ADVANCES IN AGROFORESTRY 2

Valuing Agroforestry Systems
Methods and Applications

Edited by Janaki R.R. Alavalapati and D. Evan Mercer

Kluwer Academic Publishers

Advances in Agroforestry

Volume 2

Series Editor:

P.K.R. Nair

School of Forest Resources and Conservation,
University of Florida, Gainesville, Florida, U.S.A.

Aims and Scope

Agroforestry, the purposeful growing of trees and crops in interacting combinations, began to attain prominence in the late 1970s, when the international scientific community embraced its potentials in the tropics and recognized it as a practice in search of science. During the 1990s, the relevance of agroforestry for solving problems related to deterioration of family farms, increased soil erosion, surface and ground water pollution, and decreased biodiversity was recognized in the industrialized nations too. Thus, agroforestry is now receiving increasing attention as a sustainable land-management option the world over because of its ecological, economic, and social attributes. Consequently, the knowledge-base of agroforestry is being expanded at a rapid rate as illustrated by the increasing number and quality of scientific publications of various forms on different aspects of agroforestry.

Making full and efficient use of this upsurge in scientific agroforestry is both a challenge and an opportunity to the agroforestry scientific community. In order to help prepare themselves better for facing the challenge and seizing the opportunity, agoroforestry scientists need access to synthesized information on multi-dimensional aspects of scientific agroforesty.

The aim of this new book-series, *Advances in Agroforestry*, is to offer state-of-the art synthesis of research results and evaluations relating to different aspects of agroforestry. Its scope is broad enough to encompass any and all aspects of agroforestry research and development. Contributions are welcome as well as solicited from competent authors on any aspect of agroforestry. Volumes in the series will consist of reference books, subject-specific monographs, peer-reviewed publications out of conferences, comprehensive evaluations of specific projects, and other book-length compilations of scientific and professional merit and relevance to the science and practice of agroforestry worldwide.

Valuing Agroforestry Systems

Methods and Applications

by

JANAKI R.R. ALAVALAPATI

School of Forest Resources and Conservation,
University of Florida, Gainesville, Florida, U.S.A.

and

D. EVAN MERCER

U.S. Forest Service,
Southern Research Station,
Research Triangle Park, North Carolina, U.S.A.

KLUWER ACADEMIC PUBLISHERS
DORDRECHT / BOSTON / LONDON

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 1-4020-2412-6 (HB)
ISBN 1-4020-2413-4 (e-book)

Published by Kluwer Academic Publishers,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Sold and distributed in North, Central and South America
by Kluwer Academic Publishers,
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers,
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

Cover photograph by D. Evan Mercer.

Printed on acid-free paper

Printed in the Netherlands.

EVAN MERCER AND ANN SNOOK

ANALYZING *EX-ANTE* AGROFORESTRY ADOPTION DECISIONS WITH ATTRIBUTE-BASED CHOICE EXPERIMENTS

1. INTRODUCTION

Although many cases of successful agroforestry extension efforts exist (for examples, see Chapter 2), all too often attempts to promote agroforestry have resulted in low adoption rates, with farmers reluctant to adopt new or improved agroforestry systems or abandoning agroforestry shortly after establishment. As a result, the recent increase in research on the adoption of agroforestry innovations has been motivated largely by the perceived gaps between advances in agroforestry science and extension (Mercer, in press). The theoretical and empirical literature on adoption of agroforestry innovations has been reviewed by Pattanayak, Mercer, Sills, and Yang (2003) and Mercer (in press). Significant progress has been made, especially in using binary choice regression models for *ex-post* analyses to examine how past adoption decisions are correlated with variables describing farmers, their farms, demographics and socio-economic conditions. These *ex-post* analyses have been useful for increasing our understanding of who adopts first, identifying communities and households to target as potential early adopters, and developing policies to promote agroforestry. However, the *ex-post*, binary choice regression studies have contributed little to the problem of designing agroforestry systems that appeal to potential adopters because they are not able to examine how farmer preferences vary for different combinations of characteristics of agroforestry alternatives.

Although a variety of reasons contribute to low adoption rates, they often result from inadequate assessments of farmers' preferences, priorities, and constraints prior to designing new agroforestry systems (Current, Lutz, & Scherr, 1995; Mercer & Miller, 1998). Therefore, rigorous *ex-ante* analyses that are able to provide predictive understanding of farm households' land-use decisions and the relative importance of the characteristics of land-use systems demanded by farmers should provide valuable information to project planners and agroforestry system designers.

J. R. R. Alavalapati & D. E. Mercer, Valuing Agroforestry Systems, 237–256.

Although recent progress has been made in *ex-ante* adoption analysis using a farming systems approach (Current et al., 1995; Barrett, Place, & Aboudk, 2002; Franzel & Scherr 2002), systematic, quantitative *ex-ante* assessments of adoption are relatively rare, partly because, as Franzel & Scherr (2002) point out, some scientists believe they have been too "soft" or "subjective."

In this chapter, we describe a quantitative, econometric based method for *ex-ante* analysis of the adoption potential of new agroforestry systems and provide an example of its application in southeastern Mexico. The method we apply, generally referred to as "conjoint analysis," originally developed by market researchers, is a survey-based technique that focuses attention on the trade-offs people make between the attributes of alternative goods and services. The basic requirement for any conjoint-based analysis is that the products or services tested are treated as sets of distinct attributes (or features) with a limited set of variations (or levels) for each attribute (feature). Eliciting individuals' stated preferences between goods and services with different attribute combinations allows the analyst to evaluate the importance of different attributes of the good or service, compare alternative versions of the good or service on each of the important attributes, and estimate the probability of purchase (adoption) of different attribute combinations (Louviere, 1988, 1994).

The most common application of conjoint analysis has been assisting firms in the design of new, multi-attribute products; a problem with many similarities to designing multi-attribute land use systems like agroforestry. Conjoint allows one to determine the combination of attributes of products (land-use systems) that consumers (farmers) are most likely to purchase (adopt). In analyzing agroforestry adoption potential, respondents evaluate alternative land-use systems and make trade offs among various features of the land use systems, selecting combinations of attributes (features) as better than others. Therefore, conjoint analysis can be used to assess the economic and non-economic criteria farmers use to manage their lands, how farmers value different attributes of land use systems, how these values affect adoption and subsequent management behavior, and determine the characteristics of agroforestry systems most likely to be adopted.

Although market researchers have used conjoint for new product design since the 1970s (Green & Wind, 1975), natural resource economists have only recently begun to apply conjoint analysis for valuing environmental goods (Adamowicz, Louviere, & Williams, 1994; Holmes, Zinkhan, Alger, & Mercer, 1998; Opaluch, Swallow, Weaver, Wessells, & Wichelns, 1993) and analyzing land-use decision making (Baidu-Forson, Waliyar, & Ntare, 1997; Zinkhan, Holmes, & Mercer 1997). Attribute-based choice experiments (ACE), a subset of conjoint analysis, were developed about 20 years ago in response to economists' concerns with the theoretical limitations of the typical conjoint analysis ranking and rating studies (Bennett & Blamey, 2001b; Louviere, 2001). Traditional ranking/rating models impose a variety of theoretical and practical problems for economists, including: i) problems comparing ranking or rating data across respondents, ii) respondents may have problems ranking large numbers of alternatives, iii) rating or ranking alternatives are not typical problems faced by consumers, and iv) traditional conjoint analyses are based on statistical and mathematical considerations rather than economic or behavioral theory (Bennett & Blamey, 2001b; Louviere, 2001).

ACE addresses problems with traditional conjoint analysis by asking respondents to choose between alternatives rather than rank or rate the alternatives. As a result, the pattern of choices allows one to model the probability of choosing a particular alternative in terms of the attributes used to describe that alternative (Bennett & Blamey, 2001b). ACE models are also consistent with the sound, well tested, and long-standing theory of random utility. Holmes and Adamowicz (2003) provide a thorough explication of the application of random utility theory to attribute-based choice experiments (see the Appendix for details). ACE models assume that the attributes convey utility to the respondent and that the level of utility the respondent associates with an alternative determines the probability that he/she will choose that alternative. By regressing the stated choices on attribute levels, a wealth of information can be gleaned regarding preferences for the individual attributes, and the probability of choosing programs with any combination of attributes can be predicted (Bennett & Blamey, 2001b).

In this chapter, we present a case study applying attribute-based choice experiments to the problem of designing new agroforestry systems. First we describe the study site, the Calakmul Biosphere Reserve in southeastern Mexico, and the methods we used to design the attribute-based choice experiment and analyze the data. Then we present results of the experiment and discuss how they could be used for improving agroforestry system and project design. This chapter is not intended to provide the reader with all the tools needed to immediately undertake an attribute-based choice experiment. Rather, we hope to provide an example of how these techniques can be applied to the difficult problem of *ex-ante* analysis of farmer demand for new land use systems like agroforestry. The large and growing literature on the intricacies of implementing ACE in natural resource settings can be accessed through recent reviews by Bennett and Blamey (2001a) and Holmes and Adamowicz (2003).

2. CASE STUDY SITE

The objective of this case study project was to develop information to improve the adoption potential of agroforestry projects in southeast Mexico. Research was conducted in the buffer zone of the 723,000 hectare (1.7 million acre) Calakmul Biosphere Reserve in southeastern Campeche, Mexico (Figure 1) which was created in 1989 to protect the last great frontier for Mexicans in search of farmland. Following the improvement of roads in the area in the 1970s, immigration to the Calakmul area increased sharply with poor people looking for land to cultivate.

With a population of about 15,000, Calakmul consists of the core bioreserve area where settlement is prohibited, a buffer zone of 72 communities called *ejidos* and a few privately owned properties (Bosque Modelo, 1997). *Ejidos* vary in size from

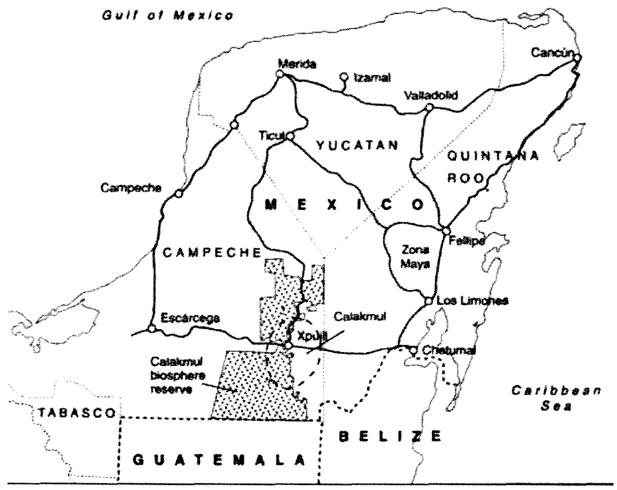

Figure 1. Map of Calakmul Biosphere Reserve, Campeche, Mexico.

100 to 50,000 hectares and from 10 – 150 members with each member family having equal rights to the use of their *ejido's* communal forest and agricultural lands. The agricultural allotments vary between *ejidos,* ranging from 25 to 50 hectares, while communal forest areas vary from 250 – 25,000 hectares per *ejido*.

The flat terrain of Calakmul is punctuated by low hills with elevations ranging from 205 to 270 meters above sea level. Rainfall is unpredictable both in distribution throughout the year and in amount, typically ranging between 600 and 1600 millimeters per year, with a dry season occurring between February and May. Tropical semi-deciduous forest is the primary natural vegetation with a mosaic of high graded old forest and large areas of secondary forests of staggered aged stands. The most abundant tree species are chiclé *(Manilkara zapota*) and breadnut or ramon *(Brosimum alicastrum*) valued respectively for their latex and leaves for fodder. The most important commercial timber species are mahogany *(Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata)*.

Agriculture is dominated by a slash and burn system known locally as *milpa*. Fields are cleared by cutting and burning the forest or forest fallow and then planted primarily with corn (the primary subsistence crop) often in association with beans and squash. Fields are typically cropped for 2 or 3 years and then left to fallow for anywhere from 3 – 15 years. With a typical household having 3-5 hectares of *milpa* in production each year, corn yields are highly variable from year to year and from field to field (250 kg/ha – 2.0 t/ha) (Snook, 1996).

Limitations to production are unpredictable and insufficient rainfall, shallow soils, lack of money to invest in improved production techniques, seasonal labor shortages, lack of technical expertise in agronomy and forestry, and poor access to markets. As a result, there is currently little hope for most Calakmul residents to move beyond subsistence agriculture.

Forests, however, provide an additional, important source of cash crops such as honey, timber, chiclé latex, and construction materials for home use and the local market. Until 1991, there was virtually no effort to plant timber trees outside of the forest areas in the active forestry *ejidos*[1]. In the early 1990s, however, an intercommunity organization, CRASX, (Regional Agrosilvocultural and Services Council of Xpujil) initiated the Calakmul Agroforestry Project to develop and disseminate agroforestry technologies in Calakmul to restore the agricultural and forest resource base while improving farm production and conserving forest cover. Between 1991-96, the Project provided 225 timber trees and 110 fruit trees to each farmer who agreed to plant the trees in association with agricultural crops in one hectare agroforestry plots (Snook & Zapata, 1998). Approximately 700 hectares were established with the goal of providing short, medium, and long term production starting with annual crops, followed by fruits, and finally timber[2]. Between 1995-97, another tree planting project concentrated only on native trees without the fruit tree component. The project provided, free of charge, 21 native tree species which were to be planted in individual or community managed plots, often in association with crops[3].

In 1997, the International Centre for Agroforestry Research, (ICRAF) initiated two studies to examine agroforestry adoption in Southeastern Mexico. The first used traditional *ex-post* analysis based on binary choice regressions of revealed preferences to examine the characteristics of past agroforestry adopters (Mercer, Snook, Haggar, & Sosa, in press). The revealed preference analysis found that households most likely to have previously planted trees on their farms were the more educated, more experienced, relatively wealthier households that immigrated from nearby states in the Yucatan peninsula, and who had cleared larger amounts of their forestland. The second approach, reported here, applied attribute-based choice experiments to examine how farmers value different attributes of agroforestry systems and which combinations of attributes are most likely to be adopted. The goal was to provide information to assist in the design of new agroforestry systems and projects that would be more attractive to farmers. In the ACE study, farmers were presented with a series of agroforestry systems with varying attribute combinations and asked to choose the system they preferred. They were also allowed to choose to reject all new systems and continue with their current land-use system. Details on methods, data and results are presented next.

3. METHODS

The main steps in implementing a choice-based experiment are (Bennett & Adamowicz, 2001):

1. *Survey and Experimental Design,* which consists of: i) characterizing the decision problem to be analyzed; ii) selecting and defining attributes and values for each attribute level; iii) constructing the choice tasks, alternatives or profiles to be presented to the respondent; iv) developing and pre-testing the questionnaire; and v) establishing sample frames and sizes (usually determined by the trade off between accuracy and data collection costs).
2. *Data Collection*: a variety of methods for data collection have been utilized for ACE ranging from pencil and paper direct interviews, to telephone and mail surveys, to computer aided surveys. Type of data collection method is determined by costs and appropriateness for the population being analyzed.
3. *Model Estimation*: typically multinomial logit (MNL) models are estimated with maximum likelihood procedures, although the particular issues being examined and nature of the data will determine the most appropriate estimation method.
4. *Policy/Decision Support Analysis*: analysts are usually interested in determining the relative values of different attributes of the products or land use systems being analyzed and the most desired combination of attributes (i.e., trade-off analysis in choosing between combinations with different attributes) to be used for system design and decision support tools and developing policies to promote desired systems.

3.1. Survey and experimental design

Designing a choice based survey instrument is typically a lengthy process of information gathering through key informant interviews, community meetings, focus groups, and extensive field testing. Casey, Mercer, and Snook (1999) provide a detailed discussion of the survey instrument design process used in this project. A series of focus groups with farmers, agricultural and forestry technicians and extension personnel, and local ICRAF professionals were used to develop the five attributes (each with 3-6 levels) used to describe the hypothetical agroforestry systems for the choice experiment. Following the initial round of focus groups, 17 potential attributes of agroforestry were identified. These were narrowed down to the 5 considered to be most useful to ICRAF in designing potential agroforestry systems in the area. The attributes and levels are presented in Table 1[4].

Table 1: Attributes and levels for Attribute-based Choice Experiment

Attribute	*Level 1*	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*Level 6*
Extra Labor* (days year^{-1})	5 days	10 days	20 days	30	40	50
Extent of Technical Assistance	1 year	3 years	5 years	n/a	n/a	n/a
Products from System	Timber only	Timber & crops	Timber, fruit, & crops	n/a	n/a	n/a
Source of tree seedlings	Gather for free in Forest	Work in local nursery	Pay for seedlings; delivered to farm	n/a	n/a	n/a
Impact on Forest Conservation	No impact on future forest environment	Forest environment better in future for your children	Forest environment worse in future for your children	n/a	n/a	n/a

**Labor variable redefined for regression as Low < 10 days year^{-1}; Medium = 20 to 30 days year^{-1}; High > 30 days year^{-1}*

The final five attributes used in the analysis are:

- Number of additional days of labor per year required to implement and maintain the new system (six levels from 5 to 50 additional days of labor per year),
- Number of years that technical assistance will be available to adopters (three levels: 1, 3, or 5 years of technical assistance),
- Types of outputs produced by new system (three levels: i) timber; ii) timber plus crops; and iii) timber plus crops and fruit trees);
- Availability of tree seedlings and how obtained (three levels: gather from forest; work for seedlings in nursery; or pay for seedlings delivered to farm),
- Impacts of the system on the forest environment (three levels: no impact on forests; forest environment better in the future; forest environment worse in the future).

This $3^4 \times 6^1$ experimental design results in 486 possible agroforestry systems for the respondents to choose between. To produce a more tractable experiment, an orthogonal fractional factorial design (Addleman, 1962; Holmes & Adamowicz, 2003) was used to generate a subset of 64 agroforestry systems that covered the range of variability between all possible combinations. An eight level blocking factor was used to split the 64 plans into eight random blocks so that each final survey contained 8 sets of paired agroforestry systems. Hence, farmers were presented with a series of 8 separate, trichotomous choice experiments each with a pair of alternative agroforestry systems and the status quo (or opt-out) option. The status quo option is provided because the farmers might not prefer to adopt either of the alternative systems.

3.2. Data Collection

Data were collected in 1998 via in-person interviews based on a stratified random sample of farmers in the *ejido*s occupying the buffer zone of the Calakmul Biosphere Reserve. The sample was stratified by *ejido* size with the final sample consisting of 176 farmers in 15 separate *ejido*s. The ACE questions, however, were only asked of those farmers who stated that they would be interested in planting trees on their farms in the future, resulting in a final sample of 142 farmers for the ACE analysis.

Following the collection of socio-economic and household specific data, the interviewer briefly explained the attributes and levels. Then, two hypothetical agroforestry systems were presented to the respondent who was asked to pick the most preferred system (or to choose neither system). The systems were depicted with line drawings combined with written statements provided next to each picture. The combination of the line drawings and verbal descriptions provided by the interviewers ensured that non-literate respondents fully understood the choices. After studying each alternative for a few minutes, respondents were asked to pick their preferred system or "none of the above." This was repeated 8 times for the 8 choice experiments presented to each farmer.

3.3. Data Coding and Model Estimation

The choice problem outlined above required each respondent to choose one of the two agroforestry alternatives to adopt or to decide not to adopt either of the given alternatives. The respondent then repeated this process for 8 different choice sets. Therefore, each respondent provided one response for each choice set which was recorded along with the attribute levels for the two agroforestry choices and the status quo option (as well as the socio-economic data for the individual making the choice). For each respondent there are 8 x 3 = 24 data points. When the status quo attribute levels are known, coding attribute levels for the status quo (none of the above) option is usually handled like the other choice alternatives (Holmes & Adamowicz, 2003). In our case, since no information was available on the attribute levels for the status quo option, zeroes were used to code all the attribute levels for the status quo alternatives. Since we based our analysis on the multinomial logit model (MNL), this approach normalizes utility relative to the status quo option.

Therefore, for these trichotomous choice sets, three lines of data were coded for each choice set with each line representing the dependent variable (i.e., "1" if chosen and "0" if not), the attribute levels for that alternative and the socio-economic characteristics of the respondent. An alternative specific constant (ASC) for the status quo option was created taking on the value of "1" if that line of data described the status quo alternative and "0" otherwise. ASCs account for variability in choice not explained by the attributes or socio-economic variables. ASCs are especially important when an opt-out option is provided, since the attributes of the opt-out alternative are usually not known or non-existent (Holmes & Adamowicz, 2003).

When coding the qualitative or categorical attribute levels, effects codes rather than dummy codes are preferred since the attribute level for the omitted category would be collinear with the regression intercept and no information about the preferences for the omitted level could be obtained (Holmes & Adamowicz, 2003). Effects codes overcome this problem by using "1", "-1", and "0" to code the variables for the attribute levels rather than just "1" and "0" for typical dummy variables. For an attribute with three levels, one level is chosen as the base and two effects codes variables are created for the other two levels. Using the technical assistance variable in our case as an example, one year of technical assistance was chosen as the base level and two variables were coded in the data set (three years (assist3) and five years (assist5) of technical assistance). Whenever the attribute level for the choice alternative was the base (i.e., one year of technical assistance) assist3 and assist5 were coded as "-1". When three years of assistance was the level included in the choice, assist3 was coded as "1" and assist5 was coded as "0". Likewise when five years was the attribute level (assist5 was coded as "1" and assist3 as "0"). Effects codes were used for all attribute variables in this experiment. Using effects codes allows one to easily compute the parameter value for the omitted attribute by simply summing the coefficients of the other two levels of that variable (Holmes & Adamowicz, 2003).

Based on random utility theory, respondents' choices for each choice set were modeled as a sequence of three equations, each of which described the probability of choosing that alternative. The appendix provides an overview of random utility theory and its application with multi-nomial logit models for estimating the preference parameters from choice experiments. The conditional indirect utility, V, can be specified for each alternative as a linear function of the attributes (Bennett & Adamowicz, 2001). Assuming that errors are independently and identically distributed (IID) and follow a type 1 extreme value (Gumbel) distribution, a conditional or multinomial logit regression model was used to estimate the trichotomous choice responses with the levels of the attributes of the systems used as explanatory variables. All variables that remained the same across the respondent's choices (such as income or farm size) drop out of the model (Holmes & Adamowicz 2003; McFadden, 1974).

Assuming no interactions effects, each choice set of 5 attributes and 3 levels (the base level for each attribute is not included in the regression) is described with three linear in parameters models:

Alternative 1: $V_1 = \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 + \ldots\ldots\ldots \beta_{10} A_{10}$
Alternative 2: $V_2 = \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 + \ldots\ldots\ldots \beta_{10} A_{10}$
Status quo: $V2 = ASC + \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 + \ldots\ldots \beta_{10} A_{10}$
where: β_i = coefficient *i* for attribute A_i
ASC = alternative specific constant for the opt-out alternative.

Since $\frac{\partial V_i}{\partial A} = \beta_i$, the regression coefficients, β_i, can be interpreted as the marginal utility of the attributes, $A_{.i}$.

The STATA (1999) maximum likelihood routine was used to estimate the resulting multinomial logit regression model (MNL) (see Appendix). Using the MNL model, socio-economic characteristics can only be introduced as interactions with either the attributes or the alternative specific constant, MNL models predict the relative attractiveness of each alternative and characteristics that don't vary across alternatives cannot be estimated. More complex models are possible, such as latent class models and random parameter models, that allow incorporation of socio-economic heterogeneity and interaction effects are possible but require experimental design and analysis that are beyond the scope of this chapter. Holmes and Adamowicz (2003) provide a detailed overview and analysis of those models.

4. RESULTS

Descriptive statistics for the entire sample are provided in Table 2. The average farmer had immigrated to Calakmul 11 years prior to the survey, was 38 years old with 4 children, and produced an average annual income of US$1,457. Farmers immigrated to Calakmul from more than 10 other states in Mexico. The education level of the farmers was very low; sixty percent had never finished primary school; only 28.98 percent had finished primary school, and only 9.8 percent had finished secondary school. The average farmer received 49 hectares of land on joining the *ejido*, 39.7 hectares of which was originally under primary forest cover and 8 hectares under secondary fallow. The average farmer had harvested 9.9 hectares of forests (about 1 hectare per year) since joining the *ejido* and, at the time of the interview, had 28 hectares under forest cover, 19 hectares under fallow, and 4.8 hectares in *milpa*.

The results from the maximum likelihood estimation of the multinomial logit model of the trichotomous choice responses of agroforestry system preference are shown in Table 3. Parameters estimates for the omitted (base case) attribute levels were computed as the sum of -1 times the parameter values for the included levels of each attribute. Although the Pseudo R^2 was 0.085, the Chi^2 value of 204.24 and significance (at the .05 or .10 level) of all but three attribute levels suggests a reasonable fit for the model. The regression coefficients can be interpreted as marginal utility values showing the rate at which the respondent's utility increases (or decreases) given a change in the attribute levels. The coefficient on the status

Table 2. Descriptive statistics for entire sample of farmers (n = 176).

Variable	*Mean*	*Standard Deviation*	*Range*
Age of farmer (years)	38	13.7	16-74
Number of children at home	4	2.9	0-12
Income (US$/year)	$1,457	$1,573	$53-8,154
Length of residence in Calakmul (years)	11	6.3	0.3-36
Distance to fields from house (km)	2.81	2.2	0-10
Total land allotted to farmer (hectares)	49	25	0-120
Area in *milpa* (hectares)	4.8	4.1	0-36
Amount of land planted with trees (hectares)	1.63	2.54	0-16
Current amount of forest in farmer's land allotment (hectares)	28	24	0-95
Original amount of forest in farmers land allotment (hectares)	39.7	26.8	0-120
Amount of forest harvested (hectares)	9.9	11.05	0-50
Current amount of fallow forest (hectares)	19	11.7	0-60
Original amount of fallow forest (hectares)	8	11	0-45

quo Alternative Specific Constant (ASC), then shows the marginal utility of the status quo relative to the agroforestry alternatives. Since the ASC is significant (5% level) and a relatively large negative value, farmers appear to strongly prefer the agroforestry alternatives to maintaining the status quo[5].

Figure 2 shows how marginal utility changes with the different levels for each attribute. As expected, the greater length of time that technical assistance is provided the higher the utility and probability of adoption. This may suggest that farmers view the systems as complicated, difficult, and/or risky to adopt without adequate assistance. Additionally, farmers may also perceive additional benefits (not necessarily related to agroforestry) from having access to technical assistance (e.g., participation in other development projects and access to general agricultural advice).

Farmers preferred agroforestry systems that produced both timber and crops over strictly forestry systems that only produced timber, reflecting their preferences for sustainable production of both wood and food products. Interestingly, the least preferred product mix was timber, crops, and fruit trees. This may be due to problems with fruit tree based agroforestry systems that were promoted beginning in 1991. The fruit trees required large amounts of weeding, and many farmers were unable to sell the fruit produced due to transportation problems and an already glutted market for oranges. Gathering seedlings for free from the forest was preferred to working in local nurseries or paying for seedlings.

Table 3. Maximum likelihood estimates of conditional logit analysis of impact of attributes on farmers' preferences for new agroforestry systems (n=142 farmers).

Variable	*Coefficient (preference weight)*	*Standard Error*	*Z-value*
Alternative Specific Constant (Status Quo)	-0.471	0.081	-5.8 [a]
Technical Assistance			
Low Level (One Year)	-0.241	------	------
Medium Level (Three Years)	0.024	0.062	0.39
High Level (5 Years)	0.217	0.075	2.87[a]
Additional Labor Required			
Low Level (5-10 days per annum)	-0.071	------	------
Medium Level (20-30 days per annum)	-0.060	0.099	-0.60
High Level (40-50 days per annum)	0.131	0.071	1.84[b]
Product Mix			
Low Level (only Timber)	-0.061	------	-----
Medium Level (Timber + crops)	0.252	0.064	3.95[a]
High Level (Timber + crops +fruit trees)	-0.191	0.062	-3.06 [a]
Source of Tree Seedlings			
Low Level (gather for free from forest)	0.296	------	------
Medium Level (work for seedlings in nursery)	-0.077	0.073	-1.06
High Level (purchase delivered seedlings)	-0.219	0.065	-3.37 [a]
Impact on Forest Environment			
Low Level (Worse in future)	-0.334	0.067	-4.96 [a]
Medium Level (No Impact)	-0.054	------	------
High Level (Better in future)	0.388	0.064	6.04[a]

Likelihood Ratio $chi^2(11) = 204.24$; Prob > chi^2 (11) = 0.000; Psuedo $R^2 = 0.085$
[a]Significant at the 5 percent level; [b]Significant at the 10 percent level

The environmental impact attribute also performed as expected, with respondents strongly preferring systems that improve future forests to those with no impact. Systems that result in a degraded future forest environment produced strongly negative reactions. Given that the average respondent had cleared almost one fourth of their forestland, this result may suggest that farmers are beginning to recognize the negative impacts of increasing deforestation and desire sustainable land-use systems that will reduce the rates and impacts of deforestation.

At first glance, the labor attributes appear to be counter intuitive with the low and medium labor levels producing negative utility values while the highest additional labor level is strongly positive and significant. However, this likely is due

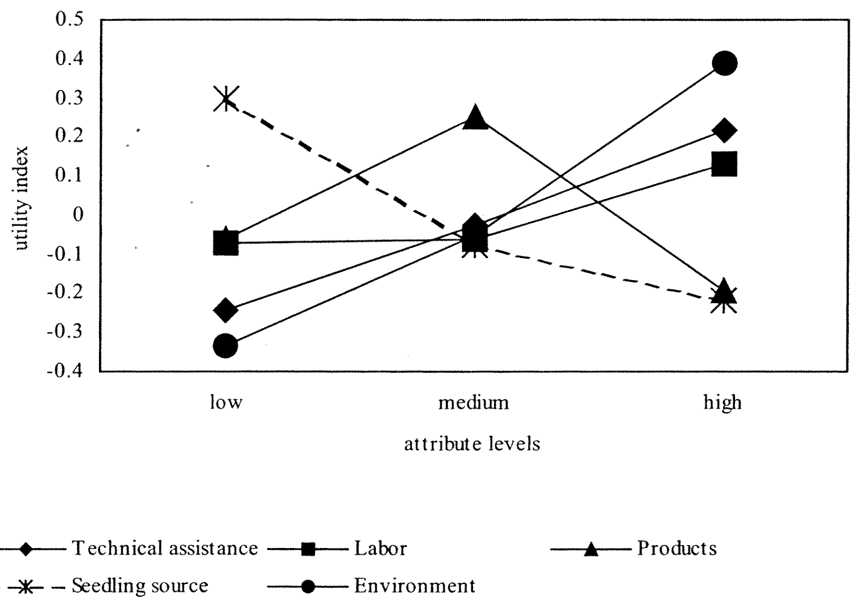

Figure 2. Marginal utilities of agroforestry system attributes.

to the farmers correlating the amount of labor input with the productivity level of the system and assuming that systems that require only a few extra days of labor a year (as in the low and medium additional labor cases) would not produce enough to be worth bothering with.

The relative impacts of the attributes on the farmers' preferences for agroforestry systems are depicted in Figure 3. Relative attribute impact was calculated by constructing a ratio where the numerator is the difference of the maximum and minimum coefficients (i.e., utility) for the levels of that attribute; the denominator of the ratio is the sum of the values in the numerator for all attributes. Surprisingly, the condition of the future forest environment had the greatest impact (31% out of 100%) on the farmers' preferences indicating the strength of farmers' concerns for future generations in their current decision-making. Nearly equal in importance were the source of seedlings (22%) (which may reflect past problems tree planting programs had with the timing of seedling delivery to farmers), technical assistance (20%), and the product mix (19%). The amount of additional labor required for the system (9%) was the least important factor indicating perhaps the existence of

Table 4. Relative agroforestry systems/projects desirability with different attribute combinations.

System	*Technical Assistance (years)*	*Additional Labor (days/year)*	*Products from System*	*Source of Tree Seedlings*	*Impact on Forests*	*Total Preference Weight*	*Rank*
A	5	40-50	Timber and crops	Collect in Forest	Better in Future	1.28	1
B	5	20-30	Timber, fruit, crops	Collect in forest	No impact	0.0127	5
C	3	5-10	Timber and crops	Purchase	Better	0.374	2
D	3	40-50	Timber only	Purchase	Better	0.263	3
E	5	20-30	Timber and crops	Work in nursery	Worse	-.002	6
F	1	5-10	Timber and crops	Work in nursery	Better	0.262	4
G	1	40-50	Fruit only	Collect	No impact	-.059	7
H	1	5-10	Timber only	Purchase	Worse	-1.056	8

excess labor at various times during the year. Labor's relatively low importance reflects the fact that the opportunity costs of labor are low during much of the year, and therefore, labor is not seen as a particularly important constraint.

ACE results also allow one to determine which combinations of the attributes of the agroforestry system and/or project would be most desirable to the farmers. This is accomplished by simply summing the parameter estimates for alternative combinations of attributes (as in Table 4) to determine the total preference weight for that system by the average respondent. The system/project with the highest total preference weight is the most preferred. For the current study the most preferred system is system A with a total preference weight of 1.28. System A would provide 5 years of technical assistance, 40-50 days of additional labor, timber plus annual crops, seedlings gathered from the forest and a better forest environment in the future. The least preferred system is system H (-1.056 total preference weight), which would provide only 1 year of technical assistance, require 5-10 days of additional labor annually, produce only timber, require seedlings to be purchased, and result in a poorer forest environment in the future. Systems B-G, which were designated by members of the ICRAF project staff, range from being perceived negatively overall (E and G) to intermediate but positive preference scores for systems B, C, D, and F.

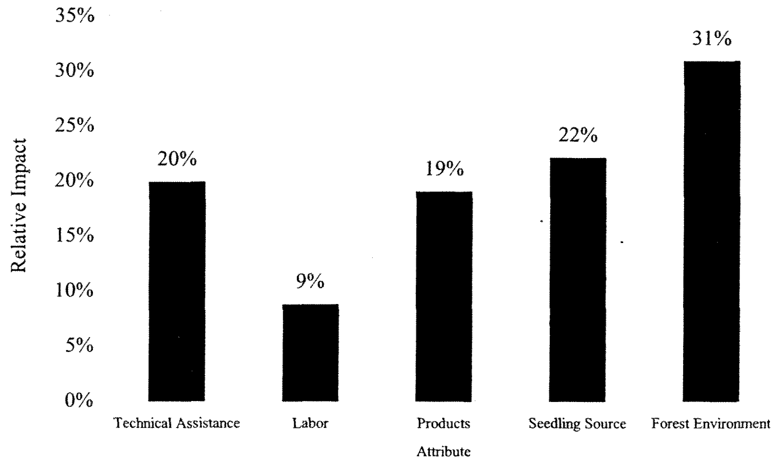

Figure 3. Relative impact of attributes on farmer preferences for new agroforestry system.

5. SUMMARY AND CONCLUSIONS

Achieving the full potential of agroforestry to contribute to sustainable land use requires improving adoption rates. No matter how elegantly designed, efficient, productive or ecologically sustainable, if the system is not adopted by a significant proportion of the target population or communities, impacts are likely to be minor. Realization that adoption rates were lagging behind the science of agroforestry has led many to call for increased research in farmer decision-making with respect to adoption of new agroforestry innovations (Adesina & Chianu, 2002; Alavalapati, Luckert, & Gill, 1995; Bannister & Nair, 2003; Lapar & Pandey, 1999; Nair, 1996; Sanchez, 1995; Thacher, Lee, & Schellas, 1997). In response, an explosion of research in agroforestry adoption began in the mid-1990's, most of which examined *ex-post* adoption decisions (Mercer, in press). Although significant progress has been made in analyzing agroforestry adoption potential prior to implementation of agroforestry extension projects (Current et al., 1995; Barrett et al., 2002; Franzel & Scherr, 2002), development of rigorous, statistically based methods for analyzing potential demand is needed. In this chapter, we present one alternative, attribute-based choice experiments (ACE).

ACE studies derive from the long history of applying conjoint analysis by market researchers to the problem of developing new, multi-attribute goods and services that will be demanded or adopted by consumers, a similar problem to designing new multi-attribute agroforestry systems and projects that will be adopted by farmers. ACE improves on traditional ranking and rating conjoint by being firmly grounded in economic and behavioral theory and by examining respondent preferences in a context that is familiar (i.e., choosing to buy different products or to adopt different farm production systems).

The approach is illustrated with a simple case study from southeast Mexico as an example of how one might approach applying ACE to an agroforestry context of primarily subsistence farmers. Responding to the needs of the research client, ICRAF, we examined the relative importance of technical assistance, labor input, products produced, source of tree seedlings and the impact on future forest environments. These subsistence farmers put heavy emphasis on future environmental impacts, suggesting a strong motive to bequeath a better world to their children. Other important considerations were the amount of technical assistance, means of acquiring seedlings, and the mix of products between timber, crops, and fruit trees.

Other potential applications of ACE to agroforestry system and project design are numerous. In the current case, ICRAF was interested in broadly defined attributes for general adoption of planting trees on farms. However, ACE has large potential to assist system designers in determining the importance and preference for such attributes as: the arrangement of alleys and crops in alley cropping; determining alternative tree and crop species mixes; the relative importance of environmental protection (e.g., erosion control) versus income generation; the distribution of income over time; and the impact of relative risk on adoption decisions. In addition, carefully designed ACE studies could provide quantitative analysis of the potential impact and relative importance of various policy incentives such as: provision of credits; markets, inputs such as seeds or tree seedlings; technical assistance and education; and risk reducing policies like price supports.

6. APPENDIX: APPLYING RANDOM UTILITY AND MULTINOMIAL LOGIT MODELS TO ACE ESTIMATION

The theoretical foundation for the empirical models used to analyze attribute-based choice experiments (ACE) is based on the theory of random utility maximization (RUM). The following explication of applying random utility theory to choice experiments is derived from Holmes and Adamowicz (2003). The basic assumption of RUM is that the true but unobservable utility of a good or service j is composed of both systematic (v) and random components (ε) as in equation 1:

$$U_j = v(x_j, p_j; \beta) + \varepsilon_j \tag{1}$$

where x_j is a vector of attributes of j; p_j is the cost of j; β is the vector of parameters; and ε_j is the random error term with a mean of zero. Whereas respondents know with certainty their choice behaviors, the researcher's knowledge is stochastic since it is based only on the behavior observed during the choice experiment. This uncertainty is modeled with the error term, ε_j. Assuming utility is linear in parameters, the estimation equation for (1) is:

$$U_j = \sum_{k=1}^{k} \beta_k x_{jk} + \beta_p p_j + \varepsilon_j \qquad (2)$$

Marginal utilities from equation 2 are the derivatives of U with respect to the βs and the marginal rate of substitution between any two parameters is the ratio of the respective βs. The estimated coefficients for the various attributes. If a price variable (p) is included, the marginal rate of substitution between any attribute and the price variable (β_k/β_p) can be interpreted as the marginal value or implicit price of that attribute.

From equation 1, the probability that a respondent will choose alternative i from choice set C is expressed as:

$$P(i \mid C) = P(U_i > U_j) = P(v_i + \varepsilon_i > v_j + \varepsilon_j) \forall j \in C \qquad (3)$$

Assuming that errors are independently and identically distributed (IID) and follow a type 1 extreme value (Gumbel) distribution), equation 3 can be re-arranged to show that :

$$P(i \mid C) = P(v_i - v_j > \varepsilon_i - \varepsilon_j) \forall j \in C \qquad (4)$$

Equation 4 shows that all variables that are constant across alternatives (for example, individual respondent characteristics such as income, household size, education, etc.) drop out of the model. Assuming that preferences are EV1 distributed (via the unobserved variables) and choices are independent from irrelevant alternatives (IIA assumption), then the multinomial (or conditional) logit model can be applied and the probability of choosing alternative i with scale parameter μ is:

$$P(i \mid C) = \frac{\exp(\mu v_i)}{\sum_{j \in C} \exp(\mu v_j)} \qquad (5)$$

If utility is assumed to be additively separable and $\mu = 1$, the probability of choosing alternative i from choice set, C, is:

$$P(i \mid C) = \frac{\exp(\sum_{k=1}^{j} \beta_k x_{ik} + \beta_p p_j)}{\sum_{j \in C} \exp(\beta_k x_{ik} + \beta_p p_j)} \qquad (6)$$

Assuming a sample size of N defining y_{in} as (1) if the respondent chooses alternative i and (0) otherwise, and the MNL likelihood function can be expressed as:

$$L = \prod_{n=1}^{N} \prod_{i \in C} P_n(i)^{y_{in}} \tag{7}$$

To estimate the MNL model and determine the values of the βs one substitutes (6) into (7) and maximizes the resulting log likelihood function (equation 8):

$$\ln L = \sum_{n=1}^{N} \sum_{j \in C} y_{in} (\sum_{k=1}^{I} \beta_k x_{ikn} + \beta_p p_{in} - \ln \sum_{j \in C} (\sum_{k=1}^{I} \beta_k x_{xkn} + \beta_p p_{jn}) \tag{8}$$

7. NOTES

[1] By law, active forestry *ejidos* are required to replace trees harvested for timber by enrichment plantings of mahogany and cedar under the forest canopy. Tree survival and growth, however, in the enrichment plantings have been very low (Sosa, 1997).
[2] Personal communication: Acopa, Miguel, Head of the Calakmul Agroforestry Project 1991- 1996.
[3] Personal communication: Mex, G., Coordinator of Bosque Modelo para Calakmul and Uc, C. ICRAF-Mexco.
[4]Production levels were initially considered as one of the most important attributes. During pre-testing, however, it became apparent that respondents were focusing solely on that attribute in their choices. So, it was dropped from the final design to enable analysis of other important attributes, realizing that achieving maximum production and income generation was the number one priority for all systems
[5] This result is not unexpected since only farmers indicating an interest in agroforestry were given the ACE task.

8. REFERENCES

Adamowicz, W., Louviere, J., & Williams, M. (1994). Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management, 26*, 271-292.

Adesina, A. A., & Chianu, J. (2002). Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agroforestry Systems, 55*, 99-112.

Addleman, S. (1962). Orthogonal main-effect plans for asymmetrical factorial experiments. *Technometrics, 4*(1), 21-46.

Alavalapati, J., Luckert, M., & Gill, D. (1995). Adoption of agroforestry practices: a case study from Andhra Pradesh, India. *Agroforestry Systems, 32*, 1-14.

Bannister, M. E., & Nair, P. K. R. (2003). Agroforestry adoption in Haiti: the importance of household and farm characteristics. *Agroforestry Systems, 57*, 149-157.

Barrett, C. B., Place F., & Aboudk, A. (2002). *Natural Resource Management in African Agriculture: Understanding and Improving Current Practices.* Wallingford, United Kingdom: CABI Publishing.

Baidu-Forson, J., Waliyar, F., & Ntare, B. R. (1997). Farmer preferences for socio-economic and technical interventions in groundnut production system in Niger: Conjoint and ordered probit analyses. *Agricultural Systems, 54*(4) 463-476.

Bennett, J. & Adamowicz, V. (2001). Some fundamentals of environmental choice modeling. In J. Bennett& R. Blamey (Eds.), *The Choice Modeling Approach to Environmental Valuation* (pp. 37-69). Cheltenham, United Kingdom: Edward Elgar.

Bennett, J., & Blamey, R. (Eds.). (2001a). *The Choice Modeling Approach to Environmental Valuation.* Cheltenham, United Kingdom: Edward Elgar.

Bennett, J., & Blamey, R. (2001b). Introduction. In J. Bennett & R. Blamey (Eds.), *The Choice Modeling Approach to Environmental Valuation* (pp. 1-10). Cheltenham, United Kingdom: Edward Elgar.

Bosque Modelo. (1997). Visión Estratégica 1997-2000. Bosque Modelo para Calakmul, Ecología Productiva.

Casey, J., Mercer, E., & Snook, A. (1999). Evaluating farmer preferences for agroforestry systems: survey instrument design. In *Proceedings of the 1998 Southern Forest Economics Workshop* (pp 153-158). Williamsburg, VA.

Current, D., Lutz, E., & Scherr, S. (1995). Costs, Benefits and Farmer Adoption of Agroforestry: Project Experience in Central America and the Caribbean. World Bank Environment Paper Number 14, pp 1-27. Washington, DC: The World Bank.

Franzel, S., & Scherr, S. J. (2002). *Trees on the Farm: Assessing the Adoption Potential of Agroforestry Practices in Africa.* Wallingford, United Kingdom: CAB International.

Green, P.E., & Wind, Y. (1975). New way to measure consumers' judgments. *Harvard Business Review, 53,* 107-111.

Holmes, T., Zinkhan, C., Alger, K., & Mercer, E. (1998). The effect of response time on conjoint analysis: estimates of rain forest protection values. *Journal of Forest Economics, 4*(1), 7-28.

Holmes, T.P., & Adamowicz, W.L. (2003). Attribute-based methods. In P. Champ, K. Boyle, & T. Brown (Eds.) *A Primer on Non-market Valuation* (pp 171-219). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lapar, M. L., & Pandey, S. (1999). Adoption of soil conservation: the case of the Philippines uplands. *Agricultural Economics, 21,* 241-256.

Louviere, J. J. (1988). Conjoint analysis modeling of stated preferences. *Journal of Transport Economics and Policy, 22*(1), 93-119.

Louviere, J. J. (1994). Conjoint Analysis. In R. Bagozzi (Ed.), *Handbook of Marketing Research* (pp. 223-259). Oxford: Blackwell Publishers.

Louviere, J. J. (2001). Choice Experiments: An overview of concepts and issues. In J. Bennett & R. Blamey (Eds.), *The Choice Modeling Approach to Environmental Valuation* (pp 13-36). Cheltenham, United Kingdom: Edward Elgar.

Mercer, E. (in press). Adoption of agroforestry innovations in the tropics: A review. *Agroforestry Systems.*

Mercer, E., & Miller, R. (1998). Socio-economic research in agroforestry: progress, prospects, priorities. *Agroforestry Systems, 38,* 177-193.

Mercer, E., Snook, A., Haggar, J., & Sosa, M. (in press). Agroforestry adoption in the Calakmul Biosphere Reserve, Campeche, Mexico. *Journal of Crop Production.*

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (Ed.) *Frontiers in Econometrics* (pp. 105-142). New York: Academic Press.

Nair, P. K. R. (1996). Agroforestry directions and trends. In P. McDonald & J. Lassoie (Eds.), *The Literature of Forestry and Agroforestry* (pp. 74-95). Ithaca, New York: Cornell University Press.

Opaluch, J. J., Swallow, S. K., Weaver, T., Wessells, C. W., & Wichelns, D. (1993). Evaluating impacts from noxious facilities: Including public preferences in current siting mechanisms. *Journal of Environmental Economics and Management, 24,* 41-59.

Pattanayak, S., Mercer, D. E., Sills, E., & Yang, J. (2003). Taking stock of agroforestry adoption studies. *Agroforestry Systems, 57,*173-186.

Sanchez, P. A. (1995). Science in Agroforestry. *Agroforestry Systems,* 30, 5-55.

Snook, A. (1996). *Annual Report.* International Centre for Research in Agroforestry-Mexico. Chetumal, Quintana Roo, Mexico.

Snook, A., & Zapata, G. (1998). Tree Cultivation in Calakmul, Mexico: Alternatives for reforestation. *Agroforestry Today, 10*(1), 15-18.

Sosa, L. (1997). Evaluación de Plantaciones de Cedro (*Cedrela odorata* L.) y Caoba (*Swietenia macrophylla* King) en Sistemas Agroforestales en la Area de Bosque Modelo , Calakmul, Campeche.

Unpublished masters thesis. División de Ciencias Forestales, Universidad Autónoma Chapingo, Mexico.
STATA. (1999). Stata Reference Manual: Release 6. Volume 1 A-G. College Station, Texas: Stata Press.
Thacher, T., Lee, D., & Schellas, J. (1997). Farmer Participation in reforestation incentive programs in Costa Rica. *Agroforestry Systems, 35*, 269-289.
Zinkhan, F. C., Holmes, T. P., & Mercer, D. E. (1997). Conjoint Analysis: a preference-based approach for the accounting of multiple benefits in southern forest management. *Southern Journal of Applied Forestry, 21*(4), 1-7.

9. AUTHOR'S NOTE

Funding for this research was provided by the USDA Foreign Agricultural Service, Research and Scientific Exchanges Division, the USDA Forest Service Southern Research Station, and the International Centre for Research in Agroforestry. Special thanks are extended to Jim Casey, Carlos Uc, Mauricio Sosa and the farmers of Calakamul for all their support in the data collection process.

ADVANCES IN AGROFORESTRY

Valuing Agroforestry Systems
Methods and Applications

Janaki R.R. Alavalapati and D. Evan Mercer (Eds.)

There is a growing interest and need for enhancing economic and policy research in agroforestry. So far, no single reference book provides adequate coverage of applied economic and policy analysis methodologies for agroforestry professionals. This book, written by the leading experts in economics and agroforestry, addresses this need with 14 case studies (covering all the continents of the world) that describe and demonstrate the application of a wide range of cutting edge economic analysis techniques to agroforestry systems, policies and projects. The applied economic methodologies include enterprise/farm budget models, Faustmann models, Policy Analysis Matrix, production function approach, risk assessment models, dynamic programming, linear programming, meta-modeling, contingent valuation, attribute-based choice experiments, econometric modeling, and institutional economic analysis. This book provides a unique and valuable resource for assisting upper division undergraduate and graduate students and rural development professionals to conduct rigorous assessment of economic and policy aspects of agroforestry systems and to produce less biased and more credible information.

ISBN 1-4020-2412-6

9 781402 024122

KLUWER ACADEMIC PUBLISHERS

ADAG 2