas emissions represent a global market failure resulting in net social welfare loss (Stern 2008). Silvopasture not only has the potential to help correct the market asymmetries of climate change, but also can improve overall economic performance of a farm enterprise through diversification and maintenance of biodiversity (Hamilton 2008). In fact, silvopasture has been identified as the most promising agroforestry regime for the Pacific Northwest and southeast United States by Sharrow (1997), Husak and Grado (2002), Brandle et al. (2005), Elser (2007), Hamilton (2008), and Cubbage et al. (2012), because both intensive livestock and forest management have occurred in these regions for generations. However, landowners often do not intensively manage both livestock and trees simultaneously.

Husak and Grado (2002), conducted an economic analysis comparing silvopasture in the Southeast United States with traditional monoculture of soybean, rice, and pine plantations. Annual and periodic cash flows from timber and livestock sales were analyzed using real discount rates of 5, 7, and 9 percent (Husak and Grado 2002). Land expectation value (LEV), equivalent annual income (EAI), and rate of return (ROR) were calculated as economic predictors. Results provide evidence that profitability of silvopasture is comparable with traditional monoculture systems, where soybean production had the lowest LEV at a real discount rate of five percent with \$1,087 $acre^{-1}$, followed by cattle (LEV \$1,106 $acre^{-1}$), rice (LEV \$1,214 $acre^{-1}$), silvopasture (\$1,341 $acre^{-1}$), and pine plantation (\$1,385 $acre^{-1}$) (Husak and Grado 2002).

Economic analysis has been used to assess the potential of silvopasture to restore longleaf pine (*Pinus palustris*) through the integration of carbon policies. Longleaf pine forests existed on up to 92 million acres of the southeast coastal plain. However, because of colonization, agricultural expansion, fire suppression, population growth, and preference for fast-growing loblolly pine, these forests exist on a small portion of historical range. Stainback et al. (2004) calculated LEV on longleaf pines in the southeast ranging from \$1,700 $acre^{-1}$ (pasture) to \$2,800 $acre^{-1}$ (silvopasture). In addition to an increased LEV, the authors found that the optimal rotation age for silvopasture was always shorter than traditional forestry for longleaf pine (Stainback et al. 2004). Silvopasture provides an economically viable way to profitably restore longleaf pine on marginal pastureland while potentially mitigating climate change (Stainback et al. 2004).

Multiple studies have examined the economics of silvopasture systems. Financial benefits from silvopasture including increased net present value (NPV) have been shown to exist for marginal lands in the south. Dangerfield and Harwell (1990) show a 71 percent increase in NPV when changing from traditional forestry to silvopasture on site index 60 and 65 in the flatwoods of the southeast United States. The authors indicate that the main driver of that increase in NPV was the extra income provided by the cattle activity. A study on introducing cattle to timber management indicated rates of return ranging from 0.5 percent to 4.5 percent in Louisiana (Lundgren et al. 1983). An analysis of multicropping black walnut with soybeans, wheat, hay, or cattle indicated that all options were economically feasible at a 6 percent discount rate. Of the options tested, grazing on land stocked with black walnut returned the lowest ROR (Garrett and Kurtz 1983). For southern pine plantations, Clason (1995) found that silvopasture was more stable than cattle and timber when prices were less stable because of the effect of diversification.

Surveys were conducted in Florida to determine Willingness to Pay (WTP) for three ecosystem services provided by silvopasture to enhance the Lake Okeechobee Watershed: (1) reduced phosphorus runoff, (2) carbon sequestration, and (3) wildlife habitat improvement (Shrestha and Alavalapati 2004a). The WTP estimates for moderate and high water-quality improvement through reduced phosphorus runoff from silvopasture practices were \$30.24 and \$71.17 per year for 5 years. Estimates for moderate and high WTP carbon sequestration levels were \$50.05 and \$67.72. Lastly, WTP estimates for wildlife habitat improvements were \$49.68 and \$41.06. Therefore, individuals may be willing to pay for moderate ecosystem service improvements, which can be achieved through agroforestry and silvopasture.

Revenues from timber and hunting licenses can offset the cost of silvopasture to some extent, but without policy incentives cattle ranchers may have little to no motivation to adopt silvopasture (Alavalapati et al. 2004). These programs encourage filter strips, riparian buffers, shelterbelts, windbreaks, and grass waterways, which provide many of the same ecosystem services and environmental benefits as silvopasture (Alavalapati et al. 2004). Cutter et al. (1999), refers to this phenomenon as direct and indirect legislation. Laws that are not specifically devoted to agroforestry are referred to as indirect laws, which are more common. Activities included in indirect laws are activities such as tree planting, riparian buffers, and wildlife habitat (Cutter et al. 1999).

Shrestha and Alavalapati (2004b), estimated rancher's mean willingness to adopt silvopasture and found that on average, a price premium of \$0.15 lb^{-1} of beef or a direct payment of \$9.32 ac^{-1} yr^{-1} was required for ranchers to adopt silvopasture practices. These estimates are lower than

Management and Policy Implications

It is widely accepted that agroforestry can increase soil fertility, manage and mitigate erosion, and increase carbon sequestration, among other environmental benefits. However, monoculture systems can potentially be more profitable over the long run. The work presented here identifies potential monetary incentives to implementing silvopasture agroforestry for landowners as compared with their corresponding monoculture system. The models used to calculate average potential income can be narrowed to the scope of an individual to assist in decisionmaking. Furthermore, policies that support silvopasture vary on a year-to-year and state-to-state basis. Enduring policies can better inform the models used here and support landowners who wish to implement silvopasture.

national average annual payments under the Conservation Reserve Program, which was \$48.93 ac^{-1} yr^{-1} (Shrestha and Alavalapati 2004b).

In this study, we examined the financial potential of silvopasture systems in the Southeast and Pacific Northwest United States through case studies of prospective land management systems in eastern North Carolina and northeastern Oregon. The objective was to determine the potential financial benefits silvopasture can provide to landowners through the use of rigorous capital budgeting techniques. Current literature in the field commonly uses survey methods, and contingent valuation to determine WTP for silvopasture adoption. Additionally, most of these studies focus on the southeast, United States; limited economic research has been conducted in the Pacific Northwest.

Our study was based on the methodology employed by Husak and Grado (2002), to examine two regions of the United States where silvopasture is most commonly adopted. Both regions have a similar history of both timber and livestock management, and could potentially benefit from managing the regimes simultaneously in an intentional way. We developed typical sets of management practices and annual cash flows for pasture, forests, and silvopasture systems, and calculated their financial potential. Expanding on Husak and Grado (2002), we allow for a 4-year delay before introducing cattle and factor in bull sale and replacement costs to better reflect in-situ practices. We also use updated prices for cattle and forest management.

Economic Indicators

Most agroforestry systems take three to six years before benefits begin to be realized, compared with a few months for annual crops (Mercer et al. 2014). Thus, discounted cash flow analyses and capital budgeting techniques are used to evaluate the financial returns of agroforestry and other long-term forestry or agriculture investments. These approaches take into account the timing and value of annual cash flows, and the time value of money, where expenses or income received in the future have less value than income in the present. Cubbage et al. (2013, 2016) provides an overview of capital budgeting, including templates and examples of the underlying financial analyses.

A discount rate is used to account for the value of future income that would be equivalent to income in the present. It represents the ROR an investor must receive to justify any investment (Mendell 2006). Discount rates are not directly observable, and therefore no perfect discount rate exists for every timberland investor. Forestry investments are generally computed with a low discount rate, as forestry is seen as a lower-risk investment option than other investment options. Investments with a lower risk are generally expected to yield a lower return indicating a lower discount rate for analyzing forestry cash flows (Hancock Timber Resource Group 2012).

The NPV most commonly determines the financial viability of a land-management investment. NPV subtracts the present value of an investment's total costs from the present value of the investments total revenues (Godsey et al. 2009). This is also defined as the sum of the discounted periodic net revenues per acre over a given time period (Mercer et al. 2014). NPV measures the amount of capital that an investment returns at a given discount rate (Cubbage and Hodges 1989, Cubbage et al. 2016). For capital budgeting decisions, or choosing among many projects, one should choose the project with the highest NPV (Mercer et al. 2014):

$$\mathrm{NPV} = \sum_{t=1}^{T}\left(\frac{\mathrm{CF}_t}{(1+i)^t}\right) - C_0$$

where: CF = cash flow (positive or negative) incurred during year t; T = time horizon; t = time period; i = interest or discount rate; and C_0 = initial investment.

The LEV measures the discounted present value of an investment in perpetuity. It is more appropriate when time horizons of different alternatives vary and thus calculates the net return per acre for all management regimes on the same infinite time horizon (Godsey et al. 2009, Mercer et al. 2014, Cubbage et al. 2016). LEV is considered the standard in long-term forestry analyses, and measures how much one could pay for a parcel of land and earn the designated discount rate (Straka and Bullard 1996):

$$\mathrm{LEV} = \left(\frac{\mathrm{NR}}{(1+i)^R - 1}\right)$$

where: NR = net revenue at the end of the first rotation; and R = length of the rotation.

The annual equivalent value (also referenced as equal annual equivalent) is a conversion of the NPV to an annual payment. This calculation is often used when comparing long-term investments in forestry with shorter agricultural crops. Decisions are based on whether the AEV is positive, and when choosing among multiple opportunities, the investment with the highest AEV should be selected.

$$\mathrm{AEV} = \mathrm{NPV}\left(\frac{i(1+i)^t}{(1+i)^t - 1}\right)$$

The internal rate of return (IRR) is a means of measuring the average annual ROR of investment (Cubbage et al. 2016). It is the discount rate that, when used, will equate the discounted costs with the discounted revenues, or when the NPV equals zero (Mercer et al. 2014). Although IRR is generally not theoretically preferred, it is appealing when a producer does not have a set discount rate (Mercer et al. 2014). The IRR can be compared with the ROR of another investment, such as a savings account. It can also be used to compare with personal, corporate, or public rates. IRRs that are greater than the discount rate would indicate investment acceptability, and vice versa (Cubbage et al. 2016).

Methods

We examined silvopasture systems in North Carolina and Oregon to assess their merits with respect to traditional forest or grazing systems. In North Carolina, we evaluated forest and agroforestry systems using loblolly and longleaf pine species, typical of the coastal plain region. In Oregon, we evaluated ponderosa pine, the major commercially grown tree in the Blue Mountain Region of northeast Oregon. We based the analyses on typical forest and cattle regimes; including yields, costs, and prices obtained from the literature, and consulted with experts in the respective subjects (see Supplemental Appendix for detailed information).

Eastern North Carolina

Loblolly pine plantations are the most productive forests in the southern United States (Amateis and Burkhart 2012). Before European settlement in the south, longleaf pine (*Pinus palustris*) dominated about 75 million acres and occurred on 17 million acres in mixed stands. Historically, longleaf grassland ecosystems dominated the Coastal

Plain regions from southeastern Virginia to east Texas because of frequent fires that occurred every 1–3 years (Van Lear et al. 2005). Longleaf trees grow slow at first, but can catch up to loblolly pine growth rates on nutrient poor sites, but not on higher site class lands (Cubbage and Hodges 1989, Longleaf Alliance 2011). In addition, whereas longleaf pine has a longer rotation than other southern pines, it does offer very good yields (Cubbage and Hodges 1989).

North Carolina has four major soil regions: Coastal Plain, Sandhills, Piedmont, and Mountains (Castillo et al. 2014). The Coastal Plain is characterized by cool winters and hot humid summers with an average of 53 inches of rainfall annually and an average temperature of 60°F (16°C) (Laiho et al. 2001). Soils in the Coastal Plain and Sandhills generally range from sandy to sandy loam and support tall fescue (*Festuca arundinacea*), Bermudagrass (*Cynodon dactylon*), bahiagrass (*Paspalum notatum*), and dallisgrass (*Paspalum dilatatum*) (Castillo et al. 2014). There is no single year-round forage in North Carolina. Grasses are split into two broad categories: cool season and warm season. Cool season species are generally preferred, as they provide forage most of the year, not including summer months (Castillo et al. 2014). Silvopastoral environments provide a unique microclimate in which forages generally start growth earlier in the spring and continue later into the fall (Cubbage et al. 2012). However, peak forage yield is generally lower than that of traditional pasture (Walter 2011).

Northeastern Oregon

Most private land in eastern Oregon can be categorized into four forest types: ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), warm mixed conifer, or cool mixed conifer. The ponderosa pine forest type is classified as nearly 100 percent pure ponderosa pine, generally in a dry climate where no other commercial tree will grow. Ponderosa pine is claimed to be the most valued and managed species in the dry interior west (Emmingham et al. 2005) and covers about 22 million acres, second only to Douglas-fir forests (Oswalt et al. 2014).

The Blue Mountain Province covers about 15 million acres. The average annual precipitation is 22 inches (McQueen 2014). Native palatable forages for livestock include Idaho fescue, western needlegrass, pinegrass, and bluebunch wheatgrass (Wagner 2016, pers. commun.). Unlike the southeast US, landowners in northeast Oregon typically do not plant forage grasses beneath trees and rely upon natural propagation of grasses.

Management and Capital Budgeting

Management regimes were constructed for eastern North Carolina as follows: (1) standard loblolly pine, (2) standard longleaf pine, (3) standard livestock, (4) silvopasture with Bermudagrass (warm season grass) and loblolly pine, (5) silvopasture with switch grass and loblolly pine (warm season grass), (6) silvopasture with cool season grass and loblolly pine, (7) silvopasture with clover and loblolly pine, (8) silvopasture with Bermudagrass (warm season grass) and longleaf pine, (9) silvopasture with switch grass and longleaf pine, (10) silvopasture with cool season grass and longleaf pine, and (11) silvopasture with clover and longleaf pine; where "standard" indicates the typical management of land production. Three management regimes were analyzed for northeastern Oregon: (1) ponderosa pine standard, (2) livestock standard, and (3) silvopasture with native forages and ponderosa pine.

For North Carolina, tree planting, management costs and revenue scenarios for loblolly pine and longleaf pine management regimes reflect accurate market values for the years from 2013 to 2014. Livestock-management practices were adapted from Husak and Grado (2002), updated with the Benson and Poore livestock budget (2013), which reflects current management practices. Loblolly pine rotations, costs, and price data were taken from Cubbage et al. (2014) and the North Carolina Forest Service (2014), based on a 25-year rotation for a site index of 70. Data from Glenn (2012), drawn from Lohrey and Bailey (1977), were used for the longleaf pine growth and yield data based on a 45-year timber rotation, updated with the same North Carolina Forest Service price data. Volumes were calculated from Lohrey and Bailey (1977) using 500 TPA. Stocking rates were reduced to 18.2 percent for warm season grass and 36.4 percent for cool season grass. The reduction in stocking rates reflects the need to allow light for maximum forage growth. Planting costs and revenues were adjusted to reflect this stocking level. For all North Carolina cases, we are assuming the initial use of the land is open pasture. To transition from cattle only to silvopasture, it will be necessary for the landowner to establish appropriate forages depending on light competition between trees and forage that may not currently exist.

For Oregon, extension agents, scholars, and landowners gave recommendations through personal communication for management scenarios. Painter and Rimbey's (2014), Enterprise Budget was used in the cattle capital budgeting analyses. Painter was contacted to discuss the Enterprise budget in further detail. Ponderosa pine growth and yield, costs, and price data were provided by Bowers (2014), and the Oregon Department of Forestry (2013). A 100-year rotation was assumed for the typical stand management regime on a site index of 80. Ponderosa pine yields are based on 400 TPA. For all Oregon cases, we are assuming initial use of the land is open pasture with native forages. In the silvopasture system, cattle will not be introduced until year 5 to allow native pioneer forages and planted pines to establish.

Eastern North Carolina Results

When comparing the livestock management regime with regimes with different timescales, for example between 25-year rotations and 45-year rotations, the best calculation comparison is between LEVs (Tables 1 and 2). Livestock on a 25-year rotation at a 4 percent real discount rate had an NPV of \$1,293 ac^{-1} and LEV of \$2,070 ac^{-1}. At a 6 percent real discount rate, the NPV was \$955 ac^{-1} and LEV of \$1,191 ac^{-1}.

Loblolly pine data provided by Cubbage and Abt (2014), and the North Carolina Forest Service (2014), on a 25-year rotation at a 4 percent real discount rate accrued an NPV \$1,110 ac^{-1} and LEV of \$1,777 ac^{-1}. Loblolly pine silvopasture at a 4 percent real discount rate accrued an NPV with Bermudagrass of \$346 ac^{-1}, NPV with switch grass of \$447 ac^{-1}, NPV with cool season grass of \$641 ac^{-1} and NPV with clover of \$596 ac^{-1}. Loblolly pine silvopasture at a 4 percent real discount rate accrued an LEV with Bermudagrass of \$553 ac^{-1}, LEV with switchgrass of \$715 ac^{-1}, LEV with cool season grass of \$1,026 ac^{-1}, and LEV with clover of \$953 ac^{-1}. Thus, traditionally stocked loblolly pine stands were more profitable than silvopastoral systems. For both discount rates, the AEV is similar between the loblolly pine and livestock standard (\$48 ac^{-1} for loblolly and livestock at 6

Table 1. Capital budgeting at a 4 percent real discount rate for eastern North Carolina, 2014.

	Scenario/capital budgeting criteria at 4 percent real discount rate	Net present value ($ ac^{-1})	Land expectation value ($ ac^{-1})	Annual equivalent value ($ ac^{-1})	Internal rate of return (percent)
	Loblolly pine standard (1)	1,110	1,777	71	8.4
	Longleaf pine standard (2)	–119	–143	–6	3.5
	Livestock standard (3)	1,293	2,070	83	20.7
Warm season grasses	Loblolly Bermudagrass silvopasture (4)	346	553	22	7.2
	Loblolly switch grass silvopasture (5)	447	715	29	8.6
Cool season grasses	Loblolly cool season grass silvopasture (6)	641	1,026	41	8.7
	Loblolly clover silvopasture (7)	596	953	38	8.2
Warm season grasses	Longleaf Bermudagrass silvopasture (8)	149	180	7	4.9
	Longleaf switch grass silvopasture (9)	250	302	10	5.9
Cool season grasses	Longleaf cool season grass silvopasture (10)	286	345	14	5.6
	Longleaf clover silvopasture (11)	240	290	12	5.3

Table 2. Capital budgeting at a 6 percent real discount rate for eastern North Carolina, 2014.

	Scenario/capital budgeting criteria at 6 percent real discount rate	Net present value ($ ac^{-1})	Land expectation value ($ ac^{-1})	Annual equivalent value ($ ac^{-1})	Internal rate of return (percent)
	Loblolly pine standard (1)	460	600	48	8.4
	Longleaf pine Standard (2)	–391	–422	25	3.5
	Livestock standard (3)	955	1,191	48	20.7
Warm Season Grasses	Loblolly Bermudagrass silvopasture (4)	102	133	8	7.2
	Loblolly switch grass silvopasture (5)	203	265	16	8.6
Cool Season Grasses	Loblolly cool season grass silvopasture (6)	641	379	23	8.7
	Loblolly clover silvopasture (7)	245	319	19	8.2
Warm Season Grasses	Longleaf Bermudagrass silvopasture (8)	–115	–124	–7	4.9
	Longleaf switch grass silvopasture (9)	–14	–15	–1	5.9
Cool Season Grasses	Longleaf cool season grass silvopasture (10)	–48	–52	–3	5.6
	Longleaf clover silvopasture (11)	–93	–101	–6	5.3

percent). All silvopasture systems produced a lower AEV at both discount rates (ranging from $23 ac^{-1} to –$1 ac^{-1} for 6 percent).

Conversely, longleaf pine data provided by Lohrey and Bailey (1977) and the North Carolina Forest Service (2014) on a 45-year rotation have negative present values for both 4 percent and 6 percent real discount rates. However, when combined with livestock management, longleaf pine silvopastoral systems accrued an NPV at a 4 percent real discount rate with Bermudagrass of $149 ac^{-1}, NPV with switch grass was $250 ac^{-1}, NPV with cool season grass was $286 ac^{-1}, and NPV with clover was $240 ac^{-1}. Longleaf pine silvopasture at a 4 percent real discount rate accrued an LEV with Bermudagrass of $180 ac^{-1}, LEV with switch grass of $302 ac^{-1}, LEV with cool season grass of $345 ac^{-1}, and LEV with clover of $290 ac^{-1}. Silvopasture enhances the system to be more economically viable than planting longleaf pine alone.

Silvopasture is profitable for Bermudagrass, switch grass, cool season grass, and clover regimes at a 4 percent real discount rate across all management regimes. Interestingly, longleaf pine is not profitable when managed alone, but is profitable when combined with livestock management. However, livestock management, loblolly pine, and loblolly pine silvopasture surpass longleaf pine and longleaf pine silvopasture systems in profitability. The economic calculations suggest that loblolly pine combined with cool season grass would be the most profitable silvopasture system.

Northeastern Oregon Results

On a 100-year rotation, ponderosa pine has negative cash flows for both 4 percent and 6 percent real discount rates. The cattle standard management regime, using the budgeting data from northern Idaho (Painter and Rimbey 2014) at 4 percent real discount rate, accrue an NPV of $936 ac^{-1}, and 6 percent real discount rate accrues an NPV of $555 ac^{-1}. Silvopasture at a 4 percent real discount rate accrues an NPV of $274 ac^{-1}, and 6 percent real discount rate accrues an NPV of –$84 ac^{-1} (Table 3).

Furthermore, the LEV for the standard livestock management regime at 4 percent real discount rate accrues $955 ac^{-1}. Silvopasture LEV at 4 percent real discount rate accrues $280 ac^{-1}. Therefore, managing cattle alone is more profitable than silvopasture. The price of cattle is expected to decrease from the 2014 fiscal year and stay steady into the future (Anderson 2016). Therefore, livestock management may be less profitable in the future, since 2014 was a peak year for cattle prices. As expected, NPVs were lower for all scenarios using the 6 percent discount rate (Table 4).

Ponderosa pine is not profitable alone but, when combined with silvopasture, is economically viable. Nevertheless, it is not advantageous to plant trees if managing a livestock herd when considering the potential loss to income. Yet, landowners often have trees established on private land and therefore do not have site preparation and planting costs.

Discussion

The methodology of our study follows that employed by Husak and Grado (2002), who conducted their study from data collected by the United States Department of Agriculture in 1999. Our study follows up on their findings, 15 years later, to provide a more current understanding of the financial potential of silvopasture and expand this methodology to the Pacific Northwest, which has also been identified in the literature as a

Table 3. Capital budgeting at a 4 percent real discount rate for northeastern Oregon, 2014.

Scenario/capital budgeting criteria at 4 percent real discount rate	Net present value ($ ac^{-1})	Land expectation value ($ ac^{-1})	Annual equivalent value ($ ac^{-1})	Internal rate of return (percent)
Ponderosa pine	–403	–411	–16	5.3
Standard livestock	936	955	38	19.5
Ponderosa silvopasture	274	280	11	2.4

Table 4. Capital budgeting at a 6 percent real discount rate for northeastern Oregon, 2014.

Scenario/capital budgeting criteria at 6 percent real discount rate	Net present value ($ ac^{-1})	Land expectation value ($ ac^{-1})	Annual equivalent value ($ ac^{-1})	Internal rate of return (percent)
Ponderosa pine	–472	–473	–28	2.4
Standard livestock	555	557	22	19.5
Ponderosa silvopasture	–84	–84	–5	5.3

promising region for silvopasture agroforestry implementation. Additionally, there is a lack of financial literature describing silvopasture potential in eastern Oregon, and the descriptive methodologies used here act as a starting-point for more dynamic analyses.

Our findings were similar to those of Husak and Grado for southern pine plantations, where they found that pine plantations alone were more profitable than silvopasture. However, they concluded that silvopasture was more profitable than cattle management alone, where we found that both cattle management and pine management were more profitable than silvopasture. The potential reason for this is that cattle prices reached a record high in the fiscal years 2014–15, with the strongest demand for beef products seen in 25 years.

The potential of silvopasture to diversify profit and reduce the risk of an investment should not be ignored (Husak and Grado 2002). Silvopasture provides a unique opportunity for enhanced biological diversity (Udawatta and Jose 2011), reduced erosion (Bishaw et al. 2002), increased nutrient uptake (Sharrow 1997, Bishaw et al. 2002), and carbon sequestration (Schoeneberger 2014). Notably, there are differences between the management scenarios in North Carolina and Oregon. North Carolina has a higher cattle-stocking rate because net primary production of grasses allows for more animals per acre. Although pasture establishment is not necessary in northeastern Oregon; a lower stocking rate of upwards of one cow–calf pair per 10 acres is needed to provide enough forage on poorest sites. One cow per 4 acres was assumed for more productive sites used in this study, as suggested by site visits to Union, Oregon.

The analyses presented here suggest a number of valuable conclusions. The financial calculations suggest that monoculture loblolly pine timber management and cattle management in North Carolina were more profitable than silvopasture. Similarly, cattle management was more profitable than silvopasture in northeastern Oregon. Ponderosa pine was not profitable in traditional timber plantations and was more financially viable when combined with livestock management. Similarly, longleaf pine in North Carolina was not profitable in plantation form and was more financially viable when combined with livestock management. When looking at NPV and LEV, silvopasture loblolly pine management is more profitable than longleaf pine. This occurs because loblolly pine grows faster and has shorter rotations and more income per acre. Overall, the broad differences between management in North Carolina and Oregon are that North Carolina can support a high cattle-stocking rate because of enhanced forage production, whereas Oregon does not require pasture establishment. North Carolina sees a higher return from loblolly pine plantation management, whereas Oregon has a higher return from cattle management.

Different site indices will produce different results. For this study, we assumed a median site index for the area studied. A lower site index would reduce the LEV for the timber only and silvopasture scenarios, as timber yield would be reduced with potential reduction in timber quality as well. An improvement in site would increase LEV for timber only and silvopasture.

In addition to the direct economic returns, broad environmental and risk diversification benefits may warrant more shifts to silvopasture systems. Livestock and forest products can help offset fluctuations in commodity prices between the systems, increasing overall portfolio returns of silvopasture systems in both regions. Climate change mitigation and adaptation may favor more diverse pasture and forest mixes with the pasture preventing catastrophic forest fires. For example, studies have found that mixed tree and cattle systems could offset greenhouse gas emissions from cattle on a stand-level basis (Dube 2010).

Conclusion

The previous nascent literature biophysical benefits of silvopasture in temperate ecosystems has considerable promise to improve base returns from either pure monoculture grasslands or forest ecosystems. Silvopasture has the potential to store significant amounts of carbon in above- and belowground biomass, thereby offsetting anthropogenic emissions. However, at this time, tradable permit markets do not exist for silvopasture systems.

Individual landowners could explore the availability of government programs to assist with costs associated with establishment of management practices that are compatible with silvopasture systems. Different states and counties have specific potential subsidies, which could further increase monetary benefits. Overall, the results of our current deterministic analyses of forest to silvopasture could assist landowners when making decisions about resources use based on more current timber and cattle market costs, prices, and profits in the southeast United States and Pacific Northwest.

Supplementary Materials

Supplementary data are available at *Journal of Forestry* online.

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