Agroforestry Systems **61:** 299–310, 2004.

Agroforestry development: An environmental economic perspective

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Key words: Contingent valuation, Externalities, Profitability, Silvopasture, Willingness to accept (WTA), Willingness to pay (WTP)

Abstract

Agroforestry systems (AFS) provide a mix of market goods and nonmarket goods and services. We postulate that if nonmarket goods and services can be internalized to the benefit of landowners, the adoption of AFS will increase. Using the theory of externality as a conceptual framework, this paper provides an environmental economic logic for developing incentive policies to internalize environmental services especially in the industrialized countries. Specifically, the paper addresses the following questions with focus on North America in general and southern United States in particular: What is the effect of environmental costs and benefits on the adoption of silvopasture? Do households care for carbon sequestration, water quality improvement, and biodiversity associated with silvopasture? Will they be willing to pay for them? If so, how much? Will ranchers adopt more silvopasture if incentives are provided? Which incentive policy, a price premium or a direct payment, is more effective? It has been found that the profitability of silvopasture would increase, relative to conventional ranching, if environmental services are included. Estimates of public willingness to pay for environmental services associated with silvopasture and estimates of ranchers' willingness to accept for the adoption of silvopasture will provide a scientific basis for policy development.

Introduction

Agroforestry is widely considered as a potential way of improving socioeconomic and environmental sustainability both in the tropics and in the temperate regions (Alavalapati and Nair 2001; Garrett et al., 2000; Nair 2001). Agroforestry systems (AFS) provide a mix of market goods such as food, wood products, and fodder to cattle, and nonmarket goods and services including soil conservation, water and air quality improvement, biodiversity conservation, and scenic beauty. As such, AFS contribute to the rural economy, employment, poverty alleviation, and environmental protection at a local, regional, and national level. One of the key factors in determining agroforestry adoption is the relative profitability of the practice in comparison with other land-use practices.

Determining AFS profitability can be complex. Profitability from a landowner perspective, generally called 'private profitability', can be different from that of a societal perspective, often referred to as 'social profitability.' The exclusion or inclusion of social benefits and costs and nonmarket values, often referred to as externalities, largely differentiates the private and social profitability.[1] In the context of AFS, private profitability analysis does not include nonmarket goods and services because these are public goods. These goods are generally indivisible and consumed by all at a level that is the same for all. Also, producers of these goods cannot exclude people from consuming these goods (Peterson 2001). Therefore, indivisibility and nonexclusivity attributes of public goods discourage landowners to consider them in their decision-making.

Research suggests that environmental services such as carbon sequestration, improvement in water quality, and biodiversity for example, associated with AFS are significant (Garrett et al. 2000). Furthermore,

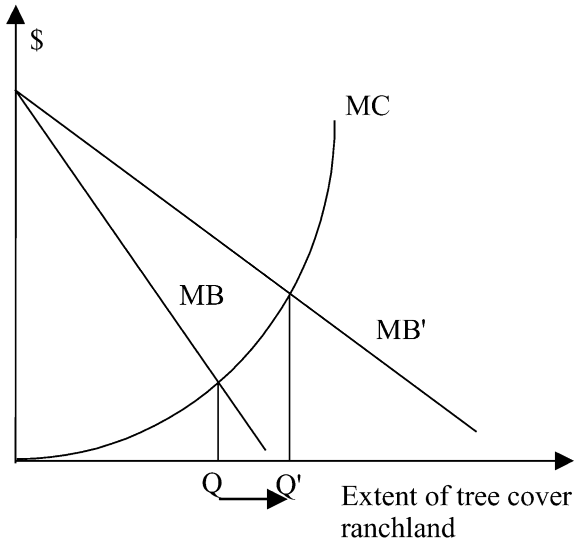

Figure 1. The effect of internalizing environmental services on the extent of tree cover on ranchlands.

there is growing appreciation for these services from scientific communities and the general public especially in the industrialized world (Montagnini and Nair 2004; Pimentel et al. 1995). Therefore, it is important and also rational to include them in ASF profitability analysis. Failure to account for them will result in gross under-valuation of AFS. Furthermore, if environmental costs of alternative land uses are greater than those of AFS[2] and if they do not enter into the analysis, it will result in over-valuation of alternative land-uses. Either way, the adoption of AFS will be less than optimal.

Figure 1 presents a graphical analysis to illustrate the effect of internalizing environmental services associated with temperate-zone silvopasture on its adoption. The horizontal axis measures the extent of trees and buffer strips on ranchlands, a proxy for silvopasture, while the vertical axis measures the costs/benefits of maintaining tree cover and buffer strips. Trees and buffer strips on ranch lands are considered beneficial to ranchers by providing shade to cattle and additional revenue from timber (MB). They also provide environmental benefits to the public by improving water quality and air quality. Research suggests that the trees' extensive root system and litter fall can reduce soil erosion; trees' uptake of nutrients can reduce fertilizer and pesticide runoff into nearby streams (Zinkhan and Mercer 1997); and growing trees sequester carbon by absorbing carbon dioxide from the atmosphere (see Montagnini and Nair 2004). The reduction in livestock numbers due to the addition of trees and buffer strips could result in further reduction of phosphorus and nitrogen wastes (Boggess et al. 1995). However, maintaining trees and buffer strips on ranchlands will cost ranchers (MC) but not the public. As forage production, a proxy for cattle production, is a function of tree basal area, an increase in the tree density will cause a reduction in the cattle output (see Stainback et al. 2004 for the relationship between tree density and cattle output).[3] Furthermore, the cost of fencing, tree seedlings, site preparation and pruning is expected to increase with an increase in the tree density.

In the absence of benefits from environmental services of silvopasture, ranchers will maintain only Q amount of tree cover on their ranches. This is determined by equating the private marginal cost of maintaining trees on ranchlands (MC) and private marginal benefit of trees (MB). However, if markets exist for environmental services and if ranchers can capitalize on water quality improvement and carbon sequestration for example, the marginal benefit of trees would be higher (MB'). This would motivate ranchers to maintain Q amount of tree cover on their ranchlands.

One of the main impediments for internalizing environmental services is limited information about public demand for these goods and the supply response of landowners. To our knowledge, very few efforts have been devoted to systematically investigate the following important questions. How do environmental costs and benefits influence the profitability of AFS and alternative land uses? Do households care for carbon sequestration, improvement in water quality, and biodiversity associated with AFS? If they do, will they be willing to pay for them and how much? Do landowners adopt AFS to improve environmental quality if incentives exist? Which incentive policy, a price premium or a direct payment, would be more effective?

The objective of this chapter is to illustrate the importance of environmental economic information in agroforestry development and suggest possible roles for government intervention. Specifically, we will attempt to address the above questions by drawing on the research that was conducted on sivlopasture in Florida. First, we present the theory of externalities to provide a framework for internalizing environmental costs and benefits of silvopasture. Second, the effect of environmental costs and benefits on the profitability of silvopasture and conventional ranching is assessed. Third, public demand for environmental services in terms of their willingness to pay is assessed. Fourth, ranchers' willingness to adopt silvopasture in the face of a price premium and a direct payment is analyzed. The final section discusses policy implications and the role of government.

Theory of externalities

An externality occurs when the activities of one agent affect the activities of another either positively or negatively and when these activities are not taken into account by the first agent in making his or her decision (van Kooten 1993). In the context of AFS, silvopasture practices on ranchlands, especially in Florida, may improve water quality in nearby streams and thus impact the utility of general public positively: chemical fertilizers used in pasture production can enter into nearby streams or groundwater and cause nonpoint source pollution (Nair and Graetz 2004) In the absence of incentives for the provision of positive externalities and penalties for generating negative externalities, a rational agent is less likely to produce them at societal optimum.

Institutional economics suggests that assigning property rights is an effective way to fix externality problems. Under exclusive, transferable, and enforceable property rights, people can be rewarded for positive externalities and penalized for negative ones. This would influence rational agents to produce externalities at optimum levels. Nobel Laureate Ronald Coase pioneered this principle in his famous article 'The Problem of Social Cost' published in 1960 (Coase 1960). He further states that under zero transaction costs, markets allocate resources such that externalities are produced at optimum levels regardless of the initial assignment of property rights to either party (Coase 1992; Felder 2001).

Consider, for example, a watershed with a group of ranchers in the upstream and a settlement of households in the downstream. Ranchers pollute a nearby stream through the application of chemical fertilizers and pesticides on pasture land. Households, who depend on the stream for clean water and other economic activities such as fishing, get affected negatively with water pollution. Ranchers, however, can withhold pollution by maintaining tree cover and buffer strips but it would cost them. On the other hand, households would benefit when ranchers can withhold pollution. In Figure 2, the horizontal axis represents the quantity of tree cover and buffer strips and the vertical axis represents costs or benefits of withholding pollution. The MC curve represents the marginal cost to ranchers and the MB curve represents the marginal benefits to households from withholding pollution.

Consider that ranchers do not have to maintain tree cover and buffer strips, i.e. ranchers have a right to pollute. However, they would be willing to maintain tree cover and buffer strips if households can cover the costs. In this scenario, households will have to pay ranchers an amount equal to area AED, the entire area under the MC curve, to enjoy clean water. Since the amount that households must pay ranchers beyond C is higher than the benefit they derive, households do not want tree cover and buffer strips beyond C. Alternatively, if households have a right to clean water, then ranchers have to pay households an amount equal to area ABD, the entire area under the MB curve to put up with the pollution. Given that the amount ranchers must pay households is initially much higher than the cost of withholding pollution, ranchers would want to maintain tree cover and buffer strips at C. At this point the amount that ranchers must pay equals the marginal cost of withholding pollution. The Coase theorem suggests that if property rights are defined, the parties will negotiate according to their benefits and costs and reach an optimal solution. Regardless of which one has the property rights, with zero transaction costs, the solution is reached at C.

A number of factors may prevent agents from realizing an optimum solution. In many cases property rights may not be clearly defined; negotiation between the parties often leads to litigation; benefits of environmental improvement are intangible; and those who benefit may have problems to get together and coordinate their actions (van Kooten 1993). In order to address these factors, a variety of information is needed including the environmental benefits and cost of silvopasture, respectively, from households' and ranchers' perspectives. Economists have recently developed a suite of environmental valuation tools to achieve this task. The following three sections will apply dynamic optimization, stated preference based choice experiment, and dichotomous contingent valuation techniques to conduct environmental economic analysis of sivlopasture in southern Florida.

Effect of environmental costs and benefits on silvopasture

Cattle ranching is an important agricultural enterprise in Florida. Ranchlands cover over 2.4 million hectares

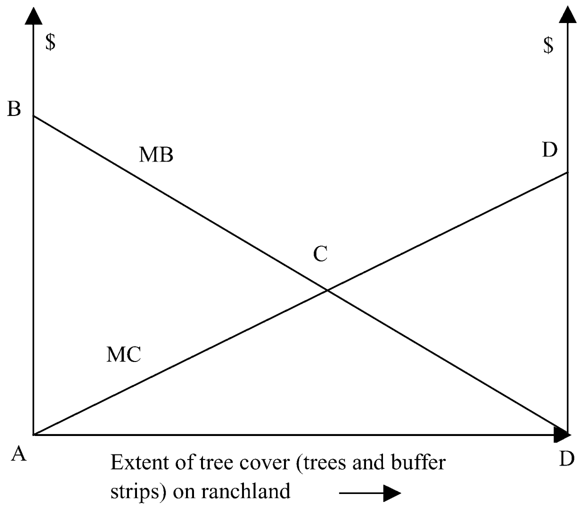

Figure 2. An illustration of optimal adoption of silvopasture with zero transaction costs.

and generate over $300 million each year with over 1.8 million cattle. More than 60% of cattle production in Florida occurs near Lake Okeechobee and the Everglades (south Florida), which is a large freshwater lake of 1891 square kilometers and a drainage basin of approximately 12 950 square kilometers (5000 square miles) (Harvey and Havens 1999). During the twentieth century, Lake Okeechobee and the Everglades have been subjected to massive water control projects to drain parts of the Everglades, to protect areas from flooding and to make land available for agriculture (including cattle ranching) and urban development. The resulting land-use changes have had a profoundly adverse impact on environmental quality in south Florida. In particular, the phosphorus content of Lake Okeechobee has more than doubled over the past century causing eutrophication and subsequent damage to its aquatic life (Harvey and Havens 1999). Since cattle ranching is one of the sources of phosphorus runoff, it has long been perceived as an environmental concern in this region.

Many studies considered silvopasture, a two-commodity system of producing trees and livestock forage, is an economically viable enterprise. Lundgren et al. (1983) found that pine based silvopasture systems in the southeastern United States could have as much as a 4.5% positive rate of return. Clason (1995) noted that silvopasture utilizing loblolly pine (*Pinus taeda*) in Louisiana could produce greater net returns than either pure pasture systems or pure timber systems. Grado et al. (2001) concluded that combining beef cattle and pine plantations can be profitable in southern Mississippi. Stainback and Alavalapati (2004) found combining longleaf pine production with cattle ranching is more profitable than conventional forestry or cattle ranching.

Stainback et al. (2004), however, found that combining slash pine with cattle production is not competitive with conventional ranching in Florida. The authors also found that silvopasture could be competitive with traditional ranching when environmental costs and benefits were factored into the analysis. Using a dynamic optimization model, they assessed the impact of a tax on phosphorus runoff and a payment for carbon sequestration on the profitability of traditional cattle ranching and silvopasture (see Stainback et al. 2004 for modeling details). The land values, which reflect the net present values of perpetual annual returns, under traditional ranching and silvopasture as a function of phosphorus runoff taxes and carbon payments are shown in Table 1. In the absence of pollution tax and carbon payments, land values under traditional ranching are shown to be greater than those of sivlopasture. As the pollution tax increases, land value decreases for both traditional ranching and silvopasture. If it is above $44 per kilogram or $20 per lb, then the land value for both traditional ranching and silvopasture would be negative. For all pollution tax rates with carbon payments of greater than $1 per ton ($10^6$ gram, Mg)land values under silvopasture are greater than those of traditional ranching. As the pollution tax increases, the carbon payment necessary for silvopasture declines. For instance, for a tax of $10 per 0.45 kg (lb), a carbon payment of $0.50 per 0.45 kg (lb) is not sufficient to make silvopasture competitive. On the other hand, with a pollution tax of $15 per 0.45 kg (lb), a carbon payment of $0.50 per 0.45 kg (lb) would make silvopasture financially competitive.

The optimal land management in terms of tree density and timber rotation age for various combinations of pollution taxes and carbon payments is also shown in Table 1. Results indicate that tree density and timber rotation age are more sensitive to carbon payments than to pollution taxes. For example, for a given pollution tax, the increase in carbon payments will result in significant changes in tree density. On the other hand, for a given carbon payment the increase in pollution tax will have modest impacts on tree density. For example, with a pollution tax of $20 per 0.45 kg (lb) doubling the carbon payment from $1 per ton to $2 per ton increases the optimal initial tree density from 200 stems per 0.4 hectare (acre) to 400 stems per 0.4 hectare (acre) and increases the optimal rotation age by 17 years. However, at a carbon price of $1.50 per ton doubling the pollution tax from $10 per 0.45 kg (lb) to $20 per 0.45 kg (lb) only increases the optimal initial tree density from 200 to 300 stems per 0.4 hectare (acre) and increases the optimal rotation age by only 10 years. Similar impacts are noticed with respect to carbon supply and phosphorus reduction.

Several conclusions can be drawn from this analysis. A pollution tax alone is not sufficient to induce landowners to adopt silvopasture. However, the profitability of silvopasture will be greater than that of traditional ranching when both costs of pollution and benefits of carbon sequestration are considered. In this case, payment for carbon is shown to be more effective in influencing ranchers to undertake silvopasture practices in Florida. Next, we will turn to questions – do households care for carbon sequestration, improvement in water quality, and biodiversity associated with silvopasture? Will they be willing to pay for these benefits? If so, how much?

Valuing environmental services of silvopasture

Welfare economics suggests that the value of a public good is the sum of what the individuals would be willing to pay for it (Varian 1992). This concept has been extensively used to value environmental services associated with forestry and agricultural practices (Cooper and Keim 1996; Lohr and Park 1994). Cameron et al. (2002) estimated nonmarket value of tree plantation on public lands accounting for the benefits of shade, windbreaks, and carbon sequestration. Loomis et al. (2000) assessed the value of buffer strips along streams in terms of erosion control, water quality improvement, and fish and wildlife habitat. Shrestha and Alavalapati (2004a) assessed the value of environmental services associated with silvopasture using a stated preference based choice experiment approach. They assume that silvopasture has a potential to reduce phosphorus run-off, sequester additional carbon dioxide, and improve the habitat for wildlife in the Lake Okeechobee watershed; silvopasture is compatible with the traditional ranching practices in this watershed; and information about public demand for environmental services is critical to formulate incentive schemes.

The theoretical construct of stated preference choice experiment (CE) approach stems from discrete choice analysis of consumer preferences. Random utility theory, which provides the basis for CE approach (McFadden 1974), considers each of the environmental attributes of silvopasture in the watershed as an alternative in a choice set.[4] The probability of choosing an alternative such that the utility of this alternative is greater than the utility of all other alternatives can be estimated using a multinomial logit (MNL) model or a random parameter logit (RPL) (McFadden 1974; Train 1998; Adamowicz et al. 1998; Louviere et al. 2000). Shrestha and Alavalapati (2004a) applied a random parameter logit (RPL) model to estimate household's willingness to pay (WTP) for environmental services.

A survey of households, who potentially benefit from silvopasture practices in the Lake Okeechobee watershed, was conducted. In designing the survey, each of three environmental attributes (water quality, carbon sequestration, and biodiversity) was identified and described at three levels (Table 2). The state utility tax that was specified at six levels chosen as a cost attribute to reflect environmental benefits of silvopasture because Florida prohibits state income tax, a commonly used variable in valuation surveys (Milon et al. 1999). Then, a choice experiment design was used to characterize these attributes and their levels in a survey questionnaire. An orthogonal main effect experimental design representing $3^3 \times 6 \times 2$ factorials was followed. Following the smallest orthogonal main effect plan 12 pairs of profiles in two blocks were identified using autocall macros of SAS version 8 (Kuhfeld et al. 1994). Each respondent was asked to value two options and a 'status quo' option in each scenario and continue with six scenarios.

The survey instrument included several sections. First, a map of the Lake Okeechobee watershed was presented and the rationale for selecting the study area was given. Second, a brief description of the traditional ranching, water pollution issues in the watershed, as well as potential environmental benefits and costs of silvopasture practices were outlined in the survey. Color photos and drawings were used to illustrate the silvopasture land-use changes. Third, the directions and an illustration of how to answer survey questions were provided. Fourth, the respondents were given six choice tasks, each with two options (A, B) and a status-quo option (C, and asked to choose one of the options. The valuation scenarios were designed in a referendum format (Figure 3). The choice question was followed by a rating question asking respondents to rate their confidence level in each choice task. Finally, the respondents were asked to provide their

Table 1. Estimated effect of payment for carbon sequestration and pollution tax on silvopasture profitability in southern Florida, USA.

Land values (U.S. $per 0.4 hectare (one acre)

	Silvopasture					Traditional ranch
	Carbon Payment ($/ ton)					
Phosphorus Tax ($/.45 kg or one lb)	0	0.5	1.0	1.5	2.0	
0	302	365	433	520	648	425
5	221	285	353	448	590	320
10	141	205	273	376	531	215
15	60	125	166	306	473	110
20	−20	45	125	242	415	5

Management and other variables

Carbon payment ($/ton)	Tree density	Timber rotation age	Carbon supply (tons per 0.4 hectare (acre)	Phosphorus reduction 0.45 kg per 0.4 ha (lb/acre)
Phosphorus tax = 0				
0.0	0	0	0	0
0.5	0	0	0	0
1.0	100	32	10	0.22
1.5	200	38	17	0.35
2.0	400	53	26	0.55
Phosphorus tax of $5 per 0.45 kg (lb)				
0.0	0	0	0	0
0.5	0	0	0	0
1.0	100	33	11	0.23
1.5	200	38	17	0.25
2.0	400	53	26	0.55
Phosphorus tax of $10 per 0.45 kg (lb)				
0.0	0	0	0	0
0.5	0	0	0	0
1.0	100	33	11	0.23
1.5	200	38	17	0.35
2.0	400	53	26	0.55
Phosphorus tax of $15 per 0.45 kg (lb)				
0.0	0	0	0	0
0.5	100	31	10	0.22
1.0	200	36	16	0.34
1.5	300	43	23	0.45
2.0	400	53	26	0.55
Phosphorus tax of $20 per 0.45 kg (lb)				
0.0	0	0	0	0
0.5	100	31	10	0.22
1.0	200	36	16	0.34
1.5	300	44	23	0.45
2.0	400	53	26	0.55

Source: Stainback et al. (2004).

Table 2. Attributes of silvopasture land-use in southern Florida, USA, used for the 'choice experiment'.

Environmental Attributes	Level of change in environmental attributes
1. Water quality	Reduce phosphorus runoff anywhere between 0 to 30%.
	Reduce phosphorus runoff anywhere between 31 to 60%.
	Reduce phosphorus runoff anywhere between 61 to 90%.
2. Carbon sequestration	Limited absorption of CO_2 from the atmosphere.
	Moderate absorption of CO_2 from the atmosphere.
	High absorption of CO_2 from the atmosphere.
3. Wildlife habitat	Limited improvement of habitats for wildlife.
	Moderate improvement of habitats for wildlife.
	High improvement of habitats for wildlife.
4. Increase in state utility tax (per year for 5 years) per household	\$0, \$10, \$20, \$40, \$80, \$120, \$140.

The first level of each attribute indicates the environmental quality without silvopasture.
Source: Shrestha and Alavalapati (2004a).

socioeconomic and demographic information. The survey was pre-tested with respondents from diverse educational and demographic backgrounds. Based on the pre-testing, the survey was revised by avoiding the use of technical terms and reducing the length of the description.

Survey sample was drawn randomly from households of ten counties in south-central Florida, namely, Glades, Hendry, Highlands, Martin, Okeechobee, Orange, Osceola, Palm Beach, Polk, and St. Lucie. A total of 504 packets were mailed, which contained a questionnaire, cover letter explaining the intent of the survey, and a magnet sticker with School of Forest Resources and Conservation and University of Florida logos. With second mailing and post card follow-ups a total of 152 survey responses were received.

The implicit values of the environmental quality improvement were estimated. The WTP estimates for moderate and high water quality improvement through reduced phosphorus runoff are, respectively, \$30.24 and \$71.17 per year for five years (Table 3). Corresponding estimates for moderate and high carbon sequestration levels are \$58.05 and \$62.72. Similarly, the WTP estimates for wildlife habitat improvements are \$49.68 and 41.06. These WTP estimates are within the range of values reported by Milon et al. (1999), who estimated household net WTP of \$59 and \$70 per year for hydrological and species restoration, respectively, in south Florida. The average WTP of household for a moderate level of improvement in all three environmental attributes is \$137.97 per year for five years. With 1.34 million households in the watershed, the total WTP for the environmental service would be \$924.40 million. This value reflects the households' total demand for environmental services associated with silvopasture in the Lake Okeechobee Watershed. Next we turn to the supply side of equation to assess ranchers' willingness to accept for sivopasture adoption and which policy incentive, a price premium or a direct payment, is more effective?

Ranchowners' willingness to adopt silvopasture

We stated before that the benefits of environmental services associated with silvopasture are external to cattle ranchers. Revenues from timber and additional hunting can offset the cost of sivlopasture only partially (Shrestha and Alavalapati 2004b). Therefore, cattle ranchers may have little or no motivation to adopt silvopasture unless policy incentives are provided. Literature suggests that landowners are responsive to policy incentives (Cooper and Keim 1996; Kingsbury and Boggess 1999; Purvis et al. 1989). Various federal and state programs such as Conservation Compliance, Sodbuster, Swampbuster, and the Conservation Reserve Program (CRP) in the United States are designed to encourage conservation practices on farmlands (Feather et al. 1999; Heimlich et al. 1998; Ribaudo et al. 1999; Westcott et al. 2002). Under these programs, conservation practices such as filter strips, riparian buffers, shelterbelts, windbreaks, and grass waterways, which are structurally and functionally similar to silvopasture, qualify for incentives.

Several studies have been conducted to assess the responsiveness of landowners to incentive programs. Cooper and Keim (1996) studied farmers' willingness to adopt water quality protection practices in the face of incentive payments. They conducted contingent valuation (CV) surveys in four watershed areas, i.e., Choice Scenario 1

Please vote for the plan that you prefer:

Environmental Response	Option A	Option B	Option C Current Condition
Water Quality Improvement (reduction of phosphorus runoff)	31 - 60%	61 - 90%	No change
Air Quality Improvement (absorption of CO_2)	No change	high	No change
Wildlife habitat Improvement (better habitat for wildlife)	Moderate	No change	No change
Annual Tax Increase (per year for 5 years)	$40	$120	$0

If the above plans are in a referendum, which one would you vote for?

☐ Option A ☐ Option B ☐ Option C

Please circle one number to indicate how certain you are with the choice you have just made:

Not certain Very certain
1 ——2 ——3 ——4 ——5

Figure 3. An example of a choice set presented to the household to elicit the value of environmental change. Source: Shrestha and Alavalapati (2004a)

Eastern Iowa and Illinois Basin areas, the Albemarle-Pamlico Drainage area of Virginia and North Carolina, the Georgia-Florida Coastal Plain, and the Upper Snake River Basin area. Kingsbury and Boggess (1999) used a contingent valuation approach to study landowners' willingness to participate in conservation reserve enhancement program in Oregon. Shrestha and Alavalapati investigated Florida ranchers' willingness to adopt silvopasture[5]. Specifically, they assessed the effect of a premium on beef price and a direct payment on the adoption of silvopasture using a dichotomous choice CV approach (see note 5 for details of survey design). They apply a logit model for empirical estimation.

Table 4 presents the effect of price premium, direct payments, rancher's socioeconomic characteristics, and natural attributes of ranches on ranchers' likelihood of silvopasture adoption. The results show that the variable representing incentive payment offer has a positive and significant on the probability of adoption. The impact is shown to increase at a decreasing rate suggesting a nonlinear relationship. The variable representing access to the urban center (*ACCESS*), in the direct payment model, is shown to have a positive and significant effect on the likelihood of silvopasture adoption. This result is consistent with Kingsbury and Boggess (1999) who found that a lower opportunity cost of land increased the probability of

Table 3. Estimates of 'Marginal Willingness to Pay' for environmental improvement by landowners in relation to perceived benefits from silvopastoral practice in Florida, USA.

Environmental Attributes	Value for environmental improvement ($ per household per year for five years)	
	Moderate	High
Water quality	30.24	71.17
	(19.63–40.86)	(53.41–88.93)
Carbon sequestration	58.05	62.72
	(43.72–72.37)	(54.38–71.06)
Wildlife habitat	49.68	41.06
	(38.08–61.28)	(35.41–46.72)

Numbers in parentheses are 95% confidence interval calculated from 1 000 draws from the distribution of coefficients in the model. Source: Shrestha and Alavalapati (2004a).

Table 4. Effect of policy incentives, socioeconomic, and natural attributes on ranchers' willingness to adopt silvopasture in Florida, USA.

Variable	Price support		Direct payment	
	Coefficient	SE	Coefficient	SE
Payment Offer and Opportunity Costs:				
Payments (PAYMT)	5.2159**	1.7901	0.2934**	0.0992
Square of payments (PAYMTS)	−4.9301**	2.0101	−0.0113**	0.0039
Plot size (ACRE)	−0.0001	0.0001	−1.83E-05	0.0001
Square of plot size (ACRES)	9.78E-07	1.22E-06	3.48E-07	1.05E-06
Northern Florida (NORTH)	0.2411	0.4042	−0.4486	0.3900
Central Florida (CENTRAL)	−0.2053	0.3535	−0.3893	0.3415
Distance to city (ACCESS)	0.0123	0.0082	0.0183**	0.0079
Natural Attributes:				
No of wildlife found (WNUM)	0.1001**	0.0519	0.1459**	0.0513
Creek and/or stream (CKST)	−0.2502	0.2680	0.4553*	0.2631
Marshland land (MARSH)	0.5935**	0.2886	−0.1990	0.2771
Forest cover (FOREST)	−0.2420	0.2692	−0.4102	0.2652
Longleaf pine (LLPINE)	0.6631**	0.2786	0.8586**	0.2680
Improved pasture (IMPPAST)	0.0024	0.0041	−0.0035	0.0040
Recreation Benefits:				
Wildlife hunting (HUNT)	0.6042**	0.2733	0.4164	0.2674
Fishing (FISH)	−0.1600	0.2701	−2.21E-01	0.2608
Horse riding (HBACK)	−0.5439	0.4736	0.0219	0.4597
Socioeconomic Characteristics:				
Household income (INC)	−0.0157	0.0107	−0.0230**	0.0095
Square of income (INCS)	0.0837	0.0660	0.0958*	0.0557
Respondents' age (AGE)	−0.0108	0.0080	−0.0091	0.0078
Respondents' education (EDU)	0.0467	0.0526	0.0438	0.0508
Member in environmental organization (MEMB)	−0.3484	0.3839	−0.2280	0.3824
Slope parameter (CONSTANT)	−1.2806	1.0485	−1.3255	1.0776
Log-L	−221.69		−231.47	
Chi-Square	52.03**		60.78**	
Correct prediction	64.45%		66.93%	
N	366		378	

*Coefficient significant at $p < 0.10$, **Coefficient/statistics significant at $P < 0.05$
Source: Shrestha and Alavalapati[5]

farmers' participation in conservation programs. The results also indicate that the existence of natural attributes will increase probability of silvopasture adoption. For example, variables representing wildlife presence (*WNUM*), existence of creeks and/or streams (*CKST*), marshlands (*MARSH*), and longleaf pine (*LLPINE*) are shown to have a positive impact on ranchers' adoption of silvopasture. The variable representing recreational hunting (*HUNT*) is positive and highly significant in the price support model suggesting that ranchers are more likely to adopt silvopasture if they currently use their ranches for recreational hunting.

Shrestha and Alavalapati estimated ranchers' mean WTA for the adoption of silvopasture[5].They found that on average, a price premium of $0.15 /lb. of beef or a direct payment of $9.32 /0.4 hectare (acre)/year was required for ranchers to adopt silvopasture practices. These estimates are much lower compared with previous studies on farmers' willingness to participate in conservation programs in the U.S. (e.g., Lohr and Park 1994; Cooper and Keim 1996). Lant (1991), for example, reported that average annual payment under Conservation Reserve Program was $48.93 /0.4 hectare (acre) at national average, while state averages ranged from $37.48 /0.4 hectare (acre) in Montana to $81.00 /0.4 hectare (acre) in Iowa. The lower WTA estimates of this study may be due to high compatibility of tree growing with cattle ranching. The authors also calculate the total annual incentive payments required for silvopasture adoption at a state level. With approximately 2.4 million hectares (6 million acres) of pasture and ranchlands (USDA 1997) and at the rate of \$9.32 per 0.4 hectare (acre) per year, the direct payment policy would cost about \$56 million annually. On the other hand, with nearly 2 million cattle resulting in annual sales of approximately 219 million kgs (482.84 million pounds) of beef (FAS, 2002) and with a premium of \$0.15 per 0.45 kg (lb) beef, the price policy would cost about \$72.43 million annually.

Although environmental economic valuation approaches that were presented here can be applied to various agroforestry practices, a caution must be taken in developing the questionnaire and collecting the data. The questionnaire must be customized with explicit consideration to locality and issue specific factors. For example, we used an increase in utility tax as a payment vehicle, as opposed to income tax, because Florida does not have state income tax. More caution must be taken in applying these methodologies in the tropics. Lack of familiarity with the issue under investigation, high illiteracy, and lack of experience in answering complex answers might pose additional challenges.

Conclusions

The importance of agroforestry systems in generating environmental services such as carbon sequestration, improvement in water quality, and biodiversity is being recognized increasingly the world over. If these services are not internalized to the benefit of landowners, the landowners (or producers)will have little incentive to produce them at a socially desirable level. Environmental economic analysis provides an effective framework for internalizing environmental services. Recent advancements in environmental valuation methodologies help quantify the potential demand for and supply of environmental services more accurately. Policy makers can use this information as a basis to formulate incentive or tax policies that further the economy and the environment.

Each policy may be unique in achieving the set objective and in bringing other desirable and undesirable effects. Policies must induce landowners search for land use innovations that reduce the cost of pollution and/or increase the profitability. For example, research findings reported in this paper indicate that phosphorus runoff taxes alone do induce desired changes in ranchland management. Payments for sequestering carbon along with pollution tax are found to be more effective in bringing desired changes. In the face of growing opposition to imposing additional taxes on farm or forest activities, the search for the least-cost incentive policies may be more desirable.

Several incentive mechanisms can be pursued including extension services, lump-sum payment on unit-area (hectare or acre) basis, price premium to reflect environmentally friendly practices, and cost-sharing programs. The opportunity cost, social acceptability, and administrative feasibility of each policy may be different. For example, results reported in this study indicate that a direct payment policy is less costly, relative to a price premium, to promote sivlopasture in Florida. It is desirable to assess these policies from a social acceptability and an administrative feasibility perspective. Institutional arrangements are critical for effective implementation of any incentive scheme. Government intervention is critical in developing institutions that help coordinate the actions of stakeholders and facilitate transactions at a minimum cost.

Acknowledgements

This publication was partially supported by U.S. Department of Agriculture, Cooperative State Research, Education, and Extension Service, Initiative for Future Agriculture and Food Systems (USDA/CSREES/IFAFS) grant number 00-52103-9702. Florida Agricultural Experiment Station Journal Series R-09892.

End Notes

1. The other factors include imperfect information, imperfect competition, ill-defined property rights, and presence of common-pool goods.
2. It is conceivable that environmental pollution such as phosphorous run-off for example, from conventional ranching would be higher than that under silvopasture system, where tree cover and buffer strips are maintained along with pasture.
3. Following Wolters (1973), the following equation specifies the forage produced, $f(t)$, in lbs of dry biomass per acre per year: $f(t) = 2048.9 - 14.7b(t)$, where $b(t)$ is tree basal area in square feet per acre. Forage production can be converted to cattle production using standard animal unit months (AUMs). One AUM is defined as the amount of forage required to support one adult cow weighing 1000 lbs for one month.
4. Alternative j represent one specific type of consumption bundle representing an improvement in the environmental quality of the watershed with its conditional indirect utility level V_j for a

household i and is expressed as $V_{ij} = v_{ij} + \varepsilon_{ij}$, where v_{ij} is the deterministic component of the model and ε_{ij} is the random component. Thus, selection of alternative j over alternative h implies that the utility of V_{ij} is greater than that of V_{ih}.

5. Shrestha R.K. and Alavalapati J.R.R. 2004. Florida ranchers' willingness to participate in silvopasture practices: an economic analysis and policy implications (In review).

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