Agroforest Syst (2025) 99:16
https://doi.org/10.1007/s10457-024-01117-0

Factors affecting Missouri land managers' willingness-to-adopt agroforestry practices

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Received: 19 July 2024 / Accepted: 8 November 2024

Abstract Temperate agroforestry practices offer various ecological, social, and economic benefits. However, data surrounding drivers of adoption for agroforestry in the U.S. remains limited. A survey of Missouri agricultural land managers was conducted to determine the extent of agroforestry adoption in the state, current knowledge and perceptions of agroforestry, and interest in implementing agroforestry practices. A choice experiment model was employed to assess participants' willingness to accept (WTA) payment for adopting agroforestry practices and to determine land managers' valuation of technical assistance and environmental benefits. Across the sample, self-reported knowledge of agroforestry practices was minimal to low (33%-78%). Perceptions of agroforestry systems for management and economic aspects were mixed, while promotion of biodiversity and environmental services were especially positive. Using a mixed logit regression model, if cost to establish a given agroforestry system was $2,500 per acre, it was determined that the average Missouri land manager would accept a per acre payment of $8,795 for alley cropping, $1,217 for forest farming, $3,080 for riparian forest buffers, $-3,546 for silvopasture, $11,458 for urban food forests, and $19,154 for windbreaks. WTA payments were lower for existing adopters of agroforestry than non-adopters. Among those who were willing to adopt agroforestry, technical assistance was valued at $1,670 per acre, while environmental benefits were valued at $2,992 per acre. In a second model testing interaction variables, participants with greater knowledge of agroforestry practices or with higher incomes were significantly more willing to adopt agroforestry practices, while participants with larger farms were less likely to adopt agroforestry.

Keywords Adoption · Choice experiment · Perennial agriculture · Survey

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10457-024-01117-0.

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Published online: 27 December 2024

Introduction

Farmers in the U.S. face mounting challenges in managing their agricultural systems due to anthropogenic climate change, which is causing losses in agricultural production for select crops and increased vulnerability to severe weather events for the entire agroecosystem (Rezaei et al. 2023; Ortiz-Bobea et al. 2021; Jägermeyr et al. 2021; Schoeneberger et al. 2017). Diversified, transformative farming strategies, such as agroforestry, have been offered as promising approaches for both climate mitigation and adaptation, while still providing economic gains and social advantages (Garrett Jose Gold 2022; Schoeneberger et al. 2017; Gold and Hanover 1987; Wilson and Lovell 2016).

The Natural Resource Conservation Service (NRCS) has identified agroforestry as a "climate-smart practice" (USDA 2021), while others consider it a "natural climate solution" (Fargione et al. 2018). However, it remains to be seen whether the ecological benefits of agroforestry are enough to entice U.S. producers to establish these practices. While some scholars have observed producer implementation of agroforestry systems, such as windbreaks and silvopasture, for their indirect economic benefits like erosion control and livestock protection (Ford et al. 2019; Smith et al. 2021), direct profit remains an exceedingly important factor for agroforestry adoption. Agroforestry systems are often recognized as effective means of diversifying agricultural products and allowing farmers the opportunity to engage in various markets. Additionally, agroforestry systems are often extolled for their ability to optimize farm acreage by increasing the Land Equivalent Ratio, providing the capability for producers to harvest yields on less land than is required by traditional agriculture (Pent et al. 2020; Nair 1993).

However, agroforestry systems can also present economic constraints that dissuade adoption. As Wilson and Lovell (2016) explain, agroforestry systems that produce tree crops, such as alley cropping with productive tree species, often experience delayed profits while the trees mature enough to produce nuts or fruits. Agroforestry systems relying on timber harvests may incorporate annual crops or livestock for short-term profits, but producers must wait many years to see a return on their investment for the tree component (Valdivia et al. 2012). These delayed profits can dissuade establishment of agroforestry systems if producers do not possess the financial means or the time to wait for a return. Other factors such as perceived competition between trees and annual crops, insufficient markets, and high establishment costs may also prevent land managers from adopting agroforestry practices. Depending on the design of the systems and the species used, there may also be limited opportunity for direct profitability (Wilson and Lovell 2016; Valdivia et al. 2012; Workman et al. 2003; Smith et al. 2021).

To address financial concerns and encourage establishment of agroforestry practices, the United States Department of Agriculture (USDA) has created multi-billion-dollar initiatives such as the Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP), the Farm Service Agency Conservation Reserve Program (CRP), and the Partnerships for Climate Smart Commodities Grants (USDA, n.d.) to name a few. While some investigations like Piñeiro et al. (2020) have examined the effectiveness of ongoing incentive programs in increasing adoption of sustainable farming practices, questions remain surrounding the rate of compensation that encourages agricultural producers to implement agroforestry. Existing programs, such as cost-share, may lessen establishment costs for producers, but agroforestry often requires investment in years following establishment to maintain tree health such as pruning, thinning, and pest management (Garrett Jose Gold 2022).

Over the past few decades several studies have explored this topic in the United States. Studies include willingness to participate or accept/adopt for silvopasture (Davis and Rausser 2020; Shrestha and Alavalapati 2003), riparian forest buffers (Motallebi et al. 2016; Lynch et al. 2002; Kingsbury and Boggess 1999; Hagan 1996), windbreaks (Grala et al. 2008) and alley cropping (Monson et al. 1991). A number of these studies found that incentive payments would have to be higher than establishment costs to induce adoption (Kingsbury and Boggess 1999; Hagan 1996), primarily due to loss of land in production or reduced management flexibility due to land planted in perennial vegetation. Given the complexity and long-term investment of agroforestry systems, further investigation is needed on whether current financial assistance programs are sufficient or if additional funding is needed to cover costs beyond establishment to increase producer willingness to adopt.

In addition to financial incentives, investigations into agroforestry adoption barriers have found that lack of knowledge and skills inhibit producers' ability and willingness to implement agroforestry practices (Workman et al. 2003; Trozzo et al. 2014; Mattia et al. 2018; Ford et al. 2019) or similar conservation agriculture practices (Prokopy et al. 2019). More broadly, the importance of technical information and support has been illustrated among new farmers implementing various forms of agriculture. For instance, Iles et al. (2023) examined barriers and motivators among new and beginning farmers in the Midwest U.S., finding that 88% of their sample reported a need for accessing relevant technical information. However, further investigation is needed regarding how producers specifically value access to knowledgeable agroforestry technical assistance providers or factor it into their adoption decisions.

To address these research gaps, this study seeks to explore the current state of agroforestry adoption, interest, and willingness to adopt agroforestry using the state of Missouri, U.S. as the study region. Specific questions investigated include:

1. What is the state of agroforestry adoption in Missouri?
2. How much knowledge of agroforestry systems do Missouri land managers hold?
3. What are land managers' perceptions of agroforestry systems?
4. What potential for future agroforestry adoption exists among Missouri land managers using a Willingness to Accept (WTA) approach? And how do factors such as technical assistance and environmental benefits influence land managers' WTA payments?

Findings from this study contribute to a greater understanding of the diverse motivators, factors, and characteristics that influence land manager decision-making related to agroforestry. Further, this study provides critical information needed by resource managers on the level of incentive payments required by producers to adopt agroforestry, and the potential financial incentives producers may be willing to forego based on technical assistance and environmental benefits offered from these systems. The assessment of whether producers are willing to forego financial incentives for other benefits is unique to this study and may offer a methodological framework for future studies investigating drivers of agroforestry adoption in other regions.

Methods

Questionnaire design and structure

Comprehensive reviews of both the global agroforestry adoption literature and US agroforestry and conservation farming adoption literature informed the design of the questionnaire for this study (Smith et al. 2022; Valdivia et al. 2012). At the end of the consent page, participants were given the option to submit their response online or via mail through prepaid return envelopes included in the packet. Within the first section of the questionnaire, we asked participants to provide general information about their farm such as their tenure status, current land usage, and their past farming experience. We then included an informational page about agroforestry to ensure adequate understanding of the term and the practices it encompasses. We first provided a general definition of 'agroforestry,' followed by definitions of the six recognized temperate agroforestry practices with images of each to aid comprehension.

Following this informational page, participants were asked to indicate how familiar they were with the term 'agroforestry' and its practices prior to beginning this questionnaire. We also asked them to rank their knowledge of agroforestry on a five-point Likert scale (1 = Very Low/None, 5 = Very High) (Croasmun and Ostrom 2011) and to report if they currently owned or managed acreage in agroforestry or had previously. If they currently practiced agroforestry, or if they practiced agroforestry in the past and elected to discontinue, we asked them to further elaborate on their experience. To gauge interest in agroforestry, the section concluded by asking respondents to select all practices they would consider implementing.

In the second section, we inquired about information sources participants use to gain knowledge about farming, land use, and conservation. Furthermore, this section assessed participants' perceptions of agroforestry by asking them to rate fifteen unique statements regarding the economics, production, and environmental benefits of agroforestry on a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). These statements were selected after a comprehensive review of agroforestry adoption studies identified several emerging factors as influential over agroforestry adoption behaviors (Stubblefield 2021).

The third section utilized a choice experiment model. Choice experiment models are employed to determine respondent preferences for certain attributes among finite choices (Bierlaire 1998), and have been used in agroforestry research for many years (Stetter and Sauer 2024; Shrestha and Alavalapati 2003; Kingsbury and Boggess 1999). Within our questionnaire, the choice experiment section assessed participant interest in adopting agroforestry, estimated their WTA for adopting agroforestry, and determined participant valuation of technical assistance and environmental benefits within their agroforestry adoption decisions. To achieve this, we first asked respondents to select one agroforestry practice that they believed would work best on their land. They were then provided with a hypothetical scenario. Within the scenario, participants were asked to imagine that the growing season had concluded, and they were considering transforming a portion of their land into the agroforestry system previously selected. For whichever agroforestry system they chose, the hypothetical cost to implement the system was $2,500 per acre. Participants were then informed that two options for the chosen agroforestry system would be offered to them, but each option would vary in the incentive payment offered ($5,000 per acre, $2,500 per acre, or $500 per acre), technical assistance provided (Yes, No), and environmental benefits offered (Low, High). Participants were asked to choose their preferred option between the pairings or select the 'Neither' option (Fig. 1). The $2,500 baseline cost, along with the incentive payment levels, were designated after consulting with local conservation professionals and a review of average USDA NRCS Environmental Quality Incentives Program (EQIP) payments awarded for agroforestry practices in 2020. The following definitions were presented to participants to assist them in conceptualizing the variables and their levels:

> *One-Time Incentive Payment: Assume that the cost to establish your chosen agroforestry system is $2,500 per acre. The choices offered to you will provide either a $500 per acre, $2,500 per acre, or $5,000 per acre payment from a funding source (such as a government entity or a non-government organization). Therefore, the $500 payment would cover 20% of the establishment costs, the $2,500 per acre payment would cover 100% of the establishment costs, and the $5,000 per acre would cover 100% of the establishment costs plus provide you with a $2,500 per acre bonus payment. These would be one-time payments provided to incentivize you and help you establish the system.*
> *Technical Assistance: Choices will either offer technical assistance or they will not. Technical assistance includes such services as consultations, visits, and regular contact/advice from agroforestry specialists.*

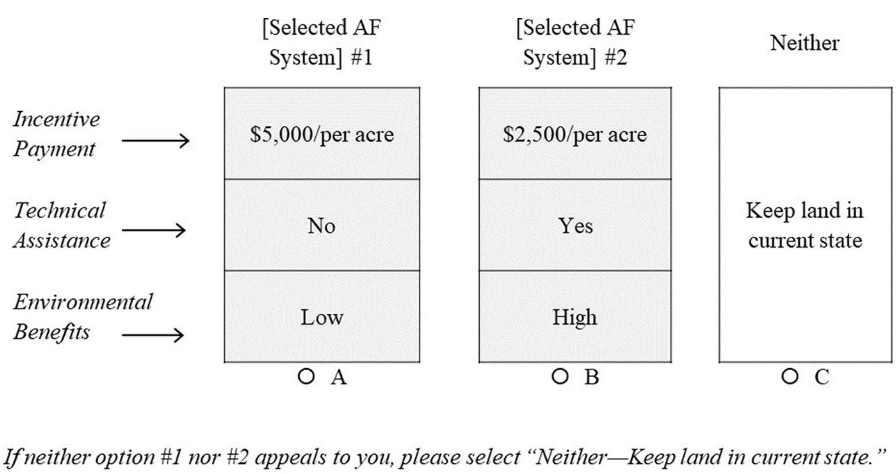

Fig. 1 Example of question pairing presented to participants to determine their WTA for agroforestry practices as well as their valuation of technical assistance and environmental benefits

Environmental Benefits: Choices will offer low or high benefits to the environment. For example, a system with low environmental benefits would provide little to no beneficial services to your farmland and the surrounding ecosystem. A system with high environmental benefits would provide many beneficial services to the farm and ecosystem, such as erosion control, water purification, air purification, carbon sequestration, wildlife habitat, improved nutrient cycling, and more.

In total, five question pairings were presented to respondents. An example question was provided to participants before the question sets to aide understanding and ensure accurate responses.

Importantly, when participants respond to hypothetical scenarios, a phenomenon known as "hypothetical bias" often appears. Hypothetical bias occurs when a person's response to a hypothetical situation does not reflect their actual behavior in authentic situations (Carlsson and Martinsson 2001; Ladenburg and Olsen 2010). Per recommendation by scholars such as Ladenburg and Olsen (2010) and Fifer et al. (2014), the following "cheap talk" script was presented to respondents before the question pairings to mitigate hypothetical bias:

Before proceeding, please read the following paragraphs carefully:
Hypothetical bias: Hypothetical bias occurs when a respondent's preferences under hypothetical conditions differ from their actual decisions in real life situations.
Why does this happen?
People generally exhibit higher willingness to participate when their answers do not have actual consequences. For example, when asked if they support environmental protection in a survey, many people would agree (e.g. be willing to donate to the protection of the environment). However, the same people may be reluctant to donate when confronted with a real-life opportunity. Please try to avoid this problem by responding to the following questions carefully as if you were truly altering your land. For each question asked, please consider whether you would really be willing to implement these practices or not.

Furthermore, the inclusion of Opt Out Reminders (OORs) has been shown to reduce hypothetical bias in choice experiment models (Ladenburg and Olsen 2010). The following OOR was included after each agroforestry question pairing: "If neither option #1 nor #2 appeals to you, please select 'Neither—Keep land in current state.'"

The fourth section collected the following participant demographic information: gender identity, age, racial identity, education, primary occupation, household income, and percentage of income attributed to farming operation. We included racial identity, defined by the U.S. Census Bureau (2022) as an individual's self-identification with sociocultural groups, national origins, or racial origins, in this study to capture any potential trends in responses or unique barriers faced by underserved land managers. Notably, a previous study found permaculture systems to be dominated by a white super majority (Ferguson and Lovell 2015) while agroforestry adoption studies have noted a disproportionately white respondent pool (Ford et al. 2019).

Questionnaire testing and data collection

Twelve Missouri counties were selected for inclusion in the study. To investigate potential differences in region types, all Missouri counties were separated into rural, peri-urban, and urban classifications prior to selection. Counties were categorized into these respective classifications based off the 2013 USDA Rural–Urban Continuum codes. Four counties from each classification were randomly selected for inclusion in the sample (Fig. 2).

We contacted tax assessor's offices for each included county to obtain agricultural lands reports containing the names, mailing addresses, and acreages for all persons owning agricultural land. Excel files with the data were collected and purged of duplicate contacts. Records with mailing addresses located outside of Missouri and records that indicated management by non-relevant organizations (such as cemeteries, real estate companies, and city governments) were also removed. Throughout the study, we refer to our respondents as land managers, which we define as anyone owning or operating agricultural land.

Prior to administration of the questionnaire, we pilot tested the instrument in June and July 2021. Following commentary and suggestions from the

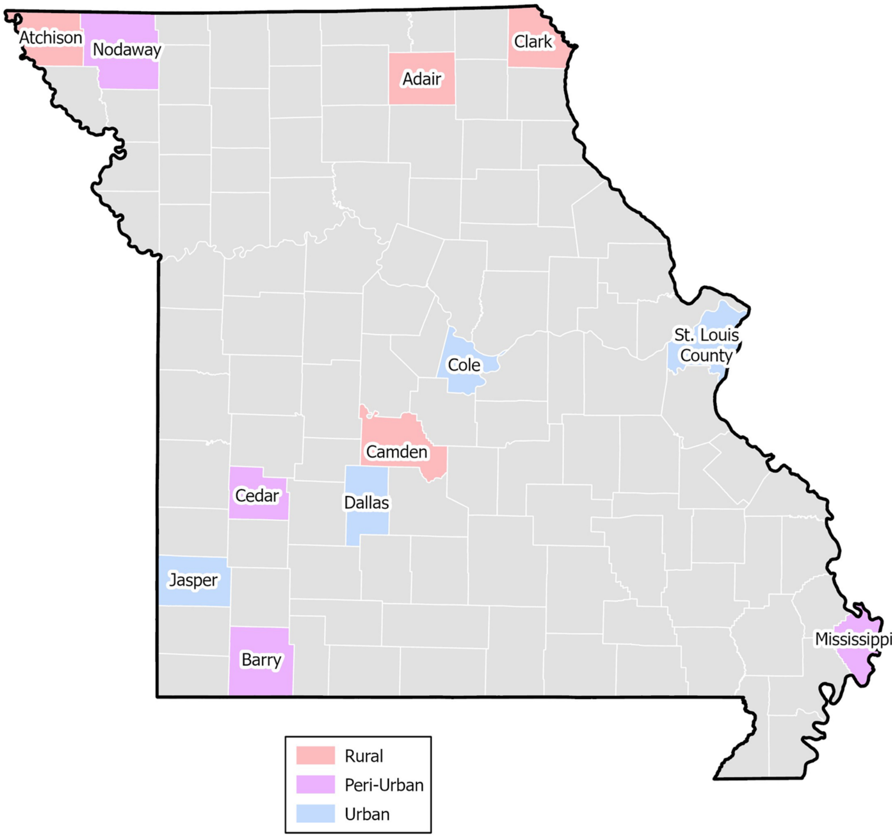

Fig. 2 Sampled urban, peri-urban, and rural counties of Missouri, U.S

groups, minor amendments were made to the instrument. Further revisions to the choice experiment section were made to enhance participant understanding and encourage consistency in responses. As added incentive, participants were offered the chance to participate in a gift card drawing to win one of ten $50 Visa gift cards. Prior to its implementation, the questionnaire was submitted to and approved by the University of Missouri's Institutional Review Board (IRB), project number 2016745.

Paper questionnaires were distributed to 209 Missouri land managers in each of the twelve selected counties (2,508 total) in August and September 2021 using a modified version of the Dillman method (Dillman et al. 2016; Hoddinott and Bass 1986). Using this approach, reminder postcards were sent via mail to the recipients three weeks after the initial packets were delivered. A final round of reminder postcards was sent to participants two to three weeks after the first. Online and paper responses were collected through November, 2021.

The first page of the questionnaire offered a QR code for participants to scan with their smart device or a URL address to input if they wished to respond online. These both contained an anonymous link to an online version of the agroforestry questionnaire hosted by Qualtrics software version 8.21 (2021, Provo, UT). While participants had the option to include their name and contact information for the gift card drawing, the introductory consent statement informed participants that all responses would be deidentified and kept in anonymous form.

Data analysis

After response collection, returned paper questionnaires were entered into Qualtrics software to merge data and ensure consistency in formatting between the online and paper samples. Data were then downloaded into Excel file format and analyzed using Stata (version 15.0, StataCorp, 2021, College Station, TX), R Statistical Software (version 4.1.1, R Core Team, 2021) and Qualtrics Stats iQ software (version 8.21, Qualtrics, 2021, Provo, UT). Stats iQ and R software were used to generate descriptive statistics, such as frequency of answers and mean values of continuous variables.

Analysis of Choice experiment questions was based on the Random Utility Model (RUM) first suggested by Thurstrone (1927), which assumes that an individual will discern between the alternatives available to them based upon personal preferences, selecting the option that offers the greatest amount of utility. Observed attributes within the utility function are represented by explanatory variables, while unobserved variables are represented as random variables (Horowitz et al. 1994; Aguilar and Cai 2010). A RUM assumes that observed, explanatory variables within the deterministic component may not fully explain choice decisions of an individual, and random disturbances are factored into the model to represent missing or latent variables, originally recognized by McFadden (1986) as affecting an individual's selection behaviors. Importantly, these random variables also account for other disturbances such unobservable measurements or measurement errors. If individual j obtains utility of U_{vj} from establishing agroforestry alternative v, it is assumed that U_{vj} is a latent utility that researchers cannot observe and that U_{vj} can also be determined by a nonstochastic component C_{vj} and a random term ε_{vj}, in which C_{vj} is observable via the attribute-specific characteristics of incentive payment, technical assistance, and environmental benefits. Within the estimate, β represents a vector of participant characteristics from individual j, and the random term ε_{vj} encapsulates effects of latent variables:

$$U_{vj} = C_{vj} + \varepsilon_{vj} = \beta_j x_{vj} + \varepsilon_{vj}$$

Stata 15 software was used for the construction and analysis of two mixed logit regression models (Wang and Puterman 1998). Mixed logit models were utilized to estimate the statistical significance and effects of chosen attributes on agroforestry adoption willingness. Within the primary model, only attributes of incentive payment, technical assistance, and environmental benefits were included. The second model incorporated various interaction variables and estimated their influence over willingness to adopt behavior.

Mixed logit models allow for variance in model coefficients across individuals, addressing possible heterogeneity in personal preferences (Aguilar et al. 2018). If probability of an agroforestry alternative being selected by individual j is represented by P_{vj} in a mixed logit model, the equation for probability would be:

$$P_{vj} = \int \mathrm{L_{vj}}(\beta) f(\beta|\theta) d\beta$$

where $L_{vj}(\beta) = \frac{\exp(\beta_j x_{vj})}{\sum_j \exp(\beta_j x_{qn})}$.

where $f(\beta|\theta)$ represents the density distribution function of β and $q \in Q$, where Q represents agroforestry alternatives and θ is the population parameter of distribution (mean and covariance of β). Accurate estimation of choice probability cannot be obtained in the mixed logit model since the integral does not always display a closed form solution. Therefore, a simulation method is used for estimation of the unbiased estimator p_{vj} of P_{vj} and the following equation is used to simulate probability:

$$p_{vj} = \frac{1}{R} \sum_{r=1}^{R} L_{vj}(\beta^r)$$

where R is the number of draws, and β^r is the value of β at the rth draw from $f(\beta|\theta)$.

Simulated log likelihood (SLL) can be estimated based on simulated probabilities as:

$$SLL = \sum_{n=1}^{N} \sum_{q}^{Q} d_{qj} \ln p_{vj}$$

where $d_{qj}=1$ if individual j chooses alternative q and $=0$ if otherwise. Parameters θ and β can be determined by maximizing SLL.

In summary, the model considers the observed variables collected through our study while also accounting for the factors that we cannot know or did not include. Table 1 provides information on the independent and dependent variables used in the models. The dependent variable captured whether an agroforestry alternative was chosen, while independent variables in the primary model captured the levels of agroforestry alternative attributes: incentive payment, technical assistance, and environmental benefits and estimates influence of these three variables on Missouri land manager agroforestry adoption willingness. Within the second model, participant characteristics and other deterministic components were added to identify the influence of interaction variables on

Table 1 Descriptions of variables included in Mixed Logit Model I and Mixed Logit Model II to assess Missouri respondents' WTA for agroforestry practices and influential factors

Variables	Description
Dependent	
Respondent Choice	Dummy variable: Respondent willingness to adopt agroforestry, Dummy = 1 if agroforestry alternative is chosen and 0 if otherwise
Independent	
Alternative Specific Constant (ASC)	"Neither" option capturing status quo, associated with the rejection of both agroforestry alternatives in choice scenarios
Payment	Continuous variable: $500, $2,500, and $5,000 per acre one-time incentive payments
Technical	Dummy variable: Technical assistance in option, Dummy = 1 if technical assistance is offered in alternative and 0 if not offered
Environment	Dummy variable: Level of environmental benefits in option, Dummy = 1 if high environmental benefits offered in and 0 if low benefits offered
AF Knowledge*ASC	Interaction Variable: Knowledge interacts with ASC, Knowledge = 1 if participant self-reported knowledge value is 3 or greater and 0 if otherwise
Income*ASC	Interaction Variable: Income interacts with ASC, Income = 1 if participant income is greater than $100,000 per year and 0 if otherwise
Farm Size*ASC	Interaction Variable: Farm Size interacts with ASC, Farm Size = 1 if participant farm size is greater than 167 (total acres/number of parcels) and 0 if otherwise
Age*ASC	Interaction Variable: Age interacts with ASC, Age = 1 if participant age over 45 years, 0 if otherwise
Gender*ASC	Interaction Variable: Gender interacts with ASC, Gender = 1 if participant gender identity female, 0 if male
Soil Health*ASC	Interaction Variable: Soil Health interacts with ASC, Soil Health = 1 if participant strongly agreed, agreed, or neither agreed nor disagreed with statement regarding agroforestry's promotion of soil health, 0 if otherwise
Urban/Peri-Urban*ASC	Interaction Variable: Urban/Peri-Urban interacts with ASC, Urban/Peri-Urba*n* = 1 if participant farm located in urban or peri-urban county, 0 if rural

adoption willingness. Normal distribution was utilized for this study. 2,000 iterations were used for each model, and the models' goodness of fit were determined via likelihood-ratio Chi square tests. Odds ratios were calculated to determine the size of variable impact.

The fixed coefficient of incentive payment across the sample assumes homogeneity in impact of payment on respondent preference. Additionally, the fixed coefficient and zero standard deviation of incentive payment allows for estimation of participant WTA payment amounts, or the amount of financial payment required to trigger indifference to the status quo alternative (not adopting agroforestry) and result in participant willingness to adopt agroforestry technologies (Cai et al. 2019; Aguilar and Cai 2010). Farmer's WTA payments for adopting agroforestry were determined when technical assistance was absent and environmental benefits were low (base). The economic valuations were estimated for technical assistance and environmental benefits as attributes moved from base level (none, low) to another level (yes, high). If k is the utility obtained by land managers from choosing agroforestry, x_a is the level of agroforestry attributes, β_a is the estimated parameter for x_a $\beta_{payment}$ is the payment coefficient, then:

$$WTA = -\frac{\partial_k / \partial x_a}{\partial_k / \partial x_{payment}} = -\frac{\beta_a}{\beta_{payment}}$$

Limitations of the study

Various factors may have contributed to the low response rate (5.5%), such as the questionnaire's length of 12 pages, which took approximately 15 min to complete. While shorter surveys often garner higher response rates, a lengthier survey was needed to adequately introduce and perform our choice experiment. Additionally, the questionnaire was distributed during harvest season. Although response rates within the last decade have been above 10%, such as Bish and Bradley's (2017) response rate of 11% from Missouri agricultural producers and Boyer et al.'s (2016) 13.76% response rate from agricultural producers across 14 states, our response rate mirrors those from more recent survey studies, such as Kronenberg et al's (2023) response rate of 6% from Missouri agricultural producers. However, we acknowledge that a response rate of 5.5% presents some limitations. Demographic data were compared to the 2017 USDA National Census of Agriculture to assess possible non-response bias, as has been done in previous works such as Sliwinkski et al. (2018), yet the presence of bias cannot be ruled out. Furthermore, the sampling methods used within the project greatly increase likelihood of contacting landowners rather than those with other arrangements such as tenant farmers, so our sample is not suited to assess effects of tenure status. We also acknowledge that the sample is male dominated. Though our methods prevented us from tailoring our mailings to certain demographics, future studies could employ different methods to achieve a more representative sample.

Low response rate of this project coupled with the high rate of agroforestry practitioners in the sample may indicate a bias in respondents. Agroforestry was identified in the title and introductory page as the primary topic of the survey, which may have disproportionately enticed individuals practicing agroforestry to respond. Yet, the University of Missouri Center for Agroforestry is also located in central Missouri, and concentrated efforts have been made by the center to encourage agroforestry education and knowledge dissemination in both adults and youth throughout the state (Hemmelgarn et al. 2019), which may also have contributed to the high number of agroforestry practitioners. Within the questionnaire, the intensive, integrated, intentional, and interactive elements of temperate agroforestry were highlighted, yet it remains possible that lingering misconceptions and misunderstandings of agroforestry may have resulted in participants identifying their unmanaged areas as agroforestry. Further research into the true standing of agroforestry systems in Missouri would provide greater insight into Missouri's contribution to the U.S. agroforestry landscape.

While the $2,500 baseline cost utilized in our choice experiment scenario allowed us to compare participant WTA payments for different agroforestry systems, we recognize that establishment costs can vary widely across practices. Future studies could include more tailored cost scenarios for each practice to further capture nuances between and among the individual practices.

Results & discussion

Demographics

A total of 163 questionnaires were returned, 124 via mail and 39 through Qualtrics online software. Responses were screened, blank and opt out replies were removed, and 137 usable responses remained. Respondents primarily identified as male (75.4%) white (86.1%) and 55 years of age or older (74.6%). Furthermore, more than half of participants reported their age as over 65 (53.7%). Most identified college (32.5%) or graduate studies (31%) as their highest level of education.

Regarding location, 40 (29%) participants managed lands in urban counties, 54 (39%) in peri-urban counties, and 43 (31%) in rural counties. A majority (79%) identified themselves as full or partial owners of their agricultural land, while 12% reported both owning and renting some farmland, and 2% had cooperative arrangements. Some participants (7%) selected 'other' and opted to explain their tenure status. Within this section, participants explained their standing as hired farm managers, sharecroppers, landlords who rent land out to other farmers, or non-farmers who chose to leave their property as fallow land. Among actively farming participants, average farming experience was approximately 27 years. Only 28% of respondents claimed farming as their primary occupation, while 72% of participants claimed their primary occupation as 'other.'

When asked to share information regarding their average annual income, 31 participants (23%) declined to respond or indicated their preference not to share. Of those remaining, 7% earned less than $25,000, 14% earned between $25,000 and $50,000, 28.7% earned between $50,000 and $100,000, 18.6% earned between $100,000 and $200,000, 7% earned between $200,000 and $300,000, and 7% earned over $300,000. On average, land managers in our sample attributed 21.8% of their annual income to their farming operation. Notably, 53 participants attributed

0–5% of their income to their farming operation while eight participants attributed 100% of their income to farming.

The demographics of the participant group closely resemble those presented in the 2017 USDA Census of Agriculture for Missouri. The Census of Agriculture found Missouri farmers to be 98% white, 62% of 55 years of age or older, and 74% with farming experience of 11 years or more. The participant sample contrasts from the census in a few key categories, however. Notably, the sample in this project skews slightly more male than the US agricultural census data, in which farmers were reported as 64% male. Additionally, 61% of Missouri farmers in the census held primary occupations other than farming (USDA NASS 2017), which is a lesser percentage than our sample.

Our participants vary somewhat from the agricultural census data, yet similar trends and patterns overall suggest that the sample collected may align well with the broader Missouri and US farming populations. However, it is worth noting that the sampling methods within this project more directly targeted Missouri land-owning persons, while the 2017 USDA Census of Agriculture included all agricultural producers regardless of tenure status.

Information sources & knowledge of agroforestry

Information sources

Participants most often identified 'Other farmers' (66%, $n=127$), 'Farming and/or conservation publications' (59%), and 'Internet sources' (51%) as sources where they gather information related to farming and conservation. Other sources such as 'University cooperative extension services' (39%), 'Federal/state agriculture, forestry, or environmental staff' (34%), and 'Conferences or workshops' (16%) were lesser utilized.

Respondents' preference for obtaining information from other farmers indicates the potential importance of peer-to-peer networks for the widespread adoption of technologies such as agroforestry. As others have suggested, opinion leaders within the land-managing community could be especially vital at encouraging positive perceptions and openness toward agroforestry (MacFarland et al. 2017; Garbach and Long 2017; Cable and Cook 1997). For example, Stanek and Lovell (2019) interviewed potential agroforestry adopters, who indicated that they wanted more peer-to-peer communication with farmers already engaged in agroforestry to learn about management and overall feasibility.

Knowledge of agroforestry terminology and practices

Within the beginning pages of the questionnaire, an informational page described the term 'agroforestry' along with the six commonly recognized temperate agroforestry practices. After these brief descriptions, participants were asked if they had heard the term 'agroforestry' prior to this survey. Only 59 (44%, $n=135$) respondents confirmed their familiarity with the term, while most indicated that they had not heard the term (41%) or were uncertain if they had heard the term previously (15%).

When asked to self-assess knowledge regarding agroforestry on a five-point Likert scale (1 = Very Low/None, 3 = Moderate, 5 = Very High), the majority of participants reported their knowledge as 'Minimal' (45%) or 'Very Low/None' (33%), resulting in an overall average agroforestry knowledge score of 2.0 across the sample. These findings are slightly higher than the 1.8 knowledge score reported in Arbuckle et al. (2009) using a similar Likert scale for a survey study of agroforestry interest conducted in the same study region. Other studies have also reported a general lack of agroforestry knowledge, such as Dyer (2012) in the state of Alabama, Strong and Jacobson (2006) in Pennsylvania, and Ford et al. (2019) for silvopasture in Minnesota.

While many in our sample were unfamiliar with the term 'agroforestry,' several were familiar with individual temperate agroforestry practices when presented with images and definitions of each. Of the six temperate agroforestry practices, 57% ($n=133$) were familiar with windbreaks/shelterbelts, 31% were familiar with riparian forest buffers, 22% were familiar with forest farming, 22% were familiar with alley cropping/intercropping, 18% were familiar with silvopasture, 13% were familiar with urban food forests, and 25% reported no familiarity with any agroforestry practices.

These results first highlight a disparity among Missouri land managers in our sample. Unfamiliarity with agroforestry terminology, yet stronger familiarity with the temperate agroforestry practices themselves, indicates that Missouri land managers' familiarity and experiences with agroforestry cannot consistently be determined with ease. While many were unfamiliar with the term 'agroforestry' itself, the various practices of agroforestry were more commonly known, and research efforts and various campaigns using agroforestry-centric terminology may miss portions of the population with understanding of specific practices. Confusion of agroforestry terminology has also been reported in studies investigating agroforestry adoption in other countries (Tsonkova et al. 2018; Rois-Díaz et al. 2018; Matthews et al. 1993), suggesting this issue extends to producers beyond the United States.

Beyond familiarity, low levels of self-reported knowledge regarding agroforestry suggest a need for greater agroforestry outreach, education, and knowledge dissemination efforts across all regions of Missouri, especially as lack of access to information and technical assistance constitutes a primary barrier to agroforestry (Current et al. 2009; Strong and Jacobsen 2006; Wilson and Lovell 2016).

Perceptions of agroforestry

Table 2 presents respondent perceptions ($n=124$) regarding agroforestry practices, which were presented to respondents as statements on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). When aggregating the fifteen statements into similar groups, those within the environmental category held the highest mean scores (3.89) when compared to production (3.50) and economic (3.48) categories. The perception of agroforestry offering more environmental benefits than economic is consistent across studies in the United States, spanning agroforestry practice, region, and year of survey implementation (Ford et al. 2019; Faulkner et al. 2014; Workman et al. 2003; Ryan et al. 2003; Schrader 1995; Dearmont et al. 1983). However, these perceptions are not unfounded, as the most commonly used agroforestry practices in the United States (windbreaks and riparian forest buffers) are often designed with conservation functions as primary objectives. Likewise, many environmental benefits offered by agroforestry, such as improved soil health, pollinator habitat, and erosion reduction, all have agronomic impacts yet can be difficult to quantify.

Table 2 Perceptions of agroforestry among Missouri respondents on a 1–5 Likert scale (1 = Strongly Disagree, 3 = Neither Agree nor Disagree, 5 = Strongly Agree). ($n=124$)

"In general, agroforestry systems would…"	Mean	Standard Deviation
Environment		
Promote wildlife habitat/biodiversity	4.09	0.75
Increase resilience to extreme weather (drought, flood, intense rain, etc.)	3.75	0.85
Improve soil health	3.75	0.83
Provide scenic beauty / pleasing aesthetics	3.98	0.77
Production		
Increase crop, livestock, and/or forage production	3.36	0.79
Improve crop and/or forage quality	3.40	0.76
Increase water use efficiency	3.46	0.78
Offer recreational opportunities	3.59	0.77
Improve marginal, unproductive, or unfarmable land	3.85	0.77
Require more labor and inputs	3.57	0.81
Be difficult to manage	3.25	0.77
Economics		
Diversify products/income	3.60	0.79
Provide valuable crops/products for personal/on-farm use	3.46	0.83
Increase land value	3.46	0.82
Be costly to plant and maintain	3.40	0.81

Statements regarding agroforestry's ability to promote wildlife habitat and biodiversity and provide scenic beauty were met with strong agreement across the sample. Statements regarding agroforestry's promotion of soil health and resilience to extreme weather events were also favorably received among the sample (3.75). Increased resilience to extreme weather and improved soil health are vital ecosystem services that agroforestry systems offer, especially as climate change exacerbates already prevalent issues such as soil loss (Schoeneberger et al. 2018; Wilson and Lovell 2016; Gold and Hanover 1987). Strong agreement with these statements may indicate land manager acknowledgement of agroforestry's abilities to mitigate these larger farm and landscape issues, a trend that may hold important implications for future outreach and research endeavors.

Within management and production, participants rated the statement regarding agroforestry systems as "difficult to manage" at 3.25, the lowest rating of the fifteen statements. The low rating of the statement may suggest contention over the claim, and varying attitudes toward agroforestry's management risks by respondents.

Current and past adoption of agroforestry

Of the 133 participants who responded regarding current agroforestry adoption, 20 (15%) indicated they were currently practicing agroforestry on their land (Table 3). Respondents in this group had been practicing agroforestry for an average of 15.3 years.

In the USDA 2017 Census of Agriculture, approximately 4.4% of farms in Missouri employed agroforestry systems, a disparate finding from the portion of our sample reportedly engaging in agroforestry practices at 15%. Moreso, the 2017 Census reported percentages of Missouri farms practicing agroforestry by county. The average rate of agroforestry adoption across the 12 counties included in this survey was 1.43%, suggesting that some bias exists within our response pool. Given the disparity, it is likely that participants who were more interested, familiar, or engaged with agroforestry responded Fig.3.

Table 3 Percentage of respondents in Missouri sample practicing each temperate agroforestry practice & average number of acres established ($n = 133$)

Temperate AF Practice	% Practicing	Avg. Acres in Practice
Riparian Forest Buffers	6.8%	30.6
Alley Cropping / Intercropping	3.8%	27.4
Windbreaks	3.8%	6.7
Silvopasture	3.0%	36.3
Forest Farming	2.2%	36.6
Food Forests	0.0%	NA
Multiple Practices	6.0%	30.9

Of the 132 participants who responded to questions regarding previous agroforestry adoption, 3 (2.3%) stated that they had previously engaged with agroforestry on their land and elected to discontinue the practice(s), while eight (6%) indicated they were unsure if they had practiced and discontinued agroforestry in the past. The agroforestry systems discontinued ($n = 3$) were alley cropping/intercropping (2), silvopasture (2), riparian forest buffers (1), and forest farming (1). Two of the respondents reported discontinuing multiple agroforestry practices. Participants had each practiced agroforestry for four (1) or 20 (2) years before discontinuing. When asked to explain why they elected to stop practicing agroforestry, all respondents cited economic reasoning such as equipment costs, minimal markets for products, decreased crop yields, and little profitability. One respondent explained their economic constraints:

> *I would have liked to [have] enhanced and expanded the Riparian Buffers on my property, but it was not economically feasible to do so. There are some glade areas I would like to preserve but am unable to afford to segregate the cattle from these areas.*

Efforts were made to consider adoption as a dynamic variable throughout this survey project, asking adopters to specify the acres devoted to their agroforestry practices and affording consideration to agroforestry practices that had previously been adopted and discontinued. While some tropical studies have examined agroforestry uptake as more complex processes of trialing, adoption, discontinuation, and readoption (Kabwe et al. 2009; Kiptot et al. 2007), few temperate agroforestry studies have examined adoption as a continuous variable. Within one Canadian study examining discontinuation of silvopasture, net profit was the strongest socioeconomic determinant in their analysis of farmer discontinuation (Opio et al. 2001). Findings from Opio et al. (2001) and this

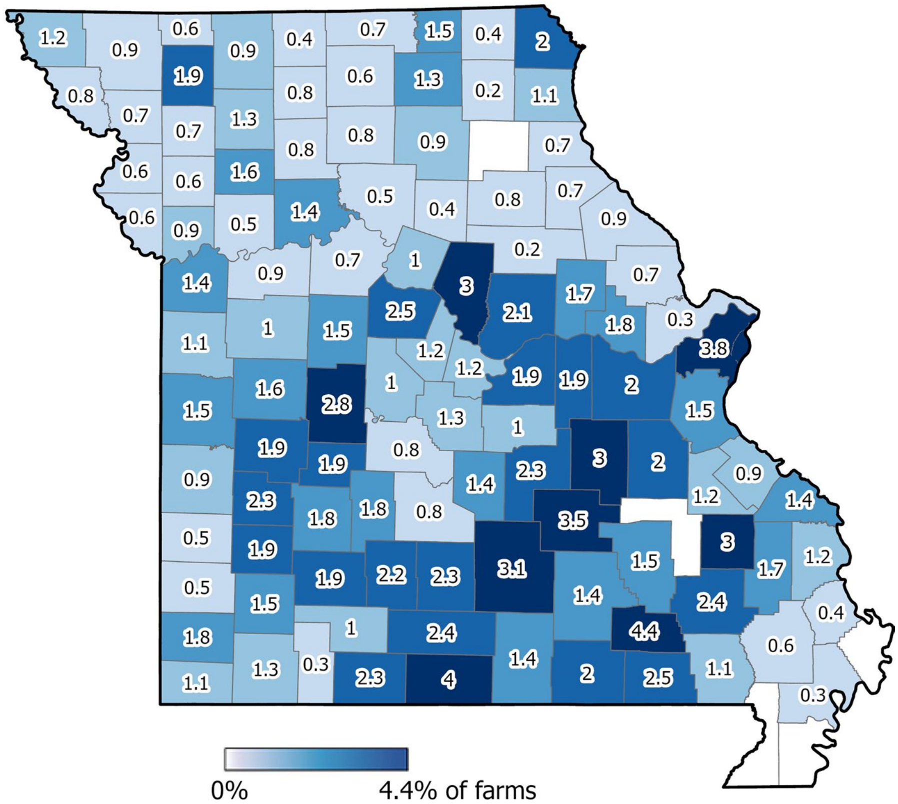

Fig. 3 Percentage of Missouri farms by county reporting use of at least one agroforestry practice in 2017 (Smith et al. 2022; USDA NASS 2017)

survey project may indicate critical importance of economic factors in long term adoption and continuation behavior.

Agroforestry adoption potential

Interest in practices

Apart from the choice experiment model, participants were asked to select all agroforestry systems that they would be interested in implementing. Participants were most interested in forest farming, with 26.3%, followed by silvopasture (21.9%), windbreaks/shelterbelts (21.2%) and riparian forest buffers (19%). Fewer respondents displayed interest in urban food forests (8.8%) and alley cropping systems (8.0%), and 46 respondents (33.6%) were not interested in any agroforestry practices. Some participants selected "other" (5.1%) and opted to explain the systems they would be interested in. Responses ranged from specific interest in chestnut trees to "food plots for wildlife" and the broader concept of "regenerative farming." However, two responses of "woodland" and "woodlot management" suggest an enduring misunderstanding of temperate agroforestry's integrated and intensive nature.

The interest among land managers in our sample towards silvopasture, windbreaks, and riparian forest buffers resembles other studies such as Arbuckle et al. (2009) in Missouri and Dyer (2012) in Alabama, who each found agricultural producers to be most interested in these three practices. The lower interest in alley cropping among our sample also mimics results from these studies. However, our respondents expressed greatest interest in forest farming, which differs from these authors' findings and could indicate a higher percentage of land managers in our sample with existing forestland.

Mixed logit model I- WTA payments for agroforestry

Results of the mixed logit model are presented in Table 4. The likelihood-ratio of Chi square test indicates the observed data is strongly compatible with our model. Estimated coefficients, standard errors, p-values and odds ratios are presented for each

Table 4 Results from Mixed Logit Regression Model I, used to estimate influence of incentive payment, technical assistance, environmental benefits on Missouri land manager agroforestry adoption willingness *(n = 1,728) Log-likelihood: −354.82; Prob > Chi^2: < 0.0001*

Variables	Coefficient	Standard Error	*p*-value	Odds Ratio
Payment	0.00067	0.0001	< 0.001	1.00067
Technical	1.11	0.35	0.002	3.03
Environment	1.99	0.40	< 0.001	7.31
ASC*	5.12	1.09	< 0.001	167.34

*Alternative Specific Constant

variable, with ASC representative of the 'neither' function or the option to not engage with agroforestry.

Results of the attribute-only model show all variables as significant at $p < 0.001$, with the exception of technical assistance which was significant at $p < 0.01$. All standard deviations for the variables have p values of < 0.001. All variables calculated have a positive value, indicating that as payment, technical assistance, and environmental benefits increase, the likelihood of selecting an agroforestry option increases.

Willingness to accept payments (WTA) were calculated using the results of the attribute-only model. When cost of establishing a given agroforestry practice is designated at $2,500 per acre, the average Missouri land manager from our sample would adopt the practice when offered a one-time payment of $7,697 per acre, a financial incentive approximately 308% of the cost of establishment. This high WTA finding is consistent with those of other agroforestry studies, such as Hagan (1996) and Kingsbury and Boggess (1999) who found that incentive payments requested by producers far exceeded establishment costs. It is possible that the land managers in our sample anticipated these future management expenses, influencing them to accept a higher incentive payment to adopt agroforestry systems.

It should be noted that many respondents in our sample elected to leave their land in its current state and not adopt agroforestry ($n = 45$). Therefore, to convince most respondents to adopt agroforestry, an incentive payment would need to be high enough to not only cover the cost of establishment, but also provide significant financial incentive beyond this amount. Many respondents were willing to adopt agroforestry practices at lesser amounts, yet this WTA estimate constitutes the average payment necessary to convince the standard participant to engage in agroforestry practices. Importantly, this WTA payment calculation also assumes null values for technical assistance and environmental benefits, which would likely hold value for most individuals.

Within the choice experiment model, we could estimate participant valuations of economic incentive payment, technical assistance, and environmental benefits. Results indicate that technical assistance was valued by our respondents at $1,670 per acre. This value suggests that, when offered a financial incentive, participants were willing to forgo $1,670 in direct payment if technical assistance, such as expert consultations and site visits, were provided. Technical assistance has been theorized by many as a crucial variable for agroforestry adoption, and the absence of expert knowledge can present a major inhibition to agroforestry success (Stutzman et al. 2019; Ford et al. 2019; Kronenberg et al. 2023). This high valuation of technical assistance by interested agroforestry practitioners indicates a strong desire for willing, knowledgeable outreach personnel.

Additionally, environmental benefits were valued at $2,992 per acre, nearly twice the dollar amount of technical assistance. This suggests that those willing to adopt agroforestry place significant value on the environmental benefits and are willing to forgo close to $3,000 per acre should those benefits be provided. This substantial appraisal from respondents may indicate opportunities and considerations for agroforestry systems to be highlighted as a strategy for providing various landscape and farm-level ecosystem services. A similar finding was reported by Davis and Rausser (2020), who conducted a willingness to accept study of silvopasture in the state of Alabama. The minimum WTA annual payment per acre decreased by 39% ($61.47 to $37.52) when ecosystem services were considered.

Given that individual agroforestry practices are unique in their establishment, management, and financial considerations, we performed regressions to estimate WTA incentive payments for individual practices and participant valuations of technical assistance and environmental benefits. Willingness to accept payments for establishing each practice varied widely, with forest farming displaying a $1,217

WTA incentive for adoption while urban food forests displayed a much higher WTA of $11,458. However, some systems like urban food forests were selected by a small number of respondents in our sample (6), and therefore these WTA payments may be skewed. Windbreaks and shelterbelts displayed the highest WTA at $19,154. Though this system was selected by more respondents, windbreaks are often implemented to protect annual crops, and respondents may have been unwilling to sacrifice their productive cropland for windbreak establishment. Notably, silvopasture displayed a negative WTA (-$3,546), suggesting that land managers might instead be willing to forgo incentive payments, instead contributing their own money to establish the practice on their site.

Various factors may inform these differing WTA amounts for agroforestry practices. For instance, the high WTA for urban food forests may be attributed to land payments and infrastructure requirements such as soil amendments, accessing city utilities, insurance, certifications, and other costs (Hemmelgarn et al. 2024; Favor et al. 2023). Additionally, the WTA of windbreaks may be high due to these systems often being established on lands with optimal soils for cultivating crops. Therefore, the payment for establishing field windbreaks must be sufficient to offset opportunity costs from removing these lands from annual crop production (Grarla et al. 2012). Similarly to windbreaks, the high WTA of riparian forest buffers may be attributed to perceived lost income from removing land from crop production. For instance, Ryan et al. (2003) and Rhodes et al. (2018) described how non-adopters of buffers were concerned with potential lost income. The WTA for forest farming may be low due to a wide continuum of management strategies, such as wild simulated methods, that require minimal investment and inputs to implement (Chamberlain et al. 2022). The negative WTA for silvopasture may be attributed to a number of factors. For instance, land managers may perceive lower establishment costs if they have suitable conditions for silvopasture, such as forages already growing in their woodlots or existing pasture suitable for tree planting. Additionally, land managers may plan to defray establishment costs by thinning trees and selling timber (Smith et al. 2022; Luhman 2021; Orefice et al. 2017).

Valuations of technical assistance and environmental benefits also varied across the practices. Respondents who selected alley cropping valued environmental benefits more highly ($5,584) than those who selected other practices, and those who selected riparian forest buffers valued technical assistance the most ($3,052) (Table 5). These variations in WTA amounts across practices suggest that further examination into the specific factors influencing adoption decisions of each practice would be novel and highly relevant.

Additionally, 6 individuals chose 'other, please specify' when asked to select a practice. Of these respondents, 3 specified promotion of wildlife habitat specifically, while others simply stated a preference to 'grow wood,' 'woodland,' 'woodlot,' further indicating a misunderstanding in the concept of temperate agroforestry systems.

We also performed regressions to explore differences in WTA among participants currently practicing agroforestry and those not currently practicing (Table 6). In our sample, current agroforestry

Table 5 Results from Mixed Logit Regressions, used to estimate influence of incentive payment, technical assistance, and environmental benefits by agroforestry practice selected in a choice experiment model

	N	Payment	Technical Assistance	Env. Benefits	ASC	WTA technical	WTA Environment	WTA asc
Alley cropping/ intercropping	9	0.0005	0.8101	2.9219	4.6025	$1,548	$5,584	$8,795
Forest farming	22	0.0009	1.4598	3.1834	1.1544	$1,539	$3,356	$1,217
Riparian forest buffers	12	0.0012	3.6127	1.7923	3.647	$3,052	$1,514	$3,080
Silvopasture	18	0.0008	1.1641	1.1729	−2.999	$1,376	$1,387	$−3,546
Urban food forests	6	0.0006	0.9672	2.7508	7.3295	$1,512	$4,300	$11,458
Windbreaks/ shelterbelts	18	0.0003	0.5080	1.2657	5.7577	$1,690	$4,210	$19,154
All practices	114*	0.0007	1.1114	1.9912	5.1228	$1,670	$2,992	$7,697

* Number of All practices not only included the listed six practices, but also individuals who selected "Other, please specify" and those who chose more than one agroforestry practice. *Notes: WTA = willingness to accept. ASC = Alternative Specific Constant*

Table 6 Results from Mixed Logit Regressions, used to estimate influence of incentive payment, technical assistance, and environmental benefits by agroforestry adoption status as adopter or non-adopter

Variables	Adopters	Non-adopters
WTA*	$1,226.81	$7,968.45
Technical	$73.89	$2,019.31
Environment	$3,446.67	$2,944.54

WTA = Willingness to accept payment

adopters would accept an incentive payment less than the $2,500 establishment cost. This suggests that they may perceive more long-term value in agroforestry systems than non-adopters or potentially less risk, which would lead to a lower incentive payment, as described in Motallebi et al. (2016). Positive experiences with their current systems may have encouraged them to accept a lower payment. Current adopters also valued technical assistance at a lower rate than non-adopters, potentially indicating that producers with prior agroforestry experience may not require as much technical assistance for establishing new systems. Additionally, current adopters valued environmental benefits more highly than non-adopters. This may suggest that land managers who have first-hand experience with the environmental benefits of agroforestry may perceive these attributes as more valuable and less risky than non-adopters.

Mixed logit model II—with interaction variables

A second mixed logit regression model was created to further explain variance in farmer willingness to engage with agroforestry practices. Interaction variables of income, age, gender, soil, farm size, urban/peri-urban, and agroforestry knowledge were included in the second model and correlated with variable ASC (unwillingness to adopt). Results of the model are presented in Table 7. The likelihood-ratio of Chi square test also indicates the suitability of this model for the observed data (p value < 0.0001).

No significant difference was observable across land managers from different regions (urban, peri-urban, rural). Furthermore, while age and gender were found insignificantly correlated with agroforestry adoption willingness, gender displayed a negative coefficient, suggesting that men were less likely to implement agroforestry than women. Age also displayed a negative coefficient, suggesting that as age increased, likelihood of selecting ‘neither—leave land in current state’ decreased, indicating an increase in older land managers’ willingness to adopt agroforestry. These findings mirror results from Stubblefield’s (2021) meta-analysis of agroforestry adoption studies, where age and gender were frequently found as insignificant variables within studies.

Agroforestry knowledge was significant ($p < 0.05$) at influencing agroforestry willingness. The significant odds ratio of 0.0014 and negative correlation of agroforestry knowledge with ASC suggests that the presence of higher agroforestry knowledge

Table 7 Results from Mixed Logit Regression Model II, used to estimate influence of income, age, gender, farm size, perceptions of agroforestry for soil health, agroforestry knowledge, and region on Missouri land manager agroforestry adoption willingness *(n = 1,728) Log-likelihood: −339.702; Prob > Chi^2: < 0.0001*

Variables	Coefficient	Standard Error	p-value	Odds Ratio
Random coefficients				
Payment	0.00006394	0.0000965	< 0.001	1.0000639
Technical	1.07	0.34	< 0.01	2.92
Environment	1.91	0.37	< 0.001	6.75
ASC	7.81	2.51	< 0.01	2465.13
AF Knowledge*ASC	−6.54	3.26	0.045	0.0014
Income*ASC	−3.84	1.74	0.027	0.0215
Farm Size*ASC	6.60	2.55	0.010	735.10
Fixed Coefficients				
Age*ASC	−6.65	1.50	0.247	0.0013
Gender*ASC	−2.35	1.86	0.205	0.0954
Soil Health*ASC	−4.74	1.70	0.005	0.0087
Urban/Peri-Urban*ASC	−0.03	1.41	0.982	0.9704

ASC = Alternative Specific Constant

significantly reduces the odds that a person would choose ‘neither—leave land in current state’ by up to 99% ($p < 0.05$). This remains consistent with the findings of Stubblefield (2021), where agroforestry knowledge was consistently significant and positively correlated with agroforestry adoption behaviors across studies.

Farm size was also significant with a p value < 0.05. The positive correlation of farm size with ASC suggests that an individual with a farm size above the mean is significantly more likely to display no willingness to adopt agroforestry than a person with a farm smaller than the mean. This contradicts most findings from Stubblefield (2021), yet most studies included in the meta-analysis were based in tropical localities, where farm size may offer land managers more flexibility to try new technologies with minimal risk. Yet, farm size may have different effects on adoption behavior in the United States. Within Missouri, land managers with bigger farms may be operating larger monoculture operations reliant on equipment and external inputs. Furthermore, these land managers may hold existing contracts to produce certain crops, and farm size may not denote the same flexibility as in other areas of the world. Notably, the odds ratio of farm size was large at 735.10, indicating that individuals with larger farms were several times less likely to engage with agroforestry than those with smaller operations. Yet, the large odds ratio may also indicate missing data points and suggest the need for further exploration of the variable. For instance, in a 2021 synthesis of windbreak adoption studies across the U.S., Smith et al. (2021) identified two survey datasets indicating larger farms as more likely to adopt windbreak systems. This may indicate that certain types of agroforestry systems are more accessible or desirable to those farming at a larger scale.

Soil health was also significant ($p < 0.005$, $OR = 0.0087$) at influencing agroforestry adoption willingness. The negative correlation of the variable with ASC suggests that a participant’s perception of agroforestry for soil health benefits significantly influences their willingness to adopt agroforestry technologies. As an individual’s perception of agroforestry for soil health becomes more positive, the more likely they are to express willingness to adopt agroforestry practices.

Income was also significant ($p < 0.05$, $OR = 0.0215$) at influencing agroforestry adoption willingness. The negative correlation of the variable to ASC suggests that as an individual’s income goes up, the less likely they are to select ‘neither—leave land in current state.’ Therefore, if a person’s income is higher than the mean, they are more likely to adopt agroforestry practices. Much as farm size affords land managers in other countries the flexibility to attempt new technologies, it is possible that income allows Missouri land managers the same flexibility to attempt agroforestry practices with reduced risk should the system prove unprofitable. Opportunity exists for further examination of this variable as it relates to agroforestry.

Conclusions & recommendations

This investigation of Missouri land managers enhances understanding of existing agroforestry plantings in the state and elucidates land manager perceptions, willingness to adopt, and factors influencing agroforestry implementation decisions. These findings highlight the obstacles and incentives agroforestry practices face within environmental, social, and financial landscapes, potentially stimulating creation of effective agroforestry research, outreach efforts, or supportive programming.

Findings from this study reveal that Missouri land managers will accept varied payment amounts for different agroforestry practices, ranging from -\$3,546/acre for silvopasture to \$19,154/acre for windbreaks. WTA payments were also much lower for those already practicing agroforestry than non-adopters. For silvopasture and forest farming, WTA payment amounts were lower than the cost of establishment (\$2,500/acre). However, for several agroforestry practices (alley cropping, urban food forests, riparian forest buffers, windbreaks/shelterbelts), Missouri land managers in our sample required considerable economic incentive beyond establishment costs to willingly adopt. Factors such as anticipated future management costs may have influenced participants to require higher payments to accept these agroforestry practices, though further investigation into these factors would provide more clarity. The high WTA payments in our investigation illustrate the importance of financial assistance programs for agroforestry beyond the establishment phase to increase adoption. However, high economic valuations of environmental benefits and technical assistance among respondents in our sample suggest willingness to trade financial incentives for other attributes. Therefore, there is value in supporting technical assistance and promoting the environmental benefits of agroforestry practices to land managers considering adoption, as this lowers their WTA to implement these systems.

Acknowledgements We would like to acknowledge Dr. Christine Spinka, University of Missouri, who assisted in mixed logit model design, statistical analysis, and interpretation, and Todd Kellerman, National Agroforestry Center, who assisted in generating figures 2 and 3. Finally, we would like to acknowledge the participants who leant their time and perspectives to help us understand the current agroforestry landscape and adoption potential in Missouri.

Author contribution K.S. designed the study, performed data collection and analysis, generated most tables and Fig. 1, and wrote the main manuscript text. Z.C. advised and assisted in study design and data analysis. Additionally, Z.C. prepared tables 5 and 6. M.S. advised on study design and prepared Figs. 2 and 3. S.L. advised on study design and data analysis. K.W. and M.H. advised on data analysis. All authors reviewed and edited the manuscript.

Funding This study was supported by National Institute of Food and Agriculture, award number 2014–68006-22041, and the Missouri Department of Agriculture, award number 00062415. This work was supported in part by the U.S. Department of Agriculture, Forest Service. The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy. This work stemmed from a chapter within a master's thesis. The provided author order is reflective of our respective contributions. The authors have no conflicts of interest to declare relevant to the content of this article. We also have no known financial or non-financial competing interests related to this manuscript.

Data availability No datasets were generated or analysed during the current study.

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