

# **Evaluating Tennessee Fruit and Vegetable Farmers' Willingness to Adopt Alley Cropping**

**A Thesis Presented for the**

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## **DEDICATION**

I dedicate my thesis to my family.

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## **ABSTRACT**

Alley cropping, which is a type of intercropping system, involves the planting of trees or shrubs alongside vegetable crops within the same production system. Alley cropping has potential benefits, including crop diversification, enhanced productivity of annual crops, reduced soil erosion, improved pollinators and wildlife habitat, decreased incidence of pests and diseases, carbon sequestration, and reduced nitrogen leaching. Despite these potential benefits, the adoption of alley cropping worldwide remains low. Consistent with this trend, according to the 2022 Ag Census of Agriculture, in Tennessee, only about 2% of the farms have used agroforestry practices, including alley cropping. This study evaluated the factors correlated with farmers' willingness to adopt alley cropping using data from a survey of Tennessee fruit and vegetable farmers and probit regressions. Regressions results suggest that risk preference, farm income, farm size, heat stress, the use of cover crops, and familiarity with alley cropping are factors significantly correlated with a survey respondents' willingness to adopt alley cropping. Findings also suggest that the type of trees or shrubs incorporated in the alley cropping systems could impact farmers' willingness to adopt this production system. The monetary compensation presented to survey respondents as a grower incentive to adopt this system was not significantly correlated with survey respondents' willingness to adopt alley cropping. These results might be useful for policymakers in designing payment or cost-share programs that properly compensate farmers for expenses and potential losses when transitioning to alley cropping, as well as for the potential environmental benefits they could provide when adopting this production system. These results might also help Extension professionals better design educational programs aiming to inform and educate fruit and vegetable farmers about alley cropping.

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## SECTION I: INTRODUCTION

Alley cropping, also referred to as intercropping, is an agroforestry<sup>1</sup> practice developed in the 1980s by the International Institute of Tropical Agriculture (IITA). This practice involves the planting of trees or shrubs alongside crops within the same production system (Adesina et al., 2000; Beer & Theuvsen, 2019; Frey et al., 2013; Garrett & Buck, 1997; Kang, 1997; Lawry et al., 1994; MacFarland, 2017; Otter & Beer, 2021; Tsonkova et al., 2018; Wilson & Lovell, 2016; Wolz & DeLucia, 2019). Specifically, trees or shrubs are planted in rows that form alleyways where companion crops, which can include various annual crops such as grains and specialty crops, are grown (MacFarland, 2017; Wilson & Lovell, 2016). Benefits of alley cropping include crop diversification, enhanced productivity of annual crops, reduced wind and soil erosion, improved pollinators and wildlife habitat, decreased incidence of pests and diseases, carbon sequestration, and reduced nitrogen leaching (Adesina et al., 2000; Beer & Theuvsen, 2020; Kang, 1997; MacFarland, 2017; Otter & Beer, 2021; Tsonkova et al., 2018; Wilson & Lovell, 2016; Wolz & DeLucia, 2019).

Despite these multiple benefits, the global adoption of alley cropping systems remains low (Beer & Theuvsen, 2020; Pattanayak et al., 2003; Wolz & DeLucia, 2019), including in the US.

According to the USDA 2022 Census of Agriculture, 32,717 farm operations in the US used alley cropping, silvopasture, forest farming, riparian forest buffers, or windbreaks (USDA, 2024), representing approximately 1.7% of all US farm operations. In Tennessee, 1,015 operations used these practices, representing 1.6% of all farm operations in the state (USDA, 2024). The USDA Census of Agriculture data, however, does not specify the number of farms exclusively using alley cropping. We suspect that a large percentage of these 1,015 farms may be using simpler agroforestry systems like silvopasture.<sup>2</sup> Factors influencing low adoption of alley cropping include the complexity of managing systems combining crops and trees, additional labor requirements, high-risk investment (i.e., high initial investment with delayed or unknown returns), lack of market mechanisms to monetize environmental benefits (e.g., carbon sequestration, reduced soil, and water erosion), and lack of information and technical assistance

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<sup>1</sup> “Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits.” (NRCS, 2024a).

<sup>2</sup> Silvopasture is the establishment or management of trees and forages on the same land unit. Some of the benefits associated with these production systems include providing forage, shade and/or shelter for livestock, reducing erosion, enhancing wildlife habitat, improving soil and water quality, and increasing carbon sequestration and storage (NRCS, 2016).

to implement this practice (Adesina et al., 2000; MacFarland, 2017; Otter & Beer, 2021; Tsonkova et al., 2018; Wilson & Lovell, 2016; Wolz & DeLucia, 2019).

The low adoption of agroforestry practices in general, and specifically alley cropping, has prompted researchers to explore the determinants of adoption and factors influencing the interest in adopting this practice (Adesina et al., 2000; Beer & Theuvsen, 2019, 2020; Borremans et al., 2016; Otter & Beer, 2021; Otter & Deutsch, 2023; Pattanayak et al., 2003). While previous studies have examined US non-operator landowners and farm operators' interest in various agroforestry practices (Arbuckle et al., 2009; Kronenberg et al., 2023; Strong & Jacobson, 2005; Valdivia et al., 2012; Valdivia & Poulos, 2009), including alley cropping, to our knowledge, there are no studies that have evaluated specifically the factors influencing US farmers' interest in adopting alley cropping.

Investigating these factors is important because of the various conservation programs that promote or provide incentives to adopt alley cropping, such as those available in some states through the USDA Natural Resource Conservation Service (NRCS) (MacFarland, 2017). In Tennessee, studying the factors correlated with alley cropping adoption is important because the Tennessee NRCS office Technical Guide does not include alley cropping in its conservation standard practices, and the Tennessee NRCS field office does not offer cost-share or incentive payments for this practice (NRCS, 2024b). For Tennessee to provide financial and/or technical assistance for alley cropping, the state must adopt it as a conservation practice standard. If the state considers there is a need to include this practice in the conservation practice standard, arguments should be presented to the state technical committee for consideration (Leslie Honicker, State Agronomist, NRCS Nashville State Office personal communication, December 14, 2023). In order to identify whether there is a need to include alley cropping in the conservation practice standard, we need to identify whether there is an interest among Tennessee growers in adopting this practice. Furthermore, the establishment of a cost-share or incentive program for the adoption of alley cropping in Tennessee requires an understanding of the cost of implementing this practice and a better understanding of the payment farmers would be willing to accept to adopt alley cropping.

Considering the potential benefits associated with adopting alley cropping and the unknown interest in adopting this practice among Tennessee farmers, this study aims to explore factors correlated with farmers' willingness to adopt alley cropping, using data from a 2024

survey of Tennessee fruit and vegetable growers and probit regressions. Additionally, considering that previous studies suggest economic incentives in the form of payments could affect alley cropping adoption (Arimi & Omoare, 2021; Borremans et al., 2016; Valdivia et al., 2012; Wilson & Lovell, 2016), this study also seeks to determine how such payments might impact adoption, and the average payment farmers would be willing to accept to implement alley cropping in Tennessee. The focus will be on the willingness of fruit and vegetable growers to adopt alley cropping, given the unique challenges associated with fruit and vegetable production, particularly their susceptibility to heat-induced stress, which can be mitigated through alley cropping (Scheelbeek et al., 2018).

## SECTION II: LITERATURE REVIEW

In this section, we reviewed previous studies related to farmer adoption or willingness to adopt agroforestry in general, and specifically alley cropping.

Previous studies have focused mainly on farmers' adoption of agroforestry systems in developing countries with tropical food production systems (Alemayehu & Simeneh, 2024; Arimi & Omoare, 2021; Kouassi et al., 2021; Pattanayak et al., 2003; Wilson & Lovell, 2016). In these countries, agroforestry has been identified as a production system that could alleviate the effects of production practices that have negatively impacted soil health and water quality, as well as help agricultural production systems become more resilient to changes related to climate change impacts.

Few studies have investigated the adoption of agroforestry in the US (Arbuckle et al., 2009; Kronenberg et al., 2023; Strong & Jacobson, 2005; Valdivia et al., 2012; Valdivia & Poulos, 2009). Only a few studies have specifically examined farmer adoption of alley-cropping systems (Adesina et al., 2000; Beer & Theuvsen, 2019, 2020; Borremans et al., 2016; Otter & Beer, 2021; Otter & Deutsch, 2023).

Given the increase in studies focusing on the factors correlated with the adoption of agroforestry systems in the 1990s and early 2000s, Pattanayak et al. (2003) conducted a meta-analysis to identify the determinants of agroforestry system adoption. According to Pattanayak et al. (2003), the increase in the number of empirical studies aiming to investigate the factors influencing agroforestry adoption decisions was motivated by the mixed results in terms of agroforestry project success across the world, where agroforestry was adopted at low rates or was abandoned after adoption. Using information from 32 studies, they grouped determinants of agroforestry adoption into five categories: farmer preferences, resource endowments, market incentives, biophysical factors, and risk and uncertainty.

Pattanayak et al.'s (2003) findings suggested that previous studies have used socioeconomic characteristics, such as age, education, and gender, as proxies of farmer preferences. Because this category was broad, they indicated it was difficult to identify a priori the positive or negative nature of the correlation between farmer preferences and the adoption of agroforestry. In contrast, resource endowments measured by land, savings, labor, and livestock were hypothesized to have a positive correlation with agroforestry adoption. Market incentives, specifically those related to changes in economic variables (e.g., prices, costs) that could impact

the net profits associated with adopting agroforestry, were hypothesized to have a positive correlation with the decision to adopt agroforestry. Biophysical factors are related to conditions that could be affected by the implementation of agroforestry. It was expected that farmers with operations that have greater slopes with high potential for erosion would be more likely to adopt agroforestry systems since one of the potential benefits of implementing these systems is erosion reduction. Finally, risk and uncertainty are related to information and experience with the production system, the long-term investments related to introducing trees in production systems, and the potential income diversification resulting from the adoption of some agroforestry systems. It was expected that factors that reduce the risk of adopting agroforestry, such as information, and farm risk reduction, such as the potential for income diversification, would positively impact the adoption of agroforestry systems.

Pattanayak et al. (2003) found that variables related to risk and uncertainty, biophysical factors, market incentives, and resource endowments were more likely to be significantly correlated with agroforestry adoption decisions compared to farmer demographic characteristics and market incentives. When looking at individual variables that were statistically significant in studies evaluating agroforestry adoption, they found assets, savings, and information provided through Extension services to be statistically significant in all studies they evaluated that included these variables in their analysis. Although age, education, and gender were commonly included as proxies of farmers' preferences in studies evaluating agroforestry adoption, only gender seemed to be significant in most studies evaluating factors correlated with agroforestry adoption decisions that included this variable. Income and labor endowments (e.g., the number of male adults in a family household) were included in a large percentage of the studies evaluated by Pattanayak et al. (2003). Income and assets were found to be significantly correlated with agroforestry adoption in a larger percentage of studies that included these variables compared to the percentage of studies that included labor endowments and found this variable to be correlated with agroforestry adoption. Although not included in many studies due to lack of information, market incentive variables such as product prices and distance to markets were found to be factors significantly correlated with agroforestry adoption. Biophysical factors, such as soil quality and slope, were included in less than half of the studies evaluated by Pattanayak et al. (2003). Nonetheless, when included, they were found to be statistically significantly correlated with agroforestry adoption, although the sign of this correlation was not

consistent across studies. For example, for soil quality as expected, some studies found that farmers with poorer soil quality were more likely to adopt agroforestry systems because of the potential soil quality benefits related to adoption. Nonetheless, some studies found a negative correlation between agroforestry adoption and soil quality. This may be related to the fact that if soil quality is very poor, investment in production systems that could marginally improve soil quality is not worth it. Finally, variables that could be directly or indirectly related to risk and uncertainty, such as land tenure, experience with tree production, and Extension and training, were included in less than half of the studies evaluated by Pattanayak et al. (2003). Since all these variables have to do with the reduction of agroforestry investment risk, they all tended to be positively and statistically significantly correlated with agroforestry adoption.

More recent studies evaluating the adoption of agroforestry systems in tropical production systems include Alemayehu and Simeneh (2024), Arimi and Omoare (2021), and Kouassi et al. (2021). Alemayehu and Simeneh (2024) evaluated the adoption of agroforestry in the central highlands of Ethiopia, and Arimi and Omoare (2021) investigated the factors that could influence Nigerian smallholder cocoa farmers' willingness to adopt agroforestry for food production, and as a climate change mitigation strategy. Kouassi et al. (2021) explored southwestern Cote d'Ivoire cocoa farmers' adoption and willingness to adopt agroforestry. All these studies used survey instruments and regression analysis, specifically logistic regressions, to evaluate the farmers' adoption or willingness to adopt agroforestry.

Alemayehu and Simeneh (2024) and Arimi and Omoare (2021) findings suggest access to information, in general, or through Extension services about agroforestry implementation and potential benefits of adopting this practice are factors that could positively impact the adoption of agroforestry. These findings are consistent with Wilson and Lovell (2016) acknowledgment of the importance of extension services and agricultural dealers in disseminating information about new agricultural technologies. Nonetheless, in the context of agroforestry, they suggest that these professionals are less likely to be trained in agroforestry production systems.

Although Arimi and Omoare (2021) found no correlation between farmer demographic characteristics and farmer willingness to adopt agroforestry systems, Alemayehu and Simeneh (2024) and Kouassi et al. (2021) found education, age, and gender as factors significantly correlated with the adoption and willingness to adopt this production system. Farmer education was related to the ability of farmers to learn and understand more complex production systems.

At the same time, gender had to do with males being more likely to consider this production system, which entails additional labor demands. Regarding age, Kouassi et al. (2021) suggested that older farmers, defined as those farmers over 40 years old, were more likely to be looking at increasing the long-term sustainability of their farm operations. Other findings from Alemayehu and Simeneh (2024) and Kouassi et al. (2021) suggested household size (as a proxy of labor availability), land tenure, and the presence of trees that provided shade on a farm were all factors that have a significant positive impact on the decision to adopt agroforestry.

Studies focusing on the adoption of agroforestry practices in the US are scarce (Arbuckle et al., 2009; Kronenberg et al., 2023; Strong & Jacobson, 2005; Valdivia et al., 2012; Valdivia & Poulos, 2009) and have focused on agroforestry in general or specific practices such as riparian buffers and forest farming. Most of the previous studies focused on the factors influencing interest in agroforestry adoption by non-operator and farm operator landowners in Missouri. Arbuckle et al. (2009), Kronenberg et al. (2023), and Valdivia and Poulos (2009) evaluated factors correlated with Missouri non-operator landowner and landowner farmers' interest in adopting various agroforestry practices using survey data and ordinary least square, one-way ANOVA analysis, and logistic regressions, respectively. Valdivia and Poulos (2009) focused on riparian buffers and forest farming, while Arbuckle et al. (2009) and Kronenberg et al. (2023) evaluated interest in adopting a comprehensive list of agroforestry practices, including silvopasture, riparian buffers, alley cropping, windbreaks, forest farming, among other agroforestry practices.

Arbuckle et al. (2009) found that among all agroforestry practices, alley cropping was the one survey respondents were least interested in adopting. Arbuckle et al. (2009) and Valdivia and Poulos (2009) found variables related to information and knowledge to be positively correlated with interest in implementing these practices, specifically the respondent's level of education, prior knowledge of agroforestry, and contact with natural resource professionals. Valdivia and Poulos (2009) and Kronenberg et al. (2023) found that age was negatively correlated with landowners' interest in adopting agroforestry. Kronenberg et al. (2023) found that survey respondents' willingness to adopt the various agroforestry systems presented to them was positively correlated with their interest in participating in conservation programs.

All studies suggested that farmer goals and motivation impacted their willingness to adopt agroforestry systems. Kronenberg et al. (2023) found that survey respondents who had

goals of conservation, recreation, education, and agrotourism were more likely to adopt agroforestry systems. Valdivia and Poulos (2009) found a positive correlation between altruistic motivations to plant trees, such as for future generations and scenic beauty, and interest in adopting agroforestry. Arbuckle et al.'s (2009) findings suggested that non-operator landowner ties with agriculture (e.g., spouse farming or prior farming experience) and financial motivations for owning the land were negatively correlated with the interest in adopting agroforestry.

Valdivia et al. (2012) and Strong and Jacobson (2005) investigated landowner perceptions of agroforestry using data from Missouri and Pennsylvania landowner surveys, respectively. Both studies used cluster analysis to classify survey respondents into various categories and evaluated differences among clusters related to demographics and perceived barriers and benefits of adopting agroforestry.

Valdivia et al. (2012) classified respondents into three categories using a K-means cluster analysis: agriculturalist, environmentalist, and disengaged. The environmentalists were more concerned about transaction costs (e.g., costs, logistics, and information related to tree establishment) than profitability related to the implementation of agroforestry. Agriculturalists had greater transaction costs and profitability concerns related to the implementation of agroforestry than the other two clusters. Finally, individuals in the disengaged cluster did not perceive any of the barriers as influential in their decisions to implement agroforestry. This study found differences in farm business characteristics, internal factors (i.e., environmental concerns, perceived benefits of planting trees), and external factors (i.e., preferred incentives for planting trees) that could support the implementation of agroforestry across these clusters.

Overall, it seems that environmentalists had more land available to implement agroforestry than the disengaged cluster. Agriculturalists and environmentalists were more concerned about soil erosion than those individuals in the disengaged cluster. Furthermore, environmentalists seemed to put greater importance on wildlife conservation and scenic beauty than the other two clusters. Additionally, environmentalists placed more importance on carbon sequestration benefits than the disengaged cluster. In terms of preference for agroforestry adoption incentives, environmentalists had a higher preference for cost-share programs compared to other groups.

In general, the agriculturalists and environmentalists' cluster shared views about transaction costs as barriers to agroforestry adoption, awareness of environmental problems, the

value they place on local community support, and the established relationship they have with public conservation and education agencies.

Findings from this study suggest that individuals in the environmentalist cluster might be more interested in agroforestry and in a better position to adopt this practice than individuals in the other two clusters. Therefore, they might be more likely to adopt agroforestry than individuals in other clusters. These results are consistent with results from Valdivia and Poulos (2009) and Kronenberg et al. (2023), suggesting that farmer conservation motivations and goals positively impacted interest in the adoption of agroforestry systems.

Strong and Jacobson (2005) investigated landowner knowledge and perception of barriers to and benefits of agroforestry adoption, as well as the potential for adopting this practice. They used interest in adopting various agroforestry practices as a variable to determine the clusters. About 90% of the survey respondents were interested in agroforestry. Similar to Arbuckle et al. (2009), Strong and Jacobson (2005) found that survey respondents were least interested in alley cropping compared to other agroforestry practices (e.g., silvopasture, windbreak, riparian buffer, patio garden).

There were four clusters identified: those more interested in timber-related practices, those interested in livestock-related practices, those interested in specialty-crop-related practices, and non-adopters. Consistent with Valdivia and Poulos (2009) and Kronenberg et al. (2023), Strong and Jacobson (2005) found that non-adopters were older than those individuals in other clusters. A large percentage of individuals interested in livestock-related practices considered farming as their main occupation when compared to other clusters. A larger percentage of those individuals in the specialty-crop-related practices cluster indicated owning less than five hectares when compared to other categories. Overall, adopters in the livestock-related and specialty-crop practices clusters provided high scores for the importance of environmental benefits related to agroforestry adoption (e.g., soil protection, improved wildlife habitat, and water quality) compared to those individuals in the timber-related practices and the non-adopter clusters. In contrast, only individuals in the livestock-related cluster who were directly receiving income from farming activities placed high importance on the economic benefits of agroforestry. With regards to barriers to adoption, costs of experimenting with agroforestry, additional management expenses, and lack of information related to where to market products received high ratings in terms of importance among individuals in all the adopter clusters.

As mentioned above, only a few studies have specifically examined farmer adoption of alley-cropping systems (Adesina et al., 2000; Beer & Theuvsen, 2019, 2020; Otter & Beer, 2021; Otter & Deutsch, 2023). Most of these studies have focused on German farmers' intentions to adopt alley cropping.

Adesina et al. (2000) used a survey of farmers located in the forest zone of southwest Cameroon and a logistic regression to evaluate factors correlated with the adoption of alley cropping in this region. They collected survey respondents' sociodemographic information, whether they have adopted alley cropping systems or not, and their perception of alley cropping farming on crop yield. They complemented this information with farmer focus group information about specific location/region characteristics related to land shortages, erosion levels, scarcity of fuelwood, and contact with extension services involved in agroforestry research or education programs. Survey results suggested that 31% of survey respondents have adopted alley cropping, while 6% have abandoned the technology due to high labor requirements, lack of information on how to manage the system, tree competition with crops, and lack of tree seeds. The number one reason for adopting alley cropping among adopters was to improve soil fertility.

Regression results suggested that the gender of the survey respondents, membership in a farmer association, contact with extension agents involved in agroforestry research and extension programs, and village fuel wood scarcity were positively correlated with the decision to adopt alley cropping. In contrast, village land pressure due to the high-density population was negatively correlated with alley cropping adoption. Similar to Alemayehu and Simeneh (2024), Arbuckle et al. (2009), Arimi and Omoare (2021), Kronenberg et al. (2023), Pattanayak et al. (2003), Valdivia and Poulos (2009), and Wilson and Lovell (2016), Adesina et al. (2000) highlighted the positive impact of information availability and technical assistance through extension agents on agroforestry adoption given the complexity of adopting a production practice that combines trees and crops in the same system. Adesina et al. (2000) suggest that the result associated with the gender variable being correlated with alley cropping adoption was an indication of differences in land tenure and wealth status between male and female farmers. Male farmers were more likely to own their land and had higher wealth than female farmers in the forest zone of southwest Cameroon. Property rights over the farmland decreased the risk of adopting a production system where benefits are not realized in the short but in the long run (Pattanayak et al., 2003). Finally, Adesina et al. (2000) findings suggested that high land pressure

in a location due to high population density negatively impacted alley cropping adoption. They suggested that in areas with high land pressure, there was less land available to plant trees, and there was a higher competition between trees and crops.

Borremans et al. (2016) investigated the perceptions of alley cropping and intentions to adopt this practice among farmers in Flanders, the northern region of Belgium. The Flemish government recognized agroforestry as a practice that meets the requirements of the Greening European Common Agricultural Policy (CAP). Greening requirements under CAP require that farmers with more than 15 hectares of arable land have 5% of their arable land managed as an ecological focus area (EFA) or is managed using specific conservation practices defined by each EU member (Beer & Theuvsen, 2019, 2020; Otter & Beer, 2021). Furthermore, they included agroforestry as a management practice qualified for a subsidy that covers up to 80% of the tree planting cost if some requirements are met (e.g., a minimum area in trees of 0.5 ha, tree density, maintenance of trees for at least ten years). Regardless of this subsidy program to incentivize the adoption of agroforestry, the adoption of agroforestry practices was low among Flemish farmers. Using data from a farmer survey and logistic regression, Borremans et al. (2016) investigated the factors influencing farmers' intention to adopt alley cropping. The variables included in the regression model were developed using the theory of planned behavior (TPB) conceptual framework. This framework hypothesizes that intentions are determined by an individual's attitudes toward a behavior, subjective norms (i.e., the influence of others in engaging in a behavior), and behavioral control (i.e., individuals' beliefs about their capacity to perform a behavior).

Regression results suggested that subjective norms and perceived control are significantly correlated with the survey respondents' intentions to adopt alley cropping. Other survey results indicated that survey respondents see challenges related to the adoption of alley cropping, specifically related to tree excessive shade that could result in crop yield and quality loss, shortage of agricultural land, and current agricultural practices that are mechanized and intensive, and may not align with this practice. Overall, survey respondents perceived some social (i.e., landscape value) and environmental (e.g., reduced erosion, increased biodiversity) benefits related to alley cropping adoption. In contrast, they did not see any economic benefits related to the adoption of alley cropping. Regarding respondents' opinions about the subsidy to implement alley cropping and agroforestry in general, there was an even distribution among

responses, with some thinking the incentive did not make sense and others thinking it was decisive for adoption. Borremans et al. (2016) suggest that the agroforestry subsidy in Flanders was criticized by farmers because it does not cover tree maintenance costs. They indicated that future research should focus on cost-benefit research that could result in a more effective subsidy program that could address investment, potential crop losses, tree maintenance costs, and potential environmental services offered by the farmers when adopting agroforestry practices.

Beer and Theuvsen (2019), Beer and Theuvsen (2020), Otter and Beer (2021), and Otter and Deutsch (2023) investigated German farmers' intentions to adopt agroforestry systems under CAP, which in Germany recognized the trees involved in the alley cropping systems as an element that will meet greening requirements. Beer and Theuvsen (2019), Beer and Theuvsen (2020), and Otter and Beer (2021) used data from a 2017 online survey of conventional German farmers, and Otter and Deutsch (2023) used a survey of conventional German farmers conducted between 2019 and 2020 to investigate German farmers intentions to adopt alley cropping. Both surveys aimed to evaluate farmers' perceptions of alley cropping under CAP and factors that could impact farmer acceptance of this practice as an EFA. Organic farmers were not included in the surveys, given that they do not need to comply with greening requirements under CAP.

Beer and Theuvsen (2019) used hierarchical cluster analysis to classify survey respondents into various clusters depending on their attitudes toward alley-cropping systems. Additionally, they used a one-way ANOVA analysis and Tamhane's T2 or Scheffè's post-hoc comparisons to identify significant differences among cluster groups. The cluster analysis identified four groups. Cluster A, "potential ACS-growers with public awareness", are individuals with no clear intentions to adopt alley cropping but who recognize the benefits of adopting this system and believe the public will recognize these benefits. Cluster B, "potential ACS-growers with advantage awareness", are those who also have no clear plan to adopt the system but would be open to adopting if there was a better political framework for adoption (i.e., higher weight of this practice as an EPA), and also recognize the benefits of alley cropping but believe the public would not recognize all the benefits of the system. Cluster C, "skeptical ACS rejecters", were individuals with the lowest adoption intentions, who were also skeptical about public perceptions and believed the public is only aware of the biodiversity benefits associated with this system. Finally, cluster D, "convinced ACS rejecters", are individuals who reject the

idea of alley cropping systems, do not recognize any benefits to adopting alley cropping, and believe the public is not aware of any benefits associated with this practice.

Results from the one-way ANOVA analysis and Tamhane's T2 or Scheffè's post-hoc comparisons suggested that those individuals in one of the two willing to adopt alley cropping clusters (clusters A) had more experience with trees or agricultural woods and had a higher percentage of their arable land on perennial crops than individuals in the not willing to adopt clusters (clusters C and D). Additionally, the share of total arable land on livestock was higher among individuals in one of the not willing to adopt clusters (cluster C) compared to cluster A. Finally, results suggested that farm location could impact farmers' intention to adopt alley cropping. In general, this study suggested that previous experience with tree planting and the type of crops grown on the farm could be significantly correlated with German farmers' willingness to adopt alley cropping.

Beer and Theuvsen (2020) used multiple linear regression to evaluate factors correlated with German farmers' intention to adopt alley cropping systems. Variables capturing farmer beliefs about the benefits of alley cropping (e.g., reducing risk through crop diversification, reduced erosion risk, improved biodiversity, opportunity to comply with CAP requirements) and social acceptance of the implementation of this system by others (e.g., family, spouse) were positively correlated with survey respondents' intentions to adopt alley cropping systems. In contrast, farmer levels of education, specifically lower levels of professional education, and annual volume of precipitation were negatively correlated with respondents' willingness to adopt alley cropping. The results related to farmer education are consistent with Alemayehu and Simeneh (2024) and Kouassi et al. (2021) results that suggested more educated farmers were more likely to understand and adopt more complex production systems such as agroforestry. The precipitation result is consistent with findings from Beer and Theuvsen (2019) that suggested location characteristics, in this case, differences in the level of precipitation by location, could impact German farmers' willingness to adopt alley cropping.

Similarly to Borremans et al. (2016), Otter and Beer (2021) used the Theory of Reasoned Action as a conceptual framework to investigate factors influencing German farmers' intentions to adopt alley cropping. They used data from the 2017 survey of German farmers and partial least squares to determine factors influencing survey respondents' intentions to adopt alley cropping and adoption behavior. They concluded that the perceived usefulness of alley cropping

influences intentions to adopt alley cropping, and these intentions are correlated with adoption behavior. Results indicated that survey respondents' perceived usefulness of alley cropping was negatively and significantly influenced by some location characteristics, specifically annual rainfall and soil quality, as well as perceived costs of implementing alley cropping (e.g., initial plantation costs). Like Borremans et al. (2016), Otter and Beer's (2021) findings suggested that subjective norms positively and significantly influenced perceived usefulness and, therefore, intentions to adopt alley cropping as EFA. Additionally, results suggested that respondents' beliefs of alley cropping positive effects on environmental sustainability, such as reduced erosion and increased biodiversity, positively and significantly influence perceived usefulness and, therefore, farmers' intentions to adopt alley cropping. Finally, the perception of alley cropping as a non-mandatory or optional practice that farmers could adopt to fulfill the greening requirement under CAP was found to be positively correlated with the adoption of alley cropping.

Otter and Deutsch (2023) complement findings from previous work by Beer and Theuvsen (2019), Beer and Theuvsen (2020), and Otter and Beer (2021) by investigating German farmers' expectations of economic benefits from planting alley cropping. Survey respondents were asked about their preferred sources of alley cropping economic benefits, including government subsidies for the implementation of this practice, the sale or on-farm use of wood chips, and the production of high-quality timber after an extended growth period. Survey respondents' preferred source of economic benefits was government subsidies, followed by the sales or on-farm use of wood chips. Only a third of the survey respondents selected the production of high-quality timber. Survey respondents were asked about their desired levels for a one-time installation subsidy and an additional yearly subsidy for alley cropping maintenance with an open-ended question to avoid biased responses. The average one-time installation subsidy preferred by the survey respondents was estimated at €2718 per hectare, while the average yearly maintenance preferred subsidy level was estimated at €512 per hectare.

### SECTION III: CONCEPTUAL FRAMEWORK

Previous studies (Davis & Rausser, 2020; Opdenbosch & Hansson, 2023) used an indirect utility function to describe a farmer's decision-making process related to the adoption of silvopasture, a specific agroforestry system. Similar to Opdenbosch and Hansson (2023), we assumed the farmers' indirect utility function is defined as:

$$(1) \quad V(I(l), E(l), \mathbf{x}),$$

where  $l$  defines farmer's land use;  $I(l)$  is farmers' income, which includes all income sources, including monetary benefits from land use;  $E(l)$  represents environmental benefits associated with the use of the land, and  $\mathbf{x}$  is a vector that accounts for farmer and farm business characteristics and other factors that capture or affect farmer preferences related to the adoption of alley cropping.

We assume the adoption of alley cropping implies a change in land use from the current agricultural production system ( $l_{no-ac}$ ) to alley cropping ( $l_{ac}$ ), where  $no - ac$  represents the use of the current agricultural practice and  $ac$  represents the use of alley cropping. Additionally, we assume going from no alley cropping to an alley cropping system will change farm income from  $I(l_{no-ac})$  to  $I(l_{ac})$ . We assume that adopting alley cropping, at least in the short run, will imply a decrease in farm income from taking some land out of production to plant trees and adding costs related to planting trees and maintaining them. Therefore, we assume  $\Delta I = I(l_{ac}) - I(l_{no-ac}) \leq 0$  is the income loss from adopting alley cropping. We also assume there will not be changes in the environmental benefits received from the production systems used by the farmer ( $E(l_{no-ac})$ ) and those received from adopting alley cropping ( $E(l_{ac})$ ) in the short run. As mentioned in the introduction section, some of the environmental benefits from alley cropping are reduced soil erosion, improved habitats for pollinators and wildlife, decreased incidence of pests and diseases, carbon sequestration, and reduced nitrogen leaching. These benefits might not be realized in the short but rather in the long run. Given the assumption presented above, we assume a farmer will need to be compensated by an amount they are willing to accept ( $WTA$ ) in order to stay at the same level of utility after adopting alley cropping. This can be represented as,

$$(2) \quad V_0(I(l_{no-ac}), E(l_{no-ac}), \mathbf{x}) = V_0(I(l_{ac}) + WTA, E(l_{ac}), \mathbf{x}),$$

where  $WTA$  is the minimum compensation a farmer will be willing to accept for switching from their current production system to alley cropping in order to stay at the level of utility ( $V_0(\cdot)$ ) they were before adopting alley cropping.

In this study, we first asked survey respondents if they were willing to adopt alley cropping in general without providing any payment or economic incentive for adoption. If no compensation is provided, the farmer will only adopt alley cropping if the utility of adopting alley cropping is higher or equal to the utility of not adopting alley cropping,

$$(3) \quad d_0 = V_1(I(l_{ac}), E(l_{ac}), \mathbf{x}) - V_0(I(l_{no-ac}), E(l_{no-ac}), \mathbf{x}) \geq 0,$$

where  $V_1$  is the level of utility from adopting alley cropping when no compensation is provided. This condition could be met when the environmental benefits from adopting alley cropping are high enough to compensate for income losses in the short run. In the long run, there may not be income losses, especially if a farmer incorporates fruit and nut trees in the system that generate additional income for the farm business.

We also presented survey respondents with a payment level they would receive from adopting alley cropping and asked them to indicate whether they would be willing to adopt it, given the payment/compensation offer.

A farmer will be willing to adopt alley cropping if,

$$(4) \quad d_1 = V_2(I(l_{ac}) + WTA_k, E(l_{ac}), \mathbf{x}) - V_0(I(l_{no-ac}), E(l_{no-ac}), \mathbf{x}) \geq 0,$$

where  $WTA_k$  is the compensation level offered at level  $k$  (i.e., dollar value of the compensation). Equation (4) implies that a farmer will be willing to adopt alley cropping if the level of compensation is high enough to leave them at the same level of utility ( $V_0(\cdot)$ ) or a higher level of utility from where they are using their current production system.

We do not observe  $d_0$  or  $d_1$ , but we do observe whether farmers are willing to adopt alley cropping in general or at a specific compensation level ( $k$ ),

$$(5) \quad y_{ac0} = \begin{cases} 1 & \text{if } d_0 \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

$$(6) \quad y_{ac1} = \begin{cases} 1 & \text{if } d_1 \geq 0 \\ 0 & \text{otherwise} \end{cases}.$$

Both  $d_0$  and  $d_1$  are latent variables capturing the underlying differences in indirect utilities driving the decision to be willing to adopt alley cropping. In equation (5)  $y_{ac0}$  takes the value of 1 if the farmer says yes to the question “Would you be willing to use alley cropping?” and zero otherwise. In equation (6)  $y_{ac1}$  takes the value of 1 if the farmer says yes to the question “Would you be willing to adopt alley cropping if you receive a one-time payment of  $WTA_k$  per acre for adopting it?” and zero otherwise. These are the dependent variables that will be used in

the regression models evaluating the factors correlated with farmers' willingness to adopt alley cropping when compensation is provided and when no compensation is provided.

## SECTION IV: DATA

### *Survey*

We used data from a survey of Tennessee fruit and vegetable growers conducted between January and June of 2024. The main objective of this survey was to evaluate the factors influencing fruit and vegetable growers' willingness to adopt alley cropping and the average payment they are willing to accept to adopt this system. We targeted farmers who produced fruit and/or vegetables in open fields for sale in 2023. The survey instrument was tested by an extension specialist and a farmer before distributing the survey to check for clarity of the questions included in the survey. The survey instrument was approved by the University of Tennessee Institutional Review Board (UTK IRB-24-07960-XM). The Tennessee Department of Agriculture provided us with a contact list of farmers affiliated with the Pick Tennessee Products program, a program that assists Tennessee farmers in marketing their products, and the Tennessee Ag Enhancement program, a program that provides cost-share for farm improvements. From these two sources, we obtained a contact list of 879 Tennessee fruit and vegetable farmers.

The survey employed a mixed-mode approach, incorporating both mail (paper) and web versions of the survey instrument. The web version of the survey was sent on February 6, 2024, to 838 Tennessee farmers for whom we have email addresses. Reminder emails were sent on February 19. We sent the paper version of the survey to the 41 farmers for whom we did not have an email address and to those who did not respond to the web version of the survey by March 1, 2024. The follow-up surveys and reminders were sent on March 25 and March 31, respectively. Both the web and paper versions of the survey contained the same questions. We advertised the survey at the Pick TN Products Conference on February 16, 2024. We let conference attendees fill out the paper version and deposit it anonymously in boxes we placed at a booth. We also publicized the survey through social media platforms, such as Facebook, and a Tennessee farmer listserv managed by the University of Tennessee Vegetable Extension Program.

The survey included 30 to 36 questions, varying based on respondents' answers, which directed them to different sections of the survey. Approximately 75% of the questions were multiple-choice. Respondents could complete the survey in approximately 20 minutes.

The survey instrument included ten sections. The survey started with an introductory section that explained its purpose and screened out respondents under 18 and those who did not grow fruits and vegetables in the open field in 2023. In the second section, we asked respondents questions about crops grown and specific production challenges farmers faced, like low organic matter and heat stress. In the third section, we asked respondents to indicate their familiarity with alley cropping and their overall willingness to adopt alley cropping systems.

In the fourth section of the survey, we asked respondents whether they would be willing to adopt alley cropping under a specific system scenario (i.e., black locust with vegetable production), including payment or compensation for adoption. We describe this system below in the contingent valuation approach section. In this section, we also asked respondents to state their reasons for being willing or unwilling to adopt this specific scenario. For those who indicated they were willing to adopt it, we asked them how many acres or row-ft they would be willing to use to implement the black locust alley cropping scenario.

In the fifth section, we asked respondents whether they had previously used an alley cropping system. For those who indicated their previous use of alley cropping, we asked them about the types of trees or shrubs they used, the time period of implementation, and how many acres or row-ft they used for alley cropping. We also asked respondents to select the benefits they had experienced from the use of alley cropping. Respondents who had never used alley cropping were asked to proceed to the next section.

In the sixth section, we asked respondents about their production practices related to irrigation, mulch, crop rotation, and cover crops. In the seventh section, we asked respondents about their use of information sources, including university extension, consultants, other farmers, and online sources.

In sections eight to ten, we asked respondents about their farm operations and demographic information, including acres in production, percentage of acres owned, number of farm workers, farm income, household income from farming, age, education, and risk preferences.

From the initial recipients' list, eight respondents stated they did not grow fruit and vegetables, one respondent reported operating a hydroponic system, one mentioned growing crops indoors, one operation indicated having only greenhouses, and two respondents indicated that their operation might be too small to add any value to the survey. Out of 879 survey

recipients, 216 completed the survey, 124 completed the web version, and 92 completed the mail version of the survey, for a 25% response rate. A copy of the paper-version survey instrument is included in the Appendix section.

### ***Assessment of Respondents' Willingness to Adopt Alley Cropping***

We assessed farmers' willingness to adopt alley cropping in two sections of the survey. In the first section, we explained the definition of alley cropping and its potential benefits, then asked respondents if they were willing to adopt this system:

“Alley cropping is an agroforestry practice where agricultural or horticultural crops are grown in the alleyways between widely spaced rows of woody plants. Specifically, alley cropping is defined as the planting of rows of trees and/or shrubs to create alleys within which agricultural or horticultural crops are produced. The trees may include valuable hardwood veneer or lumber species; fruit, nut, or other specialty crop trees/shrubs; legume trees for nitrogen fixation; or desirable softwood species for wood fiber production. Alley cropping can diversify farm income, increase crop production, improve landscape aesthetics, enhance wildlife habitat, and provide crop protection and conservation benefits. Alley cropping provides specific benefits such as reducing water surface runoff and soil erosion, improving utilization and reducing offsite movement of nutrients, modifying the microclimate for improved crop production, providing habitat for wildlife and beneficial insects, and increasing carbon storage.”

After explaining alley cropping, we asked respondents whether they would adopt the system. Respondents answered by selecting one of three options: 1) Yes, 2) No, or 3) I don't know.

In the second section, we provided the respondents with information about a specific alley cropping system that includes black locust trees (*Robinia pseudoacacia*) and vegetable production in alleys. We evaluated this system in a field study at the University of Tennessee Organic Crops Unit, that complements the 2024 Tennessee fruit and vegetable survey described above. We chose this system because it is versatile and resilient to different environmental conditions, and provides key ecosystem services, such as crop microclimate improvement, and

adds nitrogen to the soil through biological fixation. We provided information related to the costs associated with implementing this system:

“The cost per tree will be \$1.09, which implies a total tree cost of \$270 per acre. There will be other costs associated with establishing the system, such as planting costs. The planting costs are estimated at \$119 per acre. Therefore, total costs associated with planting the trees, including tree costs, are estimated at \$390 per acre. There could be income loss from taking part of the land out of production to plant trees. Future costs include pruning of trees and other maintenance costs. You will grow vegetable crops in the alleys. Black locust will not provide income in the short to medium term, but it is a woody legume species that provides shade while allowing sufficient light to be transmitted to the crops in alleys and a high nitrogen fixation rate that could potentially reduce fertilizer use.”

We also provided further information about the benefits of adopting this production system. Then, we asked respondents if they would be willing to adopt this specific alley cropping scenario if they received a one-time payment for adopting it. Similar to the previous question, survey respondents could select any of the following options: 1) Yes, 2) No, and 3) I do not know.

As mentioned in the literature review section, previous studies suggest that economic incentives (e.g., payments, cost-share programs) positively influence the adoption of agroforestry practices like alley cropping (Arimi & Omoare, 2021; Borremans et al., 2016; Valdivia et al., 2012; Wilson & Lovell, 2016). Based on these findings, we assessed respondents’ willingness to adopt this specific alley cropping system at various payment levels. There were four different versions of the survey based on the payment levels: 1) \$270/acre one-time payment; 2) \$330/acre one-time payment; 3) \$390/acre one-time payment; and 4) \$450/acre one-time payment. The four versions of the survey were randomly assigned among respondents.

We developed the payment scenarios by estimating planting costs, including the costs of the trees, for the black locust trees and vegetable alley cropping system presented to respondents. For the black locust tree costs, we used published prices for bare-root planting stock from a US nursery where the University of Tennessee purchased black locust trees for its alley cropping field trial at the University of Tennessee Organic Crops Unit. We estimated planting costs using

data from the 2023 NRCS practice scenarios documentation for Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin. These documents provide details of the planting cost for alley cropping (NRCS practice 311) in states where it is a recognized conservation practice. The \$270/acre payment scenario covers only the cost of trees. The \$330/acre payment scenario includes the cost of trees and half the planting cost. The \$390/acre payment scenario covers both tree and planting costs. Finally, the \$450/acre payment scenario covers tree and planting costs and compensates farmers for potential income losses associated with the adoption of the black locust scenario. We estimated this maximum payment using the average payment per tree (bare-root planting stock) offered by NRCS in Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin in fiscal year 2023.

## SECTION V: ESTIMATION METHODS

### *Probit Regression*

We used two probit regressions to assess the factors correlated with farmers' willingness to adopt alley cropping, in general, and the black locust alley cropping scenario when compensation or payment is offered for adoption.

The first probit regression examines the factors correlated with farmers' willingness to adopt alley cropping when no compensation or payment is provided for adoption. The second probit regression evaluates the factors correlated with farmers' willingness to adopt a black locust-vegetable production alley cropping system when compensation for adoption is provided. The variables  $d_0$  and  $d_1$  presented in equations (3) and (4) are a function of observable and unobservable variables and can be described as,

$$(7) \quad d_0 = x_0 \beta_0 + \varepsilon_0 ,$$

$$(8) \quad d_1 = x_1 \beta_1 + \varepsilon_1 ,$$

where  $x_0$  is a vector of observable variables such as farmer and farm business characteristics, familiarity with alley cropping, production practices used (e.g., cover crops), and risk preferences;  $x_1$  includes some of the abovementioned variables and compensation for adopting alley cropping at level  $k$ ;  $\beta_0$  is a vector of coefficients capturing the correlation between  $x_0$  and  $d_0$ . Similarly,  $\beta_1$  is a vector of coefficients capturing the correlation between  $x_1$  and  $d_1$ ; and  $\varepsilon_0$  and  $\varepsilon_1$  are the random disturbance terms for each of the regression models.

Following Greene (2012), the probability that farmers will be willing to adopt alley cropping, in general, or an alley cropping black locust system is defined as:

$$(9) \quad \begin{aligned} P(y_{ac0} = 1|x_0) &= P(d_0 > 0|x_0) \\ &= P(x_0 \beta_0 + \varepsilon_0 > 0|x_0) \\ &= P(\varepsilon_0 > -x_0 \beta_0|x_0) \\ &= P(-\varepsilon_0 < x_0 \beta_0|x_0) \end{aligned}$$

$$(10) \quad \begin{aligned} P(y_{ac1} = 1|x_1) &= P(d_1 > 0|x_1) \\ &= P(x_1 \beta_1 + \varepsilon_1 > 0|x_1) \\ &= P(\varepsilon_1 > -x_1 \beta_1|x_1) \\ &= P(-\varepsilon_1 < x_1 \beta_1|x_1) \end{aligned}$$

Assuming the error terms ( $\varepsilon_0, \varepsilon_1$ ) are normally distributed, the probability of farmers' willingness to adopt alley cropping or the alley cropping black locust scenario is captured by the cumulative distribution of the standard normal distribution,

$$(11) \quad P(y_{ac0} = 1|x_0) = P(-\varepsilon_0 < x_0 \beta_0 | x_0) = \Phi(x_0 \beta_0)$$

$$(12) \quad P(y_{ac1} = 1|x_1) = P(-\varepsilon_1 < x_1 \beta_1 | x_1) = \Phi(x_1 \beta_1),$$

where,  $\Phi$  is the standard normal cumulative distribution function.

We used the maximum likelihood method to estimate the probit regressions. The log-likelihood function associated with the estimated regression models can be described as (Greene, 2012),

$$(13) \quad \ln L = \sum_{y_{ac0}=0} \ln[1 - \Phi(x_0 \beta_0)] + \sum_{y_{ac0}=1} \ln \Phi(x_0 \beta_0)$$

$$(14) \quad \ln L = \sum_{y_{ac1}=0} \ln[1 - \Phi(x_1 \beta_1)] + \sum_{y_{ac1}=1} \ln \Phi(x_1 \beta_1).$$

The derivatives of the log-likelihood functions with respect to  $\beta_0$  and  $\beta_1$  are defined as,

$$(15) \quad \frac{\partial \ln L}{\partial \beta_0} = \sum_{y_{ac0}=0} \frac{-\phi}{1-\Phi} x_0 + \sum_{y_{ac0}=1} \frac{\phi}{\Phi} x_0$$

$$(16) \quad \frac{\partial \ln L}{\partial \beta_0} = \sum_{i=1}^n \left[ \frac{q_{i0} \phi(q_{i0} x_0 \beta_0)}{\Phi(x_0 \beta_0)} \right]$$

$$(17) \quad \frac{\partial \ln L}{\partial \beta_1} = \sum_{y_{ac0}=0} \frac{-\phi}{1-\Phi} x_1 + \sum_{y_{ac0}=1} \frac{\phi}{\Phi} x_1$$

$$(18) \quad \frac{\partial \ln L}{\partial \beta_1} = \sum_{i=1}^n \left[ \frac{q_{i1} \phi(q_{i1} x_1 \beta_1)}{\Phi(x_1 \beta_1)} \right]$$

where  $\phi$  is the standard normal probability density function,  $i$  indicates respondents'  $i$  response,  $q_{i0} = 2y_{ac0i} - 1$ , and  $q_{i1} = 2y_{ac1i} - 1$ .

### ***Marginal Effects of Continuous and Discrete Independent Variables***

The marginal effect of a continuous explanatory variable  $x_p$  is calculated as follows,

$$(19) \quad \frac{\partial P(y_{ac0}=1|x_0)}{\partial x_p} = \frac{\partial \Phi(x_0 \beta_0)}{\partial x_p} = \phi(x_0 \beta_0) \beta_p,$$

where,  $\phi(x_0 \beta_0)$  is the probability density function of the standard normal distribution evaluated at  $x_0 \beta_0$ . For a binary independent variable ( $x_b$ ), the marginal effect is calculated as,

$$(20) \quad Prob[y_{ac0} = 1 | \bar{x}_{(x-b)}, x_b = 1] - Prob[y_{ac0} = 1 | \bar{x}_{(x-b)}, x_b = 0],$$

where  $\bar{x}_{(x-b)}$  are the means of all the variables included in the model, excluding  $x_b$

(Greene, 2012).

### ***Diagnostic Test***

Multicollinearity can distort results associated with the significance of the independent variables' coefficients by inflating their estimated variances (Greene, 2012). We used the condition index to evaluate multicollinearity in the probit regressions (Belsley et al., 1980). Condition index values between 30 and 100 are suggested to indicate moderate to strong multicollinearity problems (Belsley et al., 1980).

To address the potential heteroskedasticity, we used heteroskedasticity-robust standard errors using the Huber-White sandwich estimator (StataCorp, 2023).

The robust variance estimator is defined as follows,

$$(14) \quad V(\hat{\beta}) = (X'X)^{-1}X'\hat{D}X(X'X)^{-1},$$

where  $X$  is the matrix of the independent variables, and  $\hat{D}$  is the diagonal matrix of the squared errors.

We used the Akaike Information Criteria (AIC) to compare various regressions and select the one that best fitted the data and minimized complexity (i.e., the number of variables). The AIC is defined as,

$$(15) \quad AIC = -2\ln L + 2k,$$

where  $\ln L$  is the maximized log-likelihood of the estimated probit regression, and  $k$  is the number of estimated parameters (StataCorp, 2023).

We used the Wald test (StataCorp, 2023) to measure the overall significance of each probit regression. This test evaluates the null hypothesis that all estimated coefficients are equal to zero,

$$(16) \quad H_0: \beta_0 = \beta_1 = \dots = \beta_k = 0.$$

The alternative hypothesis is that at least one of the coefficients is significantly different than zero.

### ***Hypotheses for Explanatory Variables***

In this section, we discuss the independent variables we included in the probit regressions. Hypotheses about the correlation between these variables and survey respondents' willingness to adopt alley cropping are based on previous literature findings and arguments previous studies used for the inclusion of specific variables in the evaluation of factors correlated with agroforestry adoption or interest in agroforestry adoption in general and alley cropping systems, specifically.

We expect that farmer demographic characteristics would be correlated with farmers' willingness to adopt alley cropping. Farmer age and education were included in previous studies as potential determinants of agroforestry practices adoption, including alley cropping (Adesina et al., 2000; Alemayehu & Simeneh, 2024; Arbuckle et al., 2009; Arimi & Omoare, 2021; Beer & Theuvsen, 2020; Kouassi et al., 2021; Kronenberg et al., 2023; Pattanayak et al., 2003; Valdivia & Poulos, 2009).

We assume older farmers would be less likely to be willing to adopt alley cropping because of the long period before the potential benefits of adopting alley cropping could be realized. Older farmers have a shorter planning horizon, and they might be less likely to invest money and time in a practice from which they might not be able to see the benefits during their lifetime (Adesina et al., 2000; Kronenberg et al., 2023).

We hypothesized that farmers with a higher level of education (i.e., bachelor's or graduate degrees) would be more willing to adopt alley cropping than farmers with lower levels of education. More educated farmers might be able to better understand more complex production systems, like alley cropping, and timing and returns from investment. They might also have a better understanding of climate change impacts and how alley cropping could help mitigate these impacts on their farms (Alemayehu & Simeneh, 2024; Arimi & Omoare, 2021; Beer & Theuvsen, 2020).

We also expect that farm business characteristics will be correlated with farmers' willingness to adopt alley cropping. We divided farm business characteristics into two categories: biophysical characteristics of the farm (i.e., erosion and heat stress) and size characteristics measured in terms of farm size in acres, number of farm workers, and gross income generated from farming activities.

We assumed that farmers who perceive erosion and heat stress to be problems on their farms would be more likely to be interested in adopting alley cropping. Similar to Valdivia and Poulos (2009) and Adesina et al. (2000), we assumed that farmers who perceive there is a problem on their land, specifically an erosion or heat-stress problem, might be more likely to consider the adoption of a practice (i.e., alley cropping) that could alleviate these problems. As suggested by Beer and Theuvsen (2020), location could also be a proxy of farm biophysical characteristics (e.g., soil conditions). We assumed that farms with better location conditions would be less likely to be willing to adopt alley cropping (Beer & Theuvsen, 2020).

Alemayehu and Simeneh (2024) found a positive correlation between landholding size and the adoption of agroforestry practices. They suggested that farmers with larger farms would be more likely to have land available to implement agroforestry systems. Therefore, we assumed a positive correlation between farm size in terms of acres and farmers' willingness to adopt alley cropping.

Alemayehu and Simeneh (2024) and Adesina et al. (2000) found a positive correlation between labor availability, measured by household size, and farmers' decisions to adopt agroforestry. Given the additional labor requirements related to the adoption of alley cropping, specifically those related to tree planting and maintenance, we expect that labor availability, measured by the number of farm workers in a farm business, would be positively correlated with farmers' willingness to adopt alley cropping.

Beer and Theuvsen (2020) hypothesized that a better economic position of the farm would have a positive effect on investment behavior, specifically investment associated with alley cropping implementation. Therefore, we assumed that gross farm income, as a proxy of the economic position of a farm business, would be positively correlated with farmers' willingness to adopt alley cropping.

We hypothesized that variables related to farmer risk preferences and uncertainty of adoption would be correlated with farmers' willingness to adopt alley cropping (Pattanayak et al., 2003). We hypothesized that because of the high upfront investment and the long period before benefits are realized, more risk-averse individuals would be less likely to be willing to adopt alley cropping (Adesina et al., 2000; Beer & Theuvsen, 2020; Otter & Beer, 2021; Otter & Deutsch, 2023). Beer and Theuvsen (2020) assumed that more risk-averse farmers might have a more defensive behavior toward investing in a new production practice.

We also hypothesized that variables related to familiarity with alley cropping could reduce the risk and uncertainty of adopting alley cropping. Therefore, we assumed that variables associated with familiarity with alley cropping would be positively correlated with farmers' willingness to adopt this practice. Arimi and Omoare (2021) suggested that information about the potential benefits of adopting alley cropping, for example, those benefits related to carbon sequestration, could positively impact farmers' willingness to adopt agroforestry systems.

We also assumed that motivations for farming would be correlated with farmers' willingness to adopt alley cropping. Kronenberg et al. (2023) and Arbuckle et al. (2009) found

that farmers or landowners who expressed conservation as an important goal or who had environmental motivations for owning the land were more likely to adopt or be interested in adopting agroforestry systems. We specifically assumed that farmers who have already adopted practices to improve or maintain soil health, such as cover crops, would be more willing to adopt alley cropping. Similar to alley cropping, the use of cover crops increases soil organic matter and helps prevent soil erosion (Wszelaki & Broughton, 2023).

We assumed that farmers who have a higher percentage of income from farming are more likely to have financial motivations for farming than those with a lower percentage of income from farming. Arbuckle et al. (2009) suggested that landowners who had financial motivations for owning the land were less likely to be interested in adopting agroforestry. Therefore, we hypothesized that the percentage of income from farming would be negatively correlated with farmers' willingness to adopt alley cropping.

Given that previous studies have suggested economic incentives in the form of payments or cost-share programs positively impact the adoption of agroforestry practices in general and alley cropping specifically (Arimi & Omoare, 2021; Borremans et al., 2016; Valdivia et al., 2012; Wilson & Lovell, 2016), we hypothesized payments offered for the adoption of alley cropping would be correlated with farmers' willingness to adopt alley cropping. Specifically, we hypothesized a positive correlation between payments for adoption and willingness to adopt alley cropping. Borremans et al. (2016), Valdivia et al. (2012), and Wilson and Lovell (2016) suggested effective subsidy or cost-share programs that cover the costs of planting and maintaining trees, potential income losses from implementing agroforestry and that could compensate farmers for the environmental services offered when implementing this practice will positively impact the adoption of agroforestry systems, including alley cropping.

## SECTION VI: RESULTS AND DISCUSSION

### *Regression Samples' Representativeness*

We evaluated the representativeness of the regression samples by comparing them to the population of vegetable farms according to the 2022 Census of Agriculture data (USDA, 2024) in terms of the distribution of farms based on acres in vegetable production.

The farm size distribution of both the sample associated with the probit regression used to evaluate the factors correlated with farmers' willingness to adopt alley cropping (WTA) and the sample associated with the probit regression used to evaluate factors correlated with farmers' willingness to adopt the black locust alley cropping scenario when an economic incentive is provided for adoption (WTAC) aligned with the distribution of vegetable farms in Tennessee according to the 2022 Census of Agriculture (**Fig. 1**). The census data shows that most Tennessee farms are small, with 84% of the farms falling between 0.1 and 4.9 acres (**Fig. 1**). However, the WTA and WTAC samples deviated slightly from this pattern. The WTA and WTAC samples underrepresented small farms, with 63% and 67% of respondents' acres in vegetable production being between 0.1 and 4.9 acres, respectively. In contrast, medium-sized farms (5 to 49.9 acres) were overrepresented in the WTA (32%) and WTAC (29%) samples, compared to the census data (14%).

This discrepancy suggests that the WTA and WTAC samples may have captured a greater percentage of farms with more available land, which could be more likely to participate in a study about adopting alley cropping systems. Farms in these medium and larger size farm categories may have more resources and operational flexibility to consider adopting practices like alley cropping. This is consistent with the findings of Alemayehu and Simeneh (2024), who suggested that farmers with larger farms are more likely to adopt agroforestry systems such as alley cropping due to their greater capacity to implement such systems.

### *Sample Descriptive Statistics*

**Tables 1 and 2** provide descriptive statistics for the observations included in both probit regressions, the WTA and WTAC. There is a difference in the number of observations included in both regressions, explained by the fact that the dependent and independent variables included in each regression are not the same. The numbers of observations are 93 and 120 for the WTA and the WTAC probit regression samples, respectively. The variables included in each regression were selected based on the Akaike Information Criterion (AIC) (see **Tables 3 and 4**). **Table 5**

shows a cross-tabulation between the dependent variables from the WTA and WTAC regressions to assess the similarities and differences in respondents' willingness to adopt alley cropping in general and the specific black locust scenario captured by the regression samples. About 45% of the respondents who indicated not being willing to adopt alley cropping did not change their minds when presented with the black locust tree alley cropping scenario at different payment levels. Additionally, only 1% of the respondents changed their mind about not being willing to adopt alley cropping in general and indicated being willing to adopt the black locust tree alley cropping scenario when payment is provided for adoption (**Table 5**).

The average age of the farmers included in both regression samples is 55, which is statistically significantly lower than the average age of farmers in Tennessee (59 years), according to the 2022 Census of Agriculture data (USDA, 2024). About 61% and 58% of the survey respondents included in the WTA and the WTAC regression samples, respectively, have a bachelor's degree or higher.

Regarding farmers' risk preference related to production, marketing, and financial aspects of the farm operation, the average score was similar across the two samples, with 3.56 for the WTA sample and 3.53 for the WTAC sample. Farmers' risk perception was measured on a 5-point Likert scale, where 1 indicates they are much less likely and 5 indicates they are much more likely to take risks compared to other operators in their industry.

The average farm size for the WTA and WTAC samples were about 219 and 179 acres, respectively. The differences in average farm size between the regression samples and the average farm size in Tennessee (170 acres), according to the 2022 Census of Agriculture data (USDA, 2024), were not statistically significant. Approximately 52% of the survey respondents included in the WTA regression sample reported that the percentage of household income from farming exceeded 25%. Similarly, about 52% of the survey respondents included in that regression sample reported that their annual farming income was above \$25,000. The 2022 Census of Agriculture data (USDA, 2024) indicated that 19% of Tennessee farms have more than \$25,000 in on-farm revenue. Therefore, we had a higher and statistically significantly different percentage of individuals with annual gross farm income above \$25,000 in the WTA sample compared to the percentage of Tennessee farms in this on-farm income category according to Ag Census data. The number of workers employed on the farm was included only in the WTA

regression sample. The average number of workers for this sample was 9, including both paid and unpaid workers.

Concerning production challenges faced in farm operations, erosion was identified as an issue by 63% of the survey respondents included in the WTA sample. Also, 58% of the survey respondents included in the WTAC regression sample identified erosion as an issue on their farms. Heat stress was noted as a significant production challenge by 38% and 37% of respondents in the WTA and the WTAC samples, respectively. The use of cover crops was similar across both samples, with 70% of the respondents in the WTA sample indicating their use of cover crops and 69% of respondents in the WTAC sample reporting its use.

Farmers' familiarity with alley cropping was measured using a 4-point Likert scale, where 1 indicates that they are not familiar at all, and 4 indicates they are very familiar. The average score of familiarity with alley cropping was 2 in both samples, indicating slight familiarity with this production system.

As mentioned in the methods section, we explored survey respondents' willingness to adopt a specific black locust alley cropping system when different payment levels were offered for adoption (i.e., \$270/acre, \$330/acre, \$390/acre, and \$450/acre). Among the 29 respondents who received the \$270 per acre payment option, and were included in the WTAC sample, 17% indicated that they would be willing to adopt this black locust alley cropping system (**Fig. 2**). When the payment level increased to \$330, the percentage of respondents willing to adopt this specific alley cropping system increased to 25% of the 36 respondents presented with the \$330 per acre payment option. In contrast, when the payment level increased above \$330 per acre, the percentage of respondents willing to adopt decreased. Among the 28 survey respondents presented with the \$390 per acre payment option, 21% indicated that they would be willing to adopt this black locust scenario. Also, when the payment level increased to \$450 per acre, 15% of the 27 survey respondents indicated they would be willing to adopt this specific alley cropping system. It is important to note that none of these percentage differences were statistically significant (**Fig. 2**).

## **Probit Regression Results**

### ***Factors Correlated with Survey Respondents' Willingness to Adopt Alley Cropping***

The results of the probit regressions are presented in **Table 6**. This table shows the estimated coefficients and marginal effects of each independent variable. The Wald test results

suggest that at least one of the coefficients associated with the independent variables included in the WTA probit regression were statistically significantly different than zero at the 1% level. The condition index was 25.8, which is below the threshold of 30, indicating that there were no major multicollinearity issues in this regression model. The regression model had the combined lowest Akaike Information Criterion (AIC) (102) and condition index among the 26 regression models we estimated (see **Table 3**). This means that this model had the best fit to the data while minimizing complexity (i.e., the number of variables included in the model) among all models (StataCorp, 2023).

Six of the 11 variables included in the WTA probit regression were found statistically significantly correlated with the survey respondents' willingness to adopt alley cropping. Risk preference (*risk\_all*), heat stress (*hstress*), familiarity with alley cropping (*fac*), and the use of cover crops (*cover\_c*) were positively correlated with respondents' willingness to adopt alley cropping. In contrast, farm size (*farm\_size*), and farming income (*f\_income1*) were negatively correlated with respondents' willingness to adopt alley cropping.

Familiarity with alley cropping (*fac*) was positively and statistically significantly correlated with respondents' willingness to adopt alley cropping at the 1% level (**Table 6**). This finding is consistent with Arbuckle et al. (2009) and Valdivia and Poulos (2009), who also found that prior knowledge of agroforestry positively impacted the interest in implementing this practice. We can infer that farmers who are familiar with alley cropping might have a better understanding of its potential long-term benefits, including reduced erosion, increased soil organic matter, and carbon sequestration. These farmers might be more willing to adopt alley cropping because of its potential long-term benefits. Farmers' risk preferences (*risk\_all*) were also statistically significant and positively correlated with respondents' willingness to adopt alley cropping at the 1% level. This result suggests that those respondents who are more willing to take risks compared to similar operators in their industry are more willing to adopt alley cropping. This result is consistent with previous studies suggesting risk averse farmers would be less likely to adopt alley cropping due to the high upfront investment and the long period before benefits from alley cropping are realized (Adesina et al., 2000; Beer & Theuvsen, 2020; Otter & Beer, 2021; Otter & Deutsch, 2023).

Regression results suggest that farm size (*farm\_size*) was negatively and statistically correlated with respondents' willingness to adopt alley cropping at the 5% level. Previous studies

found farm size to have a positive correlation with the adoption of agroforestry systems (Adesina et al., 2000; Alemayehu & Simeneh, 2024; Pattanayak et al., 2003; Valdivia et al., 2012). It is often assumed that farmers with more land might allocate some portion of their land for alley cropping because they have more land available to do so. Nonetheless, farmers with large farm operations might view alley cropping as a poor fit for their established practices or perceive it as unfeasible. This is because implementing alley cropping implies taking land out of production for planting trees. It is important to note that this variable captures acres in production. In this case, the opportunity cost of land may vary depending on the type of crops grown and the location of the operation. Larger operations in Tennessee are more likely to be growing row crops such as corn and soybeans. The average area under corn and soybean production per farm in Tennessee is 225 and 418 acres, respectively (USDA, 2024), compared to an average of 13 acres in vegetable production. In our samples, we had individuals growing both row crops and vegetable crops. Therefore, larger operations were probably more likely to be growing row crops, which implied their assessment of willingness to take land out of production to implement alley cropping, took into consideration their production system and the value of the revenue generated from the land they will take out production. This value could have been higher for a farmer growing soybeans and corn as opposed to a farmer using land for livestock production.

Farming income (*f\_income1*) was negatively and statistically significantly correlated with respondents' willingness to adopt alley cropping at the 5% level. Farmers who generate higher income from farming may not be willing to adopt alley cropping, considering the potential farm income loss in the short run from taking land out of production, and the upfront investment required for implementing alley cropping (Pattanayak et al., 2003).

The use of cover crops (*cover\_c*) was statistically significant and positively correlated with the adoption of alley cropping at the 5% level. We can infer that survey respondents who are already using cover crops, viewed alley cropping as a natural extension of their conservation efforts. Cover crops is a production practice that increases soil organic matter, improves soil fertility, raises soil moisture capacity, prevents soil erosion, and reduces soil compaction (Wszelaki & Broughton, 2023). Alley cropping offers similar benefits to cover crops while adding the potential for additional income from the tree crops or reduced fertilizer costs due to the nitrogen fixation properties of certain kinds of trees (e.g., leguminous trees). We can also assume that farmers who use cover crops are environmentally motivated and have goals of

conservation for future generations, which influence their willingness to adopt agroforestry systems such as alley cropping (Kronenberg et al., 2023; Valdivia et al., 2012; Valdivia & Poulos, 2009)

Heat stress (*hstress*) was positively and significantly correlated with the respondents' willingness to adopt alley cropping at the 5% significance level. This result suggests that farmers who face heat stress as a production challenge are more likely to be interested in adopting alley cropping. This result is consistent with previous studies (Adesina et al., 2000; Valdivia & Poulos, 2009) findings, which also suggest the correlation between farm production challenges (e.g., heat stress, low organic matter) and the adoption of alley cropping. It can be assumed that survey respondents willing to adopt alley cropping valued the microclimate that alley cropping creates and the shade provided by the trees in the production systems, which can reduce heat stress for nearby vegetable crops.

#### ***Factors Correlated with Survey Respondents' Willingness to Adopt a Black Locust-Vegetable Alley Cropping***

The results of the WTAC probit regression are presented in **Table 6**. Results from the Wald test for this regression suggest that at least one of the independent variables was statistically significantly different than zero at the 1% level. The condition index was 27.2, indicating multicollinearity was not a concern for this regression. The regression model had the combined lowest Akaike Information Criterion (AIC) (115) and condition index, as well as the highest number of observations among the 17 regression models we estimated (see **Table 4**).

Among the nine variables included in this regression, three were statistically significantly correlated with respondents' willingness to adopt this specific alley-cropping scenario. Similar to the WTA regression results, farm size (*farm\_size*) was statistically significant and negatively correlated with respondents' willingness to adopt the black locust alley cropping scenario at the 5% level. The negative correlation between farm size and the respondents' willingness to adopt alley cropping in the WTA and WTAC probit regressions emphasizes that larger farms might view alley cropping as a less economically viable option, because the opportunity cost of removing land from production to implement alley cropping might be higher for larger farms compared to smaller farms.

Similar to the result from WTA regression, heat stress (*hstress*) was statistically significant at the 1% level, and had a positive correlation with respondents' willingness to adopt

the black locus alley cropping scenario. As we discussed earlier, farmers who understand that alley cropping has the potential to mitigate heat stress that negatively impacts crop production (Jose et al., 2004) will be more likely to be willing to adopt this production system. Just like in the WTA regression, familiarity with alley cropping (*fac*) was also statistically significant and positively correlated with respondents' willingness to adopt the black locust scenario at the 5% level. We can infer that farmers familiar with general concepts of alley cropping may be more willing to adopt specific alley cropping scenarios. For example, farmers who are familiar with alley cropping might be more likely to be aware of the nitrogen fixation properties of the black locust trees and their potential impact on fertilizer use reduction. Previous studies emphasized that familiarity with and prior knowledge of agroforestry systems reduces the risk of adoption and increases the probability of adopting these systems (Adesina et al., 2000; Alemayehu & Simeneh, 2024; Arbuckle et al., 2009; Arimi & Omoare, 2021; Kronenberg et al., 2023; Pattanayak et al., 2003; Valdivia & Poulos, 2009; Wilson & Lovell, 2016).

It is important to highlight that payment or compensation for adoption was not statistically significantly correlated with survey respondents' willingness to adopt alley cropping. This result could be associated with respondents' perceptions that the payment offered does not properly compensate them for the cost they incur when implementing this practice, like yearly tree maintenance.

### ***Marginal Effects***

The marginal effects for both probit regressions are presented in **Table 6** (see Appendix). The estimated marginal effect associated with farmers' risk preferences for the WTA probit regression was 17.2%. This result suggests that a one-unit increase in respondents' perceived willingness to take risks with their farm operations compared to similar businesses increased their probability of being willing to adopt alley cropping by 17%. The marginal effect associated with the use of cover crops for the WTA probit regression was 23.4%. This result suggests that respondents who were using cover crops were, on average, 23% more likely to be willing to adopt alley cropping. In terms of farm size, the estimated marginal effects were 0.2% and 0.4% for WTA and WTAC regressions, respectively. These results suggest that for each additional acre in production, the likelihood of a respondent being willing to adopt alley cropping and the black locust alley cropping scenario will decrease by 0.2% and 0.4%, respectively. Regarding farming income, the marginal effect of farming income for the WTA probit regression was 22.6%. This

result suggests that respondents with annual gross on-farm revenue of more than \$25,000 were, on average, 22.6% less likely to adopt alley cropping. Results associated with the heat stress variable (*hstress*) marginal effects suggest that respondents who indicated facing heat stress as one of their production challenges were 19.1% and 20.4% more likely to be willing to adopt alley cropping and the black locust alley cropping scenario, respectively. The result associated with the familiarity with alley cropping (*fac*) variable suggests that a one unit increase in the Likert-scale used to evaluate familiarity will increase respondents' likelihood of adopting alley cropping and the black locust alley cropping scenario by 15% and 7.8%, respectively.

## SECTION VII: CONCLUSIONS

As discussed in the literature review section, most of the previous literature focused mostly on farmers' adoption of agroforestry systems, but only a few studies have evaluated farmers' adoption of alley cropping systems. No study, as far as we know, has evaluated the adoption or willingness to adopt alley cropping among US farmers. Using data from a survey of Tennessee fruit and vegetable farmers conducted in 2024, this study fills that gap in the literature by evaluating Tennessee fruit and vegetable farmers' willingness to adopt alley cropping. We used probit regressions to evaluate the farmers' willingness to adopt alley cropping.

Results from our study suggest that demographic factors do not significantly affect farmers' willingness to adopt alley cropping. This result is consistent with findings from Pattanayak et al. (2003) that suggested that farmers' demographic characteristics were less likely to be found significantly correlated with agroforestry adoption decisions compared to other factors, such as biophysical factors and resource endowments.

Consistent with previous studies (Adesina et al., 2000; Valdivia & Poulos, 2009), our results suggest that farmers facing production challenges such as heat stress, which alley cropping could help mitigate, might be more willing to adopt alley cropping. Similarly, just like other studies' findings (Arimi & Omoare, 2021; Beer & Theuvsen, 2019, 2020), our results suggest that familiarity with alley cropping could positively impact farmers' willingness to adopt alley cropping.

Unlike previous studies (Arimi & Omoare, 2021; Borremans et al., 2016; Valdivia et al., 2012; Wilson & Lovell, 2016), our results suggest that the variable associated with one-time payments is not correlated with farmers' willingness to adopt alley cropping, specifically the black locust alley cropping system described in the study. A likely explanation of this result is that the payment options that were presented to the survey respondents did not adequately match the actual cost and financial risks associated with the adoption of the black locust alley cropping system scenario presented to them. The cost-share programs of NRCS, such as the Environmental Quality Incentives Program (EQIP), typically provide a one-time payment or reimbursement for adopting different conservation practices. Since alley cropping is a multi-year practice requiring ongoing maintenance, a one-time payment may not be sufficient to offset long-term costs, such as tree maintenance and labor costs in the subsequent years. A survey respondent also shared the same concern about the payment scenarios presented to them:

“In general, the cost share isn't going to be adequate in its current form and there will be a higher level of maintenance required after implementation that growers should be informed of.”

From the overall survey sample, we found that 46% of the survey respondents showed interest in adopting alley cropping. This percentage plummeted to 22% when survey respondents were presented with the black locust alley cropping system scenario. This suggests that although about half of the respondents were interested in adopting alley cropping, in general, only about a quarter of the respondents were interested in adopting the black locust alley cropping scenario. The preference for alternative alley cropping scenarios where other trees, such as fruit trees, are incorporated into the system could have affected results associated with the WTAC regression. A few survey respondents mentioned that they might be interested in adopting alley cropping when presented with payments for adoption if black locust trees were replaced with other types of trees, such as fruit trees, that could generate income in the short run.

While this study complements the scarce literature evaluating the farmers' willingness to adopt alley cropping, there are a few limitations in this study that can be improved in future research. For instance, the regression samples were relatively small and were limited to Tennessee fruit and vegetable farmers. As a result, the findings and conclusions from this study might not apply to the broader population of all US farmers. Therefore, future studies should aim to include farmers from a broader geographic area. Moreover, future research could include a different alley cropping scenario where fruit trees are integrated into the system and evaluate how farmers' adoption decisions change. Finally, future studies should evaluate other payment scenarios that best represent the costs incurred and environmental benefits provided by farmers in the short and long term when implementing alley cropping.

## LIST OF REFERENCES

- Adesina, A. A., Mbila, D., Nkamleu, G. B., & Endamana, D. (2000). Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon. *Agriculture, ecosystems & environment*, 80(3), 255-265.
- Alemayehu, A., & Simeneh, S. (2024). Adoption of agroforestry technologies: a case study from central highlands of Ethiopia. *Agroforestry Systems*, 98(4), 1021-1034.
- Arbuckle, J. G., Valdivia, C., Raedeke, A., Green, J., & Rikoon, J. S. (2009). Non-operator landowner interest in agroforestry practices in two Missouri watersheds. *Agroforestry Systems*, 75, 73-82.
- Arimi, K., & Omoare, A. (2021). Motivating cocoa farmers to adopt agroforestry practices for mitigating climate change. *Renewable Agriculture and Food Systems*, 36(6), 599-604.
- Beer, L., & Theuvsen, L. (2019). Conventional German farmers' attitudes towards agricultural wood and their willingness to plant an alley cropping system as an ecological focus area: a cluster analysis. *Biomass and bioenergy*, 125, 63-69.
- Beer, L., & Theuvsen, L. (2020). Factors influencing German farmer's decision to grow alley cropping systems as ecological focus areas: a regression analysis. *International Food and Agribusiness Management Review*, 23(4), 529-545.
- Belsley, D. A., Kuh, E., & Welsch, R. E. (1980). Regression Diagnostics; Identifying Influence Data and Source of Collinearity. *John Wiley & Sons*.  
<http://dx.doi.org/10.1002/0471725153>
- Borremans, L., Reubens, B., Van Gils, B., Baeyens, D., Vandavelde, C., & Wauters, E. (2016). A sociopsychological analysis of agroforestry adoption in Flanders: understanding the discrepancy between conceptual opportunities and actual implementation. *Agroecology and Sustainable Food Systems*, 40(9), 1008-1036.
- Davis, J., & Rausser, G. (2020). Amending conservation programs through expanding choice architecture: A case study of forestry and livestock producers. *Agricultural Systems*, 177, 102678.
- Frey, G. E., Mercer, D. E., Cabbage, F. W., & Abt, R. C. (2013). A real options model to assess the role of flexibility in forestry and agroforestry adoption and disadoption in the Lower Mississippi Alluvial Valley. *Agricultural Economics*, 44(1), 73-91.

- Garrett, H. G., & Buck, L. (1997). Agroforestry practice and policy in the United States of America. *Forest Ecology and Management*, 91(1), 5-15.
- Greene, W. H. (2012). *Econometric Analysis*, 7th ed. New York, NY: Prentice Hall.:Pearson
- Jose, S., Gillespie, A., & Pallardy, S. (2004). Interspecific interactions in temperate agroforestry. *Agroforestry Systems*, 61, 237-255.
- Kang, B. (1997). Alley cropping—soil productivity and nutrient recycling. *Forest Ecology and Management*, 91(1), 75-82.
- Kouassi, J.-L., Kouassi, A., Bene, Y., Konan, D., Tondoh, E. J., & Kouame, C. (2021). Exploring barriers to agroforestry adoption by cocoa farmers in South-Western Côte d’Ivoire. *Sustainability*, 13(23), 13075.
- Kronenberg, R., Lovell, S., Thapa, B., Spinka, C., Valdivia, C., Gold, M., & Bardhan, S. (2023). Survey of Missouri Landowners to Explore the Potential of Woody Perennials to Integrate Conservation and Production. *Land*, 12(10), 1911.
- Lawry, S., Stienbarger, D., & Jabbar, M. A. (1994). Land tenure and the potential for the adoption of alley farming in West Africa. *Outlook on Agriculture*, 23(3), 183-187.
- MacFarland. (2017). *Alley Cropping: An Agroforestry Practice*.
- Natural Resource Conservation Service (NRCS). (2024a). *Agroforestry*.  
<https://www.usda.gov/forestry/agroforestry>.
- Natural Resources Conservation Service (NRCS). (2016). *Conservation practice standard sode 381*. <https://www.nrcs.usda.gov/sites/default/files/2022-09/Silvopasture-381-CPS-May-2016.pdf>
- NRCS. (2024b). *NRCS Field Office Technical Guide*. <https://efotg.sc.egov.usda.gov/#/> [accessed 1 April 2024].
- Opdenbosch, H., & Hansson, H. (2023). Farmers’ willingness to adopt silvopastoral systems: Investigating cattle producers’ compensation claims and attitudes using a contingent valuation approach. *Agroforestry Systems*, 97(1), 133-149.
- Otter, V., & Beer, L. (2021). Alley cropping systems as Ecological Focus Areas: A PLS-analysis of German farmers’ acceptance behaviour. *Journal of Cleaner Production*, 280, 123702.
- Otter, V., & Deutsch, M. (2023). Did policy lose sight of the wood for the trees? An UTAUT-based partial least squares estimation of farmers acceptance of innovative sustainable land use systems. *Land Use Policy*, 126, 106467.

- Pattanayak, S. K., Evan Mercer, D., Sills, E., & Yang, J.-C. (2003). Taking stock of agroforestry adoption studies. *Agroforestry Systems*, 57, 173-186.
- Scheelbeek, P. F., Bird, F. A., Tuomisto, H. L., Green, R., Harris, F. B., Joy, E. J., Chalabi, Z., Allen, E., Haines, A., & Dangour, A. D. (2018). Effect of environmental changes on vegetable and legume yields and nutritional quality. *Proceedings of the National Academy of Sciences*, 115(26), 6804-6809.
- StataCorp. (2023). *Stata base reference manual 18*. College Station, TX:Stata Press.
- Strong, N. A., & Jacobson, M. G. (2005). Assessing agroforestry adoption potential utilising market segmentation: a case study in Pennsylvania. *Small-Scale Forest Economics, Management and Policy*, 4, 215-228.
- Tsonkova, P., Mirck, J., Böhm, C., & Fütz, B. (2018). Addressing farmer-perceptions and legal constraints to promote agroforestry in Germany. *Agroforestry Systems*, 92, 1091-1103.
- USDA. (2024). *USDA-NASS Census of Agriculture. 2022 Census Full Report*.  
<https://www.nass.usda.gov/Publications/AgCensus/2022/> [accessed September 1, 2024].
- Valdivia, C., Barbieri, C., & Gold, M. A. (2012). Between forestry and farming: Policy and environmental implications of the barriers to agroforestry adoption. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 60(2), 155-175.
- Valdivia, C., & Poulos, C. (2009). Factors affecting farm operators' interest in incorporating riparian buffers and forest farming practices in northeast and southeast Missouri. *Agroforestry Systems*, 75, 61-71.
- Wilson, M. H., & Lovell, S. T. (2016). Agroforestry—The next step in sustainable and resilient agriculture. *Sustainability*, 8(6), 574.
- Wolz, K. J., & DeLucia, E. H. (2019). Black walnut alley cropping is economically competitive with row crops in the Midwest USA. *Ecological Applications*, 29(1), e01829.
- Wszelaki, A., & Broughton, S. (2023). *Cover Crops and Green Manures*.  
<https://rutherford.tennessee.edu/wp-content/uploads/sites/200/2022/05/W235-G-Cover-Crops-and-Green-Manures.pdf>

# APPENDIX

Table 1. Summary Statistics for the WTA probit regression sample (n = 93).

| Variables                                                                                                                                                                                                          | Mean   | Std.<br>Dev. | Min  | Max   | Hypotheses |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------|------|-------|------------|
| <i>age</i> – Age in years                                                                                                                                                                                          | 54.83  | 14.21        | 28   | 84    | -          |
| <i>education</i> – 1 if farmer has a bachelor’s degree or higher, zero otherwise                                                                                                                                   | 0.61   | 0.49         | 0    | 1     | +          |
| <i>risk_all</i> – Average score regarding farmer willingness to take risk compared to a similar operation related to financial management, production, and marketing, where 1 is “much less ” and 5 is “much more” | 3.56   | 0.82         | 1    | 5     | +          |
| <i>farm_size</i> – Acres in crop production                                                                                                                                                                        | 218.69 | 1388.30      | 0.01 | 10780 | +          |
| <i>total_labor</i> – Number of paid and unpaid workers employed on the farm in 2023                                                                                                                                | 9      | 14.39        | 1    | 100   | +          |
| <i>pfi</i> – 1 if the percentage of household income from farming is more than 25%, zero otherwise                                                                                                                 | 0.52   | 0.50         | 0    | 1     | -          |
| <i>f_income1</i> – 1 if annual gross on-farm revenue is above \$25k, zero otherwise                                                                                                                                | 0.52   | 0.50         | 0    | 1     | +          |
| <i>erosion1</i> – 1 if farmer indicated water or wind erosion has been a concern on the farm, zero otherwise                                                                                                       | 0.63   | 0.48         | 0    | 1     | +          |
| <i>hstress</i> – 1 if farmer indicated heat stress is one of the most important challenges faced on the farm, zero otherwise                                                                                       | 0.38   | 0.49         | 0    | 1     | +          |
| <i>fac</i> – 1 if farmer is not familiar at all, 2 if the farmer is slightly familiar, 3 if the farmer is moderately familiar, and 4 if farmer is very familiar with alley cropping                                | 2      | 1.04         | 1    | 4     | +          |
| <i>cover_c</i> – 1 if farmer uses cover crops, zero otherwise                                                                                                                                                      | 0.70   | 0.46         | 0    | 1     | +          |

Table 2. Summary Statistics for the WTAC probit regression sample (n = 120).

| Variables                                                                                                                                                                                                          | Mean   | Std.<br>Dev. | Min  | Max   | Hypotheses |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------|------|-------|------------|
| <i>age</i> – Age in years                                                                                                                                                                                          | 55.19  | 14.15        | 28   | 85    | -          |
| <i>education</i> – 1 if farmer has a bachelor’s degree or higher, zero otherwise                                                                                                                                   | 0.58   | 0.50         | 0    | 1     | +          |
| <i>risk_all</i> – Average score regarding farmer willingness to take risk compared to a similar operation related to financial management, production, and marketing, where 1 is “much less ” and 5 is “much more” | 3.53   | 0.85         | 1    | 5     | +          |
| <i>farm_size</i> – Acres in crop production                                                                                                                                                                        | 179.31 | 1224.85      | 0.01 | 10780 | +          |
| <i>cover_c</i> – 1 if farmer uses cover crops, zero otherwise                                                                                                                                                      | 0.69   | 0.46         | 0    | 1     | +          |
| <i>erosionI</i> – 1 if farmer indicated water or wind erosion have been a concern on the farm, zero otherwise                                                                                                      | 0.58   | 0.50         | 0    | 1     | +          |
| <i>hstress</i> – 1 if farmer indicated heat stress is one of the most important challenges faced on the farm, zero otherwise                                                                                       | 0.37   | 0.48         | 0    | 1     | +          |
| <i>fac</i> – 1 if farmer is not familiar at all, 2 if the farmer is slightly familiar, 3 if the farmer is moderately familiar, and 4 if farmer is very familiar with alley cropping                                | 2      | 1            | 1    | 4     | +          |

Table 3. Summary of probit regressions for willingness to adopt alley cropping (WTA)

| Variables                        | Model # |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----------------------------------|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                  | 1       | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    | 18    | 19    | 20    | 21    | 22    | 23    | 24    | 25    | 26    |
| age                              | x       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| education                        |         | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| risk_all                         |         |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| env_friend1                      |         |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |       | x     |       |       |       |       |       |       |
| farm size                        |         |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |       |       |       | x     |
| perc_owned                       |         |       |       |       |       | x     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| total_labor                      |         |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |       | x     |       | x     | x     |
| pfi                              |         |       |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| f_income1                        |         |       |       |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |       |       | x     | x     |       |
| erosion1                         |         |       |       |       |       |       |       |       |       | x     | x     | x     |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| organic_low                      |         |       |       |       |       |       |       |       |       |       | x     |       |       | x     |       |       |       |       |       |       |       |       |       |       |       |       |
| hstress                          |         |       |       |       |       |       |       |       |       |       |       | x     | x     |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| fac                              |         |       |       |       |       |       |       |       |       |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| cover_c                          |         |       |       |       |       |       |       |       |       |       |       |       |       |       |       | x     | x     | x     | x     |       |       | x     | x     | x     | x     | x     |
| c_rotation                       |         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | x     | x     |       |       | x     |       |       |       |       |       |
| ext_use2                         |         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | x     |       |       |       |       |       |       |       |       |
| Model Summary Statistics         | Model # |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total Variables                  | 1       | 2     | 3     | 4     | 5     | 6     | 6     | 7     | 8     | 9     | 10    | 10    | 9     | 9     | 11    | 12    | 13    | 14    | 11    | 11    | 11    | 9     | 9     | 9     | 10    | 10    |
| Wald ( $\chi^2$ )                | 0.008   | 0.008 | 0.014 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Condition Index Value            | 7.94    | 9.69  | 14.5  | 15.6  | 15.5  | 17.4  | 17.5  | 19.1  | 20.4  | 21.8  | 24.1  | 22.6  | 21.1  | 22.8  | 24.3  | 26.8  | 28.4  | 29.7  | 25.8  | 25.1  | 26    | 22.5  | 23.9  | 23.9  | 25.6  | 24.1  |
| AIC                              | 201     | 200   | 198   | 190   | 155   | 156   | 130   | 121   | 121   | 119   | 120   | 117   | 118   | 118   | 106   | 102   | 103   | 105   | 102   | 106   | 107   | 121   | 113   | 130   | 109   | 106   |
| Number of Significant Variables* | 1       | 2     | 2     | 1     | 4     | 3     | 3     | 3     | 3     | 3     | 3     | 4     | 4     | 3     | 5     | 6     | 7     | 7     | 6     | 5     | 5     | 6     | 7     | 6     | 7     | 5     |
| Number of Observations           | 149     | 149   | 147   | 142   | 128   | 128   | 111   | 100   | 97    | 92    | 92    | 92    | 96    | 92    | 92    | 92    | 92    | 92    | 93    | 92    | 93    | 109   | 103   | 113   | 99    | 96    |
|                                  |         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

Table 4. Summary of probit regressions for willingness to adopt the black locust alley cropping scenario (WTAC).

| <i>Variables</i>                        | <i>Model #</i> |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------------------------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                         | 1              | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    |
| <i>payment</i>                          | x              | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| <i>age</i>                              |                | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| <i>education</i>                        |                |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| <i>risk_all</i>                         |                |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| <i>cover_c</i>                          |                |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     | x     |
| <i>farm size</i>                        |                |       |       |       |       | x     | x     | x     | x     | x     | x     | x     | x     | x     |       |       |       |
| <i>total_labor</i>                      |                |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     |       |       | x     |       |
| <i>pfi</i>                              |                |       |       |       |       |       |       | x     | x     |       | x     | x     | x     |       |       |       |       |
| <i>f_income1</i>                        |                |       |       |       |       |       |       |       | x     | x     |       |       |       |       |       |       | x     |
| <i>erosion1</i>                         |                |       |       |       |       |       |       |       |       |       | x     | x     | x     | x     | x     | x     | x     |
| <i>hstress</i>                          |                |       |       |       |       |       |       |       |       |       |       | x     | x     | x     | x     | x     | x     |
| <i>fac</i>                              |                |       |       |       |       |       |       |       |       |       |       |       | x     | x     | x     | x     | x     |
| <i>Model Summary Statistics</i>         | <i>Model #</i> |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                                         | 1              | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    |
| <i>Total Variables</i>                  | 1              | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 8     | 9     | 10    | 11    | 10    | 9     | 9     | 9     |
| <i>Wald (<math>\chi^2</math>)</i>       | 0.644          | 0.624 | 0.507 | 0.575 | 0.475 | 0.054 | 0.174 | 0.105 | 0.072 | 0.224 | 0.317 | 0.003 | 0.000 | 0.002 | 0.006 | 0.006 | 0.008 |
| <i>Condition Index Value</i>            | 14.2           | 14.1  | 15.7  | 20.3  | 22.4  | 22.1  | 24.8  | 27.1  | 28.4  | 26.9  | 28.2  | 29    | 32.8  | 29.8  | 27.2  | 30.2  | 30.6  |
| <i>AIC</i>                              | 175            | 157   | 157   | 158   | 157   | 131   | 115   | 101   | 101   | 106   | 98    | 86    | 80    | 95    | 115   | 113   | 121   |
| <i>Number of Significant Variables*</i> | 0              | 0     | 0     | 0     | 0     | 1     | 0     | 3     | 3     | 1     | 2     | 4     | 5     | 4     | 3     | 3     | 3     |
| <i>Number of Observations</i>           | 163            | 148   | 148   | 146   | 143   | 127   | 111   | 100   | 97    | 99    | 95    | 95    | 95    | 105   | 120   | 116   | 116   |

Table 5. Cross tabulation of the number of survey respondents included in both probit regressions who are willing to adopt alley cropping and those willing to adopt alley cropping given a black locust scenario.

| <b>WTA Regression</b>                                    | <b>WTAC Regression</b>                                |                       | <b>Total</b> |
|----------------------------------------------------------|-------------------------------------------------------|-----------------------|--------------|
|                                                          | 0=Not Willing to Adopt or<br>Uncertain about Adoption | 1=Willing to<br>Adopt |              |
| 0=Not Willing to Adopt<br>or Uncertain about<br>Adoption | 42                                                    | 1                     | 43           |
| 1=Willing to Adopt                                       | 32                                                    | 17                    | 49           |
| Total                                                    | 74                                                    | 18                    | 92           |

Table 6. Parameter estimates and marginal effects for WTA and WTAC probit regressions with robust standard errors.

| <i>Variables</i>     | WTA                  |                     | WTAC                |                     |
|----------------------|----------------------|---------------------|---------------------|---------------------|
|                      | Coef.<br>St. Err     | Marginal<br>Effects | Coef.<br>St. Err    | Marginal<br>Effects |
| <i>constant</i>      | -2.938***<br>(1.094) |                     | -2.916**<br>(1.285) | —                   |
| <i>age</i>           | -0.018<br>(0.013)    | -0.004              | 0.010<br>(0.009)    | 0.002               |
| <i>education</i>     | 0.281<br>(0.373)     | 0.067               | 0.238<br>(0.303)    | 0.052               |
| <i>risk_all</i>      | 0.718***<br>(0.232)  | 0.172               | 0.230<br>(0.154)    | 0.051               |
| <i>farm_size</i>     | -0.007**<br>(0.003)  | -0.002              | -0.020*<br>(0.010)  | -0.004              |
| <i>total_labor</i>   | 0.013<br>(0.014)     | 0.003               | —                   | —                   |
| <i>pfi</i>           | -0.015<br>(0.401)    | -0.004              | —                   | —                   |
| <i>f_income1</i>     | -0.941**<br>(0.399)  | -0.226              | —                   | —                   |
| <i>hstress</i>       | 0.755**<br>(0.353)   | 0.181               | 0.923***<br>(0.288) | 0.204               |
| <i>fac</i>           | 0.624***<br>(0.198)  | 0.150               | 0.355**<br>(0.152)  | 0.078               |
| <i>cover_c</i>       | 0.975**<br>(0.456)   | 0.234               | -0.274<br>(0.357)   | -0.060              |
| <i>erosion1</i>      | -0.444<br>(0.409)    | -0.107              | 0.009<br>(0.312)    | 0.002               |
| <i>payment1</i>      | —                    | —                   | -0.0007<br>(0.002)  | -0.000              |
| Observations         | 93                   |                     | 120                 |                     |
| Log pseudolikelihood | -39.378              |                     | -47.570             |                     |
| Wald chi2            | 36.71***             |                     | 23.31***            |                     |

Note. Values in parenthesis are robust standard errors. Statistical significance at the 10%, 5%, and 1% levels are indicated by \*, \*\*, and \*\*\*, respectively.

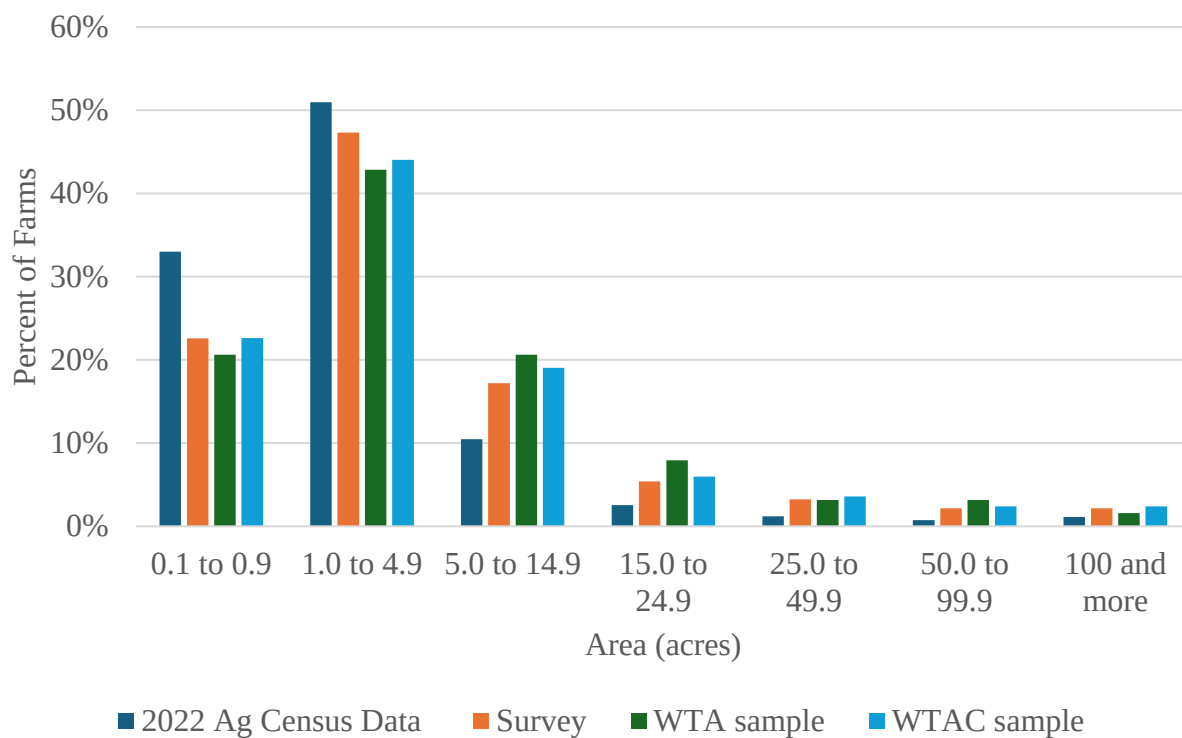


Fig. 1. Percentage of farms in each farm size category based on acres in vegetable production according to the 2022 Census of Agriculture data (USDA, 2024) for the survey and the regression samples.

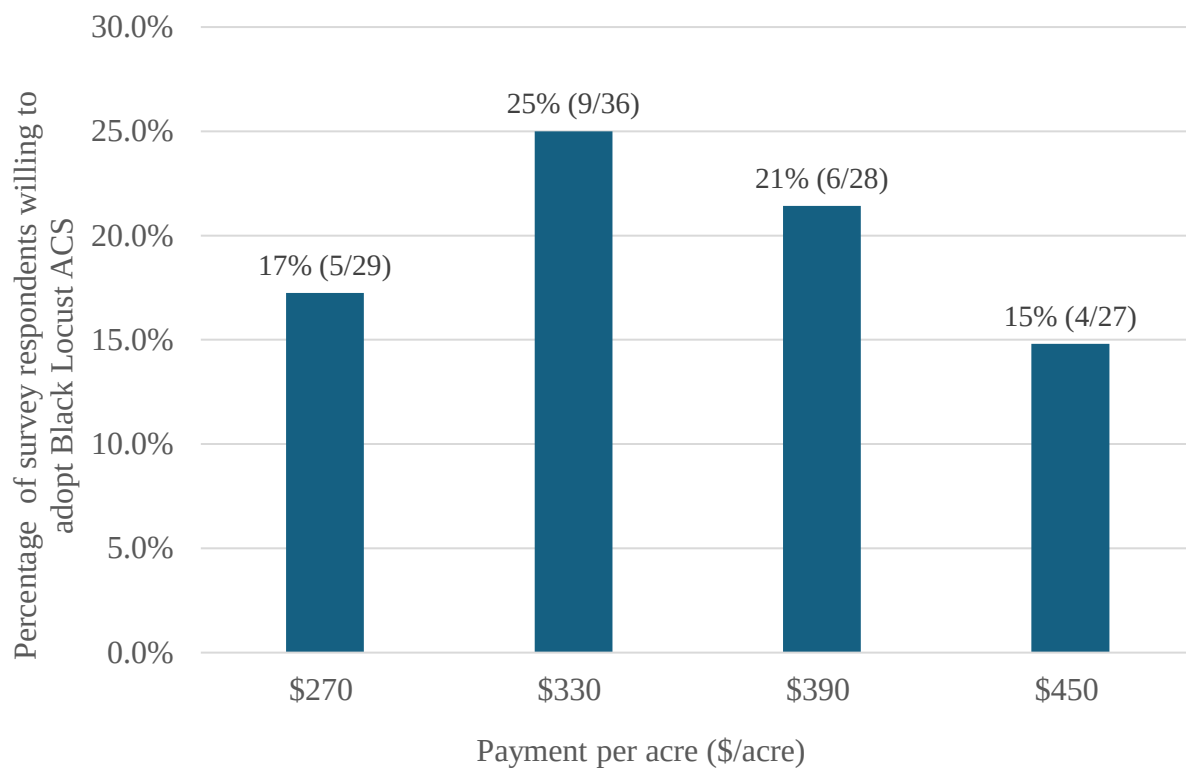


Fig. 2. Percentage of respondents in the WTAC regression sample willing to adopt the black locust alley cropping scenario (ACS) at different per acre payment levels.

## SURVEY INSTRUMENT

### Use and Willingness to Use Alley Cropping Systems in Tennessee

You have been selected to participate in this study because you were identified as a fruit and/or vegetable grower. The information in this consent form is to help you decide if you want to be part of this research study. If you agree to be in this study, you will complete a survey. Please take your time reading this form and contact the researcher(s) (contact information is at the end of this text) to ask questions if there is anything you do not understand. We at the University of Tennessee Department of Agricultural & Resource Economics and the Department of Plant Sciences will use information from this survey to better assess the use and willingness to use alley cropping systems in vegetable production. Alley cropping is defined as the planting of rows of trees and/or shrubs to create alleys within which agricultural or horticultural crops are produced. The survey includes questions about your use of management and production practices, your farm, and you, and should take **15 to 20 minutes to complete. You can skip questions you do not want to answer.**

We cannot promise that your participation will result in any personal or immediate benefits to you or your community. Your participation may help us learn about the factors influencing the use of management and production practices in fruit and vegetable production. There are no foreseeable risks other than those encountered in everyday life. Being in this study is up to you. You can stop up until you submit the survey. After you submit the survey, we cannot remove your response because we will not know which response came from you. Either way, your decision will not affect your relationship with the University of Tennessee and the services you receive from this institution. The survey is anonymous, and no one will be able to link your response back to you. Please do not include your name or other information that could be used to identify you in your survey responses. Data obtained from this survey will be stored securely and will be made available only to researchers conducting the study unless participants specifically give written permission to do otherwise. Information collected for this study will be published and possibly presented at scientific meetings. No reference will be made in oral or written reports which could link participants to the study.

You have the opportunity to enter into a random drawing for a \$500 gift card. Participation in the survey is not required to participate in the drawing. Please use the following link and provide your name and e-mail address so we can include you in the drawing [tiny.utk.edu/QLVHo](https://tiny.utk.edu/QLVHo). If you do not have access to internet to enter your information, call Margarita Velandia at (865)974-7409. The winner will be randomly drawn from the list of those who provided their names and contact information by May 1, 2024. The winner will receive the \$500 gift card via U.S. mail.

If you have questions at any time about the study or the procedures (or you experience adverse effects as a result of participating in this study), you may contact the researcher, Margarita Velandia, at [mvelandi@utk.edu](mailto:mvelandi@utk.edu) or at (865)974-7409. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at [utkirb@utk.edu](mailto:utkirb@utk.edu) or (865)974-7697. Thank you for assisting the University of Tennessee with this survey.

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Consent

I have read this form, been given the chance to ask questions and have my questions answered. If I have more questions, I have been told who to contact. By completing and returning the survey, I understand that I agree to be in this study. I can keep a copy of this consent information for future reference. If I do not want to be in this study, I do not need to do anything else.

**Q1. Are you eighteen years of age or older? Mark your selection with an X.**

☐ Yes  Please go to **Q2**

☐ No  Please go to **Q40**

**Q2. In 2023, did you produce fruit and/or vegetables for sale in the open field? ( i.e., not in a high tunnel or a greenhouse) Mark your selection with an X.**

☐ Yes  Please go to **Q3**

☐ No  Please go to **Q40**

### Production Challenges

**Q3. Select the vegetable and fruit crops you have grown in the past five years in the open field (not in high tunnels or greenhouses). Mark your selection with an X.**

|                                                                                   | Past Five Years          |
|-----------------------------------------------------------------------------------|--------------------------|
| Cucurbits (squash, zucchini, cucumbers, melons, pumpkin)                          | <input type="checkbox"/> |
| Solanaceous vegetables (tomatoes, eggplant, peppers)                              | <input type="checkbox"/> |
| Leafy greens (lettuce, kale, Swiss chard, arugula, collard greens, spinach, etc.) | <input type="checkbox"/> |
| Root vegetable crops (carrots, potatoes, turnips, radishes, beets, etc.)          | <input type="checkbox"/> |
| Allium vegetables (onion, leeks, chives, shallots, etc.)                          | <input type="checkbox"/> |
| Legumes (beans, peas)                                                             | <input type="checkbox"/> |
| Brassica crops (broccoli, cauliflower, cabbage, Brussels sprouts, kohlrabi)       | <input type="checkbox"/> |
| Small fruits (strawberries, blueberries, blackberries)                            | <input type="checkbox"/> |
| Fruit trees (apples, peaches, etc.)                                               | <input type="checkbox"/> |
| Others, please specify: _____                                                     | <input type="checkbox"/> |

**Q4.** Select any of the items or issues that are currently or have historically been a concern on your farm

(select all that apply). **Mark your selection with an X.**

- ☐ Water-driven erosion
- ☐ Wind-driven erosion
- ☐ Soil Compaction
- ☐ Low organic matter
- ☐ Water availability

**Q5.** What are the most important production challenges you are facing on your farm? (select all that apply). **Mark your selection with an X.**

- ☐ Disease pressure
- ☐ Insect pressure
- ☐ Weed pressure
- ☐ Heat stress
- ☐ Others, please specify: \_\_\_\_\_

### **Alley Cropping Agroforestry Systems**

Alley Cropping is an agroforestry practice where agricultural or horticultural crops are grown in the alleyways between widely spaced rows of woody plants. Specifically, alley cropping is defined as the planting of rows of trees and/or shrubs to create alleys within which agricultural or horticultural crops are produced. The trees may include valuable hardwood veneer or lumber species; fruit, nut, or other specialty crop trees/shrubs; legume trees for nitrogen fixation; or desirable softwood species for wood fiber production. Alley Cropping can diversify farm income, increase crop production, improve landscape aesthetics, enhance wildlife habitat, and provide crop protection and conservation benefits. Alley cropping provides specific benefits such as reducing water surface runoff and soil erosion, improving utilization and reducing offsite movement of nutrients, modifying the microclimate for improved crop production, providing habitat for wildlife and beneficial insects, and increasing carbon storage.



Q6. How familiar are you with alley cropping? (select only one option)  
Mark your selection with an X.

- ☐ Not familiar at all
- ☐ Slightly familiar
- ☐ Moderately familiar
- ☐ Very familiar

Q7. Would you be willing to use alley cropping? Mark your selection with an X.

- ☐ Yes
- ☐ No
- ☐ I don't know

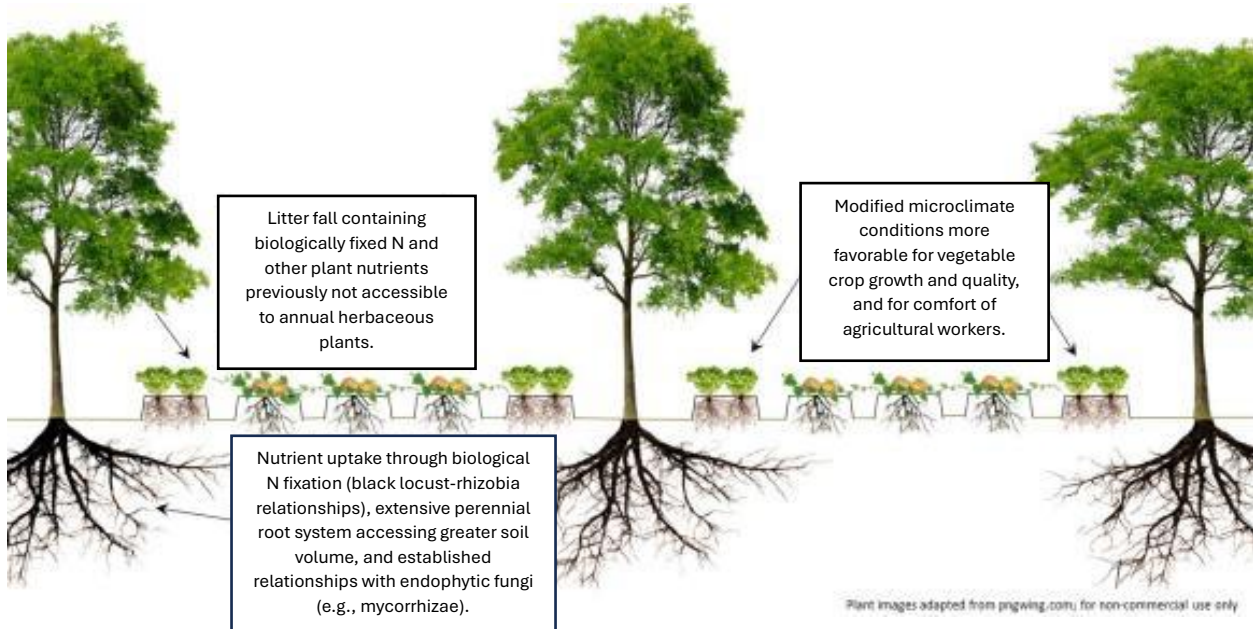
### Willingness to Use Alley Cropping

The next question will ask you about your willingness to adopt alley cropping for a specific scenario. You will plant black locust trees (*Robinia pseudoacacia*, a nitrogen-fixing legume) in rows 26-ft apart with 6.5 ft interrow spacing (see Figure below). That will allow you to plant about 248 trees per acre. Alternative spacing is possible; we provide this specific spacing as an example. **The cost per tree will be \$1.09, which implies a total tree cost of \$270 per acre. There will be other costs associated with establishing the system, such as planting costs. The planting costs are estimated at \$119 per acre. Therefore, total costs associated with planting the trees, including tree costs, are estimated at \$390 per acre. There could be income loss from taking part of the land out of production to plant trees.** Future costs include pruning of trees and other maintenance costs. You will grow vegetable crops in the alleys. Black locust will not provide income in the short to medium term, but it is a woody legume species that provides shade while allowing sufficient light to be transmitted to the crops in alleys and a **high nitrogen fixation rate that could potentially reduce fertilizer use.** Other potential benefits of this alley-cropping system include:

- Reduced sheet, rill, wind, and gully erosion
- Increased organic matter.
- Restoration of soil structure and reduced compaction.
- Trees provide a windbreak to vegetable crops.
- Crop productivity could increase.
- Plant diversity improves wildlife habitat.

- Less runoff with increased water infiltration.
- Reduced nutrient leaching to groundwater.
- Trees and shrubs intercept pesticide drift.
- Increased carbon sequestration.
- Pest and disease control.
- Modified microclimate conditions that are more favorable for vegetable crop growth and quality, and maybe the comfort of agricultural workers.

Limitations of this system include changes to your production system that imply new management practices, like more complex pesticide applications, changes in how equipment is used, and investments for initial tree establishment.



**Q8.** Would you be willing to adopt the alley cropping system described above if you received a one-time payment of \$390 per acre for adopting it? This payment would cover the \$270 per acre tree cost (100% of tree cost) and provide you with an extra \$120 per acre, which will cover 100% of the planting costs.

- ☐ Yes Please go to **Q9**.
- ☐ No Please go to **Q11**.
- ☐ I don't know Please go to **Q11**.

**Q9.** If you were to adopt alley cropping, given the payment offered to help cover establishment costs, on how many acres/row-ft do you believe you would use alley cropping? (**write the number of acres on the “acres” line or row-feet in the “row-ft” line or specify another unit of production**).

\_\_\_\_\_ acres    or    \_\_\_\_\_ row-ft    or    other  
(specify) \_\_\_\_\_

**Q10.** Please assess how important each of the following factors is in explaining why you would be willing to adopt alley cropping (please evaluate each statement). **Mark your selection with an X and then go to Q12.**

|                                                                                                                       | Not at all<br>Important  | Slightly<br>Important    | Moderately<br>Important  | Very<br>Important        |
|-----------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Reduced sheet, rill, wind, and gulley erosion.                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Increased soil organic matter.                                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Receiving payment for adoption.                                                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Reduced fertilizer use.                                                                                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Restoration of soil structure and reduced compaction.                                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Less runoff with increased water infiltration.                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Reduced nutrient leaching to groundwater.                                                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Trees intercept pesticide drift.                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Trees provide windbreak.                                                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Crop productivity could increase.                                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Plant diversity improves wildlife habitat.                                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Increased carbon sequestration                                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Pest and disease control                                                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Modified microclimate conditions favorable for vegetable crop growth and quality, and comfort of agricultural workers | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Others, please specify: _____<br>_____<br>_____                                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

**Q11.** Please assess how important each of the following factors is in explaining why you would not be willing to adopt or are unsure about adopting alley cropping (please evaluate each statement). **Mark your selection with an X and then go to Q12.**

|                                                                                           | Not at all Important     | Slightly Important       | Moderately Important     | Very Important           |
|-------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| I do not have enough information about alley cropping.                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Taking land out of production to plant trees will hurt the economic viability of my farm. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| I do not have experience producing and maintaining trees.                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Recurring costs (maintenance, inputs).                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| I do not have the additional labor necessary to manage trees on my farm.                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Increased complexity in production system.                                                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Others, please specify: _____<br>_____<br>_____                                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### Use of Alley Cropping

**Q12.** Have you used alley cropping? **Mark your selection with an X.**

☐ Yes  Please go to **Q13.**

☐ No  Please go to **Q18.**

**Q13.** What trees and/or shrubs did you use for alley cropping? (select all that apply). **Mark your selection with an X.**

☐ Fruit tree crops

☐ Nut tree crops

☐ Other trees or shrubs (please specify) \_\_\_\_\_

**Q14.** When did you begin using this practice? (Please enter approximate month and year, for example, 01/90 for January of 1990)

\_\_\_\_\_

**Q15.** When did you stop using this practice? If you are still using the practice, put N/A (Please enter approximate month and year, for example, 01/90 for January of 1990)

\_\_\_\_\_

**Q16.** On how many acres or row-ft do/did you use this practice? (Enter number of acres or row-ft, for example, 4 acres).

\_\_\_\_\_ **acres**

\_\_\_\_\_ **row-ft**

Other (specify): \_\_\_\_\_

**Q17.** Please select the benefits you have experienced from the use of alley cropping (**select all that apply**). **Mark your selection with an X.**

- |                                                                             |                                                                                                                                              |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="radio"/> Future income from tree crops (fruit/nut trees).      | <input type="radio"/> Trees provide windbreak.                                                                                               |
| <input type="radio"/> Reduced sheet, rill, wind, and gulley erosion.        | <input type="radio"/> Increased crop productivity.                                                                                           |
| <input type="radio"/> Increased soil organic matter.                        | <input type="radio"/> Plant diversity improves wildlife habitat.                                                                             |
| <input type="radio"/> Restoration of soil structure and reduced compaction. | <input type="radio"/> Increased carbon sequestration.                                                                                        |
| <input type="radio"/> Less runoff with increased water infiltration.        | <input type="radio"/> Pest and disease control.                                                                                              |
| <input type="radio"/> Reduced nutrient leaching to groundwater.             | <input type="radio"/> Modified microclimate conditions favorable for vegetable crop growth and quality, and comfort of agricultural workers. |
| <input type="radio"/> Trees intercept pesticide drift.                      | <input type="radio"/> Others, please specify:<br>_____<br>_____                                                                              |

### Management Practices

**Q18.** Which of the following irrigation systems do you use? (**select all that apply**). **Mark your selection with an X.**

- ☐ Drip Irrigation

- ☐ Sprinkler system
- ☐ Others, please  
specify: \_\_\_\_\_
- ☐ I do not have an irrigation system

**Q19.** Do you use plastic mulch and/or landscape fabric to grow your fruit and/or vegetable crops? **Select only one option. Mark your selection with an X.**

- ☐ Yes. I use plastic mulch
- ☐ Yes. I use landscape fabric
- ☐ No, I don't use plastic mulch or landscape fabric

**Q20.** Do you use crop rotation? **Select only one option. Mark your selection with an X.**

- ☐ No.
- ☐ Every year/season (please describe):  
\_\_\_\_\_
- ☐ Other (please describe): \_\_\_\_\_

**Q21.** Do you use cover crops? **Mark only one option.**

- ☐ Yes
- ☐ No

### Information Sources

**Q22.** Indicate how often you use these information sources when looking for fruit and vegetable production information. (**Mark your selection with an X.**)

|                                             | Never                    | Rarely                   | Sometimes                | Very Often               | Always                   |
|---------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| University Extension personnel              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Consultants                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Other farmers                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Online sources<br>(Specify): _____<br>_____ | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

|                                            |                          |                          |                          |                          |                          |
|--------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Other sources (Specify):<br>_____<br>_____ | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|--------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|

### About Your Farm Operation

**Q23.** Which production system type do you use? (select all that apply). Mark your selection with an X.

- ☐ Conventional (not Certified Naturally Grown or USDA Certified Organic)
- ☐ Certified Naturally Grown
- ☐ USDA Certified Organic
- ☐ Other (describe) : \_\_\_\_\_

**Q24.** How many row feet/acres did you grow in 2023 in the open field? **Use row-ft or acres, whatever works best for you.**

|                                                          | Rent row-ft | Rent acres | Own row-ft | Own acres |
|----------------------------------------------------------|-------------|------------|------------|-----------|
| <b>Vegetable Crops</b>                                   |             |            |            |           |
| <b>Non-tree fruits (e.g., strawberries, blueberries)</b> |             |            |            |           |
| <b>Fruit Tree Crops</b>                                  |             |            |            |           |
| <b>Tree nuts</b>                                         |             |            |            |           |
| <b>Row Crops</b>                                         |             |            |            |           |
| <b>Other Tree Crops (specify):</b><br>_____              |             |            |            |           |
| <b>Other Crops (specify):</b><br>_____                   |             |            |            |           |

**Q25.** If you indicated that you grow trees in **Q24**, how many years have you been involved in managing tree crops for commercial production?

\_\_\_\_\_ years

**Q26.** In the past five years, my fruit/nut tree chilling hours have (mark your selection with an X):

- ☐ Decreased
- ☐ Stayed the same
- ☐ Increased

**Q27.** The percentage of cropland on my farm that is flat is (**mark your selection with an X**):

- ☐ Less than 50%
- ☐ More than 50%

**Q28.** In the table below, we are requesting you to provide information about the number of paid and unpaid workers you employed in your farm business in 2023.

|                                                                          | Numbers of workers |
|--------------------------------------------------------------------------|--------------------|
| Hired labor                                                              |                    |
| Contract labor (workers indirectly hired through farm labor contractors) |                    |
| Independent contractors (e.g., 1099 worker)                              |                    |
| Paid family labor                                                        |                    |
| Paid interns                                                             |                    |
| Unpaid family labor                                                      |                    |
| Volunteers                                                               |                    |
| Other                                                                    |                    |

### About You

**Q29.** You are: **Mark your selection with an X.**

- ☐ Male
- ☐ Female
- ☐ Prefer not to disclose.

**Q30.** In what year were you born? \_\_\_\_\_

**Q31.** In what state is your farm located? \_\_\_\_\_

**Q32.** In 2023, in what county(s) were your farm(s) located? \_\_\_\_\_

**Q33.** What is the highest level of formal education that you have completed? **Mark your selection with an X. Mark only one option.**

- ☐ Some high school or less.
- ☐ High school diploma or equivalent
- ☐ Some college, but no degree
- ☐ 2-year college or technical degree
- ☐ 4-year college degree
- ☐ Some graduate school
- ☐ Graduate degree
- ☐ Other, please specify: \_\_\_\_\_

**Q34.** Select the option that best describes your occupational status. **Mark your selection with an X. Mark only one option.**

- ☐ Full-time farmer with no other employment
- ☐ Farm and employed full-time off the farm
- ☐ Farm and employed part-time off the farm
- ☐ Retired and farming part-time
- ☐ Usually employed (full-time or part-time) off the farm, but currently not employed off the farm
- ☐ Other, specify. \_\_\_\_\_

**Q35.** When you compare yourself to other operators in your industry, would you say that you are willing to take more or less risks with respect to the following aspects of your operation?

|                                       | Much less                | Somewhat less            | About the same           | Somewhat more            | Much more                |
|---------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <b>Introduction of a new practice</b> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Financial management</b>           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Production</b>                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <b>Marketing</b>                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

**Please keep in mind we will only use summarized financial information in anything we report. Your financial information is not associated with your name in the data this survey generates and will not be shared with individuals outside the project research team.**

**Q36.** Select the range that best represents the percentage of your taxable household income from farming in 2023. **Mark your selection with an X. Mark only one option.**

- |                                     |                                              |
|-------------------------------------|----------------------------------------------|
| <input type="radio"/> Less than 25% | <input type="radio"/> More than 75%          |
| <input type="radio"/> 25%- 49%      | <input type="radio"/> Prefer not to disclose |
| <input type="radio"/> 50% - 74%     |                                              |

**Q37.** In 2023, what was your gross on-farm revenue generated from all farm business? **Mark your selection with an X. Mark only one option.**

- |                                             |                                                 |
|---------------------------------------------|-------------------------------------------------|
| <input type="radio"/> Less than \$25,000    | <input type="radio"/> \$500,000 - \$999,999     |
| <input type="radio"/> \$25,000 - \$49,999   | <input type="radio"/> \$1,000,000 - \$2,499,999 |
| <input type="radio"/> \$50,000 - \$74,999   | <input type="radio"/> More than \$2,500,000     |
| <input type="radio"/> \$75,000 - \$99,999   | <input type="radio"/> Prefer not to disclose.   |
| <input type="radio"/> \$100,000 - \$249,999 | <input type="radio"/> Not applicable.           |
| <input type="radio"/> \$250,000 - \$499,999 |                                                 |

**Q38.** Are you currently a member of the Pick Tennessee Products (PTP) program? **Mark your selection with an X. Mark only one option.**

- ☐ Yes
- ☐ No

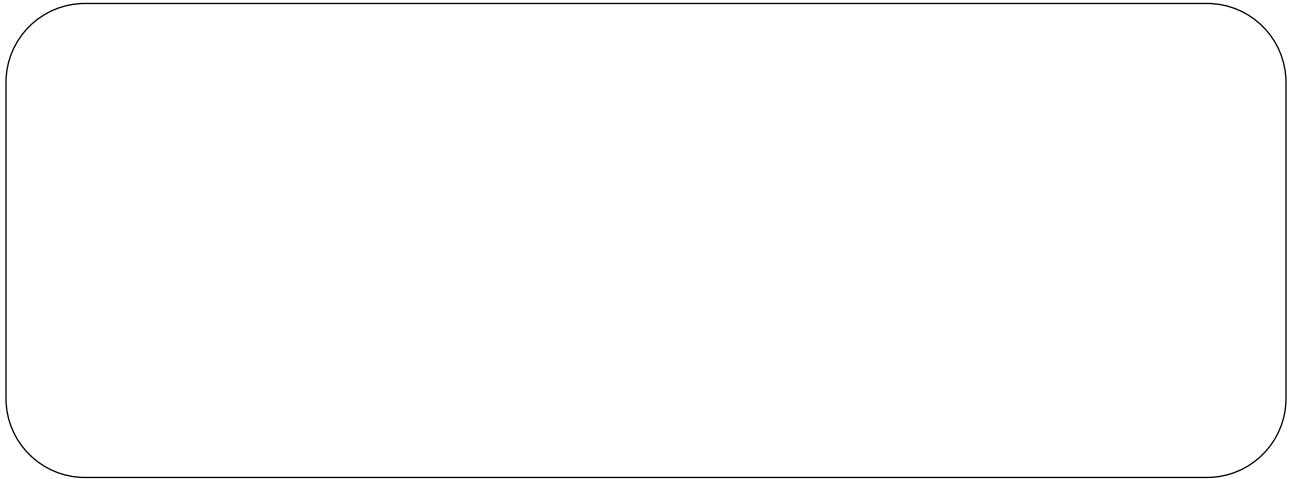
**Q39.** Is your contact information updated on the Pick Tennessee Products (PTP) program website

(<http://www.picktnproducts.org>)? **Mark your selection with an X. Mark only one option.**

- ☐ Yes
- ☐ No

If you want to become a member of or update your contact information with the PTP program, send your contact information to [pick.tn@tn.gov](mailto:pick.tn@tn.gov) to help the program personnel advertise your farm and the products you sell (**you can become a member of PTP at no cost**).

**Q40.** Thank you for completing the survey. If you have any other comments you would like to share, please note them here.



**We thank you for your time spent taking this survey.**

*Please send your completed survey in the enclosed postage-paid business reply envelope. If that is misplaced, please send to:*

*Margarita Velandia  
UT Agricultural & Resource Economics  
2621 Morgan Cir. 314 C Morgan Hall  
Knoxville, Tennessee 37996*

## **VITA**

Hasibul Hasan Shanto is from Kishoreganj, Bangladesh. He graduated from the Sher-e-Bangla Agricultural University with a Bachelor of Science degree in Agricultural Economics in February of 2022. Hasibul Hasan Shanto also attended the University of Tennessee-Knoxville from August 2023 to May 2025, where he earned a Master of Science degree in Agricultural and Resource Economics.