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Adoption of Agroforestry Practices in Northwest Washington State: An Ex-ante Case-Study

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By

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Abstract

Agroforestry (AF) practices mitigate climate change, provide ecosystem services, benefit communities, and create long-term economic opportunities for farmers and land managers worldwide. Despite these well-documented benefits, however, the adoption of agroforestry practices remains low. This study aimed to understand the barriers and incentives to adoption by applying the stated choice method to a case study of direct-to-market farmers in the four counties of northwest Washington State: Whatcom, Skagit, San Juan, and Island. Our results indicate that the scale of initial implementation and the upfront costs of seedlings had the largest relative impact on respondent decision making. Similarly, one early adopter in a community had an outsized effect on recruiting future adopters. These results provide important information for local extension and other support agencies, namely a predictive understanding of adoption behavior given different combinations of agroforestry attributes. More generally, our study demonstrates how to apply an easily scalable and replicable econometric method to better understand landholder preferences for agroforestry systems. Agroforestry adoption has long been hampered by a lack of rigorous ex-ante research, and the stated choice method provides an exciting way forward for future AF adoption studies.

Key words: agroforestry, adoption, stated choice method, ex-ante, Washington State

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This research would not have been possible without all the participants who agreed to meet with me or take our survey. I would like to extend my sincerest gratitude to everyone who shared their time, energy, and invaluable insights to support this project. Thank you for your contribution.

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Acronyms and Vocabulary

AF Agroforestry

DIT Diffusion of Innovation Theory

IPCC Intergovernmental Panel on Climate Change

SCM Stated Choice Method

PNW Pacific Northwest

QCA Qualitative Content Analysis

Chapter 1: Introduction, Literature Review, Methods

1.1 Background

As the world contends with accelerated climate change and environmental degradation, how we use land is increasingly recognized as both a driver and a potential solution to these problems. The land and agriculture sectors currently account for an estimated one-quarter of global carbon emissions (Hawken, 2017). Better land use practices have the potential to not only eliminate these emissions but sequester additional carbon from other sources. Agroforestry, a land management approach that integrates trees and shrubs with food crops and/or livestock production, is one such practice gaining significant traction in the scientific community (P. K. Nair & Mercer, 2005). The United States Department of Agriculture (USDA) recognizes five agroforestry (AF) practices, including alley-cropping, forest farming, silvopasture, riparian forest buffers, and windbreaks. In addition to its role in climate change mitigation, AF has the potential to provide other agriculture-related social, environmental, and economic benefits as well (Nair, 2007). Such benefits include but are not limited to improved economic resilience from enhanced agricultural diversity and ecosystem service co-benefits such as soil erosion control and water quality protection (Bentrup et al., 2019).

Though a robust body of research supports the benefits of AF (Franzel & Scherr, 2002; Garrett, 2009; Jose, 2009), landholder adoption of AF practices remains low. In the U.S., for example, just 1.5% of farmers reported practicing AF in the 2017 agriculture census (USDA NASS, 2017). This low adoption rate may be attributed to specific AF knowledge gaps, namely 1) a dearth of AF studies in temperate climates, 2) an overemphasis on the biophysical rather than the social components of AF, and 3) a general lack of rigorous ex-ante studies[1] within the adoption literature. In light of the benefits of AF previously discussed, addressing the reasons behind these low adoption rates represents a significant opportunity to expand AF practices.

1.2 Research Statement

To address these gaps, I conducted an ex-ante case study of current and potential agroforestry practitioners in northwest Washington State to better understand their relative preferences for various attributes of AF systems. I used a case-study approach that incorporated qualitative semi-structured interview methods and quantitative stated choice methods, as supported by the agri-environmental adoption literature (Mamine et al., 2020; Nair & Mercer, 2005). This approach was iterative, such that the results from the qualitative analysis informed the quantitative survey design.

In this research, I addressed the following question and sub-questions:

1. What agroforestry attributes are most influential to landholder adoption in Washington State?

    a) What are the relative impacts of these attributes on landholder adoption?

    b) Are there boundary conditions (i.e., specific levels of an attribute) associated with the adoption or non-adoption of agroforestry in Northwest Washington State?

    c) How can these attributes inform more appealing agroforestry programs?

Integrating landholder input helps identify the current barriers to adoption and those attributes most influential to landholder decision-making. This information could be useful in designing

[1] *Ex-ante* studies seek predictive understanding of landholder preferences for various AF alternatives. The results can be used to design more appealing AF support programs based on landholder input.

more appealing AF programs in Northwest Washington and eventually increase the adoption of AF practices statewide.

1.3 Literature Review

1.3.1 History of Agroforestry Adoption Research

AF research began in earnest in the late 1970s when the international scientific community began recognizing the significant potential of this integrated land management and agricultural practice (Nair & Mercer, 2005). Early AF research was largely descriptive, focusing primarily on the biophysical components of AF in tropical ecosystems. Despite significant scientific improvements in AF research through the early 1990s, landholder adoption of AF remained low (Mercer, 2004). This perceived gap soon motivated an explosion of adoption research in the mid-1990s, dominated by sociologists, economists, and geographers who pursued distinct theoretical and methodological paths. Though improved understanding of adoption behaviors led to some successful extension efforts, overall adoption rates of AF remained low (Pattanayak et al., 2003; Trozzo et al., 2014, USDA/NASS, 2017). Certain gaps in the literature may be contributing to this problem, namely a lack of AF studies in temperate environments, a dominance of biophysical rather than socioeconomic AF studies, and a lack of rigorous ex-ante adoption studies (Bentrup et al., 2019; Current et al., 1995; Mercer & Snook, 2005; Montambault & Alavalapati, 2005; Romanova, 2020).

Based on a recent review by Romanova, only about twenty percent of relevant AF adoption studies concern temperate climates (Romanova, 2020). Of the 35 temperate region studies identified in the literature, only two occurred in Washington State (Lawrence et al., 1992; Lawrence & Hardesty, 1992). This represents a significant hurdle to increasing local AF adoption. Furthermore, while the overwhelming majority of AF research investigates the ecological suitability of different AF systems to various environments, even this type of research is lacking in the Pacific Northwest region (Franzel & Scherr, 2002; Montambault & Alavalapati, 2005; Romanova, 2020). While important, such biophysical research does not correlate with increased landholder adoption of AF. To address this problem, there has been an increase in studies exploring the socioeconomic and behavioral components of AF (Pattanayak et al., 2003). However, most of these studies have examined how past adoption decisions are correlated with farmer, farm, and project characteristics using binary regression models. While useful for increasing our understanding of who adopts first, these *ex-post* studies have contributed little to the problem of designing more appealing AF programs (Mercer & Snook, 2005).

By contrast, *ex-ante* studies use landholder preferences to inform the practical design of AF systems (Franzel & Scherr, 2002). Ex-ante adoption studies have the potential to provide a predictive understanding of land use decisions at the farm household level, as well as describe the relative importance of various land-use system attributes (Mercer & Snook, 2005). Interest in ex-ante adoption research has blossomed since the turn of the century as researchers, professionals, and policymakers have recognized the importance of including landholder input in the design of agri-environmental programs (Mamine et al., 2020). However, as noted in the literature, there is still a need for ex-ante studies backed by rigorous empirical analyses and sound theoretical frameworks (Franzel & Scherr, 2002; Mercer & Snook, 2005; Trozzo et al., 2014).

1.3.2 Theoretical Framework

The theoretical framework for this research is grounded in the Diffusion of Innovation Theory (DIT). First developed by Rogers (2003) in 1962, this theory models how innovations spread through a population. DIT has a long history of application to agricultural research, starting with extension efforts to spread technological innovations during the “green revolution” (Griliches, 1960; Haven & Rogers, 1961). More recently, DIT has been used to model the adoption and diffusion prospects of sustainable agriculture techniques, such as AF (Barrett et al., 2002; Evans, 1988, p. 19; Glendinning et al., 2001; Romanova, 2020). According to the DIT, different groups of individuals adopt innovations at different rates (Rogers, 2003). Adoption behaviors follow predictable patterns, such that any society can be stratified into five distinct groups based on time to adoption: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16.5%). As shown in Figure 1 below, innovators and early adopters significantly influence the diffusion rate to the rest of the population. Because the adoption of AF in Washington State is currently around 3% (USDA NASS, 2017), we have yet to reach the “tipping point” toward greater diffusion. As such, understanding the preferences of innovators and early adopters is crucial to reaching future adopter groups.

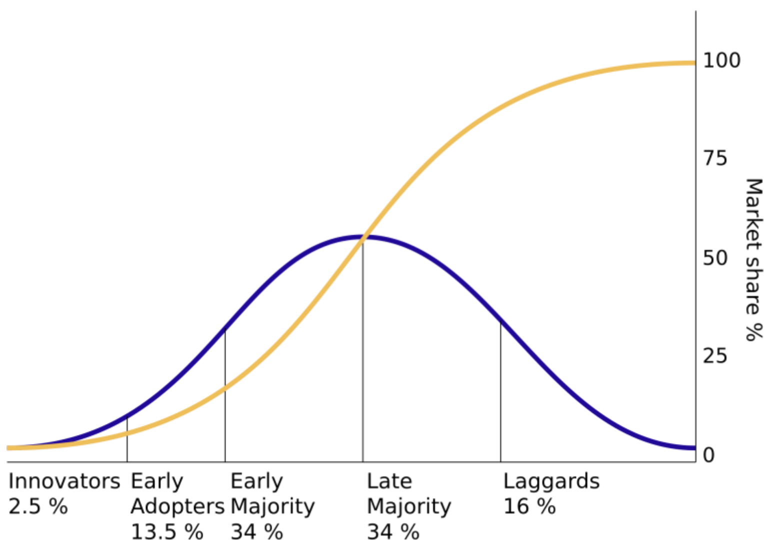

Figure 1.1. *The diffusion of innovation theory model, adapted from Everett M. Rogers. This figure highlights the five adopter categories and the diffusion process, as shown by the yellow line. Source: https://prezibase.com/shop/diffusion-of-innovation-diagram-prezi-template/*

1.3.3 Introduction to the Stated Choice Method

One method used to understand the preferences of different groups of people is the Stated Choice Method (SCM). SCMs represent a suite of techniques to study the choices, or "trade-offs," individuals or groups make when presented with scenarios containing varying goods or services (Hensher et al., 2005). The basic requirement for this method is that the products or services are treated as sets of distinct attributes with limited variations for each attribute (Mercer & Snook, 2005). Eliciting respondents' preferences for these different goods or services allows the analyst to evaluate the relative importance of the various attributes, compare alternative versions of the good or service, and estimate the probability of adoption (in this case of an AF practice), given different combinations of attributes (Louviere, 1988). Unlike most survey data, where information on both the dependent and explanatory variables is captured directly from respondents, in SCM surveys, only the choice response variable is provided by the respondent (Hensher et al., 2015). Excluding covariate information, often ignored in most analyses, the primary variables of interest (consisting of attributes and their associated levels) are designed in advance and presented to the respondent as sets of paired alternatives.

SCMs are grounded in random utility theory (RUM), a behavioral theory that models choice decisions as a set of systematic and stochastic utility functions (Adamowicz et al., 1998). RUM provides a rigorous theoretical basis for stated choice methods, differentiating them from other choice-based methods not grounded in sound behavioral theory (Louviere et al., 2010). Under RUM, choices are made based on the utility differences across alternatives, thus mimicking the actual market behavior (Holmes & Adamowicz, 2003). To set up the appropriate response format, SCM experiments are generally divided into seven sequential steps: 1) characterize the decision problem, 2) identify and describe the attributes, 3) develop an experimental design, 4) develop the survey, 5) collect data, 6) estimate the model, and 7) interpret the results for policy analysis and decision support (Adamowicz et al., 1998; Holmes & Adamowicz, 2003). Though the details of each step vary by study, this general process is unanimous across all SCM agri-environmental studies.

1.3.4 History of the Stated Choice Method

Since the early 2000s, there has been a rapid evolution in the number of papers using SCMs in ex-ante agri-environmental adoption studies (Mamine et al., 2020). SCMs originated in behavioral science and marketing and have since expanded to many other disciplines concerned with the adoption and diffusion of various innovations. This method has become popular in agricultural and environmental sectors due to its ability to include market and non-market attributes that are often difficult to observe in real-life innovation situations (Mamine et al., 2020). A common critique of early adoption research is that it was siloed between sociologists, economists, and geographers who did not communicate across disciplines (Mercer, 2004). Thus, early adoption studies were often limited in the scope of variables they considered and tended to overemphasize the importance of singular aspects of variables rather than recognizing their interactive components. SCMs represent an antidote to this problem by incorporating a swath of attributes historically investigated by particular disciplines.

Though now widely used across agri-environmental studies, there are relatively few applications of this method specifically to AF. One example comes from the book "Valuing Agroforestry Systems," where SCMs were applied to a case study of farmers in southeastern Mexico (Mercer & Snook, 2005). Here, the authors highlight the value of SCMs compared to other choice models because SCMs ask respondents to choose between alternatives rather than rank or rate the alternative. Traditional ranking methods have been critiqued for their lack of theoretical rigor and the problems they create for respondents (Bennett & Blamey, 2001). These include difficulty ranking large numbers of alternatives and creating a choice situation not often encountered by consumers. By contrast, the patterns of choice recorded in SCMs effectively model the probability of choosing a particular alternative based on the relative importance of its various attributes (Hensher et al., 2005). Grounded in sound behavioral theory and backed by robust empirical analyses, SCM studies provide an exciting way forward for ex-ante AF adoption research.

1.3.5 Incorporating Qualitative Interviews

The most important component of conducting an effective SCM study is the development of an appropriate survey that includes those attributes most impactful to adoption behavior (Mamine et al., 2020). In previous studies, "attributes" have included factors such as additional labor, years of technical assistance, and the type of AF practice such as alley cropping (Mercer & Snook, 2005). Generally, attribute specification occurs in step two of the experiment (Holmes & Adamowicz, 2003). This can best be done by thoroughly reviewing relevant studies, conducting focus groups and interviews of key stakeholders and panel experts, or combining these methods. Qualitative methods inform which attributes to include in the survey design (Coast et al., 2012). However, lack of attention to qualitative data collection and methods of analysis in SCM designs has impaired the utility of SCM results for policy implementation. This is due to the dependence of SCM results on the qualitative inputs used to inform the survey design. Therefore, choosing an appropriate qualitative method based on the research question and the availability of existing qualitative data is imperative.

Based on the review by Coast et al. in 2012, I conducted semi-structured interviews of local agroforestry experts, including extension agents, relevant conservation district professionals, and natural resources conservation agents, to determine which attributes of AF programs are most influential to landholder adoption. Using non-probability snowball sampling techniques, I also interviewed local practitioners. Expert interviews used to collect information on the relative importance of various attributes can successfully supplement landholder interviews, which are often more difficult to obtain (Coast et al., 2012). Interviews are lauded for the richness of attributes they generate and the reduced potential for attribute misspecification if populations are sampled to saturation. Though there is no official registry of AF professionals in Washington State, I interviewed the majority of people recommended through the Northwest Agroforestry Workgroup, the state's preeminent group of agroforestry professionals.

1.3.6 Using Content Analysis for Attribute Identification

After conducting and transcribing all interviews, I used qualitative content analysis (QCA) to identify those attributes most impactful to decision-making. QCA is a method used to "systematically describe the meaning" of written or oral materials based on the research questions of interest (Schreier, 2014, pp. 3-4). QCA focuses on extracting categories from the data to identify core consistencies and meanings (Patton, 2014). QCA is the most direct way of systematically analyzing a text or set of texts and is commonly used to analyze interview transcripts (Huckin, 2003). QCA does not provide a holistic understanding of the entire dataset. Rather it is focused on the properties identified by the research questions. This is an important difference from other qualitative methods that allow the researcher to arrive at a more comprehensive sense of the material. Because the goal of qualitative research in SCM studies is attribute identification, QCA is well suited to the task. However, as noted in the previous section, many SCM studies do not disclose how attributes/levels are determined. To increase transparency regarding this integral step, the benefits and applications of QCA to SCM studies are described in more detail below.

Important characteristics of QCA include the flexibility to use inductive or deductive approaches (or a combination of both) to extract manifest or latent content meaning (Cho & Lee, 2014). This flexibility allows researchers using QCA to reduce data to only those most relevant to the research questions (Schrier, 2014). In the inductive approach, a coding scheme is developed directly from the data. In the deductive approach, preconceived codes are derived from prior relevant theory, research, or literature (Cavanagh, 1997; Kondracki et al., 2002). Whereas manifest content focuses on the visible or surface content of the material, latent content refers to the underlying meaning of the material (Graneheim & Lundman, 2004). No matter the approach, QCA requires the researcher first to translate the findings of interest into categories of a coding scheme, then classify successive parts of the material according to these categories (Schrier, 2014). Finally, the researcher must trial, evaluate, and modify the coding frame. A valid coding frame is achieved through adaptation until the extent of the categories accurately represents the underlying concepts of the study. The research questions again guide the appropriate approach.

1.3.7 Designing a Tractable Experiment

Conceptually, an experimental design is a matrix of values used to determine what goes where in an SCM survey (Rose & Bliemer, 2009). During this phase, the alternatives and choice scenarios are determined based on the attributes and levels identified during qualitative analysis (Holmes & Adamowicz, 2003). The researcher must design a tractable yet statistically efficient survey instrument, considering factors such as attribute level balance, dominance, priors, coding type, labeling scheme, statistical modeling, and heuristics (Louviere et al., 2000). Rather than assigning random combinations of attribute levels to respondents, design theory systematically allocates attribute levels to alternatives based on the above considerations. This process aims to arrive at a set of choice scenarios, each with paired alternatives of varying attribute levels. If designed appropriately, the researcher can glean information regarding relative preferences for the various attributes from respondents' choices (Bennett & Blamey, 2001). No matter the type of design used, the two common objectives of design theory include: 1) the ability to independently detect the effects of multiple variables on some observable outcome (in this case, stated choice), and 2) the improvement of the statistical efficiency of the experiment (Hensher et al., 2015).

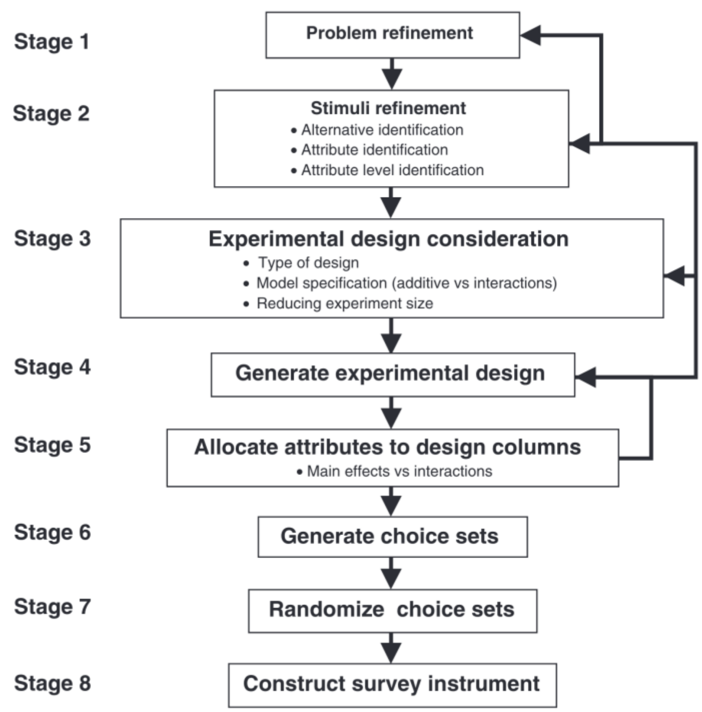

Figure 1.2. *An overview of the experimental design process, from problem refinement to constructing the survey instrument (Hensher et al., 2015).*

Though a majority of SCM studies have used orthogonal fractional factorial designs to reduce the total number of choice scenarios presented to each respondent, efficient designs are gaining traction in the recent SCM literature (Bliemer & Collins, 2016; Hensher et al., 2005; Rose & Bliemer, 2009). While orthogonal designs seek to avoid correlation within and between alternatives, efficient designs focus on optimizing various statistical efficiency measures, namely more reliable parameter estimates using an equal or lower sample size (Rose & Bliemer, 2009). Characteristics of orthogonal designs, particularly their ability to produce unconfounded estimates of the population parameters, may be less relevant to SCM studies than previously thought (Hensher et al., 2005; Rose & Bliemer, 2009; Ngene, 2015). Despite strict adherence to statistical independence between the attributes, even well-designed orthogonal studies are rarely orthogonal. Consider a blocked orthogonal design in which respondents see only a subset of the total number of scenarios created. Unless each blocked group has the same response rate, the results will not be orthogonal. Additionally, any covariate information collected (such as age, farm type, etc.) will not be orthogonal across the different groups. For these reasons, even a thoughtful orthogonal design rarely leads to orthogonal data in practice (Hensher & Barnard, 1988; Rose & Bliemer, 2009).

Efficient designs, by contrast, are more suitable to the nonlinear econometric models used in SCM studies (Train, 2003). However, these designs depend on the researcher having at least some prior information about the parameters of the various attributes (Ngene, 2015). These estimates are obtained from literature reviews of similar studies or pilot surveys. Even without specific prior values, it is often possible to estimate the direction of the priors. For example, higher prices have a negative prior because they are less desirable for respondents. Recent SCM literature suggests that in these situations, even when only the direction of the prior is known, efficient designs are preferable to orthogonal ones (Rose & Bliemer, 2009; Ngene, 2015).

1.4 Methods

To conduct an effective SCM study, four iterative phases must be completed: qualitative data collection, qualitative analysis, quantitative data collection, and quantitative analysis. The methods used for each will be described in detail below.

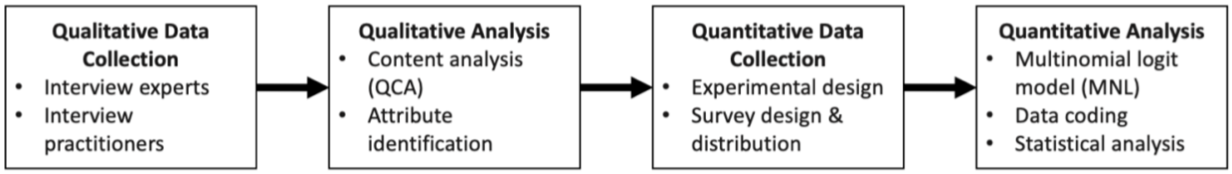

Figure 1.3. *The four phases of a stated choice study.*

1.4.1 Qualitative Data Collection

Semi-structured interviews were conducted to identify the attributes and attribute levels of interest. As recommended, not all participants were presented with a prescribed set of questions (Raworth et al., 2012). Instead, the researcher provided a general framework for the interview but allowed the conversation to flow based on individual interests and expertise. Of the fourteen interviews conducted between August and October 2022, nine included local AF professionals and five local AF practitioners. All interviews lasted between 25-55 minutes. Most (eleven) of these interviews took place over Zoom Video and were recorded using the same technology. Two interviews occurred over the phone, and the conversations were recorded using Otter.ai software. One interview occurred in person and was also recorded using Otter.ai software. The researcher transcribed all interviews using Otter.ai software and later edited them to correct transcription mistakes. All identifying qualifiers were then removed from the transcripts and randomized before analysis.

Interviewees were first identified through the Northwest Agroforestry Workgroup. Additional participants were recruited using snowball sampling techniques from these initial interviews. Because the community of practicing AF professionals is relatively small in Washington State, AF-adjacent professionals, or those providing technical assistance related to AF in roles with the extension, NRCS, or conservation district offices were considered in the interview process. In total, 24 potential interviewees were contacted, four self-identified as ill-suited to the position, two were unable to participate over Zoom or phone and were too far for the researcher to meet in person, and four did not respond after two emails and a follow-up phone call.

1.4.2 Qualitative Analysis

After anonymizing the transcripts, the researcher analyzed interview data using content analysis methods to identify those attributes most important to the adoption of AF. An inductive approach was used to identify an initial coding frame based on the research questions, resulting in three higher-order categories: barriers to adoption, incentives, and demographics. These were further broken down into subcategories, including 12 types of barriers, 10 types of incentives, and four demographic traits. These categories/subcategories were developed from keywords and quotations identified in the transcripts. Each important passage was coded and given a category label. In total, the researcher analyzed 392 pieces of coded data. Excerpts with similar themes across transcripts were grouped into the same category. The initial coding round was completed using hard-copy printouts of the transcripts, which were then uploaded into Atlas.ti software to help organize the categories and subcategories.

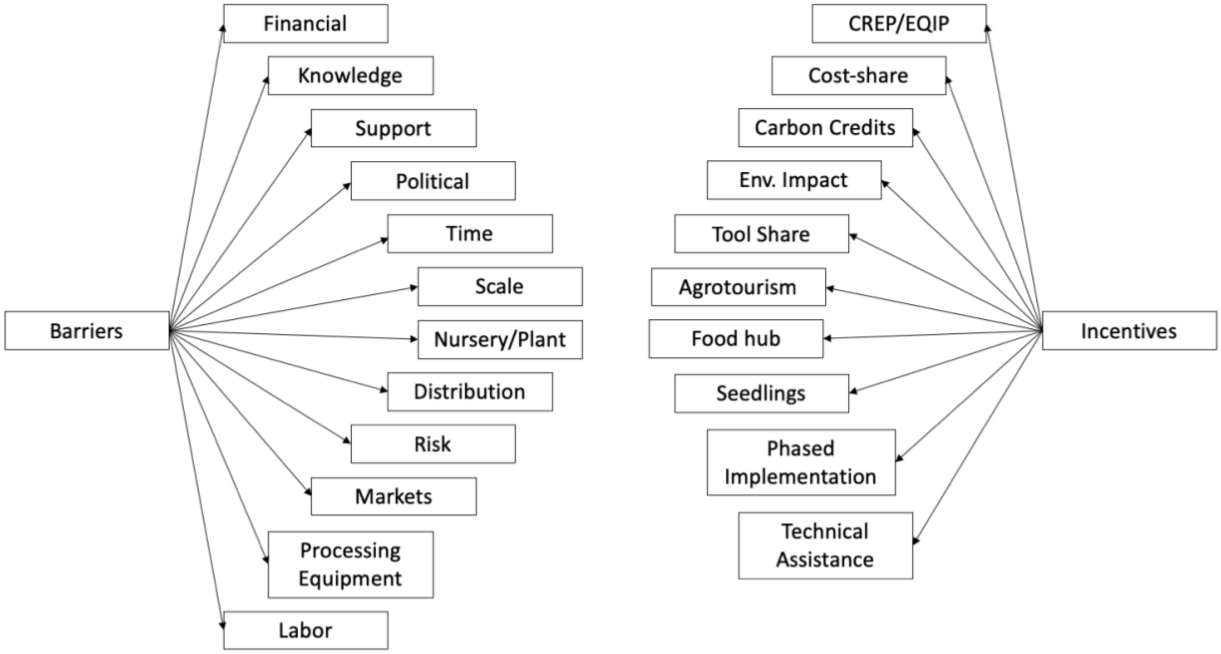

Figure 1.4*. Initial coding frame showing the 12 barriers and 10 incentives identified from the interview transcripts.*

After all the transcripts were coded, overlapping subcategories in the barriers and incentives categories were grouped and refined to reduce the total to eight. In this process, the researcher combined initial subcategories such as “markets”, “food hub”, and “processing equipment” into “available markets.” Similarly, “carbon credits” and “CREP” were combined into “ongoing cost-share options”, with “carbon credits” and “federal payment programs such as CREP or EQIP” included as the attribute levels. The eight categories each had >10 appearances across all coded data. The demographic subcategories were excluded from this analysis because covariate information is not included in the choice scenario design (Hensher et al., 2005).

After considering this initial coding frame within the context of the research questions, the eight attributes were further refined to six. These six attributes were chosen based on the prevalence with which they appeared in the coded interview transcripts and their relevance to potential extension effort programs. The ability to translate the results from the survey into actionable recommendations for agroforestry support programs is a key part of the research questions and, thus, the key to developing an effective coding frame. The final language used to describe the six attributes, each with three levels, is shown in Table 1 below.

Table 1.1. *Attributes and levels for the stated choice experiment.*

Attribute	*Level 1*	*Level 2*	*Level 3*
Cost of seedlings	Must fund and obtain your own seedlings. No initial cost-share program available.	50% of your seedling costs will be covered through an available cost-share program.	100% of your seedling costs will be covered.
Extent of technical assistance	1 year	5 years	10 years
Local examples	No local examples	1 local example	2 local examples
Scale of initial implementation	Convert marginal spaces (acreage not currently in production) to an agroforestry system.	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Enroll in a federal payment program such as CREP or EQIP.	Annual carbon credit payments available.
Available Markets	Raw and/or processed goods must be sold direct to market.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.

1.4.3 Quantitative Data Collection

Given the six attributes and three levels (3^6) used in this experiment, the complete factorial design yielded 729 possible alternatives. Because it is unreasonable to present respondents with this many alternatives, an efficient main effects design was used to reduce this number to a subset of 18 alternatives that covered the range of variability between all possible combinations. The main effects include the impact of individual attributes on the choice made but do not consider the impact of groups of attributes on this decision (Hensher et al., 2005). Because no prior knowledge was known of the relationships between the various attributes, a main effects design is appropriate.

The design was created using Ngene 1.3 software from Choice Metrics and considered factors such as dominance and attribute level balance. See Appendix D for an overview of the Ngene coding syntax used. A three-level blocking factor was used to split the 18 plans into three random blocks so that each final survey contained six choice scenarios of paired alternatives. Thus, respondents were presented with a series of six separate, trichotomous choice experiments, each with a pair of alternative agroforestry systems and the status quo option. The status quo (or "I would not adopt either alternative" option) is included should the respondent prefer not to adopt either of the alternative systems.

I recruited participants through the Washington Food and Farm Finder Database. Using a query, I subsetted all farms in the database by county, and included only those in Northwest Washington, specifically Whatcom, Skagit, San Juan, and Island Counties. This yielded 239 farms, 211 of which I contacted in the initial outreach email. Twenty-eight farms were not contacted because further research indicated they had permanently closed or no contact information was found. I used a random number generator to evenly divide these farms into three groups, then assigned each to one of the three survey blocks. Block one contained 70 farms, block two 71, and block three 70. I first contacted participants via an outreach email that included contact information for the researcher, a short description of the study, and a link to the survey. During this process, the sample size was further reduced to 195 potential participants. I removed additional respondents after email correspondence indicated they were ill-suited to the study (i.e., the farm had shut down, stopped production, traded ownership, or were unable to implement AF practices, for example, the farmer leased the land and was not allowed to establish perennials). I sent non-respondents a follow-up email one week later with another link to the survey. Two weeks later, I sent a final email with another link to the survey.

I developed the survey in Qualtrics, which took participants approximately 10-15 minutes to complete. 25 graduate and undergraduate students at Western Washington University piloted the survey to gauge word choice and clarity of instruction. Their feedback was used to edit and rearrange the survey components to produce the final version (please see Appendix B for a transcript of the final survey). In the final version, I presented each respondent with a study description, asked for their consent, and then provided background and definitions of the five agroforestry practices before they began the survey. Each survey consisted of six choice scenario questions and seven demographic questions. Survey links were individualized so only the individual with the associated email address could open the link. This decreased the chance of security scanners and bots starting the survey and prevented multiple submissions from the same respondent. I anonymized all survey results before analysis.

1.4.5 Quantitative Analysis

Given the survey design, each respondent was presented with six choice scenarios in which they were asked to choose between two agroforestry alternatives and a status quo option. Their choice was recorded as a single row of data, including the attribute levels for the chosen and non-chosen alternatives and the status quo option. Since no information was available on the attribute levels of the status quo option, zeroes were used to code the status quo alternatives. Effect codes were used to code the attribute levels for the two agroforestry alternatives. With effects coding, one attribute level is chosen as the reference level while the other two levels are coded into the data set (Bech & Gyrd-Hansen, 2005). The parameter value for the omitted attribute can be computed by summing the coefficients of the other two levels of that attribute. This coding scheme is preferred, because, unlike dummy coding, it provides information about the preferences for all attribute levels, including the one that was omitted (Holmes & Adamowicz, 2003).

Based on random utility theory, respondents' choices for each scenario were modeled as a set of three equations, each describing the probability of choosing that alternative. A multinomial logit regression model (MNL) was used to estimate the trichotomous choice responses, as is common in agri-environmental SCM experiments (Holmes & Adamowicz, 2003; Hoyos, 2010; Kanninen, 2007). By regressing the stated choices (response variable) on attribute levels (explanatory variable), the researcher can elicit a wealth of information regarding landholder preferences for individual attributes, as well as combinations of those attributes (Mercer & Snook, 2005). In the MNL model, the conditional indirect utility, *V*, can be specified for each alternative as a linear function of the attributes (Bennett & Blamey, 2001). The MNL model predicts the relative attractiveness of each alternative such that 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 (Mercer & Snook, 2005). Similarly, the coefficient on the status quo shows the marginal utility of the status quo option relative to the two alternatives. This model assumes that errors are independently and identically distributed (IID) and follow a type 1 extreme value (Gumbel) distribution.

Assuming no interaction effects, each choice set of 6 attributes and 3 levels is described with three linear in parameters models:

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

The regression coefficients, β_i, can be interpreted as the marginal utility of the attributes, A_i.

The Apollo (Hess & Palma, 2019) maximum likelihood routine was used to estimate the resulting multinomial logit regression (MNL) model (see Appendix E). MNL models predict the relative desirability of each alternative by considering factors that change across alternatives. Thus covariates (such as income or age) that remain the same across alternatives can only be introduced as interactions with either the attributes or the alternative-specific constant (Holmes & Adamowicz, 2003). Though more complex models are possible, they are not the focus of this case study.

The findings of our study are presented in article format in the following chapter. There is some redundancy from this chapter in the Introduction, Background, and Materials and Methods sections. The thesis concludes with Chapter 3 in which I review the limitations and challenges of the study, provides suggestions for future study, and reflects on the research process.

Chapter 2: Article

2.1 Abstract

Agroforestry (AF) practices mitigate climate change, provide ecosystem services, benefit communities, and create long-term economic opportunities for farmers and land managers worldwide. Despite these well-documented benefits, however, the adoption of agroforestry practices remains low. This study aimed to understand the barriers and incentives to adoption by applying the stated choice method to a case study of direct-to-market farmers in the four counties of northwest Washington State: Whatcom, Skagit, Island, San Juan, and Island. Our results indicate that the scale of initial implementation and the upfront costs of seedlings had the most significant relative impact on respondent decision making. Similarly, one early adopter in a community had an outsized effect on recruiting future adopters. These results provide important information for local extension and other support agencies, namely a predictive understanding of adoption behavior given different combinations of agroforestry attributes. More generally, our study demonstrates how to apply an easily scalable and replicable econometric method to better understand landholder preferences for agroforestry systems. Agroforestry adoption has long been hampered by a lack of rigorous ex-ante research, and the stated choice method provides an exciting way forward for future AF adoption studies.

2.2 Introduction

As the world contends with accelerated climate change and environmental degradation, land use practices are increasingly recognized as both a driver and a potential solution to these problems. Though land and agriculture sectors currently account for an estimated one-quarter of global carbon emissions, better land use practices have the potential to not only eliminate these emissions but sequester additional carbon from other sources (Hawken, 2017). Agroforestry , a land management approach that integrates trees and shrubs with food crops or livestock production, is one such practice gaining significant traction in the scientific community (Nair & Mercer, 2005). In addition to its role in climate change mitigation, AF has the potential to provide other agriculture-related social, environmental, and economic benefits as well (Nair, 2007). Such benefits include, but are not limited to, improved economic resilience from enhanced agricultural diversity and ecosystem service co-benefits such as soil erosion control and water quality protection (Bentrup et al., 2019). Though a robust body of research supports the benefits of AF (Franzel & Scherr, 2002; Garrett, 2009; Jose, 2009), landholder adoption of AF practices remains low. In the U.S., for example, just 1.5% of farmers reported practicing AF in the 2017 agriculture census (USDA NASS, 2017). These low adoption rates may be attributed to specific AF knowledge gaps, namely 1) a dearth of AF studies in temperate climates, 2) an overemphasis on the biophysical rather than the social components of AF, and 3) a general lack of rigorous ex-ante studies[2] within the adoption literature.

2.3 Background

The benefits and application of AF are better recognized in the tropics, though awareness of its potential for temperate and boreal systems is growing (Kreitzman et al., 2022; Lovell et al., 2021; Morgan et al., 2010). Based on a recent review by Romanova, approximately 20% of relevant AF adoption studies concern temperate climates (Romanova, 2020). However, of the 35 temperate region studies identified in the literature, only two occurred in Washington State (Lawrence et al., 1992; Lawrence & Hardesty, 1992). Furthermore, while the overwhelming majority of AF research investigates the ecological suitability of different AF systems to various environments, even this type of research is lacking in the Pacific Northwest region (Franzel &

[2] *Ex-ante* studies seek predictive understanding of landholder preferences for various AF alternatives. The results can be used to design more appealing AF support programs based on landholder input.

Scherr, 2002; Montambault & Alavalapati, 2005; Romanova, 2020). While important, such biophysical research does not correlate with increased landholder adoption of AF. To address this problem, there has been an increase in studies exploring the socioeconomic and behavioral components of AF (Pattanayak et al., 2003). However, most of these studies have examined how past adoption decisions are correlated with farmer, farm, and project characteristics using binary regression models. While useful for increasing our understanding of who adopts first, these *ex-post* studies have contributed little to the problem of designing more appealing AF programs (Mercer & Snook, 2005).

By contrast, *ex-ante* studies use landholder preferences to inform the practical design of AF systems (Franzel & Scherr, 2002). Ex-ante adoption studies have the potential to provide a predictive understanding of land use decisions at the farm household level, as well as describe the relative importance of various land-use system attributes (Mercer & Snook, 2005). Though interest in ex-ante adoption research has blossomed since the turn of the century, there is still a dearth of ex-ante studies backed by rigorous empirical analyses and sound theoretical frameworks (Franzel & Scherr, 2002; Mamine et al., 2020; Mercer, 2004; Strong & Jacobson, 2005; Trozzo et al., 2014).

The theoretical framework for this research is grounded in the Diffusion of Innovation Theory (DIT). First developed by Rogers (2003) in 1962, this theory models how innovations spread through a population. DIT has a long history of application to agricultural research, starting with extension efforts to spread technological innovations during the "green revolution" (Griliches, 1960; Haven & Rogers, 1961). More recently, DIT theory has been used to model the adoption and diffusion prospects of sustainable agriculture techniques such as AF (Barrett et al., 2002; Evans, 1988; Glendinning et al., 2001; Romanova, 2020). According to the DIT, different groups of individuals adopt innovations at different rates (Rogers, 2003). Adoption behaviors follow predictable patterns, such that any society can be stratified into five distinct groups based on time to adoption: innovators (2.5% of society), early adopters (13.5%), early majority (34%), majority (34%), and laggards (16.5%). Innovators and early adopters significantly influence the diffusion rate to the rest of the population. Because the adoption of AF in Washington State is currently around 3% (USDA NASS, 2017), we have yet to reach the "tipping point" toward greater diffusion. As such, understanding the preferences of innovators and early adopters is crucial to reaching future adopter groups.

2.4 Materials and Methods

2.4.1 Overview

In light of the benefits of AF previously discussed, addressing the reasons behind low adoption rates represents a significant opportunity to expand AF practices. To do so, we applied a quantitative, econometric method for ex-ante analysis of the adoption potential of new AF systems using a case study of current and potential AF practitioners in northwest Washington State. This method, known as the stated choice method (SCM), integrates landholder input to identify those attributes most influential to landholder decision-making.

2.4.2 Study Area

Northwest Washington has a predominantly maritime climate, with relatively cool and dry summers and comparatively wet and mild winters (*Western Regional Climate Center*, 2023). Average annual precipitation in the study area ranges from 25 inches in the rain-shadowed San Juan Islands to 100 inches at the upper elevations of the Cascade Foothills. The growing season lasts from the latter half of April until the middle of October, although this varies slightly between the four counties. Ordinarily, drought is not a problem in Washington agriculture as the dry season begins at approximately the same time each summer. Within the study area, agriculture is confined to the river valleys and well-drained lowlands of the mainland and the San Juan Islands. The climate is generally favorable for growing berry crops, cool-season vegetable crops, flower bulbs, seed potatoes, and grass, although plenty of other crops relevant to AF thrive as well. These include mushrooms, medicinal plants, Christmas trees, orchard fruits, nuts, and big leaf maples. Dairy and poultry production are also important agricultural industries in the region. The study area and distribution of respondents are shown in Figure 2.1.

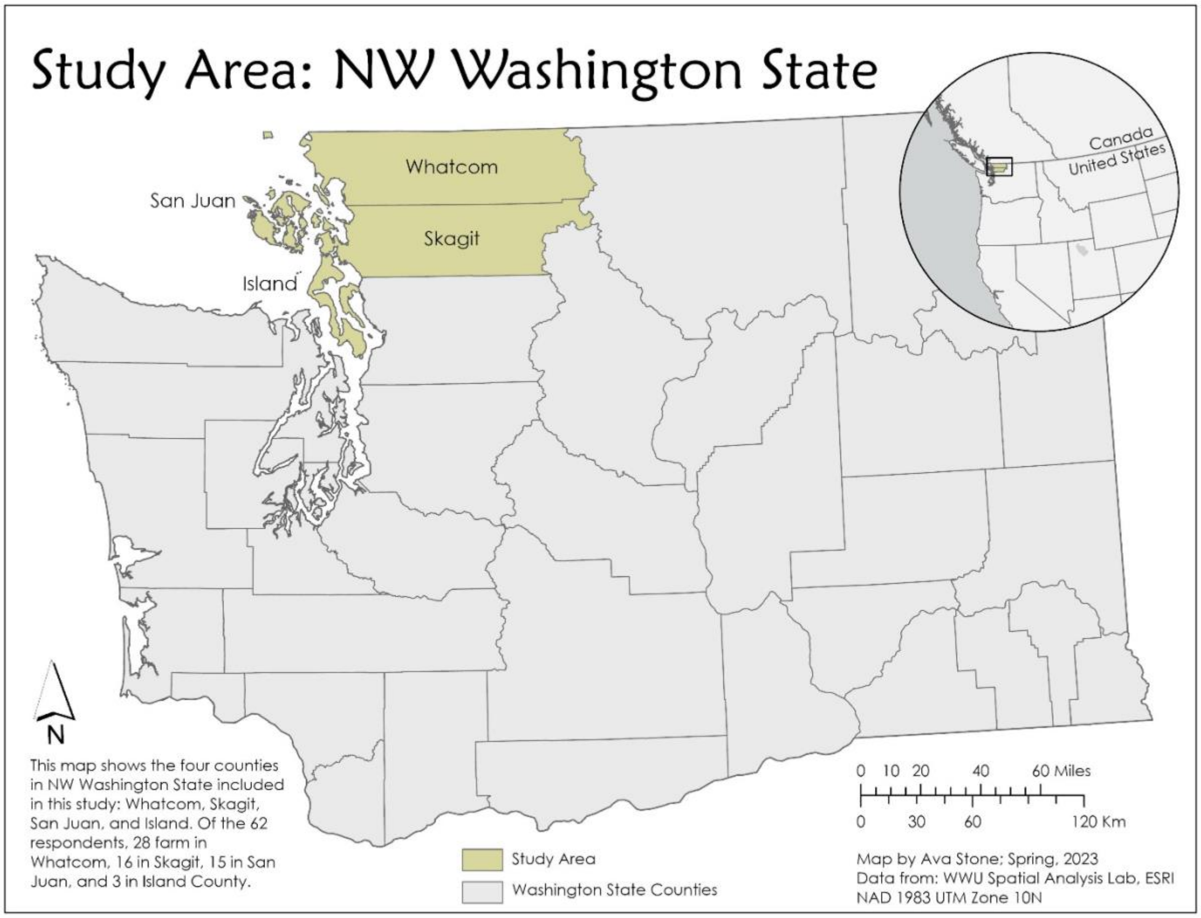

Figure 2.1. *Study area map showing the four counties included in this study: Whatcom, Skagit, San Juan, and Island.*

2.4.3 Stated Choice Method

Stated choice studies examine the choices, or “trade-offs,” individuals, or groups of individuals make when presented with scenarios containing varying goods or services (Hensher et al., 2005). The basic requirement for this method is that the products or services tested are treated as sets of distinct attributes with a limited set of variations for each attribute (Mercer & Snook, 2005). Eliciting respondents' preferences for these different goods or services allows the analyst to evaluate the relative importance of the various attributes, compare alternative versions of the good or service, and estimate the probability of adoption (in this case of an AF practice), given different combinations of attributes (Louviere, 1988). SCMs are grounded in random utility theory (RUM), a behavioral theory that models choice decisions as a set of systematic and stochastic utility functions (Adamowicz et al., 1998). RUM provides a rigorous theoretical basis for stated choice methods, differentiating them from other choice-based methods that are not grounded in sound behavioral theory (Louviere et al., 2010). Under RUM, choices are made based on the utility differences across alternatives, thus mimicking actual market behavior (Holmes & Adamowicz, 2003). To our knowledge, this is the first application of an efficient stated choice survey to study AF adoption.

Unlike most survey data, where information on both the dependent and explanatory variables is captured directly from respondents, in SCM surveys, only the choice response variable is provided by the respondent (Hensher et al., 2015). Excluding covariate information, the primary variables of interest (consisting of attributes and their associated levels), are designed in advance and presented to the respondent as sets of competing alternatives. The process of designing and conducting an SCM experiment is divided into seven sequential steps: 1) characterize the decision problem, 2) identify and describe the attributes, 3) develop an experimental design, 4) develop the survey, 5) collect data, 6) estimate the model, and 7) interpret the results for policy analysis and/or decision support (Adamowicz et al., 1998; Holmes & Adamowicz, 2003).

2.4.4 Interviews and Content Analysis

Steps one and two above were completed using semi-structured interviews and qualitative content analysis (QCA) methods. Interviews are lauded for the richness of attributes they generate and the reduced potential for attribute misspecification if populations are sampled to saturation (Coast et al., 2012). QCA is an effective way to extract themes from written and oral data and is thus well suited to attribute identification (Huckin, 2003; Schrier, 2014). Qualitative data collection and analysis are imperative to the utility of SCM results, yet notoriously underreported in SCM studies (Huckin, 2003). To increase transparency, a complete guide to the interview questions is included in Appendix A, and an overview of the thematic codebook developed using QCA is included in Appendix C.

Between August-October 2022, 14 semi-structured interviews were conducted: nine with local agroforestry experts and five with local agroforestry practitioners. Interviewees were identified through the Northwest Agroforestry Workgroup, the state's preeminent group of Agroforestry Professionals. Additional interview candidates were recruited using snowball sampling techniques (citation). Data collection proceeded until no new themes emerged. Because the community of practicing AF professionals is relatively small in Washington State, AF adjacent professionals, or those providing technical assistance related to AF in roles with the extension, NRCS, or conservation district offices were also included in the interview process. In total, 24 potential interviewees were contacted: four self-identified as being ill-suited to the position, two were unable to participate over Zoom or phone and were too far for the researcher to meet in person, and four did not respond after two emails and a follow-up phone call.

All interviews lasted between 25 and 55 minutes. Most (eleven) of these interviews took place over Zoom and were recorded using the same technology. Two interviews occurred over the phone, and the conversations were recorded using Otter.ai software. One interview occurred in person and was also recorded using Otter.ai software. All interviews were transcribed using Otter.ai software and later edited by the researcher to correct transcription mistakes. All identifying qualifiers were then removed from the transcripts and randomized before analysis.

An inductive approach was used to identify an initial coding frame based on the research questions, resulting in three higher-order categories: barriers to adoption, incentives, and demographics. The barriers and incentivees are shown in Figure 2.2. The deomographic codes included farmer type, farm type, and climate orientation.

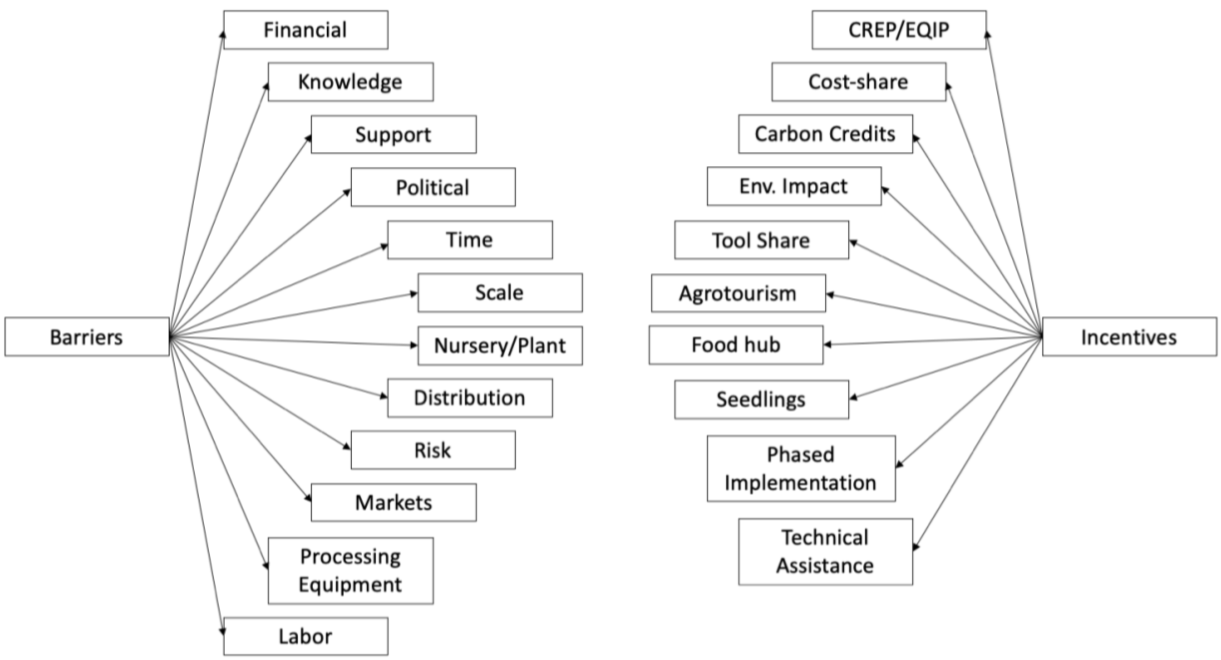

Figure 2.2. *Initial coding frame showing the 12 barriers and 10 incentives identified from the interview transcripts.*

After all transcripts were coded, overlapping subcategories in the barriers and incentives categories were grouped and refined to reduce the total to six. In this process, initial subcategories such as “markets,” “food hub,” and “processing equipment” were combined into “available markets.” Similarly, “carbon credits” and “CREP” were combined into “ongoing cost-share options”, with “carbon credits” and “federal payment programs such as CREP or EQIP” included as the attribute levels. The final attributes were chosen based on the prevalence with which they appeared in the coded interview transcripts and their relevance to potential extension effort programs. The ability to translate the results from the survey into actionable recommendations for AF support programs is a key part of the research questions and, thus, the key to developing an effective coding frame. Before finalizing the selection, these attributes were also compared to those used in other AF adoption studies. We found them well-supported (Amare & Darr, 2020; Mercer & Snook, 2005; Wilson & Lovell, 2016). The final language used to describe the six attributes, each with three levels, is shown in Table 2.1.

Table 2.1*. Attributes and levels for the stated choice experiment.*

Attribute	*Level 1*	*Level 2*	*Level 3*
Cost of seedlings	Must fund and obtain your own seedlings. No initial cost-share program available.	50% of your seedling costs will be covered through an available cost-share program.	100% of your seedling costs will be covered.
Extent of technical assistance	1 year	5 years	10 years
Local examples	No local examples	1 local example	2 local examples
Scale of initial implementation	Convert marginal spaces (acreage not currently in production) to an agroforestry system.	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Enroll in a federal payment program such as CREP or EQIP.	Annual carbon credit payments available.
Available Markets	Raw and/or processed goods must be sold direct to market.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.

2.4.5 Experimental Design and Survey Data Collection

Conceptually, an experimental design is a matrix of values used to determine what goes where in an SCM survey (Rose & Bliemer, 2009). During this phase, the alternatives and choice scenarios are determined based on the attributes and levels identified during qualitative analysis

(Holmes & Adamowicz, 2003). The researcher must design a tractable yet statistically efficient survey instrument, considering factors such as attribute level balance, dominance, priors, coding type, labeling scheme, statistical modeling, and heuristics (Louviere et al., 2000). Rather than assigning random combinations of attribute levels to respondents, design theory systematically allocates attribute levels to alternatives based on the above considerations.

Given the six attributes and three levels (3^6) used in this experiment, the complete factorial design yielded 729 possible alternatives. To produce a more tractable experiment, an efficient main effects design was created using the Ngene 1.3 software package from Choice Metrics. This design reduced the total 729 possible combinations to a subset of 18 alternatives that covered the range of variability between all possible combinations. Because there is little prior knowledge of the relationships between the various attributes, only the main effects, or the effects of individual attributes on the choice decision, were considered (Hensher et al., 2005). A three-level blocking factor split the 18 plans into three random blocks, so each final survey contained six choice scenarios of paired alternatives. Thus, respondents were presented with a series of six separate, trichotomous choice experiments, each with a pair of alternative AF systems and the status quo option. The status quo (or “I would not adopt either alternative” option) is included should the respondent prefer not to adopt either of the alternative systems. An example of scenario one is included in Figure 2.3.

Scenario 1

Attribute Description	Alternative A	Alternative B
Cost of seedlings	Must fund and obtain your own seedlings. No initial cost-share program available.	100% of your seedling costs will be covered.
Extent of technical assistance	5 years	10 years
Local examples	2 local examples	1 local example
Scale of initial implementation	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Annual carbon credit payments available.
Available markets	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.

Figure 2.3*.* An example of a choice scenario used in the survey. Respondents were asked to choose whether or not they would implement their preferred agroforestry practice under the circumstances described in Alternative A, Alternative B, or "neither."

Though a majority of SCM studies have used orthogonal fractional factorial designs to reduce the total number of choice scenarios presented to each respondent, efficient designs are gaining traction in the recent SCM literature (Bliemer & Collins, 2016; Hensher et al., 2005; Rose & Bliemer, 2009). While orthogonal designs seek to avoid correlation within and between alternatives, efficient designs focus on optimizing various statistical efficiency measures, namely more reliable parameter estimates using an equal or lower sample size (Rose & Bliemer, 2009). Characteristics of orthogonal designs, particularly their ability to produce unconfounded estimates of the population parameters, may be less relevant to SCM studies than previously thought (Hensher et al., 2005; Rose & Bliemer, 2009; Ngene, 2015).

Efficient designs, by contrast, are more suitable to the nonlinear econometric models used in SCM studies (Train, 2003). However, these designs depend on the researcher having at least some prior information about the parameters of the various attributes (Ngene, 2015). These estimates are obtained from literature reviews of similar studies or pilot surveys. Even without specific prior values, it is often possible to estimate the direction of the priors. For example, higher prices have a negative prior because they are less desirable for respondents. Recent SCM literature suggests that in these situations, even when only the direction of the prior is known, efficient designs are preferable to orthogonal designs (Ngene, 2015; Rose & Bliemer, 2009).

Survey participants were recruited through the Washington Food and Farm Finder, a public database that connects direct to market producers with local consumers. Potential participants were contacted by email three times over a one-month period. Each email contained a personalized link to the Qualtrics survey and background and contact information for the researchers. Only farms in Northwest Washington, specifically Whatcom, Skagit, San Juan, and Island Counties, were considered. This yielded 239 farms, 195 of which met the recruitment requirements, namely, they were currently operating and practicing some form of "sustainable" agriculture. Sixty-two farmers completed the survey in full, giving us a response rate of 31.8%. "Sustainability" was interpreted using the Western Sustainable Agriculture Research and Education (SARE) definition of "environmentally sound and good for communities" (USDA, 2023). Previous studies overwhelmingly suggest that land managers concerned with sustainability are more likely to adopt AF practices (Mercer & Snook, 2005; Stubblefield, 2021). Given the low adoption rates of AF in Washington State, a predisposition toward "sustainability" is thus important to screen innovators and early adopters from later adopter groups.

2.4.6 Data Coding and Model Estimation

Given the survey design, each respondent was presented with six choice scenarios in which they were asked to choose between two AF alternatives and a status quo option. Their choice was recorded as a single row of data, including the attribute levels for both the chosen and non-chosen alternative, and the status quo option. Since no information was available on the attribute levels of the status quo option, zeroes were used to code the status quo alternatives. Effects codes were used to code the attribute levels for the two AF alternatives. With effects coding, one attribute level is chosen as the reference level while the other two levels are coded into the data set (Bech & Gyrd-Hansen, 2005). The parameter value for the omitted attribute can be computed by summing the coefficients of the other two levels of that attribute. This coding scheme is preferred, because, unlike dummy coding, it provides information about the preferences for all attribute levels, including the one that was omitted (Holmes & Adamowicz, 2003).

Based on random utility theory, respondents' choices for each scenario were modeled as a set of three equations, each describing the probability of choosing that alternative. A multinomial logit regression model (MNL) was used to estimate the trichotomous choice responses, as is common in agri-environmental SCM experiments (Holmes & Adamowicz, 2003; Hoyos, 2010; Kanninen, 2007). By regressing the stated choices (response variable) on attribute levels (explanatory variable), the researcher can elicit a wealth of information regarding landholder preferences for individual attributes, as well as combinations of those attributes (Mercer & Snook, 2005). In the MNL model, the conditional indirect utility, *V*, can be specified for each alternative as a linear function of the attributes (Bennett & Adamowicz, 2001). The MNL model predicts the relative attractiveness of each alternative such that 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 (Mercer & Snook, 2005). Similarly, the coefficient on the status quo shows the marginal utility of the status quo option, relative to the two alternatives. This model assumes that errors are independently and identically distributed (IID) and follow a type 1 extreme value (Gumbel) distribution.

Assuming no interaction effects, each choice set of 6 attributes and 3 levels is described with three linear in parameters models:

Alternative 1: $V_1 = \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 + \ldots\ldots\ldots\ldots\ldots\ldots \beta_{10} A_{10}$
Alternative 2: $V_2 = \beta_1 A_1 + \beta_2 A_2 + \beta_3 A_3 + \ldots\ldots\ldots\ldots\ldots\ldots \beta_{10} A_{10}$
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

The regression coefficients, β_i , can be interpreted as the marginal utility of the attributes, A_i.

The Apollo (Hess & Palma, 2019) maximum likelihood routine was used to estimate the resulting MNL model (see Appendix E). MNL models predict the relative desirability of each alternative by considering factors that change across alternatives. Thus covariates (such as income or age) that remain the same across alternatives can only be introduced as interactions with either the attributes or the alternative-specific constant (Holmes & Adamowicz, 2003). Though more complex models are possible, they are beyond the scope of this case study.

2.5 Results

Descriptive statistics and demographic information for the entire sample are provided in Table 2.2 and Table 2.3. The average respondent has 24.09 acres of land in production, is 50 years old, has farmed the property for 13.75 years, and derives 45.16% of their income from their farming operation. Of the 62 farmers sampled, five operate entirely on leased land, and 11 leased some of their land to other farmers. Seventy seven percent of respondents currently practice some form of AF, and of those, 47% would prefer to expand one of their current practices rather than implement a new one. Fifty two percent of respondents expect a descendant or other family member to take over their farm operations in the future, and 86% live on the farm property full-time.

Table 2.2. *Descriptive statistics for the entire sample of respondents (n = 62).*

Variable	*Mean*	*Median*	*Standard Deviation*	*Range*
Land owned (acres)	55.58	21	146.81	0-1122
Land leased FROM (acres)	3.55	0	10.21	0-45
Land leased TO (acres)	1.08	0	3.72	0-21
Land in production (acres)	24.09	10	40.41	0.25-195
Age of respondent (years)	50.43	48	12.58	28-74
Time respondent has farmed property (years)	13.75	10	12.41	1-60
% of total income respondent derives from property	45.16%	30%	37.42	0-100%

Table 2.3. *Demographic responses for entire sample of respondents (n = 62).*

Variable	*Yes*	*No*
Do you currently practice agroforestry?	77.4	22.6
Do you expect a descendant or other family member to take over your farm operations in the future?	51.7	48.3
Do you live on this farm property full-time?	85.5	14.5
Variable	*Expand*	*New*
Do you prefer to expand a current agroforestry practice (or implement a new one)?	46.8	53.2

The results from the maximum likelihood estimation of the MNL model are shown in Table 3. The coefficients for the base-level attributes were computed as the sum of -1 times the coefficients of the included levels for each attribute. These regression coefficients show the rate at which respondent's utility for a particular attribute increases or decreases given a change in the attribute levels. When summed, these marginal utilities equal the total utility respondents have for a particular alternative. Similarly, the coefficient on the Alternative Specific Constant (ASC) for the status quo option shows the marginal utility of the status quo relative to the agroforestry alternatives. A rho-squared value of 0.1824, the LL (final) of -346.73 compared to the LL(0) of -424.06, and significance (at the 0.05 or 0.10 level) of all but five attribute levels suggest a good fit for the model. Given that the ASC is a relatively large negative value and significant (at the 5% level), respondents appear to strongly prefer AF alternatives to maintaining the status quo.

Table 2.4. *Maximum likelihood estimates for conditional logit analysis of the impact of attributes on respondents' preferences for new AF systems (n = 62).*

Variable	*Coefficient (preference weight)*	*Standard Error*	*t-ratio*
Alternative Specific Constant (Status Quo)	-0.558	0.137	-4.081[a]
Cost of Seedlings			
Low Level (No coverage)	-0.703	0.116	-6.064[a]
Medium Level (50% coverage)	0.040	------	------
High Level (100% coverage)	0.663	0.111	5.995[a]
Technical Assistance			
Low Level (1 year)	-0.182	0.112	-1.631[b]
Medium Level (5 Years)	0.045	------	------
High Level (10 years)	0.137	0.106	1.287
Local Examples			
Low Level (0 examples)	-0.182	0.104	-1.740[b]
Medium Level (1 example)	0.059	------	------
High Level (2 examples)	0.123	0.118	1.040
Scale of Initial Implementation			
Low Level (Marginal space only)	0.786	0.114	6.879[a]
Medium Level (15% of current acreage in production)	-0.045	------	------
High Level (30% of current acreage in production)	-0.741	0.127	-5.838[a]
Ongoing cost-share options			
Low Level (No payments available)	-0.08	------	------
Medium Level (Federal payment program)	-0.020	0.112	-0.181
High Level (Carbon credits)	0.100	0.110	0.878
Available markets			
Low Level (Direct to market only)	-0.277	0.114	-2.437[b]
Medium Level (Processed goods to food hub)	0.244	------	------
High Level (Raw and processed good to food hub)	0.053	0.116	0.452

Loglikelihood Estimation: -331.98; Rho^2=0.188

[a]*Significant at the 5% level;* [b]*Significant at the 10% level*

Figure 8 shows how marginal utility changes across attribute levels. As expected, respondents' utility for the seedling attribute increases as cost coverage increases. Similarly, as the number of years of technical assistance provided increases, so does utility and the probability of adoption. Utility also increases as the number of local examples increases. Interestingly, the rate of change is nearly four times greater between levels zero-one compared to one-two. This finding suggests that early adopters (that serve as the first example in a community) have a strong influence on overall adoption rates.

The "scale of initial implementation" attribute shows the inverse relationship: the smaller the scale, the higher the utility and probability of adoption. This may suggest that landowners view AF systems as risky and complicated to adopt and are thus reluctant to replace their current practices with new or expanded AF practices.

Market availability was the only attribute whose levels did not correspond with a nearly linear change in marginal utility. Instead, respondents were more likely to adopt the medium level "processed goods may be sold to a local food hub that can market and distribute your goods" rather than the high level "raw and/or processed goods may be sold to a local food hub that can market or distribute your goods." Though initially surprising, this may reflect respondents' preferences to maintain their current distribution modes for raw goods (direct to market), allowing them to interact with consumers rather than involving a third-party buyer.

Lastly, respondents preferred cost-share payments over no payments and carbon credit payments to enrollment in a federal program such as CREP or EQIP. However, the marginal utility for the federal payment option was negative, indicating that current payment options do not increase the probability of adoption.

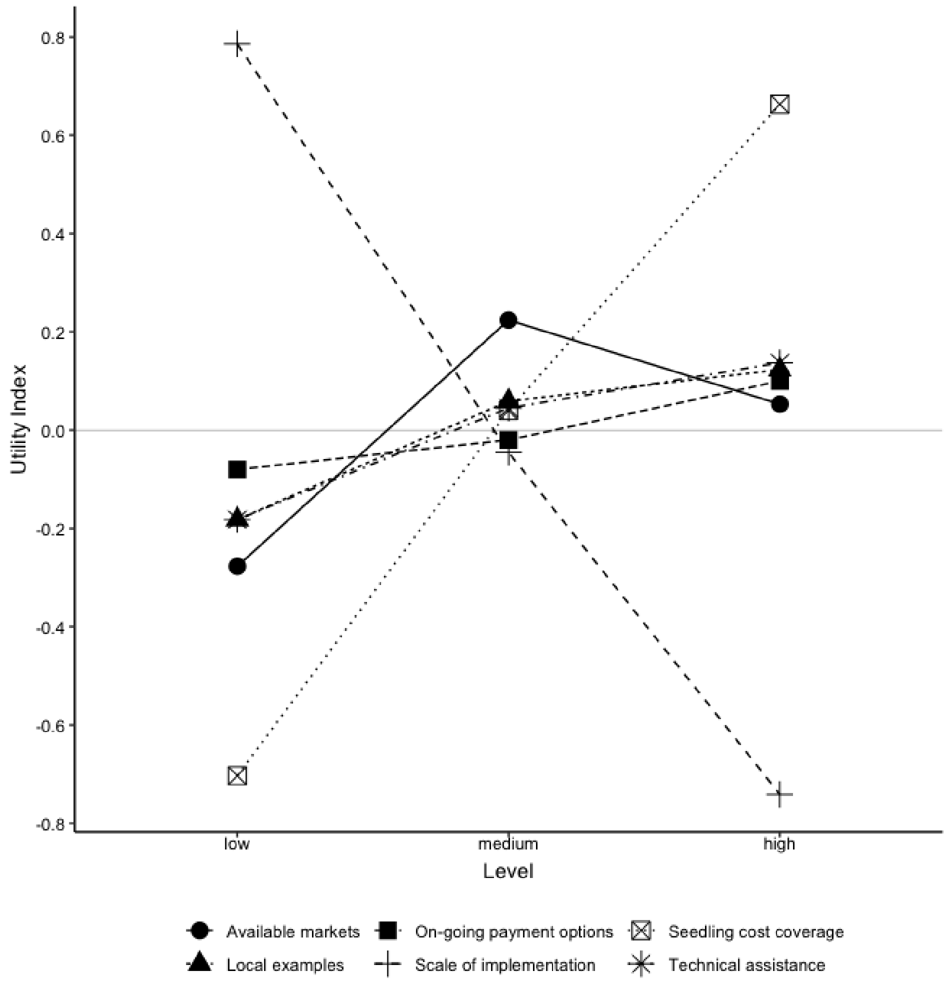

Figure 2.4. *Marginal utilities of agroforestry system attributes*.

The relative impacts of the six attributes on respondents' willingness to adopt AF practices are shown in Figure 9. Relative impact was calculated using the difference between the maximum and minimum coefficients for the three levels of each attribute. This difference was then summed across all attributes to get the total utility value. To construct a ratio, the utility difference for individual attributes was then divided by the total utility value across all attributes, yielding the relative impact of each attribute.

Results indicate that the cost of seedlings and the scale of implementation attributes had the most significant relative impact on respondents' decision making, at 36.9% and 41.3%, respectively. Interestingly, the cost-share attribute had the least impact on relative preference (4.9%), indicating that up-front costs are more influential than ongoing costs for AF adoption. The remaining three attributes had near equivalent relative impacts of 8-9%.

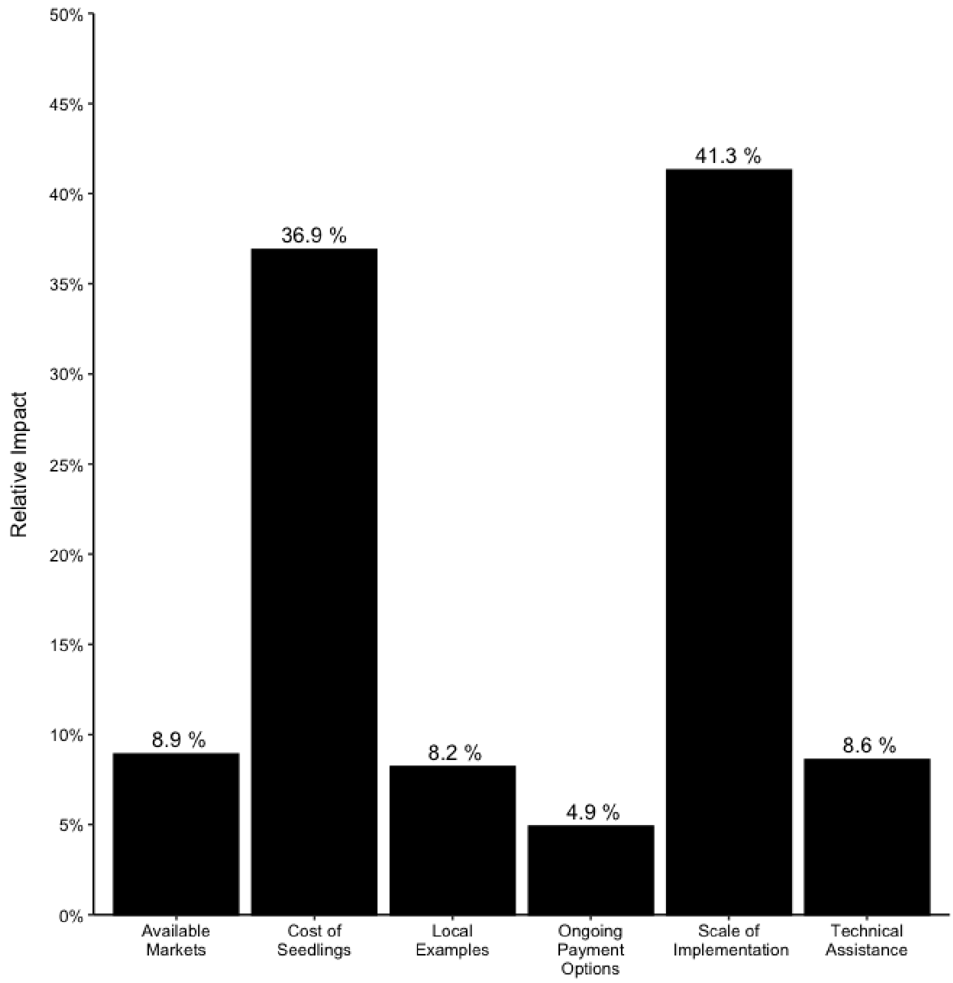

Figure 2.5. *Relative impact of attributes on respondent preferences for new agroforestry systems.*

SCM results also provide a predictive understanding of the adoption potential of AF systems (i.e., alternatives) containing various attribute levels. This is accomplished by summing the coefficient estimates for the attribute levels included in any alternative. To demonstrate, the preference weights for all alternatives presented in survey block 1 are included in Table 2.4, along with the most and least desirable possible combinations of levels. This could be a useful tool for extension or other support agencies looking to understand the relative attractiveness of their current AF programs and identify areas for improvement.

Table 2.5. *Relative desirability of the agroforestry systems included in Survey Block 1.*

System	Seedling Costs Covered	Technical Assistance (years)	Local Examples	Scale of Initial Implementation	Ongoing Cost-Share Options	Available Markets	Total Preference Weight	Rank
A	0%	5	2	15%	None	Distribution & processing	-0.607	10
B	100%	10	1	30%	Carbon credits	Distribution	0.442	4
C	100%	1	0	30%	None	Direct to market only	-0.799	11
D	50%	5	1	Marginal spaces	Federal payment program	Distribution	1.134	3
E	0%	5	1	15%	Carbon credits	Distribution & processing	-0.399	7
F	50%	1	0	30%	None	Distribution	-0.921	12
G	50%	1	2	30%	Carbon credits	Distribution & processing	-0.607	9
H	100%	5	0	15%	Federal payment program	Direct to market only	0.184	5
I	50%	5	1	15%	None	Direct to market only	-0.258	6
J	0%	10	2	30%	Federal payment program	Distribution & processing	-1.151	13
K	100%	10	1	Marginal spaces	Federal payment program	Direct to market only	1.348	2
L	0%	1	2	15%	Carbon credits	Distribution	-0.483	8
M*	100%	10	2	Marginal spaces	Carbon credits	Distribution	2.033	1
N*	0%	1	0	30%	No payments	Direct to market only	-2.165	14

2.6 Discussion

Central to this research effort was the desire to produce actionable results relevant to local conservation districts, extension services, and other organizations that work directly with landholders in AF. Our results show that the "scale of initial implementation" attribute had the most significant relative impact on marginal utility and, thus, the probability of adoption. In line with previous studies, respondents strongly prefer AF systems that can be initially implemented in the marginal spaces of their farms (Flexen et al., 2014; Rois-Díaz et al., 2018). Marginal spaces include areas not currently in production, such as along fences or between rows. This strategy, often referred to as "phased implementation," decreases the upfront costs and risks associated with adopting a new practice, both of which have been identified as significant barriers to adoption in previous studies (Pannell, 2003; Pattanayak et al., 2003). Scaled implementation allows adopters to engage in the dynamic process of learning by doing, during which they become more familiar and comfortable with the complexities of the practice over time (Amare & Darr, 2020; de Souza et al., 2012; Mercer et al., 2005). Because the environmental benefits of AF are high per unit area, even the conversion of small areas will provide substantial benefits such as increased carbon sequestration and improved wildlife habitat (Schoeneberger et al., 2012). In a population of farmers concerned with sustainability, these benefits may encourage the expansion of AF practices over time (de Souza et al., 2012).

Table 2.6. *Summary of actionable results for local agroforestry programs or agencies.*

Attribute	*Finding*	*Implication*
Scale of initial implementation	Respondents strongly prefer to implement AF systems in the marginal spaces of their farms. This attribute had the largest relative impact on adoption decisions.	Agencies should pursue a "phased implementation" approach that encourages landholders to implement AF systems incrementally over time. Specifically, agencies should encourage landholders to start by converting less than 15% of their productive land to a new AF system.

Seedling cost coverage	Respondents are strongly impacted by the upfront costs of implementing a new AF system. They are much more likely to adopt an AF practice if these seedlings costs are fully covered.	Upfront costs significantly impact decision making. Resource limited agencies or programs should allocate assistance to cover capital costs rather than ongoing costs.
Local examples	The first adopter in a community has an outsized impact on future adopters in that community.	Rather than recruiting a second adopter, support agencies should instead target different areas or different AF practices in communities with low adoption rates.
Ongoing cost-share options	Direct payments have the lowest impact on decision making of the six attributes included in this study. Current federal payment programs (CREP, EQIP) have a negative impact on decision making.	Current direct payment options are not an effective tool to increase AF adoption. This is an area that needs further study. Perhaps reframing the outreach language, payment structure, and type of payment would be more effective.

The seedling cost attribute had the second highest relative impact on respondents' preferences, suggesting that a seedling cost-share program could significantly increase adoption of AF. Interestingly, the other financial attribute, "ongoing cost-share payments," had the smallest relative impact on respondent decision making. Though at first counterintuitive, this contrast provides valuable information for resource-limited support programs: allocate assistance to cover capital costs, rather than operational costs. Similarly, other studies have found that payments based on ecological benefits, cost-share programs, or direct economic benefits have little influence on adoption behavior (Mercer & Snook, 2005; Rois-Díaz et al., 2018; Sereke et al., 2016; Smith et al., 2021). However, this is not to say that economic payments do not impact decision making. Our results show that payments are preferred to no payments and carbon credit payments are preferred to current federal payment options. Interestingly, the federal payment attribute level had a negative coefficient (albeit higher than the coefficient for no payment), which indicates that current federal payment options do not incentivize farmers to adopt AF practices. Further study could help to elucidate the nuances behind farmers' preferences for various payment options and provide another opportunity to incorporate farmer perspectives into the design of AF support programs. The two highest-ranked attributes had a combined relative impact of 78.2% on respondent decision making, far outweighing the impact of all the other attributes combined.

One of the benefits of SCM studies is their ability to assess boundary conditions by comparing the marginal utility values of the different levels of an attribute. Similar to previous studies, our results indicate that increased exposure to local examples (whether by farm tours, visits, or promotional materials) increases respondents' utility for implementing AF practices (Rois-Díaz et al., 2018; Tsonkova et al., 2018). More specifically, marginal utility increases at nearly four times the rate between levels zero (no local examples) and one (one local example), compared to levels one and two (two local examples). This is important because it provides insight into the underlying AF adoption and diffusion process. The first person to implement a new AF practice in their geographical area has an outsized impact on the adoption-diffusion of that practice to nearby farmers. Rather than recruiting a second adopter, support agencies should instead target different areas or different AF practices in communities with low adoption rates.

Another common barrier to AF adoption cited in the literature is the need for more processing equipment, reliable markets, and distribution systems (Mercer, 2004; Pattanayak et al., 2003). This attribute was included as "available markets" in our study and included three levels: direct-to-market only, a local food hub to distribute processed goods, or a local food hub to distribute raw or processed goods. Though important, this attribute had a relatively small impact on utility at 8.9%. Our results indicate that respondents would prefer to sell their raw goods using their current distribution systems, but perhaps need more support producing and selling value-added products such as nut butters or jams. Without food hubs with available processing equipment, our results suggest that support programs should encourage farmers to grow AF commodities that can be sold directly to market.

2.7 Conclusion

Agroforestry has enormous potential to mitigate climate change, provide ecosystem services, improve rural livelihoods, and sustain communities. Achieving this potential, however, requires improving adoption rates, particularly in low-adoption areas such as Washington State. No matter how productive, beneficial, well-designed, or ecologically sustainable, the benefits will be minimal if AF is not adopted by a substantial proportion of the target community. Though significant strides have been made, adoption rates still need to catch up to the science of AF, particularly in temperate locations around the world (Amare & Darr, 2020; Romanova, 2020). This is due in part to a lack of rigorous, quantitative methods for analyzing the adoption potential of AF.

Our study attempts to fill this gap by applying the stated choice method to a sample of direct-to-market, sustainable farmers in northwest Washington. To our knowledge, this is the first application of this method to better understand the adoption potential of agroforestry in a particular region. Our goals with this research were to 1) provide actionable results relevant to local conservation districts and other AF support agencies, and to 2) demonstrate how the stated choice method can be used to assess the ex-ante adoption potential of agroforestry.

The stated choice method is a mixed-method approach used to understand respondents' preferences for various attributes of a good or service, in this case AF. By regressing stated choice on attribute levels, we gleaned a wealth of information regarding the relative impact of each attribute on decision making, the boundary conditions of each attribute, and the probability of adoption given different combinations of attribute levels. These results are particularly useful for extension and other support agencies looking to increase the adoption of AF locally.

Because AF systems are complex and bio-regionally specific, so too is the process of adopting them. If we can conclude anything from the diversity of findings within the adoption literature, it's that a one-size fits all approach will not improve adoption rates equally across social, geographical, and ecologic boundaries (Amare & Darr, 2020; Dumont et al., 2019). Instead, local agencies need information specific to the communities and climates they serve, especially those lacking in AF research, such as the Pacific Northwest. To obtain this information, we need to incorporate farmer input into the design of agri-environmental studies, especially those which provide a predictive understanding of adoption behaviors (Barrett et al., 2002; García de Jalón et al., 2018; Mercer & Snook, 2005; Rois-Díaz et al., 2018). Our study highlights one example using the SCM, a mixed-method approach that provides meaningful results for local extension services and a roadmap for future AF adoption research. We describe the entire SCM process, from qualitative interviews through quantitative analysis, in the hopes that it will be emulated and adapted to fit a variety of AF contexts. While our specific results are indicative only of the preferences of direct-to-market farmers in northwest Washington State, the process for choosing an appropriate population and designing and implementing an SCM study broadly applies to anyone studying the adoption potential of AF around the world. AF adoption has been hampered by a lack of rigorous ex-ante research, and the SCM method is an exciting way forward for future AF adoption studies.

Chapter 3: Reflections, Limitations, and Opportunities for Future Research

3.1 Limitations and Opportunities for Future Research

In this study, we applied an efficient stated choice survey design to a sample of farmers in northwest Washington State. To our knowledge, this is the first application of this method to better understand the adoption potential of agroforestry in a particular region. Our goals with this research were to 1) provide actionable results relevant to local conservation districts and other AF support agencies, and to 2) demonstrate how the stated choice method can be used to assess the ex-ante adoption potential of agroforestry. With these goals in mind, it is important to acknowledge the limitations of this research.

Primarily, this research was limited by a relatively small sample size and geographical region. Our qualitative data was based on 14 recorded and transcribed interviews with local AF professionals and practitioners. Although I could not interview four of the people originally identified on the list, this small sample size largely indicates the limited number of AF professionals in Washington State. Indeed, the lack of practicing professionals and expert knowledge in our region is an important barrier identified in the interviews and supported in the literature (Bishaw & McFarland, 2017). Similarly, our survey results likely suffered from a non-response bias. Though our survey response rate was 32%, given the small population of farmers eligible for the survey, this equated to only 62 survey responses. Despite these limitations, the majority of our results were significant at the 5 or 10% level, indicating they are relevant to local agencies and our local context.

While our results are context-specific, our demonstration of how to apply the SCM to study AF adoption is universal. The beauty of the SCM method is that it is highly adaptable to different populations and geographies and can be altered to study various questions related to AF adoption. Some directions for future study using the SCM method include attribute-specific studies, particularly those focused on different types of payment options, practice-specific studies focused on a single type of agroforestry relevant to the study area, and adopter-specific studies focused on different types of farmers (i.e., conventional farmers, organic farmers, etc.).

For example, though direct payments do not appear to strongly influence decision making in our study and others, the desire to improve the environment for future generations does (Mercer & Snook, 2005). The SCM could be used to understand whether reframing the discussion around carbon credits impacts adoption decisions. Perhaps monitoring carbon and other ecosystem service benefits to understand the environmental benefits of the project, rather than soley for payment, would be more compelling for sustainably minded innovators and early adopters. These impacts could be marketed to fetch higher prices for "climate smart commodities" which would simply be a different form of payment to support the adoption of AF. The SCM presents an exciting way forward for the ex-ante assessment of AF adoption because it can be replicated, scaled, and adapted to fit a variety of contexts and research questions of interest.

Another limitation of this research was that only a subset of attributes could be included in the final survey. Though every effort was made to ensure these attributes accurately represented the themes identified in the interviews and literature, some important attributes were inevitably excluded. One such attribute included labor, which was found to influence adoption decisions in previous studies (Mercer, 2004, 2004; Mercer et al., 2005; Pattanayak et al., 2003). Though labor clearly impacts adoption decisions, we omitted it from our survey design because it appeared less frequently in our coded interviews and was deemed less relevant to local support agencies. While a local conservation district can target grants to support a seedling cost-share program, they may be less able to provide labor support to a growing number of AF practitioners in their district.

3.2 Reflections and Challenges

While conducting this research, I encountered two points of confusion repeatedly from respondents. First, agroforestry appears to still be relatively unknown and ill-defined, even amongst sustainably minded farmers. Some potential participants replied that they could not participate in the survey because they didn't own forestland. Others implied they already practiced agroforestry, but the practices they described did not fit into the USDA definition. This problem has been identified in many other studies concerning the adoption and diffusion of AF as well (Rois-Díaz et al., 2018; Tsonkova et al., 2018).

Second, it was challenging to create a survey format and questions that were relevant to those who were already practicing AF and those who were not. Some farmers who already had extensive AF systems in place said they were not interested in expanding their practices, and thus the hypothetical scenarios did not fit their context. At the same time, other AF practitioners did not see this as a hindrance and completed the survey without confusion. Though it is unclear how best to overcome this problem, one option might be to create different scenario question instructions for the two groups or two entirely different surveys.

Lastly, though not directly relevant to the research questions explored in this study, another important theme that emerged from the interview and survey data was the problem of equity around ownership and access to land. Because the benefits of AF are largely realized over a time horizon of decades, not years, many farmers I contacted who leased land said they were unable to implement AF practices. As land ownership becomes increasingly unattainable for a growing proportion of the population, particularly for younger farmers and farmers of color, there may be fewer farmers able or willing to implement AF practices. Many studies have found that younger farmers are more likely to adopt AF practices (Fregene, 2007; Gao et al., 2014; Strong & Jacobson, 2005; Valdivia & Poulos, 2008), and unless we can find ways to increase pathways to land ownership, we will likely inhibit the adoption potential of AF. Though the SCM method is not well suited to this research area, the problem of equity and land ownership is foundational to increasing AF adoption worldwide.

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Appendix A: Interview Guide

Interview Guide Example – Practitioner

1. Tell me a little more about your farm! I'd love to hear more about your role, farm type, and current practices.
2. How long have you been practicing AF?
3. How did you first get involved or start experimenting with AF practices?
4. I understand you teach a lot of permaculture and other related classes. Who participates in these classes?
5. In your experience, what is the most effective way to increase interest and adoption of AF in the farming community?
6. What barriers did you face when you first began practicing AF?
7. If you were to create an AF extension or support program, what practices would you promote?
    a. What incentives would you provide?
    b. How would you convince people to adopt AF practices?
8. Is there anyone else I should talk to who has experience practicing AF or working with others to implement AF practices?
9. Do you have any questions for me?

Interview Guide Example – Expert

1. What is your primary role with the conservation district?
2. How long have you been working with landholders interested in AF?
3. How did you first learn about AF?
4. In your experience, what is the most effective way to increase interest and adoption of AF in the farming community?
5. What techniques have you used to enable landowners to implement new farm practices?
6. What barriers do landowners you work with face in implementing AF?
7. If you were to create an AF extension or support program, what practices would you promote?
    a. What incentives would you provide?
    b. How would you convince people to adopt AF practices?
8. Is there anyone else I should talk to who has experience practicing AF or working with others implement AF practices?
9. Do you have any questions for me?

Appendix B: Survey Questionnaire (Block A)

Section 0. Introduction

Adoption of Agroforestry Practices in Northwest Washington State

Welcome to our study! Thank you for being here. Please click on the following button to learn more about your rights, roles, and responsibilities as a participant.

Consent Form

Do you consent to participate in this study?

By choosing "yes" below, you are indicating that you have read the consent form, you understand the tasks involved, are 18 years old or older, and agree to take part in this research.

- ○ Yes. I would like to participate in this study
- ○ No. I do not want to participate in this study.

Thank you for your consideration. You may now exit the survey.

Please type your name. By typing your name below, you are signing this document electronically. You agree that your electronic signature is the legal equivalent of your manual signature on this application.

Overview of the Survey

This survey is concerned with the adoption of all agroforestry practices defined by the USDA, including forest farming, alley cropping, riparian buffers, windbreaks or hedgerows, and silvopasture. The following page will provide more detailed definitions of each.

In section 1, you will determine which of these practices is most practical or feasible for your farm, forest, or other land type. In section 2, you will be presented with six scenarios that ask you to choose between two alternatives. By choosing an alternative, you are indicating that, under the circumstances described, you would implement your preferred agroforestry practice. In section 3, you will be asked some questions related to farm and farmer demographics.

Definitions

Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. It has been practiced in the United States and around the world for centuries. The USDA currently recognizes five agroforestry practices: forest farming, alley cropping, riparian buffers, windbreaks or hedgerows, and silvopasture.

Adopt: A landholder's decision to implement a new practice, in this case agroforestry. For the rest of the survey, adoption will refer to a willingness to implement any of the five practices described below.

Forest Farming operations grow food, herbal, botanical, or decorative crops under a forest canopy that is managed to provide ideal shade levels as well as other products. Forest farming is also called multi-story cropping, and the woodland crops grown under a canopy are called non-timber forest products. Some examples of forest farming crops include ginseng, goldenseal, shiitake and other mushrooms, and decorative ferns. Forest farming can provide short term income while high-quality trees are being grown for wood and other tree products. More information can be found here.

Alley Cropping means planting crops between rows of trees to provide income while the trees mature. The system can be designed to produce fruits, vegetables, grains, flowers, herbs, bioenergy feedstocks, and more. This type of system may also be called intercropping, when the trees and crops are not in defined rows and alleys. The trees may include valuable hardwood veneer or lumber species; fruit, nut or other specialty crop trees/shrubs; or desirable softwood species for wood fiber production. More information can be found here.

Riparian Buffers are natural or re-stablished areas along rivers and streams made up of trees, shrubs, and grasses. These buffers can help filter farm runoff while the roots stabilize the banks of streams, rivers, lakes and ponds to prevent erosion. These areas can also support wildlife. Riparian buffers can be managed to include trees and shrubs that produce a harvestable crop along with the conservation benefits, although this is less common. Buffers are used in agricultural, row crop, range, suburban, and urban settings. More information can be found here.

Windbreaks or Hedgerows shelter crops, animals, buildings, and soil from wind, snow, dust, and odors. These areas can also support wildlife and provide another source of income. They are also called shelterbelts, hedgerows, vegetated environmental buffers, or living snow fences. Windbreaks can be and often are designed to serve more than one purpose. However, windbreaks are not a one size fits all practice. The location, orientation to the wind, height, width, density and species selection all play a role in determining the benefits that the windbreak will provide. More information can be found here.

Silvopasture combines trees with livestock and forage on one piece of land. The trees may provide timber, fruit, fodder, or nuts as well as shade and shelter for livestock and their forages, reducing stress on the animals from the hot summer sun, cold winter winds, or a downpour. These systems are intensively managed for both forest products and forage, providing both short- and long-term income sources. More information can be found here.

Section 1. Agroforestry Practices

Which type(s) of agroforestry do you currently practice? Please choose all that apply.

- ☐ forest farming
- ☐ alley cropping
- ☐ riparian buffers
- ☐ windbreaks or hedgerows

- ☐ silvopasture
- ☐ I do not currently practice agroforestry

Which agroforestry practice are you most interested in implementing? Please choose one.

If you currently practice agroforestry, you may choose to expand on a current practice, or implement a new one.

- ○ forest farming
- ○ alley cropping
- ○ riparian buffers
- ○ windbreaks or hedgerows
- ○ silvopasture

Section 2. Scenario Questions

Instructions

The following questions will ask you to choose an alternative based on the attributes described below:

Cost of Seedlings: Refers to what percentage of seedling costs would be covered for the initial planting of your agroforestry system.

Extent of Technical Assistance: Refers to how much technical assistance a local agency (such as your local extension office, conservation district, etc) would provide to you throughout your project.

Local Examples: Refers to whether you have visited or otherwise seen other examples of agroforestry systems in your area. This could include farm tours or other events where you get to see and ask questions about someone else's local agroforestry system.

Scale of initial implementation: Refers to the amount of land you would convert to agroforestry in the initial year of implementation. Marginal space is defined as an area of a farm that is not currently in production.

Cost-share: Refers to different types of financial assistance you would receive annually throughout your project. These payments could be based on the increased conservation or carbon sequestration benefits of the agroforestry planting.

Markets: Refers to the availability of a local distribution and/or processing food hub to purchase your agroforestry commodities (eg. mushrooms, nuts, apples, etc). Learn more about EQIP and CREP .

*You will be able to refer back to these definitions using the "review attribute descriptions" dropdown button at the bottom of each choice scenario.

You selected ${q://QID4/ChoiceGroup/SelectedChoices} as your preferred agroforestry practice. Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 1

Attribute Description	Alternative A	Alternative B
Cost of seedlings	Must fund and obtain your own seedlings. No initial cost-share program available.	100% of your seedling costs will be covered.
Extent of technical assistance	5 years	10 years
Local examples	2 local examples	1 local example
Scale of initial implementation	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Annual carbon credit payments available.
Available markets	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 2

Attribute Description	Alternative A	Alternative B
Cost of seedlings	100% of your seedling costs will be covered.	50% of your seedling costs will be covered through an available cost-share program.
Extent of technical assistance	1 year	5 years
Local examples	No local examples.	1 local example
Scale of initial implementation	Convert 30% of my acreage currently in production to an agroforestry system.	Convert marginal spaces (acreage not currently in production) to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Enroll in a federal payment program such as CREP or EQIP.
Available markets	Raw and/or processed goods must be sold direct to market.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 3

Attribute Description	**Alternative A**	**Alternative B**
Cost of seedlings	Must fund and obtain your own seedlings. No initial cost-share program available.	50% of your seedling costs will be covered through an available cost-share program.
Extent of technical assistance	5 years	1 year
Local examples	1 local example	No local examples
Scale of initial implementation	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	Annual carbon credit payments available.	No ongoing cost-share payments are available.
Available markets	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 4

Attribute Description	Alternative A	Alternative B
Cost of seedlings	50% of your seedling costs will be covered through an available cost-share program.	100% of your seedling costs will be covered.
Extent of technical assistance	1 year	5 years
Local examples	2 local examples	No local examples
Scale of initial implementation	Convert 30% of my acreage currently in production to an agroforestry system.	Convert 15% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	Annual carbon credit payments available.	Enroll in a federal payment program such as CREP or EQIP.
Available markets	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.	Raw and/or processed goods must be sold direct to market.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 5

Attribute Description	**Alternative A**	**Alternative B**
Cost of seedlings	50% of your seedling costs will be covered through an available cost-share program.	Must fund and obtain your own seedlings. No initial cost-share program available.
Extent of technical assistance	5 years	10 years
Local examples	1 local example	2 local examples
Scale of initial implementation	Convert 15% of my acreage currently in production to an agroforestry system.	Convert 30% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	No ongoing cost-share payments are available.	Enroll in a federal payment program such as CREP or EQIP.
Available markets	Raw and/or processed goods must be sold direct to market.	Raw and/or processed goods may be sold to a local food hub that can market and distribute your goods.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Please select whether you would implement or expand ${q://QID4/ChoiceGroup/SelectedChoices} under the circumstances described in Alternative A or B. If neither alternative is preferred, please select "I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided."

Scenario 6

Attribute Description	Alternative A	Alternative B
Cost of seedlings	100% of your seedling costs will be covered.	Must fund and obtain your own seedlings. No initial cost-share program available
Extent of technical assistance	10 years	1 year
Local examples	1 local example	2 local examples
Scale of initial implementation	Convert marginal spaces (acreage not currently in production) to an agroforestry system.	Convert 15% of my acreage currently in production to an agroforestry system.
Ongoing cost-share options	Enroll in a federal payment program such as CREP or EQIP.	Annual carbon credit payments available.
Available markets	Raw and/or processed goods must be sold direct to market.	Processed goods (nut butter, etc) may be sold to a local food hub that can market and distribute your goods.

Review Attribute Descriptions

- Alternative A
- Alternative B
- I would not implement ${q://QID4/ChoiceGroup/SelectedChoices} under either alternative provided

Section 3. Demographics

Instructions

The following section will ask questions related to farm and farmer characteristics. When asked for answers in acres, please respond with your best estimate, rounded to the nearest half acre. If you do not have acreage in one of the categories listed below, please write "0".

Acreage in 2022

The following questions will help determine the amount of acres you operated in 2022. Please fill in each box with a number in acres.

Number of Acres Owned

Number of acres rented or leased FROM others

Number of acres rented or leased TO others

Number of acres in production

What is your primary crop? (in terms of income generated) Write N/A if you do not sell any crops or products from your farm.

How old are you? (please enter age in years)

Do you expect a descendent or other family member to take over your farm operations in the future?

- Yes
- No

How long have you farmed this property? (please round to the nearest year)

Do you live on this farm property full-time?

- Yes
- No

What percent of your total income do you derive from this property?

Would you like to receive a copy of the study results at the completion of this project?

- Yes
- No

Appendix C: Thematic Codebook

Initial subcodes within the "barrier" category.

Barrier Codes	Description	Example Quotation
Financial	Includes capital and operational costs.	*"No young person I know can really afford farmland on any sort of scale right now.*
Knowledge	General lack of knowledge about how to manage agroforestry systems in our regionally specific context.	*"We're quite a ways behind [the Midwest]. Our maritime climate is really different, so the best practices here are quite different."*
Support	Lack of support for agroforestry or unaware of the support that does exist.	*"You know, a lot of people don't even really know what the role of the conservation district it."*
Political	Landholder hesitancy to work with government agencies or funding programs.	*"Well number one, it's been tricky to message because some people hear no compensation and think that people's land is being taken, which in our basin is the number one concern. Government stealing from you."*
Time	Additional time to learn and implement a new agroforestry practice.	*"I don't think there are many people out there that really have the time or capacity or wherewithal to actively cultivate more diverse products."*
Scale	Scale of initial implementation.	*"That's a barrier for CREP. They're not even looking at projects less than an acre to fund. And so, people are not going to want to commit a fifth of their land to straight conservation."*
Nursery and plant availability	Having enough plant material available to implement new agroforestry plantings.	*"The genetic material to plant is not super readily available. There are some nurseries you can get this stuff from but they're not scaled up to have the quantity at the price that you can really throw in 1000's of trees at a reasonable cost."*
Distribution	Lack of local coop or food	*"We need some sort of depot or way to*

	hub to distribute goods.	*market and distribute so that each individual person isn't having to overcome all that."*
Risk	Associated risk with implementing a new agroforestry system.	*"A lot of farmers are not going to just put in permanent trees and lose production if they don't even know that ten years from now, they're going to have a market, or if the trees will even survive under the changing climate."*
Markets	Lack of clear markets for some agroforestry products.	*"If you don't already have a market garden presence, it's a bit challenging to try to figure out how to harvest your yields in a rational way."*
Processing equipment	Lack of centralized processing equipment for agroforestry products like hazelnuts. Impractical for individual farmers to purchase such equipment.	*"I also think that access to large scale processing facilities is going to be important. I know with our nut orchards, we just have no idea how that's going to play out when we have mature nut trees that are producing crops."*
Labor	Additional labor required to implement and manage a new system.	*"There's just not enough labor to help with the maintenance."*

Initial subcodes within the "incentives" category.

Incentive Codes	**Description**	**Example Quotation**
Federal payment program	Annual federal payments based on the amount of land enrolled in a conservation program.	*"I keep hoping that someone can come up with something like CREP that would be more applicable to agroforestry and have some kind of financial incentive."*
Upfront cost-share	Payments made to landholders the beginning of a project to cover the initial costs of implementation.	*"If you're a small scale person that doesn't have a lot of extra money that might be open to some of the non-standard growing practices, it comes down to money and support."*
Technical assistance	Ongoing technical support from an extension service provided for free to those	*"I mean to be perfectly honest I think it's upfront payments and clear*

	implementing an agroforestry system.	*coaching or mentorship."*
Carbon credit payments	Ongoing payments based on the amount of additional carbon sequestered by an agroforestry system compared to the baseline.	*"I would love to have somebody come in and measure the carbon in my agroforestry systems here. If you can get paid for sequestering carbon, that could help. My agroforestry systems really sequester carbon."*
Ecological impact	A desire to improve the environment for themselves or future generations.	*"The biggest enticement for the farmers is the idea of reducing erosion."*
Tool share	A program to make specialized agroforestry tools available to farmers looking to implement agroforestry.	*"Having a pool of tools that you can use to get started would be super helpful. Like a tool library. Just way bigger tools."*
Agrotourism	U-pick and other activities that increase farm visitation and potentially exposure to agroforestry.	*"I think they do some U-pick and some agrotourism. If you can combine some of these agroforestry practices and then actually get people on the farm to see them, that is a really powerful model."*
Food hub	A centralized distribution center that can purchase agroforestry commodities from producers.	*"Some kind of aggregation facility, essentially a food hub, that has the processing facility, the cold storage, the distribution, the marketing, all that."*
Seedlings	The plants needed for the initial implementation of a new or expanded agroforestry system.	*"I think providing the seedlings would be huge."*
Phased Implementation	Strategic planting practices to slowly phase in a new agroforestry system rather than transitioning all at once.	*"It's all about marginal space. Every farm has a fenceline, a road, a contour. So that's where you plant first. It's not your cropping area."*

Appendix D: Experimental Design and Ngene Syntax

Final Ngene syntax used to create the experimental design. This design achieved attribute level balance such that each level appeared an equal number of times across the experiment. It also minimized alternative dominance such that no alternative was clearly dominant (i.e. more supportive and higher paying) to the other in any given choice scenario. Lastly, this design yielded the lowest D-error score of all trialed designs.

```
? This creates an efficient design assuming non-zero priors, effects coding, using actual attribute levels, base level = the first one
alts=alt1*,alt2*, alt3
;rows=18
;eff = (mnl, d)
;block=3
;model:
U(alt1) = b1.effects[-0.00001|0.00001]* A[0,100,50] + b2.effects[0|0]* B[1,10,5] + b3.effects[-0.00001|0.00001]* C[0,2,1] + b4.effects[0|0]* D[0,50,25] + b5.effects[0.00001|0.00001]* E[1,2,0] + b6.effects[-0.00001|0.0001]* F[0,2,1] /
U(alt2) = b1* A        + b2* B        + b3* C        + b4* D        + b5* E        + b6* F
$
```

Appendix E: Applying the Multinomial Logit Model using the "Apollo" Package for Choice Modeling in R

Final R syntax used to estimate the multinomial logistic regression model for the trichotomous choice experiment.

LOAD LIBRARY AND DEFINE CORE SETTINGS

```
### Clear memory
rm(list = ls())
### Load Apollo library
library(apollo)
### Initialise code
apollo_initialise()
### Set core controls
apollo_control = list(
  modelName       = "MNL_SP_effects",
  modelDescr      = "MNL model on AF choice data using effects coding",
  indivID         = "ID",
  outputDirectory = "output"
)
```

LOAD DATA AND APPLY ANY TRANSFORMATIONS

```
### Loading data from package
database = read.csv("AF_results.csv",header=TRUE)
database = AF_results
```

DEFINE MODEL PARAMETERS

```
### Vector of parameters, including any that are kept fixed in estimation
      apollo_beta=c(asc_SQ   = 0,
                  b_seed0    = -0.00001,
                  b_seed100  = 0.00001,
                  b_assist1  = 0,
                  b_assist10 = 0,
                  b_example0 = -0.00001,
                  b_example2 = 0.00001,
                  b_scales0  = 0,
                  b_scale30  = 0,
                  b_pay1     = 0.00001,
                  b_pay2     = 0.00001,
                  b_market0  = -0.00001,
                  b_market2  = 0.00001,

      )
### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta
apollo_fixed = c()
```

GROUP AND VALIDATE INPUTS

apollo_inputs = apollo_validateInputs()

DEFINE MODEL AND LIKELIHOOD FUNCTION
apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

Attach inputs and detach after function exit
apollo_attach(apollo_beta, apollo_inputs)
on.exit(apollo_detach(apollo_beta, apollo_inputs))

Create list of probabilities P
P = list()

Effects coding constraint
b_seed50 = -b_seed0-b_seed100
b_assist5 = -b_assist1 - b_assist10
b_example1 = -b_example0 - b_example2
b_scale15 = -b_scale0 - b_scale30
b_pay0 = -b_pay1 - b_pay2
b_market1 = -b_market0 - b_market2

List of utilities: these must use the same names as in mnl_settings, order is irrelevant
V = list()
V[["A"]] = (b_seed50*(seedA == 2) + b_seed0*(seedA == 1) + b_seed100*(seedA ==3) + (b_assist5*(assistA == 2) + b_assist1*(assistA == 1) + b_assist10*(assistA ==3) + b_example1*(exampleA == 2) + b_example0*(exampleA ==1) + b_example2*(exampleA == 3) + b_scale15*(scaleA ==2) + b_scale0*(scaleA ==1) + b_scale30*(scaleA ==3) + b_pay0*(payA ==1) + b_pay1*(payA ==2) + b_pay2*(payA ==3) + b_market1*(marketA == 2) + b_market0*(marketA ==1) + b_market2*(marketA ==3))
V[["B"]] = (b_seed50*(seedB == 2) + b_seed0*(seedB == 1) + b_seed100*(seedB ==3) + (b_assist5*(assistB == 2) + b_assist1*(assistB == 1) + b_assist10*(assistB ==3) + b_example1*(exampleB == 2) + b_example0*(exampleB ==1) + b_example2*(exampleB == 3) + b_scale15*(scaleB ==2) + b_scale0*(scaleB ==1) + b_scale30*(scaleB ==3) + b_pay0*(payB ==1) + b_pay1*(payB ==2) + b_pay2*(payB ==3) + b_market1*(marketB == 2) + b_market0*(marketB ==1) + b_market2*(marketB ==3))
V[["SQ"]] = (b_seed50*(seedSQ == 0) + b_seed0*(seedSQ == 0) + b_seed100*(seedSQ ==0) + (b_assist5*(assistSQ == 0) + b_assist1*(assistSQ == 0) + b_assist10*(assistSQ ==0) + b_example1*(exampleSQ == 0) + b_example0*(exampleSQ ==0) + b_example2*(exampleSQ == 0) + b_scale15*(scaleSQ ==0) + b_scale0*(scaleSQ ==0) + b_scale30*(scaleSQ ==0) + b_pay0*(paySQ ==0) + b_pay1*(paySQ ==0) + b_pay2*(paySQ ==0) + b_market1*(marketSQ == 0) + b_market0*(marketSQ ==0) + b_market2*(marketSQ ==0))

Define settings for MNL model component
mnl_settings = list(
  alternatives = c(cA=1, B=2, SQ=3),
  avail   = 1,
  choiceVar   = choice,
  utilities   = V
)

 ### Compute probabilities using MNL model
 P[["model"]] = apollo_mnl(mnl_settings, functionality)

```
  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}
```

MODEL ESTIMATION

```
model = apollo_estimate(apollo_beta, apollo_fixed,
                        apollo_probabilities, apollo_inputs)
```

MODEL OUTPUTS

```
apollo_modelOutput(model)
apollo_saveOutput(model)
```