Species Diversification for Climate Adaptation in Perennial Systems: Trading off Annual Costs for Long-term Resilience Benefits

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October 31, 2026

Abstract

Species diversification can enhance the resilience of agroecosystems to climate-related shocks and serve as a climate adaptation strategy. We study how producers in perennial systems weigh the annual costs against the delayed resilience benefits of species diversification, and how climate projection information shifts this trade-off. Given that private investments in resilience generate public good benefits, we test whether producers view diversification by others as strategic complements or substitutes. We develop a dynamic optimization model of a producer choosing the optimal diversification intensity and test its predictions with U.S. maple producers using a discrete choice experiment with a randomized climate-impact information treatment. The annual payment required rises by about $47 per acre for each percentage point increase in diversification intensity. Older producers require more than twice as much payment as their younger peers when asked to commit to longer contracts, and most prefer to keep their current monocultures. Through a salience effect, region-specific climate projection information shifts how producers weigh costs and benefits over time, by increasing the weight they place on future resilience benefits and reducing the weight placed on annual yield losses. Peer adoption shifts this weighing across space, as producers view diversification by peers as a strategic complement to their own investments, reducing the required payment by 29% when 50% of peers have diversified. These results suggest three strategies for conservation programs seeking to increase agroecosystem resilience through species diversification while lowering costs: accounting for older producers' temporal constraints in longer contracts, coordinating adoption among neighbors, and pairing payments with climate information.

Keywords: Agroecosystem resilience; Climate adaptation; Discrete choice experiment; Dynamic optimization; Maple forests; Perennial systems; Species diversification
JEL Codes: C35, Q23, Q54, Q57

We are grateful to Madhu Khanna, Ben Gramig, Frank Lupi, Petr Mariel, Klaus Moeltner, Roger von Haefen, and Simanti Banerjee, as well as participants at the JEEM/REE Workshop on Nonmarket Valuation, 2026 WCERE, AERE Summer Conference, BIOECON Conference, AAEA, Heartland Workshop, and pERE seminar at the University of Illinois, for helpful discussions, comments, and feedback. We also thank David Moore and Chris Evans of Illinois Extension for sharing their insights on the maple industry and providing feedback on the survey design, Jawad Khan for assistance with pilot data collection, and the maple producers who participated in our survey. The survey was approved by the University of Illinois IRB (IRB23-0084). This work is supported by the U.S. Department of Agriculture's National Institute of Food and Agriculture, award No. 2022-67019-36394.

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1 Introduction

Climate change poses significant challenges to agriculture and natural resource management, affecting the productivity and biodiversity of ecosystems (Dawson et al., 2011; Ortiz-Bobea et al., 2021; Weiskopf et al., 2020). These challenges are particularly acute in perennial systems such as forests, where recovery from disturbances can take decades, and climate conditions may change at rates that exceed the natural adaptive capacity of ecosystems (Seppälä et al., 2009). Managed adaptation in these long-lived systems often requires long-term investments that entail substantial upfront and recurring opportunity costs and are difficult to reverse, while benefits are delayed, uncertain, and partly shared with ecologically connected neighbors and the broader society (Keenan, 2015; Roshani et al., 2022). Effective climate adaptation therefore depends not only on biophysical effectiveness but also on the economic and behavioral constraints that shape long-term management decisions.

The U.S. maple syrup industry, a forest-based production system, provides a salient context for examining these issues. It relies heavily on a single tree species, sugar maple (*Acer saccharum*). This monoculture concentrates exposure to host-specific pest and disease outbreaks, and climate stresses such as severe drought further increase vulnerability (Skinner et al., 2010; Wood et al., 2009). In this context, species diversification has been widely proposed as a climate adaptation strategy to enhance socio-ecological resilience (Bolte et al., 2009; Messier et al., 2022). Ecological evidence shows that greater tree-species diversity reduces forest susceptibility to pest and disease outbreaks (Bauhus et al., 2017; Jactel et al., 2021). In maple forests, species diversification can be achieved by letting other native tree species, including syrup-producing trees such as birch, beech, walnut, and sycamore, regrow alongside sugar maple as opposed to being thinned (Jactel et al., 2017, 2021; Knoke et al., 2005; van den Berg et al., 2013). However, adapting through species diversification involves important intertemporal trade-offs for producers. Other species may reduce annual syrup yields through interspecies competition, while resilience benefits materialize only in the long run (Wildberg and Möhring, 2019). Moreover, the benefits of species diversification - increased resilience and ecosystem service provision - are non-excludable. As a result, producers bear the private costs of investment while part of the benefits accrues to neighbors and society more broadly, creating a divergence between the privately and socially optimal levels of species diversification (Hanley et al., 2012; Hanley and Perrings, 2019). Understanding how producers weigh these trade-offs is therefore critical for assessing the potential adoption of species diversification and designing more cost-effective policies that encourage climate-resilient forest management.

This paper addresses the question of how producers in perennial systems weigh the in-

tertemporal trade-offs of species diversification as a climate adaptation strategy, and how climate projection information shifts these trade-offs. Because species diversification generates an impure public good, we also ask whether producers' species diversification decisions are strategic complements or substitutes. To answer these two questions, we first develop a dynamic optimization model in which a producer chooses the optimal diversification intensity, defined as the share of non-maple trees in the sugarbush (the forest stand tapped for maple syrup). The model captures the intertemporal trade-off: species diversification imposes transition costs and reduces annual maple yields through shading, while its resilience benefits, a reduction in expected climate-related damage, arrive with a lag that reflects the time needed for non-maple species to grow. Species diversification by peers alters the local expected climate-related damage a producer faces, capturing spatial spillovers of resilience to pest outbreaks across ecologically connected neighboring stands. An annual incentive payment over a fixed contract period offsets part of the costs. The model predicts how these factors affect producers' adoption decisions, but the magnitude, and in some cases the direction, of their effects depend on producers' preferences, beliefs, and risk attitudes, making empirical analysis necessary. To empirically quantify how producers assess the intertemporal trade-offs and how climate information shifts their values, we then implement a discrete choice experiment with a randomized climate information treatment. A stated preference approach suits this setting because species diversification in sugarbushes remains rare and no public incentive program targets it, so observed land use reveals little about producers' preferences for species diversification under future climate change. The experiment elicits producers' preferences for hypothetical species diversification scenarios characterized by diversification intensity, maple yield loss, resilience benefits, contract length, peer adoption, and incentive payment. Between two identical sets of choices, half of the producers received region-specific projections of climate impacts on syrup production under RCP8.5 (Rapp et al., 2019), and the other half received neutral information.

Producers' baseline choices reveal how they weigh the costs of species diversification against its delayed benefits in the absence of climate information. On the cost side, the required annual payment rises by about $47 per acre for each percentage point increase in diversification intensity, and an expected 20% loss in maple yield increases the payment by about $525 per acre. Although longer contracts align commitments with the long-term horizon of resilience benefits, older producers require more than twice as much payment as their younger peers when asked to commit to longer contracts, and most of them prefer to keep their current monocultures. On the benefit side, on average, producers place no positive value on future resilience benefits that arrive 15 to 20 years later. Younger and environmentally oriented producers, however, value these benefits significantly more, as do

producers with longer self-reported planning horizons. For older producers, whose planning horizons are shorter, delayed resilience benefits carry little weight. As a result, they require compensation that covers most of the cost of species diversification.

Climate projection information provision affects both sides of this intertemporal trade-off. Region-specific climate projections raise the weight producers place on future resilience benefits and lower their weight on annual yield losses. These effects concentrate among producers with strong prior beliefs that climate change will affect their sugarbush, suggesting salience rather than belief updating. Payments are therefore more effective when paired with climate information, which is most salient among producers who already perceive climate risk. Whereas climate information shifts how producers weigh resilience benefits over time, peer adoption shifts how they weigh benefits across space, and both lower the required payment. Producers treat species diversification by peers as a strategic complement. When half of a producer's peers have diversified, the payment required for a 25% diversification intensity falls by 29%. This response concentrates among producers who view their stands as ecologically connected to neighboring ones. Coordinating program enrollment among neighbors can lower the cost of achieving a given level of species diversification across a landscape.

This paper contributes to three strands of literature. First, it contributes to the literature on climate adaptation on working lands. This literature examines how farmers reduce climate damages by adjusting the timing and intensity of input use within the growing season, switching crops, or diversifying crops (Bozzola and Smale, 2020; Burke and Emerick, 2016; Kurukulasuriya and Mendelsohn, 2008; Ortiz-Bobea and Just, 2013). However, it focuses on annual crops, in which adaptation decisions can be revised each season. Adaptation in perennial systems instead requires long-term investments with long establishment periods and large establishment and opportunity costs, while benefits are realized only years later (Ghorbani and Atallah, 2024; Trilnick and Zilberman, 2021). Existing work on species diversification in these systems consists largely of agronomic or normative studies (Clément et al., 2023; Macpherson et al., 2017), and offers limited insight into producer preferences. We extend this literature to species diversification as a long-term climate adaptation strategy in perennial systems and examine how producers trade off its upfront and recurring costs against delayed resilience benefits. We also provide experimental evidence on whether information about future climate impacts changes how producers weigh this trade-off.

Second, it contributes to the literature on the private provision of public goods and the literature on impure public goods. Species diversification is an impure public good, generating private resilience benefits for the producer, local public benefits for neighboring stands, and broader public benefits for society (Cornes and Sandler, 1984; Holtermann,

1972). Bergstrom et al. (1986) show that private contributions to a public good are strategic substitutes, as provision by others crowds out own provision and leads to free-riding and underprovision. However, when the level of a public good depends disproportionately on its smallest contributions, as in weakest-link and weaker-link public goods, the return to one's own contribution rises with others' contributions, and contributions become strategic complements (Cornes, 1993). The control of forest pests and diseases has this weaker-link public good characteristic, because these mobile public bads spread across property boundaries and the effectiveness of one landowner's control depends on whether neighbors also control them (Burnett, 2006). Bioeconomic models show that pest and disease controls on neighboring properties are strategic complements and that heterogeneity among landowners in resource values or preferences determines which equilibrium emerges and who acts as the weaker link (Atallah, 2025; Costello et al., 2017; Fenichel et al., 2014; Martinez et al., 2024). However, these predictions come from theoretical and simulation models that abstract away from landowner preferences and characteristics or consider theoretical representations of these preferences to provide conceptual insights. We identify the nature of strategic interactions among landowners empirically by experimentally varying the share of peers who have diversified. We also measure producers' perceptions of ecological connectedness with neighboring stands, allowing us to test whether the nature of strategic interaction arises from beliefs about ecological connectivity of land parcels.

Third, it contributes to the literature on the design of payments for ecosystem services. Hanley et al. (2012) review incentive programs for biodiversity conservation on private land and identify how the cost of provision varies with the amount supplied, how long contracts should last, and how to achieve spatial coordination as central design questions. Experimental studies on conservation contracts typically estimate the extensive margin of adopting a practice or whether practices are adopted as a bundle (Canales et al., 2024; Howard et al., 2024; Palm-Forster et al., 2016). Instead, we study here the intensive margin as a contract feature to identify the diversification level at which marginal cost equals marginal benefit. On contract length, most studies focus on annual cropping systems and find that farmers dislike longer contracts regardless of age (Gramig and Widmar, 2018; Howard et al., 2024). However, in perennial systems, when ecological benefits mature slowly, theory predicts that optimal contracts are longer (Ando and Chen, 2011). We extend this literature by estimating the marginal willingness to accept payment for the intensive margin of species diversification and producer demand for contract length in a perennial system.

The remainder of the paper proceeds as follows. Section 2 describes maple production, the climate risks facing sugarbushes, and the policy context for species diversification. Section 3 develops the dynamic model and derives its predictions. Section 4 describes the survey

and the choice and information experiments, and Section 5 presents the empirical models. Section 6 reports baseline preferences and their heterogeneity, latent preference classes, information treatment effects, and the implied enrollment and compensation schedules. Section 7 concludes.

2 Background

2.1 Maple Production, Climate Risk, and Species Diversification

Maple syrup is produced from sap collected in sugarbushes, which consist of naturally regenerated forest stands managed to promote productive maple trees (Gibbs and Smith, 1970). Within these stands, production-oriented management has historically favored sugar maple because of its high sap sugar concentration and established commercial importance (Gregory and Hawley, 1983; Larochelle et al., 1998; Whitney and Upmeyer, 2004). Silvicultural practices such as thinning and crop-tree release reduce competition by other native tree species, increasing the access of maple trees to growing space and resources (Richardson, 2015). When applied preferentially to sugar maple over time, these practices reduce the relative abundance of other tree species and shift stand composition toward the maple dominance characteristic of a managed monoculture (Richardson, 2015; Schwartz et al., 2005; Whitney and Upmeyer, 2004).

The industry's reliance on sugar maple amplifies climate-related production risks. Maple trees face direct climatic impacts through changes in temperature and precipitation and indirect impacts such as more frequent and damaging pest and disease outbreaks during droughts (Horsley et al., 2002; Wood et al., 2009). Sap volume and sap sugar concentration jointly determine syrup yield, and both are sensitive to temperature dynamics (Rapp et al., 2019; Whitney and Upmeyer, 2004). During the late-winter and early-spring tapping season, warmer conditions can shift and shorten the sap-collection period, affecting sap volume (Graf et al., 2015; Rapp et al., 2019; Tyree, 1983). During the preceding growing season, higher temperatures affect carbohydrate storage and reduce sap sugar concentration in the subsequent tapping season (Rapp et al., 2019). In addition to these direct impacts, climate change affects maple production indirectly as heat and drought increase trees' susceptibility to pests and pathogens, thereby reducing forest productivity and increasing the risk of decline and mortality (Horsley et al., 2002; Wood et al., 2009). The high density and spatial continuity of susceptible hosts in managed sugar-maple monocultures may facilitate pest and pathogen transmission and increase exposure to maple-favoring insect defoliators, vascular diseases, and root pathogens (Houston et al., 1990; Jactel and Brockerhoff, 2007; Keesing

et al., 2010).

In this context, species diversification offers a potential adaptation strategy by increasing the maple agroecological system's resilience to these indirect impacts. This can be achieved by letting non-maple native syrup-producing tree species such as birch, beech, walnut, and sycamore grow in the sugarbush. Greater tree-species diversity can reduce forest susceptibility to pests and diseases as climate stress increases. Low density and spatial continuity of host trees limit pest and pathogen transmission through dilution effects and reduce exposure to specialist insect herbivores through associational resistance, and odors released by non-host species make it harder for insect pests to locate their hosts (Jactel et al., 2011; Jactel and Brockerhoff, 2007; Keesing et al., 2010; Zhang and Schlyter, 2004).

These resilience gains are not costless. Letting non-maple species grow alongside sugar maple increases crown competition and reduces maple sap yields (Wildberg and Möhring, 2019). Producers may also incur transition costs associated with learning, planning, and adapting management practices as the stand develops a more diverse composition. Although alternative species can generate syrup and other forest products, markets for these products remain thin, and harvesting seasons, sap sugar concentrations, and processing requirements vary across species (Farrell, 2013; van den Berg et al., 2013).

2.2 Intertemporal and Spatial Incentive Problems

Species diversification creates intertemporal and spatial incentive problems because its private costs and resilience benefits are misaligned across time and space. The intertemporal mismatch arises because producers incur adjustment costs and annual yield losses, whereas resilience benefits emerge as stand composition changes over a longer horizon (Hanewinkel, 2001; Hanewinkel and Pretzsch, 2000; Knoke et al., 2008). These delayed benefits have a lower private present value for producers with shorter management horizons. This mismatch can discourage current investment in species diversification even when it increases the forest's long-run expected value. Risk attitudes also shape this trade-off. Risk-averse producers may value reduced outbreak risk more highly, but they may also be deterred by the uncertainty of managing unfamiliar species and selling their products in thin markets.

The spatial mismatch arises because producers make management decisions at the parcel level, whereas forest pests and diseases move across parcel boundaries. Such threats constitute mobile public bads that connect management outcomes across spatially linked properties (Blackwood et al., 2010; Costello et al., 2017; Fenichel et al., 2014). Host density and continuity influence pest and pathogen transmission across the landscape (Jactel and Brockerhoff, 2007; Keesing et al., 2010; Macpherson et al., 2017). Diversification on one

parcel may therefore reduce pest and disease pressure on neighboring forests. The magnitude and geographic reach of these effects depend on the dispersal processes and ecological characteristics of the particular threat (Ferrenberg, 2016; Holdenrieder et al., 2004). When benefits extend beyond the diversified parcel, the investing producer does not capture the full return, creating an uncompensated spatial spillover (Sheremet et al., 2018). Figure 1 illustrates this mechanism. One producer bears the cost of diversification, while neighboring parcels may capitalize on the resulting pest and disease resilience benefits, as diversified parcels act as barriers to pest and disease spread and protect neighbors' parcels from future pest infestations.

These local spillovers make each producer's return to species diversification depend on neighbors' choices. If a neighbor's diversified parcel already acts as a barrier, a producer can benefit without bearing the cost, so diversification by others substitutes for one's own and creates incentives to free ride (Sheremet et al., 2018). If instead pests concentrate on the remaining maple hosts as neighbors diversify, the return to one's own diversification rises with neighbors' adoption, and diversification becomes a strategic complement that requires coordination across landowners (Sheremet et al., 2018; Vokoun et al., 2010). Which interaction prevails is an empirical question. Either way, species diversification presents a collective-action problem within an ecologically connected landscape (Fischer et al., 2019). Widespread adoption can strengthen landscape-level resilience, whereas limited adoption can reduce the private value of acting alone. The policy problem concerns not only the level of diversification provided on each parcel, but also the coordination of independently made management decisions across the landscape.

The benefits of species diversification also extend beyond neighboring stands. More resilient forests sustain ecosystem services that accrue to society more broadly, from carbon storage at the global scale to tourism and the cultural significance of maple at the regional scale (Hinrichs, 1998; Knoke et al., 2005; Messier et al., 2022). Species diversification is therefore an impure public good, with benefits accruing to the producer, to neighbors, and to society. Because producers bear the full cost but capture only part of these benefits, species diversification falls below the socially optimal level (Hanley et al., 2012; Hanley and Perrings, 2019).

2.3 Policy Context for Sugarbush Diversification

The intertemporal and spatial incentive problems described above provide an economic rationale for public support. Producers bear the near-term costs of diversification, while some resilience benefits arise in the future or partly accrue to other landowners or broader

society. The resulting divergence between private costs and privately captured benefits can lead to diversification below the socially desirable level (Hanley et al., 2012; Sheremet et al., 2018). The Environmental Quality Incentives Program (EQIP), administered by the USDA Natural Resources Conservation Service (NRCS), provides an established federal policy instrument to address these incentive gaps. Through EQIP, NRCS provides financial and technical assistance to agricultural producers and nonindustrial private forest managers who implement approved conservation practices (USDA NRCS, n.d.). Payment rates vary by practice, implementation scenario, state, and fiscal year (USDA NRCS, 2026).

Within the existing EQIP framework, Forest Stand Improvement, Conservation Practice Standard (CPS) 666, most closely aligns with sugarbush diversification. CPS 666 standard defines Forest Stand Improvement as manipulating forest species composition, structure, or density to improve forest health and productivity, reduce risks from pests, disease, and moisture stress, and restore or maintain natural plant communities (USDA NRCS, 2022). These objectives and management activities overlap with those of species diversification for agroecological resilience. However, the national standard and the FY2026 state payment schedules reviewed for this study do not identify species diversification as a distinct conservation practice nor do they adjust payments for diversification intensity, forgone maple revenue, or resilience benefits extending beyond the enrolled parcel (USDA NRCS, 2022, 2026).

This institutional gap raises several program-design questions. For species diversification, the diversification intensity defines an intensive policy margin that determines the level of diversification provision and may affect both ecological benefits and maple opportunity costs. A program must therefore determine not only whether to support diversification, but also how much diversification to require, how compensation should vary with the provision level and diversification intensity and how long contractual commitments should last. Because the returns to species diversification depend on neighbors' adoption, the compensation a program needs to offer may also vary with the share of neighboring producers who have diversified. These considerations frame the economic and policy analysis developed in the remainder of the paper.

3 Conceptual Model

We model a representative maple syrup producer who manages a tapped sugarbush of fixed area, A. In each year t, the producer chooses the area, $L_{n,t} \in [0, A]$, in which native non-maple species are growing alongside existing sugar maple trees. Expanding $L_{n,t}$ therefore does not involve removing sugar maple trees or reallocating land away from maple syrup

production; it increases the portion of the existing sugarbush managed as a mixed maple-non-maple stand. The producer's objective is to maximize the expected present value of future profits from maple syrup production and government incentive payments over an infinite horizon, T. Producers optimally choose the proportion of the sugarbush managed as mixed maple–non-maple stands to balance immediate economic returns against long-term resilience benefits under biotic and abiotic shocks. Following the dynamic acreage framework of Bareille and Letort (2018), the producer's diversification decisions affect both current and future production. The maximization problem is defined as follows[1]:

$$\begin{aligned}\max_{\phi_t} E\left(\sum_{t=0}^{T}\rho^t\pi_t\right) = \max_{\phi_t} E\Big[\sum_{t=0}^{T}\rho^t\Big(R_{m,t}\left(L_{n,t},\ peer_t\right) \\ - C_t\left(\phi_t\right) + \mathbf{1}\{t \le H\}(G_t(L_{n,t}) - \tau)\Big)\Big]\end{aligned} \tag{3.1}$$

$$\text{s.t.} \quad L_{n,t+1} = L_{n,t} + \phi_t, \qquad 0 \le L_{n,t} \le A, \qquad \phi_t \ge 0.$$

In this framework, annual profit in year t, represented as π_t, is determined by revenue from maple syrup production, $R_{m,t}$, the transition cost of expanding mixed-stand management, $C_t\ (\phi_t)$, and the government payment with a fixed annual contract cost, $G_t - \tau$, during the contract period. The government payment and contract cost terms apply only if the producer invests in diversification under the offered program, and in every year of the contract period ($t \le H$); otherwise, the producer remains in the status quo with no diversification ($\phi_t = 0$ for all t). ρ represents the inter-temporal discount factor (equivalent to $1/(1+r)$), with r as the annual discount rate. The benchmark model excludes revenue from syrup and other products obtained from non-maple species because markets for these products remain limited and underdeveloped. This exclusion provides a conservative benchmark for the private return to diversification.

The state variable $L_{n,t}$ denotes the areas under mixed maple-non-maple management in period t; the remaining area, $A - L_{n,t}$, is managed as status quo monoculture (maple-dominant management). The control variable ϕ_t denotes the additional area brought under mixed-stand management during that period, such that $L_{n,t+1} = L_{n,t} + \phi_t$. The mixed species area cannot exceed the fixed land endowment, $L_{n,t} \le A$, and the area allocated to mixed species (ϕ_t) must be non-negative. Diversification occurs by retaining and letting naturally occurring syrup-producing tree species regenerate and grow alongside existing sugar maple trees. The transition to mixed species management therefore represents a change in management regime rather than the removal of sugar maple trees or the conversion of land

[1]To simplify the analysis, the conceptual model assumes risk-neutral producers and formulates their decision as an expected profit-maximization problem.

away from maple syrup production.

To reflect the ecological and economic trade-offs associated with sugarbush diversification, we define the maple syrup revenue function as follows:

$$R_{m,t}\left(L_{n,t}, peer_t\right) = P_m a_m A^{\beta} \cdot \left[1 - S\left(L_{n,t}\right)\right] \cdot \left[1 - \left(1 - \theta \cdot peer_t\right) \cdot D\left(L_{n,t-k}\right)\right] \tag{3.2}$$

$$S\left(L_{n,t}\right) = a_s + \frac{b_s - a_s}{1 + e^{-k_s\left(L_{n,t} - x_{0s}\right)}}$$

$$D\left(L_{n,t}\right) = a_d + \frac{b_d - a_d}{1 + e^{k_d\left(L_{n,t} - x_{0d}\right)}}$$

The term $P_m a_m A^{\beta}$ denotes baseline maple syrup revenue under monoculture (maple-dominant management). The function $S\left(L_{n,t}\right) \in (0,1)$ captures contemporaneous yield losses from interspecies competition (e.g., shading), with $\frac{dS(L_{n,t})}{dL_{n,t}} > 0$. The function $D\left(L_{n,t}\right) \in (0,1)$ represents expected production damage from biotic and abiotic shocks (e.g., drought and pest outbreaks), with $\frac{dD(L_{n,t})}{dL_{n,t}} < 0$. Greater mixed-stand area may therefore reduce current maple yields while lowering expected future production damage due to external shocks. Yield losses from interspecies competition arise largely contemporaneously, whereas resilience benefits, measured as reductions in expected damage, accrue with a lag of k years, the time needed for non-maple trees to grow large enough to buffer the stand against weather and pest shocks. We specify $S(\cdot)$ and $D(\cdot)$ as sigmoid functions to allow their marginal effects to vary with the mixed-management area. Peer diversification enters through the term $(1-\theta \cdot peer_t)$, where θ captures the net effect of neighbors' diversification on the damage a producer faces and may take either sign. When $\theta > 0$, diversification by neighbors lowers pest and disease pressure on the producer's stand regardless of the producer's own management, which reduces the gain from the producer's own diversification and gives rise to free-riding. When $\theta < 0$, pests and diseases become concentrated on the remaining maple hosts as neighbors diversify, so that producers who remain undiversified become the weaker links in the landscape (Cornes, 1993; Fenichel et al., 2014). Because a diversified stand is buffered by non-maple species, this concentration widens the gap in expected damage between undiversified and diversified stands, increasing the return to the producer's own diversification.

We represent transition costs using the convex function, $C_t\left(\phi_t\right) = c\phi_t^2$. This specification captures increasing marginal costs associated with expanding mixed-stand management, including greater management complexity and potential learning barriers. This quadratic form reflects that small-scale diversification may be relatively affordable, while larger-scale shifts become increasingly costly. The government payment takes the form, $G_t\left(L_{n,t}\right) = gL_{n,t}$, during the contract period, where g is a constant annual payment per diversified acre. The payment therefore increases with the area under mixed-stand management.

We solve the first-order condition (FOC) of this maximization problem. Let $V_t(\cdot)$ denote the maximum expected discounted profit from period t onward, conditional on the current mixed-management area. The dynamic optimization problem can be solved using the Bellman equation:

$$V_t(L_{n,t}) \ = \max_{\phi_t} E \ \left\{ R_{m,t}\left(L_{n,t},\ peer_t\right) - c\phi_t^2 + \mathbf{1}\{t \le H\}(gL_{n,t} - \tau) + \rho E[V_{t+1}(L_{n,t+1})] \right\} \tag{3.3}$$

Based on Eq. (3.3), the FOC is defined as:

$$\frac{\partial R_{m,t}}{\partial L_{n,t}} \frac{\partial L_{n,t}}{\partial \phi_t} - 2c\phi_t + \mathbf{1}\left\{t \le H\right\} g \frac{\partial L_{n,t}}{\partial \phi_t} + \rho E\left[\frac{\partial V_{t+1}}{\partial L_{n,t+1}} \frac{\partial L_{n,t+1}}{\partial \phi_t}\right] = 0 \tag{3.4}$$

Since $\frac{\partial L_{n,t}}{\partial \phi_t} = 0 \ and \ \frac{\partial L_{n,t+1}}{\partial \phi_t} = 1$, then

$$\phi_t^* = \frac{1}{2c} \rho E\left[\frac{\partial V_{t+1}}{\partial L_{n,t+1}}\right] \tag{3.5}$$

Because the payment is earned annually on the mixed species area, it enters through the marginal value of mixed area: each additional acre earns g in every remaining contract year. By recursively substituting the envelope condition, we expand the $\frac{\partial V_{t+1}}{\partial L_{n,t+1}}$, which yields the final expression:

$$\phi_t^* = \frac{1}{2c}\left[g \sum_{i=1}^{H-t} \rho^i + \sum_{i=1}^{T-t} \rho^i E\left(MR_{t+i}^S\right) + \sum_{i=k+1}^{T-t} \rho^i E\left(MR_{t+i}^D\right) \right] \tag{3.6}$$

$$MR_{t+i}^S = -K \cdot S'\left(L_{n,t+i}\right) \cdot \left[1 - (1 - \theta \cdot peer_t) \cdot D\left(L_{n,t+i-k}\right)\right] < 0$$

$$MR_{t+i}^D = -K \cdot \left[1 - S\left(L_{n,t+i}\right)\right] \cdot (1 - \theta \cdot peer_t) \cdot D'\left(L_{n,t+i-k}\right) > 0$$

$$K = P_m a_m A^{\beta}$$

where i indexes future periods, with $i = 1$ referring to one year ahead of the current period t, and the summation continues incrementally up to T. The first term in Eq. (3.6) captures payments over the remaining contract years and is zero for $t \ge H$. Yield losses from competition enter from $i = 1$, whereas resilience benefits enter only from $i = k + 1$. The FOC reflects a trade-off: the producer balances short-term costs with long-term gains from resilience and government incentives.

Eq. (3.6) characterizes how much to diversify once the producer participates. Because participation entails a fixed annual contract cost, the decision whether to diversify compares the value of diversifying along the optimal path in Eq. (3.6), V_0^A, with the value of the status

quo, V^{SQ}. The producer diversifies if:

$$\Delta V \equiv V_0^A - V^{SQ} = \sum_{t=0}^{T} \rho^t \left[R_{m,t}\left(L_{n,t}^*\right) - R_{m,t}(0) - c(\phi_t^*)^2 + \mathbf{1}\{t \leq H\}\left(gL_{n,t}^* - \tau\right)\right] > 0, \tag{3.7}$$

Because ΔV varies across producers with characteristics not captured by the model, a parameter that raises ΔV increases the share of producers for whom $\Delta V > 0$, and hence the likelihood of diversification. Based on this dynamic optimization problem, we derive the following hypotheses on how program terms and conditions affect the likelihood of diversification. Each follows from the envelope theorem: the effect of a parameter on V_0^A equals its direct effect on discounted payoffs along the optimal path, with $L_{n,0} = 0$. Below, $L_{n,t}$ denotes the optimal path.

Hypothesis 1 *Higher incentive payment increases the likelihood of diversification.*

$$\frac{\partial \Delta V}{\partial g} = \sum_{t=0}^{H} \rho^t L_{n,t} > 0$$

Hypothesis 2 *Higher diversification costs, including transition costs and a requirement for new processing equipment, reduce the likelihood of diversification.*

$$\frac{\partial \Delta V}{\partial c} = -\sum_{t=0}^{T} \rho^t \phi_t^{*2} < 0$$

A requirement for new processing equipment imposes a one-time cost, F, which reduces the value of adopting to $\Delta V - F$:

$$\frac{\partial \Delta V}{\partial F} = -1 < 0$$

Hypothesis 3 *Larger annual maple yield losses from interspecies competition (e.g., shading) reduce the likelihood of diversification.*

Formally, let $y > 0$ denote the severity of yield loss from competition, entering the revenue function as a proportional reduction in output through the shading term, so that revenue is given by:

$$R_{m,t} = K \cdot \left[1 - y \cdot S\left(L_{n,t}\right)\right] \cdot \left[1 - \left(1 - \theta \cdot peer_t\right) \cdot D\left(L_{n,t-k}\right)\right]$$

$$\frac{\partial \Delta V}{\partial y} = -K \sum_t \rho^t \left\{S\left(L_{n,t}\right)\left[1 - (1 - \theta \cdot peer) D\left(L_{n,t-k}\right)\right] - S(0)\left[1 - (1 - \theta \cdot peer) D(0)\right]\right\} < 0$$

because $S\left(L_{n,t}\right) \geq S(0)$ and $D\left(L_{n,t-k}\right) \leq D(0)$.

Hypothesis 4 *Stronger resilience benefits increase the likelihood of diversification.*

Formally, write expected damage as $D(L) = a_d + (b_d - a_d)\,\sigma(L)$, where $\sigma(\cdot) \in (0,1)$ is decreasing in L, so that stronger resilience benefits correspond to a lower a_d. Then

$$-\frac{\partial \Delta V}{\partial a_d} = K(1-\theta \cdot peer)\sum_t \rho^t \left[\left(1-S\left(L_{n,t}\right)\right)\left(1-\sigma\left(L_{n,t-k}\right)\right) - \left(1-S(0)\right)\left(1-\sigma(0)\right)\right].$$

A lower a_d increases the damage avoided by a diversified stand relative to the status quo, since $1-\sigma\left(L_{n,t-k}\right) > 1-\sigma(0)$, but competition leaves the diversified stand with less yield to protect, since $1-S\left(L_{n,t}\right) < 1-S(0)$. Hypothesis 4 holds when the first effect dominates.

Hypothesis 5 *Peer diversification increases the likelihood of diversification if diversification decisions are strategic complements and reduces it if they are strategic substitutes.*

$$\frac{\partial \Delta V}{\partial peer} = K\theta \sum_t \rho^t \left[\left(1-S\left(L_{n,t}\right)\right) D\left(L_{n,t-k}\right) - \left(1-S(0)\right) D(0)\right]$$

Since the bracket is negative, as $S\left(L_{n,t}\right) \geq S(0)$ and $D\left(L_{n,t-k}\right) \leq D(0)$, peer diversification reduces the likelihood of diversification when $\theta > 0$ (strategic substitutes) and increases it when $\theta < 0$ (strategic complements). The sign of θ is therefore an empirical question.

Hypothesis 6 *The effect of contract length on the likelihood of diversification is ambiguous.*

A longer contract extends the stream of payments but also the period of contractual obligations:

$$\Delta V(H+1) - \Delta V(H) \approx \rho^{H+1}\left(gL_{n,H+1} - \tau\right)$$

A longer contract therefore reduces the likelihood of diversification when the annual contract cost exceeds the payment earned in the additional year.

Hypothesis 7 *Information that increases perceived climate risk increases the likelihood of diversification.*

Let $\mu > 0$ denote a subjective weight placed on climate-related damages, reflecting perceived risk severity. Revenue is given by:

$$R_{m,t} = K \cdot \left[1 - S\left(L_{n,t}\right)\right] \cdot \left[1 - \left(1-\theta \cdot peer_t\right) \cdot \mu \cdot D\left(L_{n,t-k}\right)\right]$$

$$\frac{\partial \Delta V}{\partial \mu} = -K\left(1-\theta \cdot peer_t\right)\sum_t \rho^t \left[\left(1-S\left(L_{n,t}\right)\right) D\left(L_{n,t-k}\right) - \left(1-S(0)\right) D(0)\right] > 0$$

The bracket is negative for the same reason as in Hypothesis 5.

4 Data and Survey Design

4.1 Survey Design

The survey targets maple syrup producers located in the Midwestern and Northeastern regions, which are the main areas of syrup production in the United States. Our sampling strategy for the full survey used convenience sampling from databases held by syrup producer associations and forest extension services[2], and a sample from Dynata, a sampling company that generates address lists based primarily on government reporting. We obtain the mailing addresses of maple syrup producers from Dynata based on the Standard Industrial Classification (SIC) code. The dissemination of the survey involved a mixed approach of web and mail-push-to-web surveys (Dillman, 2017). Respondents for whom we have physical addresses initially received a letter containing a link to complete the survey online, followed by a mailed paper survey to those who did not respond after two reminders. Others received emails from their producer associations and extension agents.

We conducted a pilot survey at the International Maple Conference in October 2023 to test and refine the survey instrument. Based on the pilot findings, we added questions on producers' current sugarbush practices, including whether they process sap into syrup or sell it to other producers. Additionally, based on feedback from the pilot survey, we clarified the spatial boundaries of peer adoption rates within the same regions due to the extensive size of maple forests, which may lack neighboring producers.

Our final survey consists of five parts. It begins by capturing the current situation (status quo) of producers' maple forests, including yield, syrup production, tree species composition, forest ownership, and syrup-related operations. Also, we ask about producers' experience with drought, pests, and diseases, including questions about yield stability and the main drivers of yield fluctuation, as well as involvement in any insurance or disaster recovery programs. Next, the survey explores producers' perceptions of forest diversification, including potential motivations and barriers, and examines their beliefs about climate change. Our CE is then introduced to elicit preferences for different forest diversification programs (details in the next subsection). We present all respondents with two identical sets of CE choice tasks (three tasks in each set, totaling six tasks). Between sets, the treatment group receives a targeted information script, while the control group receives neutral information. Following the CE, the survey concludes with a section on demographic characteristics, capturing data

[2]One potential bias of convenience sampling is the overrepresentation of smaller-scale and hobby producers, who tend to be overrepresented in Extension databases. To address this bias, we get the proportion of hobby producers from the USDA report and use it as a quota during the survey to ensure that our sample does not overrepresent this category and more accurately reflects the broader population of maple syrup producers.

on gender, age, education, and household income, as well as their risk preferences, time preferences, and loss aversion. An example choice card and the information materials are included in the Appendix.

4.2 Experimental Design

4.2.1 Discrete Choice Experiment

A discrete choice experiment (DCE) can elicit producers' preferences for hypothetical forest diversification programs with experimental information provision. This stated preference method is suitable in this case, given the absence of existing public incentive programs for forest diversification and the absence of relevant revealed preference data due to the current low level of diversification (Johnston et al., 2017; List et al., 2006).

In the CE, we present producers with several decision situations consisting of different alternatives. Each choice set includes two mutually exclusive alternatives, labeled as 'Option A' and 'Option B,' as well as a status quo option (opt-out option) labeled 'remain in the current situation.' The inclusion of the status quo option is intended to be consistent with the voluntary nature of conservation programs where there are no forced choices and to ensure consistency with demand theory (Hanley et al., 2001). Each diversification program option (a choice alternative) is described by seven attributes: diversification intensity, two outcomes from diversification (yield decrease and enhanced resilience to weather shock), equipment needed, peers' adoption rates, contract length with annual inspection, and annual payment. The CE design of the seven attributes with detailed descriptions and associated levels is summarized in Table 1.

We used a Bayesian approach to generate our choice set design (Scarpa et al., 2007). Firstly, we used the D-optimal approach to derive the choice design (zero priors) in the pilot phase. This was achieved through the maximization of the determinant of the information matrix |X'X|, which identified the best subset from all possible combinations. Then, based on the pilot data (19 respondents, 114 choice observations), we estimated a multinomial logit model and used the estimates as Bayesian priors to generate the final Bayesian D-efficient design for the final CE (data from the pilot sample were not used in the final analysis). The resultant CE was structured into eight blocks, each comprising three choice cards, with a total of 24 choice scenarios. Respondents were randomly assigned one block and completed 3 choice tasks. Appendix Figure A1 illustrates an example of the choice set that presents two diversification program scenarios and an opt-out option. The final experimental design accounts for main effects and selected two-way interaction effects. It includes the following two-way interactions: diversification intensity and expected maple yield loss; peer adoption

and diversification intensity; and peer adoption and increased resilience.

To mitigate hypothetical bias due to respondents' limited experience or knowledge of forest diversification, the survey incorporates both visual and textual descriptions of forest diversification, including the benefits, economic trade-offs, and non-maple tree species that can also be used to produce syrup. To ensure that every producer understands our hypothetical forest diversification program, we first defined forest diversification within the context of maple forests, using images to illustrate tree species diversification and its associated benefits. Then we provided a detailed explanation of the alternatives and attributes presented in the choice experiment. To promote consequentiality as suggested by Johnston et al. (2017), we stated the funding source from USDA and highlighted how the results will be disseminated, which could potentially influence the formulation of policies such as cost-share programs.

4.2.2 Information Treatment

Our goal is to identify how region-specific information about climate effects influences producers' willingness to accept compensation for species diversification, given that climatic impacts are heterogeneous across regions. The information treatment is illustrated in Appendix Figure A2. Rapp et al. (2019) project the future syrup production across the U.S. by the year 2100 in an RCP8.5 climate change scenario.

We combine within- and between-subject variation in exposure to information (Charness et al., 2012). First, we obtain within-subject variation by presenting respondents with two sets of DCE choice tasks with an information script between the two sets (Allcott and Taubinsky, 2015; Allcott and Wozny, 2014; Lang et al., 2021). The second source of experimental variation is between-subjects and involves a control group and a treatment group. More specifically, after completing 3 choice tasks, we assign half of the respondents to receive information interventions. Respondents then complete a second set of choice tasks (identical to the first set), which allows us to identify the impact of information on WTA estimates. In addition, producers answer a question that tests their attention and understanding of the information treatment[3].

Since respondents complete the choice cards sequentially, our within-subject treatment design introduces potential time-variant factors commonly associated with repeated choices, such as learning and fatigue (Campbell et al., 2015; Day et al., 2012). These factors are unrelated to the specific information content of our treatments and might bias the estimation

[3]After the information treatment, respondents indicated whether the map projected an increase or a decrease in future syrup production for their region. Because respondents reported their ZIP code earlier in the survey, each answer can be compared with the projection for the respondent's location.

of treatment effects. To control general time trends such as learning or fatigue, we include a neutral control group that receives information unlikely to influence their choices but still relevant to the context. Specifically, respondents are shown the percentage of maple syrup production by state in the U.S. in 2023 (Appendix Figure A2). After completing a screening question, participants proceed to the same three choice tasks they had completed before the treatment.

5 Empirical Models

5.1 Baseline Model

We utilize a random utility framework, which incorporates random (unobserved) preference variation and heterogeneity. Maple syrup producer i's utility from alternative j in choice occasion t, denoted as U_{ijt}, is a function of a vector of choice attributes $\mathbf{X_{ijt}}$:

$$U_{ijt} = V_{ijt} + \epsilon_{ijt} = \beta_i' \mathbf{X_{ijt}} + \epsilon_{ijt} \tag{5.1}$$

where V_{ijt} is a deterministic component based on observable attributes of each alternative; and ϵ_{ijt} is an unobserved stochastic component. We assume that ϵ_{ijt} has the Type 1 extreme value distribution. β_i is a vector capturing producer i's latent preference parameters for the attributes of alternative j. $\mathbf{X_{ijt}}$ is a set of attributes that include our CE attributes (diversification intensity, expected maple yield decline, increased resilience, new equipment requirement, share of peers diversifying, contract length), and a status quo alternative-specific constant (ASC) that equals one for the status quo alternative. The ASC captures utility from remaining in the current situation that is not explained by the attributes. Because the status quo is respondent-specific, its attribute levels reflect each producer's current conditions. Under this framework, the probability that producer i selects alternative j from a set of J alternatives in choice occasion t is given by:

$$Pr_{it}(j) = \frac{\exp(\beta_i X_{ijt})}{\sum_j \exp(\beta_i X_{ijt})} \tag{5.2}$$

Equation (5.2) is the conditional logit probability, which holds conditional on β_i. When preferences vary randomly across the sample population, the mixed logit model integrates this conditional probability over the distribution of β to account for random variations in taste:

$$Pr_{it}(j) = \int_\beta \left(\frac{exp\left(\beta_i X_{ijt}\right)}{\sum_j \exp(\beta_i X_{ijt})} \right) f(\beta) d(\beta) \tag{5.3}$$

Because each producer makes several choices, we held random parameters constant over choice situations (Train, 2009). Thus, Equation (5.3) becomes:

$$Pr_{it}(j) = \int_{\beta} \left(\prod_{t} \frac{exp\left(\beta_i X_{ijt}\right)}{\sum_j exp\left(\beta_i X_{ijt}\right)} \right) f(\beta) d(\beta) \tag{5.4}$$

The integral in Equation (5.4) has no closed form, so we approximate it by simulation and maximize the simulated log-likelihood function LL over R simulation runs:

$$LL = \sum_{i} \ln \frac{1}{R} \sum_{r} \prod_{t} \frac{exp\left(\beta_i X_{ijt}\right)}{\sum_j exp\left(\beta_i X_{ijt}\right)} \tag{5.5}$$

We further calculate the marginal willingness to accept payment for the attributes. For this step, we divide the estimated non-monetary attribute parameter by the estimated parameter of the monetary attribute (Champ et al., 2003; Hu et al., 2012; Schulz et al., 2014):

$$WTA_i = \frac{\beta_i}{-\beta_{ip}} \tag{5.6}$$

where β_i and β_{ip} are the estimated coefficients of the attributes and the payment.

In our setting, each producer i chooses 6 times ($t \in 1,\ 2,\ ...,\ 6$) from a set of three alternatives ($j \in 1,\ 2,\ 3$), here diversification programs that vary in six attributes and the payment.

$$\begin{aligned} V_{ijt} = \beta_i' \mathbf{X}_{ijt} = \beta_{i1} Intensity_{ijt} + \beta_{i2} YieldDecline_{ijt} + \beta_{i3} Resilience_{ijt} + \beta_{i4} Equip_{ijt} \\ + \beta_{i5} Peer_{ijt} + \beta_{i6} Contract_{ijt} + \beta_{i7} Payment_{ijt} + \beta_{i8} SQ_{ijt} \end{aligned} \tag{5.7}$$

5.2 Heterogeneity Analysis

Producers with different characteristics may differ in how much weight they place on each attribute, which in turn influences their utility or choice. We apply two methods to investigate preference heterogeneity. First, we interact producers' individual characteristics Z_i with the attribute:

$$U_{ijt} = \beta_i^{'}\ \mathbf{X}_{ijt} + \theta_i^{'}\ (\mathbf{X}_{ijt}\ \times\ \mathbf{Z}_i) + \varepsilon_{ijt}$$

Identification comes from attribute variation within each choice set. Characteristics such as age do not vary within a choice set, so they cancel out on their own and enter only through their interactions with attributes. Each element of θ_i therefore measures how a characteristic changes the relative importance of an attribute. We report the total effect of each attribute at selected values of Z_i. Second, we estimate a latent class model (LCM) to segment producers

into distinct groups to uncover unobserved preference heterogeneity (Greene and Hensher, 2003; Scarpa and Rose, 2008). The respondents are divided into C preference classes. The model assumes homogeneous preferences within the group but heterogeneous preferences across groups.

In the LCM, individuals are assumed to belong to a class c with a certain probability w_{ic}. This means that $\beta_i = \beta_c$ with a probability of w_{ic} for $c = 1, \ldots, C$ (where $w_{ic} > 0$ and $\sum_c w_{ic} = 1$). Here, C denotes the total number of classes. The class assignment probability (w_{ic}) is unknown but is commonly parameterized using a semi-parametric multinomial logit form:

$$w_{ic} = \frac{\exp\left(h_i^T \vartheta_c\right)}{\sum_{c=1}^{C} \exp\left(h_i^T \vartheta_c\right)}, \qquad \vartheta_1 = 0 \tag{5.8}$$

where h_i denotes a vector of socio-demographic variables that are used to determine the class assignment probabilities. Normalizing ϑ_1 to zero allows the identification. In the simplest form, only a constant is included, without any potential socio-demographic characteristics.

By combining (5.2) and (5.8), individual i's choice probability for alternative j in choice situation t is expressed as:

$$Pr_{it}(j) = \sum_{c=1}^{C} w_{ic} \frac{\exp(\beta_c X_{ijt})}{\sum_j \exp(\beta_c X_{ijt})} \tag{5.9}$$

The LCM is estimated using an expectation-maximization algorithm (Train, 2008)[4]. To determine the optimal number of classes, we estimate the model across a range of class specifications and evaluate model fit using the Bayesian information criterion (BIC) and the corrected Akaike's information criterion (AIC).

5.3 Information Treatment Model

We estimate the effect of the climate-impact information by pooling the three pre-information and three post-information choices. Let Post_t equal one for the post-information choice occasions ($t = 4,\ 5,\ 6$), and zero otherwise. Let Info_i equal one if producer i received the climate projection information and zero if the producer received the neutral information. Utility is

$$V_{ijt} = \beta_i^{'}\ \mathbf{X}_{ijt} + \eta_i' \left(X_{ijt} \times \text{Post}_t\right) + \gamma_i' \left(X_{ijt}\ \times\ \text{Post}_t\ \times\ \text{Info}_i\right) \tag{5.10}$$

The coefficients η_i account for time-variant changes that are common to both groups in repeated-choice scenarios, including the learning and fatigue effects. The coefficients

[4]The latent class model is estimated in Stata using lclogit2.

γ_i are coefficients of interest and measure the climate information treatment effects. To examine for whom the information works, we allow the treatment effects to vary with a producer characteristic $\mathbf{Z}_i$, either region or the producer's standardized pretreatment belief that climate change will affect their sugarbush. The coefficients on $X_{ijt} \times Z_i \times \text{Post}_t \times \text{Info}_i$ measure how the effect of the information on each attribute's valuation varies with Z_i.

6 Results and Discussion

We present empirical results in four parts. First, we describe the sample and examine producers' baseline preferences. Second, we report preference heterogeneity results from the interaction and latent class models. Third, we estimate climate-impact information treatment effects and explore the behavioral channels underlying producers' responses. Finally, we translate the preference estimates into predicted participation and compensating-payment schedules across alternative levels of diversification provision and varying production, social, and contractual conditions.

6.1 Summary Statistics

Respondents are predominantly male (85.0%), have a mean age of 62 years, and 83% have at least some college education (Table 2). Maple production accounts for no more than 20% of household income for 78.7% of respondents. Existing production systems exhibit little tree-species diversification: About 95.0% of respondents report that their sugarbush currently contains only maple species. Operation size varies considerably. The median sugarbush area is 40 acres, with an interquartile range of 20 to 95 acres. About 62.6% own but do not lease sugarbush land, 9.5% lease but do not own, and 27.9% both own and lease. Production is highly vertically integrated, with 96.8% processing their own sap rather than selling it to other producers. Producers also face substantial yield variability and limited formal risk protection: Only 23.2% report that yields fluctuated by less than 5% around their average over the preceding decade, and 16.8% purchased crop insurance for syrup production in 2023.

Knowledge and beliefs measures provide additional context for diversification decisions. About 33.7% classify themselves as low risk-takers, while 58.4% have an implied discount rate of at least 20%. These characteristics may reduce the value placed on diversification, which involves immediate costs and resilience benefits that are delayed and uncertain. About 62.1% report at least average knowledge of non-maple syrup-producing tree species, and 56.9% expect climate change to affect sugarbush productivity within their lifetime. In

contrast, 33.7% believe that diversifying their own sugarbush would improve its resilience, and around 22% report that resilience benefits spill over between neighboring sugarbushes. Therefore, awareness of climate risk and of alternative tree species does not necessarily translate into perceived resilience benefits from species diversification, either on one's own sugarbush or across neighboring sugarbushes. Observed choices indicate substantial reluctance to participate in diversification programs. About 77.0% of respondents selected the status quo alternative in all six choice cards. This pattern suggests that aggregate preference estimates may combine attribute-level trade-offs among potential participants with persistent non-participation by other producers. It therefore motivates the subsequent analyses of observed and latent preference heterogeneity.

Formal assessment of sample representativeness is limited because USDA-NASS does not report national producer-level demographic or operation-level distributions for the maple industry, and we are not aware of larger-scale surveys for this industry. As a descriptive benchmark, the sample median syrup yield of 0.30 gallon/tap is close to the average annual national yield of 0.31 gallon/tap reported by USDA-NASS for 2019-2023 (USDA-NASS, 2022, 2024, 2026).

6.2 Baseline Preferences and Observed Heterogeneity

Table 3 reports conditional logit estimates based on the pre-information choice tasks. The main finding in Column (1) is a strong preference for the status quo, as indicated by a positive alternative-specific constant that is statistically significant at the 1% level. Maple diversification presents an inherently intertemporal choice. Producers decide whether to alter current forest management practices now, while the resilience attribute represents benefits realized in 15-20 years. The positive status quo coefficient indicates that, under the program conditions presented in the experiment, producers place substantial value on retaining their current management practices rather than initiating this transition.

Among the program attributes, only the required diversification intensity is statistically significant, with a negative effect at the 10% level. This result provides modest evidence that producers prefer less intensive diversification and are less likely to select programs requiring a larger departure from maple-dominant production. None of the remaining attribute coefficients are statistically significant at the 10% level. Given the concentration of choices in the status quo and substantial differences in producer characteristics and operations, a common-coefficient model may average over positive, negative, and negligible responses to the same attributes. We therefore next examine observed heterogeneity in attribute preferences.

The interaction estimates in Columns (2) - (5) reveal several systematic differences in how

producers weigh the choice attributes. Environmentally oriented producers place more weight on resilience improvements, arguably because they value the broader environmental benefits of a more diverse forest system. The weight on future resilience declines with producer age. One interpretation is a finite-horizon investment problem, in which diversification entails current costs while its resilience benefits are delayed and may not be realized within an older producer's remaining management horizon. Older producers may therefore assign a lower present value to these benefits, particularly if the benefits are not capitalized into land values or transferred through succession. A specification using self-reported planning horizon yields a similar result.[5]

The interaction coefficients show how the weight on an attribute changes with a characteristic, but not whether the attribute raises or lowers the likelihood of choosing a program for a given producer. Table 3, Panel D therefore reports total effects, the attribute coefficient plus the interaction terms evaluated at given characteristics. For increased resilience, the total effect is positive only for younger environmentally oriented producers (0.023 at age 52.5, $p < 0.05$). For environmentally oriented producers at the mean and upper-quartile ages, it is not statistically different from zero. For producers who are not environmentally oriented, it is negative at all three ages and becomes more negative with age, from -0.012 ($p < 0.10$) at 52.5 years to -0.036 ($p < 0.01$) at 72 years.

Age similarly shapes preferences for contract length. Studies of annual agricultural programs generally find that producers dislike the loss of flexibility associated with long-term contractual lock-in (Gramig and Widmar, 2018; Howard et al., 2024). In perennial systems, however, longer contracts also align the commitment with the time needed for resilience benefits to mature, and theory predicts that optimal contracts for slowly maturing ecological benefits are longer (Ando and Chen, 2011). Whether a producer can make such a commitment depends on their remaining time horizon. Older producers face shorter horizons and greater uncertainty about succession, so a long contract may bind them, or their successors, beyond the period in which they expect to manage the stand. Consistent with this temporal constraint, the weight on contract length declines with age. The total effect is close to zero at the lower-quartile age of 52.5 years (0.002) and becomes significantly negative at the upper-quartile age of 72 years (-0.082, $p < 0.05$). Younger producers are thus willing to accept the long commitments that perennial benefits require, whereas older producers are not. The interaction remains negative but is not statistically significant in Column (5), which uses a substantially smaller sample. Because most producers in the sample are older, these age

[5]Age is used in the main specification because it is objectively measured and predetermined relative to the choice tasks, whereas self-reported planning horizon could have been informed by the information in the experiment and jointly determined with the choices presented to respondents.

gradients in the weights on resilience and contract length also give a glimpse into how the payments needed for species diversification may change as the demographic composition of producers changes.

Heterogeneity also arises in how producers respond to diversification on the surrounding landscape. The weight on peer adoption is higher among producers who believe that their own diversification affects the resilience of neighboring sugarbushes, and that neighbors' diversification affects their own. For these producers, the total effect of peer adoption is positive and significant (0.015, $p < 0.05$), so diversification by peers is a strategic complement to their own. For producers without this perception, it is not statistically different from zero (-0.007). Coordinating enrollment among neighbors is therefore likely to be most effective where producers already perceive their stands as ecologically connected.

We next use latent class analysis to identify producer groups characterized by different combinations of status quo orientation and attribute valuations and to assess whether the strong aggregate status quo preference is concentrated within a particular segment.

6.3 Latent Class Analysis

We estimated latent class models with two, three, and four classes. Specifications with three or four classes did not converge to stable solutions and therefore provided no reliable basis for distinguishing additional preference groups. The two-class model identifies a large status-quo-oriented class and a smaller class more willing to consider diversification alternatives. We retain the two-class model, allowing the status quo constant and all nonpayment attribute coefficients to vary across classes. We constrain the annual-payment coefficient to be equal across classes because a test on the unrestricted specification does not reject equality of the class-specific payment coefficients, and the constrained specification has lower AIC and BIC than the unrestricted one. Results from the unrestricted model are reported in Appendix Table A1.

Table 4 reports the preferred two-class specification. The principal distinction between the two classes is their orientation toward the status quo. Class 1 has a positive and statistically significant status quo alternative-specific constant, whereas the corresponding coefficient for Class 2 is not statistically different from zero. The difference between the two coefficients is statistically significant. The strong status quo preference observed in the aggregate results is therefore concentrated within Class 1 rather than shared uniformly across producers. The classes also differ in how they respond to program attributes. For Class 1, annual payment is the only attribute that significantly affects program choice; none of the nonpayment attributes is statistically significant. Class 2, by contrast, responds positively

to annual payments and negatively to expected maple yield losses, indicating that these producers evaluate whether annual payments are sufficient to compensate for the opportunity cost of forgone maple production.

Class 1 accounts for 82.7% of the sample, while Class 2 accounts for 17.3%. The strong aggregate preference for the status quo therefore reflects both the pronounced status quo orientation of Class 1 and its large share. We refer to Class 1 as the status-quo-oriented class and to Class 2 as the diversification-receptive class, reflecting the latter's greater willingness to consider diversification programs and make trade-offs over program attributes. Class membership shows which producers are more likely to remain with the status quo, a question the attribute interactions do not address. Older producers, those with low risk tolerance, and those with a timber-related income objective are more likely to belong to the status-quo-oriented class. Producers who emphasize biodiversity protection are less likely to belong to it, suggesting that a biodiversity objective itself is a determinant of willingness to diversify. Gender and education do not significantly predict class membership.

This segmentation points to different barriers to diversification. The diversification-receptive class weighs annual compensation against the opportunity cost of expected annual maple yield losses. For the status-quo-oriented class, compensation increases enrollment, but changes in the nonpayment attributes have no detectable effects on program choice. Because most producers in the sample are older, the current age structure of landowners acts as a barrier to species diversification, although this barrier may ease as land passes to younger producers through succession.

6.4 Information Treatment Effects

The survey randomly assigned respondents to one of 16 groups formed by crossing eight choice-task blocks with two information conditions, the climate-impact information treatment and the neutral-information control. Appendix Figure A3 reports the number of choice observations generated by respondents who completed the relevant choice tasks in each block-by-condition group. The 16 groups differ in their realized counts, but every choice-task block contains both treatment and control observations, and neither experimental condition is systematically concentrated in a particular subset of blocks. This distribution mitigates concern that differential exposure to the choice scenarios across blocks drives the estimated treatment effects.

Appendix Table A2 reports estimates that exploit within- and between-subject variation in exposure to climate-impact information. We jointly estimate choices from the three pre-information and three post-information tasks. The attribute-by-post coefficients account for

changes between the two choice sequences in the neutral-information control group, including time-varying factors associated with repeated choices. The attribute-by-information-by-post coefficients measure the average incremental effect of the climate-impact information on the marginal utility of each attribute, net of the corresponding change in the control group.

Column (1) first examines whether the information treatment affects producers' general propensity to choose the status quo. The interaction is not statistically significant, indicating that the information does not generate an attribute-independent shift toward or away from program participation. Columns (2) - (4) then examine whether the treatment affects producers' valuation of the program attributes by sequentially expanding the set of attribute-specific treatment interactions. Column (2) allows the treatment to operate through the increased resilience attribute and shows that information raises producers' valuation of future resilience benefits. Column (3) adds the treatment interaction with expected maple yield decline. Here, we find that information increases producers' tolerance for the yield penalty, while the positive effect on resilience valuation remains statistically significant. Column (4) allows the treatment to operate through all nonpayment attributes. The full specification confirms the resilience and yield-loss results but shows no statistically significant effects through diversification intensity, equipment requirements, peer adoption, or contract length. Post-estimation tests in Column (4) evaluate the overall post-information valuation of resilience and expected maple yield loss. Receiving the climate-impact information increases producer valuation of increased resilience, a result that is statistically significant at the 10% level, compared with a statistically insignificant baseline valuation. For maple yield decline, the positive treatment interaction shifts the attribute coefficient upward, but the resulting post-information valuation remains not statistically significant. Thus, the treatment reduces the deterrent effect of expected yield losses without implying that producers value such losses positively. Together, these results indicate that the climate-impact information treatment increases producers' valuation of future resilience benefits and their tolerance for the near-term opportunity cost of diversification. It thus affects both the benefit and cost sides of the intertemporal trade-off rather than uniformly increasing producers' propensity to enroll.

Figure 2 translates the estimated information-treatment-induced changes in attribute valuation into predicted changes in program enrollment. In each panel, we compare predicted post-information enrollment under the estimated treatment response with a counterfactual that sets the corresponding information-treatment interaction to zero, while retaining the common post-task effects and holding the remaining attributes at their reference levels. We evaluate these changes at the midpoint of each attribute's experimental range, a 25% increase in resilience (range 0–50%) and a 10% expected decline in maple yield (range 0–20%). At

these levels, the climate-impact information raises predicted enrollment by 5.6 percentage points through the resilience channel and by 6.1 percentage points through the yield-loss channel, because treated producers are less deterred by a given expected yield loss. These estimates illustrate the participation implications of the two treatment channels. Information increases enrollment both by raising the value producers place on future resilience benefits and by reducing the extent to which expected near-term yield losses discourage diversification. Both probability changes are statistically significant at the 10% level.

We next examine heterogeneity by pretreatment climate-impact beliefs to assess whether the observed response pattern is more consistent with belief updating or with increased salience of existing climate concerns. Climate information may lead producers to revise their assessments of climate-related production risk, or it may bring existing concerns more directly into the diversification decision. A stronger response among producers with weaker pretreatment beliefs would be more consistent with belief updating, whereas a stronger response among those who already expect climate change to affect their sugarbushes would be more consistent with salience.

The models in Columns (5) - (7) of Appendix Table A2 use a standardized measure constructed from producers' pretreatment responses to whether climate change will affect sugarbush productivity during their lifetime, with higher values indicating stronger climate-impact beliefs. These models interact this measure with the treatment effects to examine belief-related heterogeneity. The model in Column (5) allows the resilience response to vary with these beliefs. The positive and statistically significant interaction indicates that the treatment-induced increase in resilience valuation is larger among producers with stronger pretreatment climate-impact beliefs. The model in Column (6) separately examines the yield-loss response and shows a similar pattern. Producers with stronger initial beliefs exhibit a larger increase in their tolerance for expected maple yield losses after receiving the climate-impact information. When considered separately, both attribute responses are stronger among producers with stronger pretreatment climate-impact beliefs. The model in Column (7) estimates the belief interactions for resilience and expected yield loss jointly. The belief-dependent resilience effect remains positive and statistically significant, whereas the corresponding yield-loss interaction becomes smaller and is no longer statistically significant. The joint specification therefore provides stronger evidence that pretreatment beliefs shape the treatment response to resilience than the response to expected yield losses.

Figure 3 translates the joint estimates into predicted changes in enrollment at two representative values of the standardized belief measure. Panel A evaluates the treatment response at one standard deviation below the sample mean, representing weaker initial beliefs that climate change will affect sugarbush productivity during the producer's lifetime. Panel B

evaluates the response at one standard deviation above the mean, representing stronger initial beliefs. At a 25% increase in resilience, the climate-impact information raises predicted enrollment by 9.9 percentage points for producers with stronger initial beliefs. For those with weaker initial beliefs, the estimated change is −4.9 percentage points and is not statistically different from zero.

The concentration of the resilience response among producers with stronger initial beliefs is more consistent with salience than with belief updating. The climate projections bring existing concerns about future production risk more directly into the diversification decision, increasing the weight placed on resilience benefits. By contrast, the information produces little detectable change in resilience valuation among producers with weaker initial beliefs. The effectiveness of climate information therefore depends not only on its content but also on the beliefs producers bring to the decision. Regional differences in the projections further test this interpretation. Midwest producers face more severe projected declines in syrup production, whereas Northeast producers, who account for most U.S. maple production, have more production at risk. If producers responded mainly to the content of the projections, either region could have shown a stronger response. The information effects, however, do not differ significantly between the two regions ($p = 0.25$; Appendix Figure A4). Producers' responses therefore track the beliefs they already hold more closely than the severity of the projections they receive.

6.5 Diversification Provision, Enrollment, and Compensation

Appendix Table A3 establishes the empirical basis for translating the estimated preferences into policy-relevant predictions of enrollment and compensating-payment schedules. To provide a common benchmark, the table reports the model-implied probability of selecting the status quo when all program attributes and the annual payment are set to zero, thereby isolating the contribution of the status quo alternative-specific constant. This counterfactual differs from observed status quo behavior, which reflects choices under the specific program and payment combinations presented in the experiment. It instead represents the baseline resistance that individual program benefits, requirements, and payments must overcome. The conditional and mixed logit models produce nearly identical counterfactual status quo probabilities of 79.1% and 78.3%, respectively, showing that this central result is robust across the two specifications. We use the mixed logit model for the subsequent analysis because it produces substantially lower AIC and BIC values and accommodates preference heterogeneity across producers. Its predicted enrollment probabilities reflect the estimated distribution of preferences rather than those of a single representative producer. We then

use the fixed annual-payment coefficient to translate the estimated utility effects of program requirements into monetary compensation.

Figure 4 translates the mixed logit estimates into predicted relationships between annual payments and program enrollment. Enrollment is defined as the probability of selecting either diversification program over the status quo. The solid blue curve provides a common benchmark across all four panels. It represents a program requiring a 25% diversification intensity, with no expected maple yield loss, no peer adoption, no contract requirement, no increase in resilience, and no new equipment requirement. Panel A compares this benchmark with higher levels of diversification provision, while Panels B-D retain the 25% intensity and vary expected yield loss, peer adoption, and contract length, respectively. The blue curve is therefore identical across panels, allowing each shift to be interpreted relative to the same underlying program.

Higher annual payments increase enrollment in every scenario, while diversification intensity, expected yield loss, peer adoption, and contract length each shift the payment–enrollment relationship. A leftward shift means that a given payment generates less enrollment, or equivalently that a given enrollment target requires greater compensation. A rightward shift means that the same enrollment target can be achieved with a lower payment. Under the benchmark specification, increasing the annual payment from \$600 to \$1,400 per acre raises predicted enrollment from 20.2% to 22.7%. At the \$1,400 payment level, increasing the required diversification intensity from 25% to 50% lowers predicted enrollment to 19.9%. A 20% expected maple yield loss reduces enrollment to 21.6%, whereas increasing peer adoption to 50% raises it to 23.9%. Requiring a 10-year contract lowers predicted enrollment to 19.7%.

The movements across panels identify several economic margins through which program design can influence participation. Panel A shows that higher levels of diversification provision require either greater compensation or acceptance of a lower enrollment rate. Panel B indicates that technologies and management practices that reduce expected maple yield losses can complement financial incentives. By lowering the opportunity cost of diversification, such improvements can increase enrollment without an equivalent increase in direct payments. Panel C shows that greater peer adoption can support higher levels of diversification provision at a given payment, suggesting a role for coordinated participation across producers. Panel D shows that longer contracts reduce enrollment at any given payment, indicating that contractual flexibility can substitute in part for higher compensation. This average reflects the age composition of the sample, since aversion to longer contracts arises mainly among older producers (Table 3, Panel D).

Table 5 translates the mixed logit estimates into the annual payment per diversified acre

required to compensate for a marginal change in each attribute, holding the other attributes constant. Each additional percentage point of diversification intensity raises the required payment by about \$46.6 (95% CI: 33.7 to 59.5), so a 25% diversification intensity requires about \$1,164 per acre per year. Each percentage point of the expected maple yield decline adds \$26.2, and each additional contract year adds \$118.7. Each percentage point of peer adoption lowers the required payment by \$6.7, so the payment falls by about \$334 when half of peers have diversified.

Appendix Figure A5 extends these marginal values to the full schedule of required payments, plotting against each level of diversification intensity the model-implied annual payment that offsets the associated utility loss. Because utility is linear in diversification intensity, the required payment rises proportionally, from about \$1,164 at 25% to \$2,329 at 50% and \$3,493 at 75%. The vertical distance between curves measures the payment associated with moving between levels of a given program attribute. A 20% expected maple yield loss adds approximately \$525 per acre per year relative to no yield loss. Increasing peer adoption from zero to 25%, 50%, and 75% reduces the required payment by approximately \$167, \$334, and \$501, respectively. Moving from no contract requirement to a 5-year, 10-year, or 15-year contract increases required compensation by approximately \$594, \$1,187, and \$1,781, respectively. Under the linear and additive specification, these dollar adjustments remain constant across required diversification intensity, producing the parallel schedules shown in the figure. Appendix Figure A5 therefore quantifies how required compensation varies with both the intensity of diversification provision and the level of each production, social, and contractual condition.

Figure 5 brings the compensation schedules together to compare the monetary effects of different program attributes. Panel A presents the full schedules across levels of diversification provision and marks the total annual payment implied by each schedule at a representative 25% required diversification intensity. Panel B isolates the vertical shift of each schedule relative to the benchmark, showing the additional payment or payment reduction associated with the corresponding change in each program attribute.

At the 25% diversification provision level, the benchmark program requires \$1,164 per acre per year. A 20% expected maple yield loss increases the required payment by \$525 to \$1,689, a 45% increase relative to the benchmark. Eliminating this expected yield loss through species selection or management would allow the same diversification intensity to be obtained for approximately 69% of the payment required under the yield-loss scenario, equivalent to a 31% reduction in program expenditures. Increasing peer adoption from zero to 50% reduces the required payment from \$1,164 to \$830, a reduction of \$334 or 29%. The model therefore implies that the same required diversification intensity can be obtained for

approximately 71% of the benchmark payment when half of the producer's peers have already diversified. A 10-year contract increases required compensation by $1,187 to $2,351 per acre, more than doubling the benchmark amount. The payment associated with the contractual commitment alone is slightly larger than the $1,164 required for the 25% diversification intensity itself. This contract estimate, however, averages across producers with different management horizons and must be interpreted in conjunction with the age heterogeneity shown in Figure 6.

Figure 6 shows that the average contract effect masks substantial heterogeneity by producer age. The compensation required for a 10-year contract rises steadily with age, indicating that younger producers are more willing to accept long-term commitments, whereas older producers place a substantially higher cost on contractual lock-in. The point estimate crosses zero at approximately 38.7 years. Below this threshold, the negative compensating payment implies a positive willingness to pay for the 10-year contract rather than a requirement for additional compensation. Within the observed age distribution, the estimated annual compensation increases from approximately $505 per acre at the lower-quartile age of 52.5 years to $1,220 at the upper-quartile age of 72 years. Appendix Figure A6 shows that the sample is concentrated among older producers. The large average contract adjustment in Figure 5 therefore reflects, in part, the age composition of the sample and should not be interpreted as uniform aversion to long-term contracts. This age gradient is consistent with differences in remaining management horizons and succession considerations between younger and older producers.

The age heterogeneity has direct implications for contract design in perennial systems. Although forest diversification generates benefits over a long horizon, age-related differences in management horizons imply that producers do not value a corresponding contractual commitment uniformly. A uniform 10-year requirement may require relatively high payments to retain older producers or exclude some of them from participation, while setting payments at that level for all participants would reduce program cost-effectiveness because younger producers require less compensation for the same commitment. Offering a menu of contract durations would allow producers to select options that better match their management horizons, thereby reducing participation barriers and improving the cost-effectiveness of program payments. Shorter or renewable contracts may better accommodate succession uncertainty, while longer contracts may secure durable diversification provision at lower cost from younger producers. Allowing contracts to transfer with the property could further reduce the cost of long-term commitment without sacrificing program durability. The policy objective is therefore not to differentiate contract terms mechanically by age, but to accommodate heterogeneity in management horizons and succession conditions.

The compensation results show that program cost-effectiveness depends not only on the payment level but also on how diversification provision is structured. Lowering expected yield losses through technical or management support, coordinating adoption across neighboring producers, and offering contracts that accommodate differences in management horizons can each reduce the payments required to secure a given level of diversification. These instruments operate through distinct economic margins. Technical assistance lowers the opportunity cost of participation, coordinated adoption increases the value of diversification across an ecologically connected landscape, and flexible contracts reduce the cost of long-term commitment. A cost-effective program may therefore combine financial incentives with technical, coordination, and contractual provisions rather than relying on uniform payments alone.

6.6 External Validity and Limitations

The economic mechanisms identified in this study extend beyond maple syrup production. In forestry and other perennial systems, altering species composition or production practices may impose immediate adjustment costs and forgone output, while resilience benefits accrue gradually over biological growth cycles. This temporal separation makes investment decisions sensitive to producers' management horizons, succession expectations, and the duration of contractual commitments. When pests, pathogens, and other ecological processes cross property boundaries, the return to one producer's investment may also depend on management decisions in the neighboring landscape, creating spatial externalities and incentives for coordination or free riding. These mechanisms are most relevant to long-lived production systems characterized by slow biological adjustment and ecological interdependence. The qualitative roles of management horizons, risk tolerance, contractual commitments, and neighboring adoption may therefore generalize to settings in which private land management contributes to landscape-level resilience.

Although the underlying mechanisms may generalize, their estimated magnitudes remain context-specific. Maple syrup production relies heavily on sugar maple, and diversification modifies the species composition of an existing, naturally regenerated forest rather than reallocating annually cultivated land. Estimated enrollment responses and model-implied compensating payments therefore depend on the baseline production system, associated opportunity costs, and the attribute levels and payment range represented in the experiment. These estimates can inform program design in comparable perennial systems but should not be transferred directly to other commodities, regions, or conservation practices.

Several limitations should be considered when interpreting these results. First, sugarbush

diversification remains uncommon, and no established conservation program treats it as a distinct practice. Revealed-preference data suitable for estimating participation in such programs are therefore unavailable, so the analysis relies on choices made under experimentally specified conditions. Actual participation may also depend on administrative requirements, payment reliability, implementation capacity, and uncertainty about realized ecological outcomes that the experiment does not fully capture. Second, we recruited respondents through state maple producer associations, extension services, and a commercial sample from Dynata, and the analytic sample excludes very small operations. The findings therefore apply most directly to association-affiliated producers with established maple operations and may not generalize to the smallest or less industry-connected producers. Finally, the experiment estimates producers' responses to stated resilience benefits, peer adoption, and climate information but does not independently quantify the magnitude or spatial reach of the underlying ecological effects. The results identify how producers value these outcomes when making diversification decisions, not the intensity or spatial configuration of diversification that would maximize social welfare. Integrating these behavioral estimates with empirically calibrated forest-growth, climate-risk, and landscape models would let future research evaluate the socially efficient intensity and spatial allocation of diversification.

7 Conclusion

Climate adaptation in perennial systems requires investments whose costs arrive every year, while their resilience benefits arrive years later and partly accrue to neighbors and society. This paper studies how U.S. maple syrup producers weigh these trade-offs in deciding whether and how intensively to diversify tree species, and how climate information and peer adoption shift the trade-off over time and across space.

Producers show a strong preference for their current monocultures. The required annual payment rises by about $47 per acre for each percentage point of diversification intensity, and an expected 20% loss in maple yield raises it by about $525 per acre. On average, producers place no positive value on resilience benefits that arrive 15 to 20 years later, but younger and environmentally oriented producers value them more. Older producers require more than twice as much compensation as younger producers to commit to a 10-year contract. Region-specific climate projections increase the weight producers place on resilience benefits and reduce the weight they place on yield losses, mainly among producers who already expect climate change to affect their sugarbush. Climate information therefore helps producers act on concerns they already hold, rather than changing their beliefs. Producers also treat diversification by peers as a strategic complement, and the required payment falls by 29%

when half of their peers have diversified.

These results suggest several ways to lower the cost of programs that promote species diversification. Favoring species and management practices that limit competition with sugar maple lowers the opportunity cost of diversification. Contract terms that account for older producers' shorter time horizons lower the cost of long-term commitment, and this cost may fall as ownership passes to younger producers. Coordinating enrollment among neighbors draws on the complementarity of diversification decisions, and pairing payments with climate information makes payments more effective among producers who already perceive climate risk.

Future research can link these preference estimates with calibrated forest-growth and pest-spread models to identify the intensity and spatial allocation of species diversification that maximize landscape resilience, and to target payments to producers who would not diversify without compensation. Payment structures that match the timing of costs and benefits, such as front-loaded or performance-based payments, and markets for syrup from non-maple species offer further ways to align private incentives with the social value of resilient forests.

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Figures and Tables

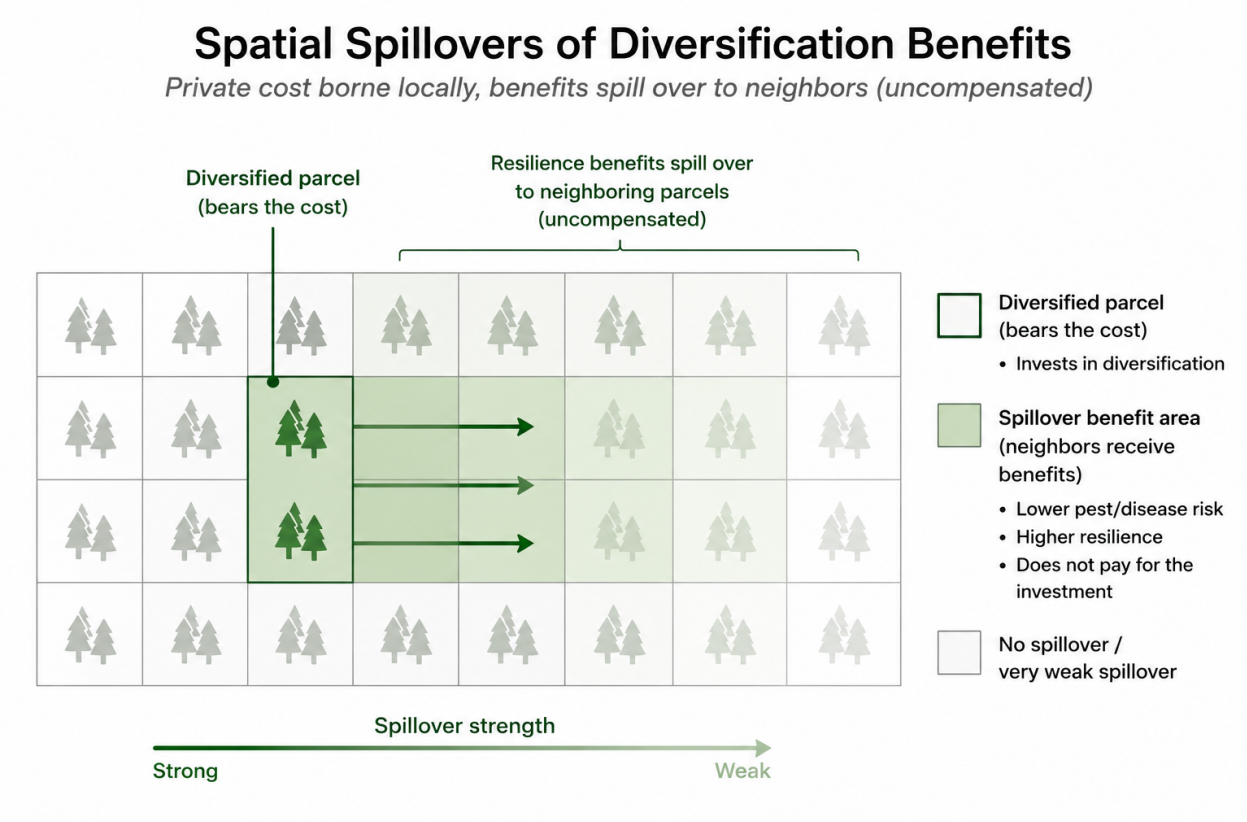


Figure 1. Spatial Spillovers from Forest Diversification

Notes: The figure illustrates how diversification on one parcel may generate benefits for neighboring parcels, although the diversified parcel bears the investment cost. Darker shading indicates stronger spillover benefits, which diminish with distance from the diversified parcel.

Table 1. Choice Experiment Attributes and Levels

Description	Variable name	Levels
Share of non-maple syrup-producing trees (e.g., birch, beech, etc.) relative to total syrup trees (maple + non-maple)	Diversification Intensity	25, 50, 75 (%)
Reduction in the likelihood of below-average yields in 15–20 years due to weather extremes, as a result of diversifying sugarbushes	Increased Resilience	0, 50 (%)
Annual decrease in maple syrup yield because of diversifying sugarbushes due to competition (e.g., shading)	Maple Yield Decline	0, 20 (%)
New processing equipment needed	New Equipment Required	0 (No), 1 (Yes)
Share of your producer peers in your state or neighboring state that have diversified their sugarbushes	Share of Peers Diversifying Sugarbushes	0, 25, 50, 75 (%)
Multi-year contract with annual inspection	Contract Length	5, 10, 15 (years)
Annual cost-share payment per diversified acre to you (above 10% share of non-maple)	Annual Payment	100, 350, 500 (Round 1) 600, 1,000, 1,400 (Round 2) ($/acre/year)

Notes: Each choice task presented two hypothetical diversification alternatives and a respondent-specific status quo alternative. Status quo levels for diversification intensity, increased resilience, maple yield decline, new equipment required, and the share of peers diversifying their sugarbushes were constructed from respondents' reported current conditions. Respondents reporting no non-maple trees were not asked the follow-up questions concerning maple yield decline, increased resilience, or new equipment requirements; these attributes were coded as zero for their status quo alternative. Peer diversification was elicited from all respondents. Contract length and annual payment were set to zero for all status quo alternatives. Annual payment levels were $100, $350, and $500 per diversified acre per year in the first survey round and $600, $1,000, and $1,400 in the second round. The payment levels were revised upward following feedback from early respondents that the initial amounts were too low. All other experimental attribute levels remained unchanged across rounds. The analysis retains the payment amount displayed to each respondent and treats annual payment as a continuous attribute. Robustness tests fail to reject equality of the payment coefficients across the two payment schedules and provide no evidence of a quadratic payment effect, supporting the use of a common linear payment coefficient in the pooled analysis.

Table 2. Sample Characteristics, Production, and Observed Choice Behavior

Variable	Definition	Statistic	Value	N
Panel A. Respondent characteristics				
Male	Indicator equal to 1 if respondent is male	Share	0.850	173
Age	Respondent age (years)	Mean (SD)	61.60 (14.36)	172
High school or less	Highest education is high school or less	Share	0.169	178
College	Some college or bachelor's degree	Share	0.590	178
Graduate or professional	Master's, doctoral, or professional degree	Share	0.242	178
Household income	Approximate annual household income ($1,000; category midpoint)	Mean (SD)	96.25 (48.38)	166
Maple-related income share ≤20%	Maple production and associated activities account for 0–20% of total household income	Share	0.787	178
Panel B. Operation and production characteristics				
Maple-only sugarbush	Sugarbush currently contains only maple species (monoculture practice)	Share	0.950	190
Sugarbush area	Owned plus leased sugarbush area (acres)	Median [Q1-Q3]	40 [20–95]	186
Own only	Respondent owns but does not lease sugarbush land	Share	0.626	190
Lease only	Respondent leases but does not own sugarbush land	Share	0.095	190
Own and lease	Respondent both owns and leases sugarbush land	Share	0.279	190
Taps: 100–499	Number of taps, reported as survey range	Share	0.302	189
Taps: 500–999	Number of taps, reported as survey range	Share	0.201	189
Taps: 1,000–4,999	Number of taps, reported as survey range	Share	0.376	189
Taps: ≥5,000	Number of taps, reported as survey range	Share	0.122	189
Processes own sap	Respondent processes own sap rather than selling sap to another producer	Share	0.968	189
Annual syrup production	Average annual syrup production over the preceding five years (gallons/year)	Median [Q1-Q3]	218.35 [60–757.5]	174
Syrup yield per tap	Reported gallons of syrup collected per tap	Median [Q1-Q3]	0.30 [0.25–0.485]	151
Crop insurance	Purchased insurance for syrup production in 2023	Share	0.168	185
Stable yields	Ten-year yields fluctuated less than 5% around their average	Share	0.232	190
Timber objective	Owns the sugarbush for timber production	Share	0.447	190
Biodiversity objective	Owns the sugarbush to protect nature and biodiversity	Share	0.695	190
Panel C. Behavioral Preferences, Knowledge, and Beliefs				
Low risk preference	Indicator equal to 1 if respondent identifies as a low-risk taker	Share	0.337	190

Continued on next page

Table 2 (continued)

Variable	Definition	Statistic	Value	N
High risk preference	Indicator equal to 1 if respondent identifies as a high-risk taker	Share	0.158	190
High implied discount rate	Indicator equal to 1 if estimated discount rate is at least 20%	Share	0.584	190
Knowledge of non-maple species	Reports average-or-higher knowledge of non-maple syrup-producing tree species	Share	0.621	190
Climate-impact belief	Agrees or strongly agrees that climate change will affect sugarbush productivity within the lifetime	Share	0.569	188
Own action to own resilience	Agrees or strongly agrees that own diversification affects own sugarbush resilience	Share	0.337	181
Own action to others' resilience	Agrees or strongly agrees that own diversification affects the resilience of other sugarbushes	Share	0.218	179
Others' action to own resilience	Agrees or strongly agrees that others' diversification affects own sugarbush resilience	Share	0.223	179
Environmental orientation	Donated to or was a member of an environmental group in 2023	Share	0.291	179
Panel D. Observed Choice Behavior				
Serial non-participants (SNP)	Selected the status quo alternative in all choice cards	Share	0.770	190

Notes: The full survey sample includes 190 respondents. Statistics are calculated using non-missing observations, and the final column reports variable-specific sample sizes. Binary and categorical variables are reported as sample shares. Household income was elicited as ordered ranges; the reported mean and standard deviation are calculated using response-category midpoints and should therefore be interpreted as approximate. Tap counts were elicited as ranges and are therefore reported categorically. Sugarbush area, annual syrup production, and syrup yield per tap are highly right-skewed, so we report medians, with the first and third quartiles in brackets. Annual syrup production and syrup yield per tap are reported among respondents who process their own sap and provided valid responses to the corresponding questions. USDA-NASS publishes national maple statistics on aggregate acreage, taps, production, yield, sales, and prices, but does not report producer demographic characteristics or operation-level distributions; therefore, no separate national-comparison column is shown. For descriptive context, the average of the USDA-NASS annual national syrup yield estimates for 2019–2023 was 0.313 gallon/tap, compared with a median of 0.30 gallon/tap in our sample. This comparison is descriptive because the sample statistic is a median across respondents, whereas the USDA benchmark is an average of annual national aggregate yields.

Table 3. Conditional Logit Estimates of Attribute Preferences and Observed Heterogeneity

	(1)	(2)	(3)	(4)	(5)
Panel A. Choice Attribute Coefficients					
Diversification Intensity	−0.0109*	−0.0119*	−0.0131*	−0.0137**	−0.0138*
	(0.0061)	(0.0064)	(0.0069)	(0.0069)	(0.0077)
Increased Resilience	−0.0016	−0.0091	0.0536***	0.0114	0.0301
	(0.0048)	(0.0062)	(0.0174)	(0.0173)	(0.0225)
Maple Yield Decline	−0.0015	−0.0012	−0.0005	0.0005	0.0021
	(0.0118)	(0.0119)	(0.0125)	(0.0128)	(0.0160)
New Equipment Required	0.0673	0.0174	0.1086	0.1599	0.4629
	(0.2374)	(0.2454)	(0.2694)	(0.2745)	(0.3960)
Share of Peers Diversifying Sugarbushes	0.0048	0.0047	0.0041	0.0040	−0.0075
	(0.0031)	(0.0031)	(0.0035)	(0.0036)	(0.0074)
Contract Length	−0.0041	−0.0004	−0.0048	0.2259***	0.1476
	(0.0250)	(0.0259)	(0.0291)	(0.0753)	(0.1075)
Annual Payment	0.0001	0.0000	0.0000	0.0001	0.0004
	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0006)
Status Quo ASC	2.0271***	1.8986***	1.8003***	1.6636***	2.1339***
	(0.4419)	(0.4651)	(0.5365)	(0.5491)	(0.6534)
Panel B. Observed Preference Heterogeneity					
Resilience × Environmental orientation		0.0196**	0.0343***	0.0333***	0.0219*
		(0.0092)	(0.0104)	(0.0108)	(0.0131)
Resilience × Age			−0.0012***	−0.0005*	−0.0007*
			(0.0003)	(0.0003)	(0.0004)
Contract length × Age				−0.0043***	−0.0032
				(0.0013)	(0.0020)
Peer share × Perceived interdependence					0.0225**
					(0.0099)
Panel C. Model Statistics					
Choice observations	1,710	1,611	1,530	1,530	1,107
Respondents	190	179	170	170	123
Pseudo R-squared	0.5162	0.5074	0.5478	0.5636	0.6369
Log pseudolikelihood	−302.943	−290.606	−253.352	−244.537	−147.196
AIC	621.89	599.21	526.70	511.07	318.39
BIC	665.44	647.67	580.03	569.74	378.50

Notes: The dependent variable equals one for the selected alternative and zero otherwise. All models use pre-information choice tasks (trials 1–3), and robust standard errors clustered by respondent are reported in parentheses. Column (1) presents the baseline conditional logit model. Column (2) adds the interaction between increased resilience and environmental orientation, where environmental orientation equals one if the respondent donated to or was a member of an environmental group in 2023. Column (3) adds the interaction between increased resilience and age, and Column (4) further adds the interaction between contract length and age. Age is measured in years. Column (5) adds the interaction between peer adoption and perceived landscape-level resilience interdependence. This column is estimated on the restricted sample of respondents who agreed or strongly agreed with all three of the following statements or with none of them: (i) their own diversification affects the resilience of their own sugarbush, (ii) their own diversification affects the resilience of other sugarbushes in the region, and (iii) diversification by others affects the resilience of their own sugarbush. The interaction indicator equals one for respondents agreeing with all three statements and zero for those agreeing with none. The smaller restricted sample in Column (5) should be considered when comparing its estimates with those in Columns (1) – (4). AIC and BIC are not comparable across models estimated on different samples. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Conditional Logit Estimates of Attribute Preferences and Observed Heterogeneity (continued)

	(1)	(2)	(3)	(4)	(5)
Panel D. Total Effects at Selected Producer Characteristics					
Increased Resilience, not environmentally oriented					
Age 52.5 (Q1)			−0.012*		
			(0.006)		
Age 62 (mean)			−0.024***		
			(0.006)		
Age 72 (Q3)			−0.036***		
			(0.008)		
Increased Resilience, environmentally oriented					
Age 52.5 (Q1)			0.023**		
			(0.009)		
Age 62 (mean)			0.011		
			(0.008)		
Age 72 (Q3)			−0.002		
			(0.008)		
Contract Length					
Age 52.5 (Q1)				0.002	
				(0.032)	
Age 62 (mean)				−0.039	
				(0.034)	
Age 72 (Q3)				−0.082**	
				(0.041)	
Share of Peers Diversifying Sugarbushes					
No perceived interdependence					−0.007
					(0.007)
Perceived interdependence					0.015**
					(0.006)

Notes: Panel D reports total effects, computed as the attribute coefficient plus the interaction coefficient evaluated at the indicated producer characteristics (Stata `lincom`), using the models in Panels A and B. Total effects for increased resilience are based on Column (3), for contract length on Column (4), and for the share of peers diversifying on Column (5). Age values correspond to the first quartile, mean, and third quartile of the sample age distribution. Standard errors clustered by respondent are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Latent Class Estimates of Attribute Preferences and Class Membership

	Class 1 (status quo oriented)		Class 2 (diversification receptive)
Panel A. Choice Attribute Coefficients			
Diversification Intensity	−0.0229		−0.0095
	(0.0178)		(0.0089)
Increased Resilience	−0.0741		−0.0050
	(0.0602)		(0.0080)
Maple Yield Decline	0.0458		−0.0475**
	(0.0411)		(0.0187)
New Equipment Required	0.7562		0.1218
	(0.8738)		(0.3361)
Share of Peers Diversifying Sugarbushes	0.0199		0.0085
	(0.0168)		(0.0063)
Contract Length	−0.2396		0.0253
	(0.1571)		(0.0398)
Status Quo ASC	3.5469**		−1.1959
	(1.6352)		(0.8594)
Annual Payment		0.0011*	
		(0.0006)	
Difference in Status Quo ASC: Class 1 – Class 2		4.7428***	
		(1.7806)	
Panel B. Class Membership Class 1 (status-quo oriented group) relative to Class 2			
Male	−0.4617		
	(0.7684)		
Age	0.0597***		
	(0.0177)		
Education	0.2189		
	(0.5388)		
Low risk preference	1.9319**		
	(0.9115)		
High risk preference	−0.0553		
	(0.6641)		
Timber-related income	1.4025**		
	(0.5914)		
Biodiversity protection	−1.8954***		
	(0.6957)		
Constant	−0.8914		
	(1.2069)		
Panel C. Model Statistics			
Posterior class share	82.7%		17.3%
Log likelihood		−157.092	
AIC		360.18	
BIC		482.30	

Notes: The dependent variable equals one for the selected alternative and zero otherwise. The model is estimated using the pre-information choice tasks (trials 1 – 3). Standard errors are reported in parentheses. Attribute definitions and units are provided in Table 1. Choice-attribute coefficients are allowed to vary across classes, except for Annual Payment, which is constrained to be equal across classes. A test fails to reject equality of the payment coefficients across classes, and the constrained specification has lower AIC and BIC than the class-varying specification. The difference in the Status Quo ASC is calculated as the Class 1 coefficient minus the Class 2 coefficient using a post-estimation linear combination. Class labels are descriptive and reflect the principal statistically significant preference patterns within each class. Class-membership coefficients represent changes in the log odds of membership in Class 1 relative to Class 2, the reference class. Posterior class shares are averages of respondent-level posterior class-membership probabilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

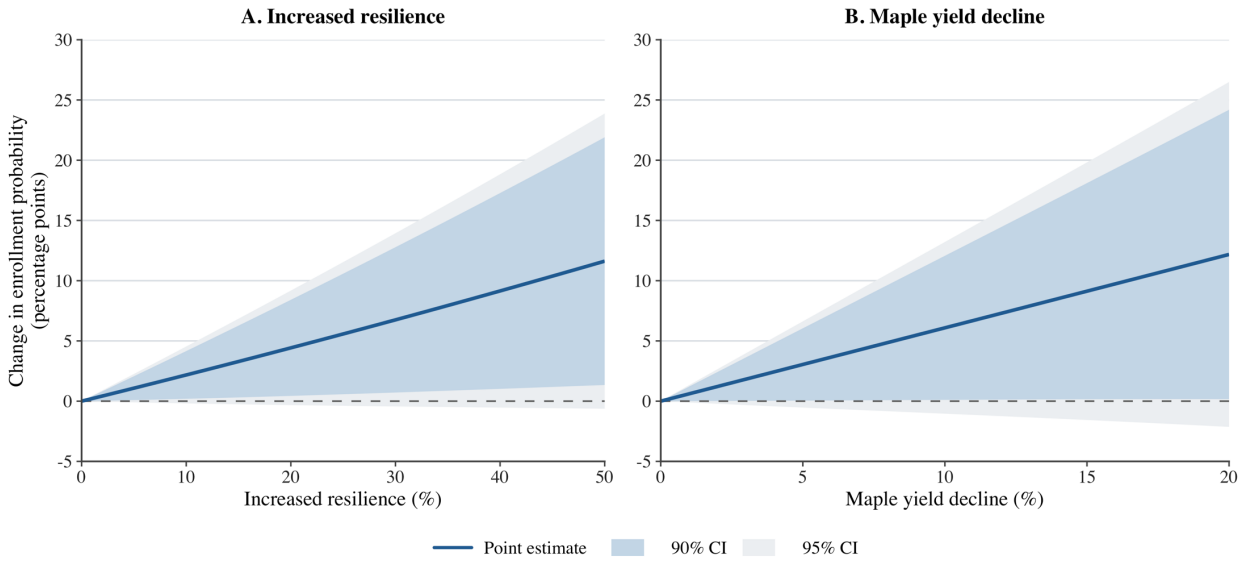


Figure 2. Information-induced changes in diversification enrollment probability

Notes: Solid lines show the estimated change in enrollment probability attributable to the information treatment through the indicated attribute channel. The estimates compare post-information choices with a counterfactual that excludes the corresponding attribute × information × post interaction, while retaining the common post-task effects and holding all other attributes at their reference levels. Shaded areas represent 90% and 95% confidence intervals. The dashed horizontal line denotes zero treatment effect.

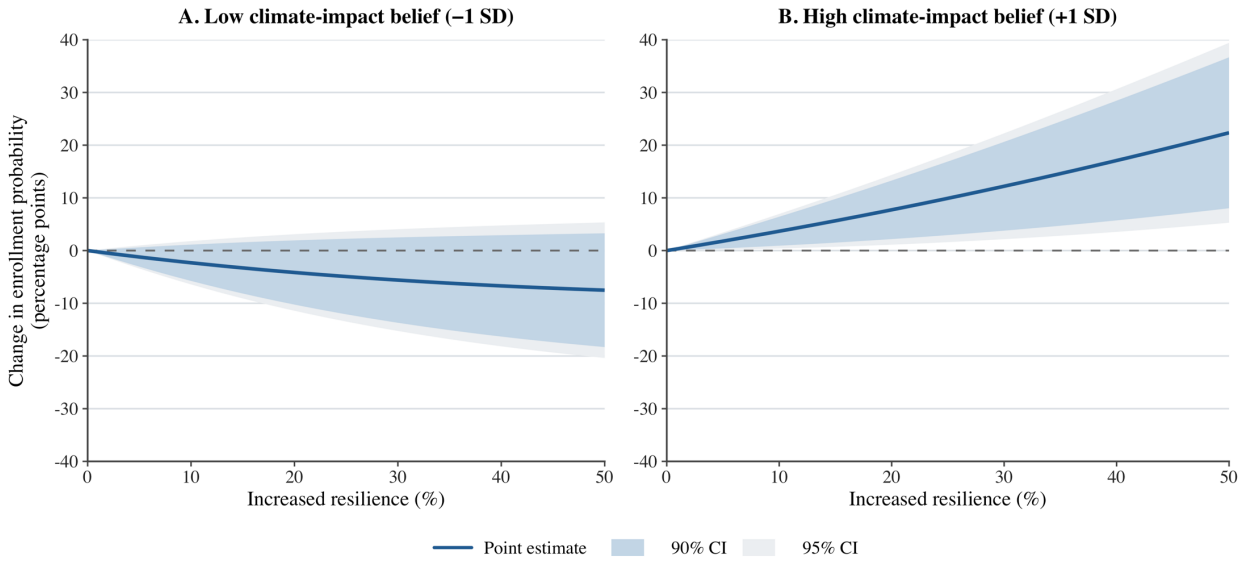


Figure 3. Information-induced resilience effects by pre-treatment climate-impact beliefs

Notes: Solid lines show the estimated change in enrollment probability attributable to the information treatment through the increased-resilience channel for respondents with climate-impact beliefs one standard deviation below and above the sample mean. Climate-impact belief is standardized and measures agreement that climate change will affect sugarbush productivity during the respondent's lifetime. Estimates are based on Table A2, Column (7), and compare post-information choices with a counterfactual that excludes the resilience-related information effects while retaining the common post-task effects and holding other attributes at their reference levels. Shaded areas represent 90% and 95% confidence intervals. The dashed horizontal line denotes zero treatment effect.

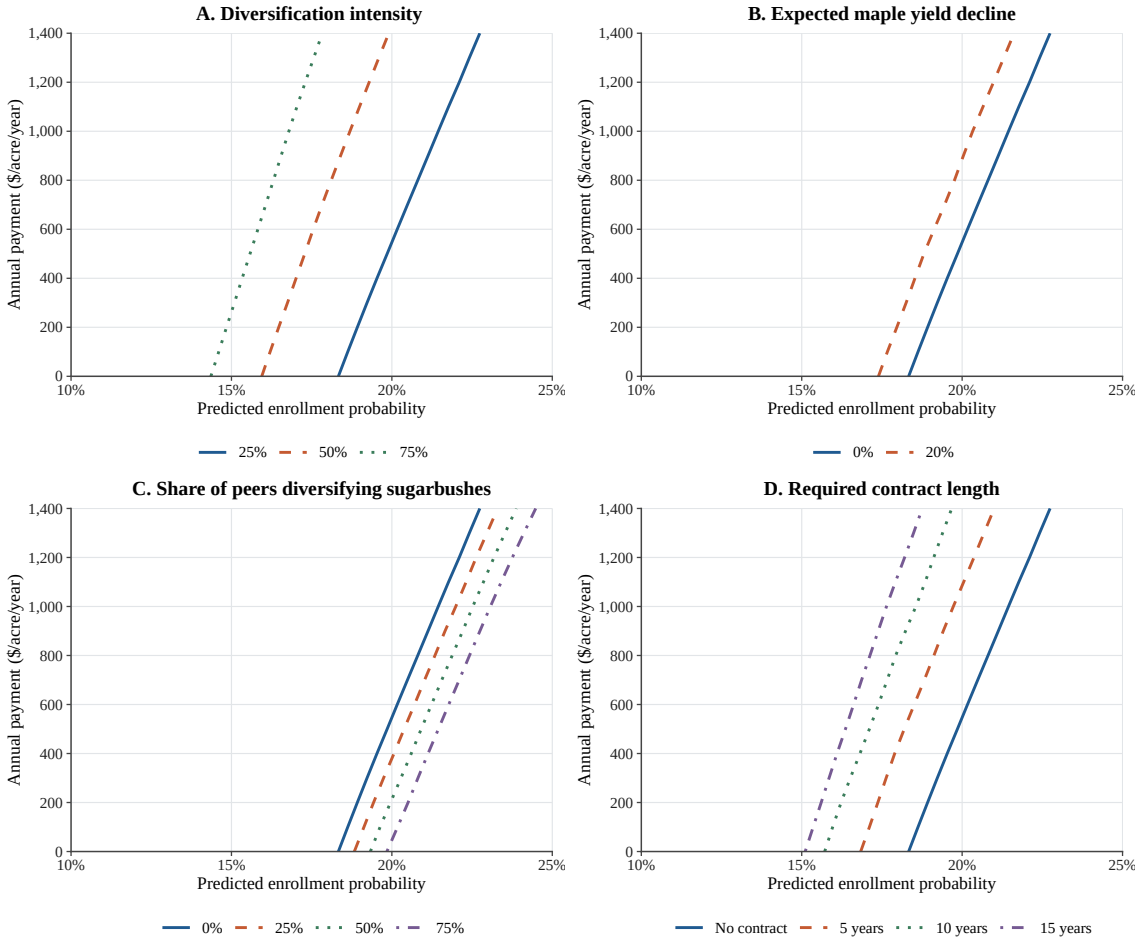


Figure 4. Payment–Enrollment Relationships under Alternative Program Requirements

Notes: Each curve plots the mixed logit prediction of enrollment probability against annual payments ranging from $0 to $1,400 per acre per year. Enrollment is defined as the probability of selecting either program alternative rather than the status quo. Predictions are based on the pre-information choice tasks and are averaged over the estimated random-coefficient distribution. To facilitate comparisons across panels, the solid blue curve shows the same benchmark specification in each panel: a 25% required diversification intensity, with no expected maple yield decline, no peer diversification, no contract requirement, no increase in resilience, and no new equipment requirement. Panel A compares alternative levels of diversification intensity. Panels B–D retain the 25% intensity and vary expected maple yield decline, the share of peers diversifying their sugarbushes, and required contract length, respectively, while holding all other attributes at their benchmark levels. The $0 payment level is included as a counterfactual benchmark outside the experimental payment range. Curves report model-implied point estimates.

Table 5. Compensation Required by Program Attribute

	Marginal compensation		Policy-relevant change		
Program attribute (unit)	$/acre/year	95% CI	Change	$/acre/year	95% CI
Panel A. Diversification requirement and production conditions					
Diversification intensity (pp)	46.6	[33.7, 59.5]	25% intensity	1,164	[841, 1,486]
Maple yield decline (pp)	26.2	[15.4, 37.1]	10% decline	262	[154, 371]
Increased resilience (pp)	18.9	[12.5, 25.3]	25% gain	473	[313, 633]
New equipment required (0/1)	−24.8	[−175.8, 126.1]	Required	−25	[−176, 126]
Panel B. Social and contractual conditions					
Share of peers diversifying (pp)	−6.7	[−8.9, −4.5]	50% of peers	−334	[−445, −224]
Contract length (year)	118.7	[83.1, 154.2]	10-year contract	1,187	[831, 1,542]

Notes: Marginal compensation is the change in annual payment per diversified acre that holds utility constant when the attribute changes by one unit, calculated as $-\beta_k/\beta_p$ from the mean coefficients of the mixed logit model in Table A3, Column (2). Because the payment coefficient is fixed across respondents, the ratio of mean coefficients is the mean marginal compensation. Positive values indicate additional payment required; negative values indicate a reduction in the required payment. The policy-relevant change multiplies marginal compensation by the attribute change shown, relative to a benchmark program with no yield decline, no resilience gain, no new equipment, no peer adoption, and no contract. 95% confidence intervals are computed with the delta method. pp = percentage point.

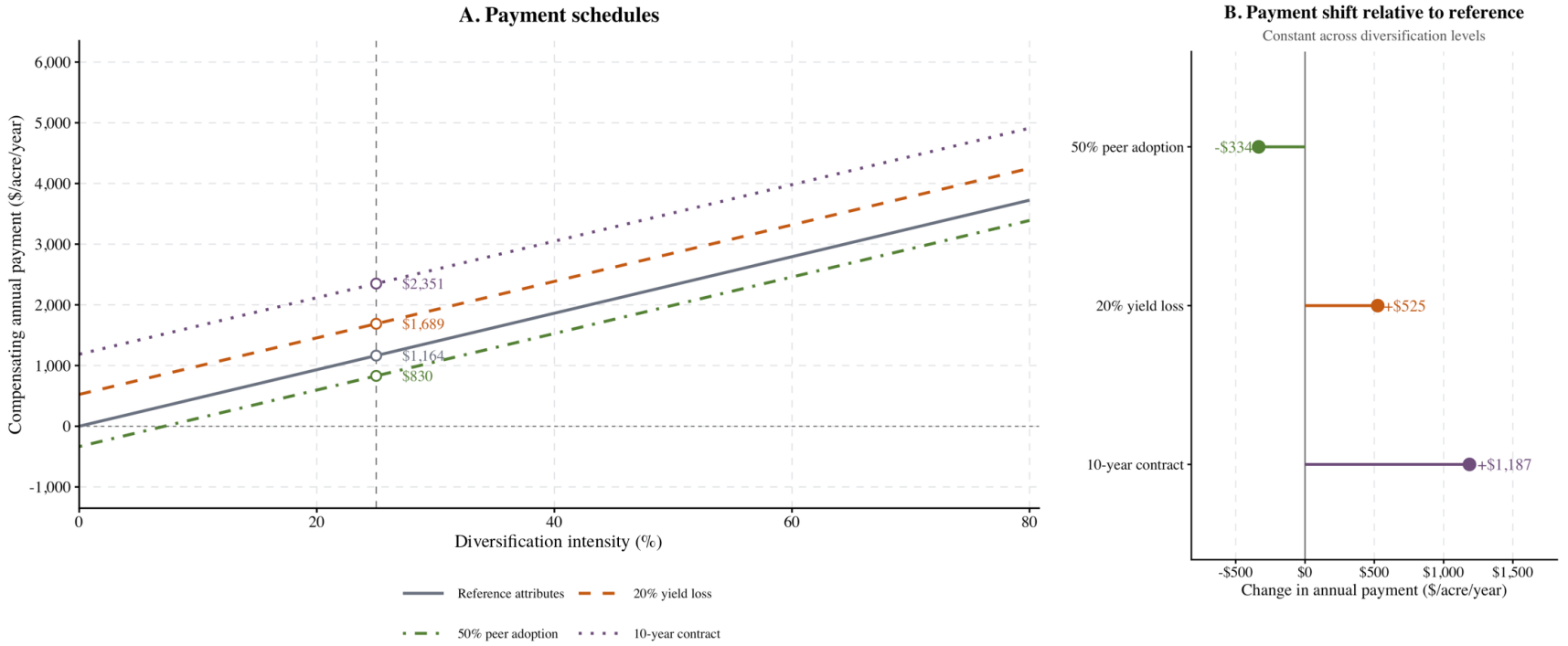


Figure 5. Model-Implied Compensating-Payment Schedules and Payment Shifts under Alternative Program Requirements

Notes: Panel A reports the annual payments required to offset the utility effects of increasing the required diversification intensity under the benchmark attribute specification and under three alternative program requirements: a 20% expected maple yield decline, 50% of peers diversifying their sugarbushes, and a 10-year contract. The benchmark specification assumes no expected maple yield decline, no peer diversification, no contract requirement, no increase in resilience, and no new equipment requirement. The marked values in Panel A report the model-implied annual payments at a 25% required diversification intensity. Panel B reports the payment shift associated with each alternative requirement relative to the benchmark specification. These shifts are constant across required diversification intensities because the utility specification is linear and additive. Estimates are derived from the pre-information mixed logit model using the mean attribute coefficients and the fixed annual-payment coefficient. Curves and payment shifts report model-implied point estimates. Diversification intensities and annual-payment amounts exceeding the experimental ranges are extrapolations and should be interpreted accordingly.

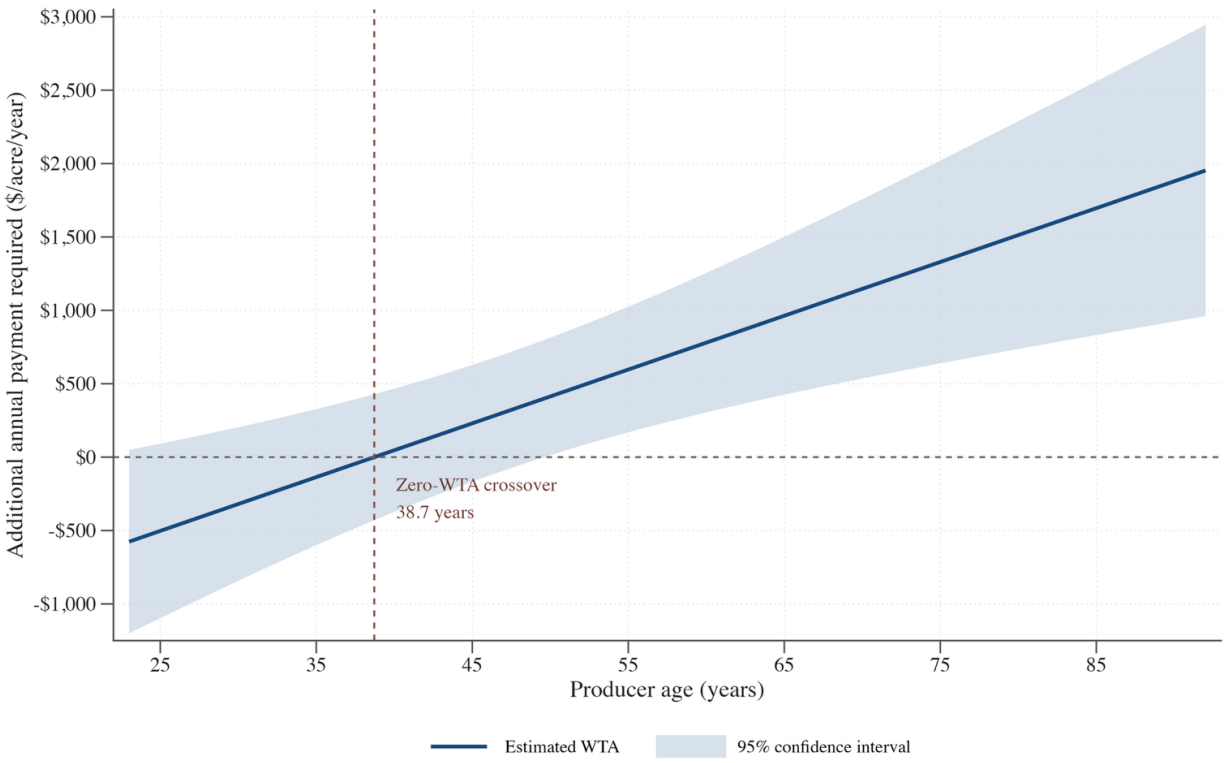


Figure 6. Estimated Compensation Required for a 10-Year Contract by Producer Age

Notes: The solid line reports the estimated willingness to accept (WTA) for a 10-year contract at each producer age, and the shaded area represents the 95% confidence interval. The horizontal dashed line indicates zero WTA. The vertical dashed line marks the estimated zero-WTA crossover at age 38.7 years. Estimates are based on the mixed logit model using the pre-information choice tasks.

Online Appendices

You are on Choice Card X of 6: Please consider the terms of Programs A & B and choose the program that you most prefer for diversifying your sugarbush if it became available: Program A, Program B, or 'Neither' if you prefer to maintain the current situation in your sugarbush without any changes.

	Program A	Program B	Neither
Share of non-maple syrup-producing trees (e.g., birch, beech, etc.) relative to total syrup trees (maple + non-maple)	50%	25%	I prefer to stay in my current situation
Annual decrease in maple syrup yield because of diversifying sugarbushes due to competition (e.g., shading)	No decrease	20% decrease	
Reduction in the likelihood of below-average yields in 15–20 years due to weather extremes, as a result of diversifying sugarbushes	50% reduction	50% reduction	
New processing equipment needed	Yes	No	
Share of your producer peers in your state or neighboring state that have diversified their sugarbushes	0%	75%	
Multi-year contract with annual inspection	15 years	5 years	
Annual cost-share payment per diversified acre to you (above 10% share of non-maple)	$1,000/acre/year	$1,400/acre/year	
CHECK ONE:	○	○	○

What percentage (%) and how many acres of your sugarbush would you like to subscribe to the diversification program you selected? (Note: The percentage could exceed 100% if you plan to buy or lease additional land for this program. If you chose 'Neither,' please skip this question.)

Percentage: _____%; Acre: _____ acre.

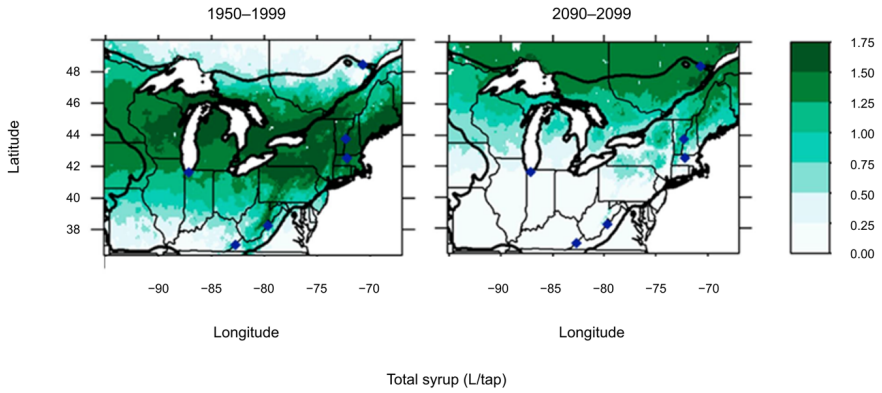
Figure A1. Example Choice Card Presented to Survey Respondents

Notes: The figure reproduces a representative choice card from the survey. Respondents selected between two hypothetical diversification programs and the option to remain in their current situation. Attribute levels varied across choice cards, as specified by the experimental design.

A. Climate-impact information treatment

In the next part of the survey, we will show you recent predictions of how climate change will affect syrup production in the US by the year 2100. Please carefully review the total syrup production map, which projects the maple syrup production by the end of the century.

D13. Based on the map, is the total syrup production in your region going to increase or decrease in the future? (1 L = 0.264 gallon) □ Increase □ Decrease



B. Neutral-information control

In the next part of the survey, we will show you the percentage of maple syrup production in the U.S. by state. In 2023, the state of Vermont produced over two million gallons of maple syrup, making it the top producer of maple syrup in the United States. The second leading producer, New York, had a production volume of about 750 thousand gallons of maple syrup in that year.

D13. To make sure you are still paying attention, please answer the following question: What is the percentage (%) of maple syrup production in New York? _____ %.

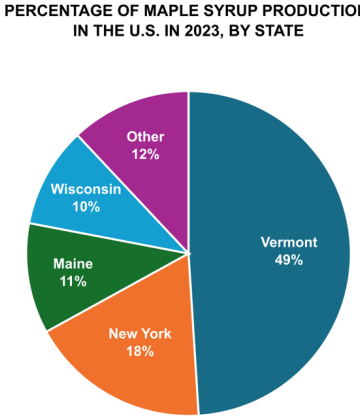


Figure A2. Information Materials Presented Across Experimental Conditions

Notes: Panel A presents the climate-impact information shown to respondents assigned to the information-treatment group. Panel B presents the neutral information shown to respondents assigned to the control group. After reviewing the assigned information, respondents answered the corresponding comprehension or attention question before completing the remaining three choice tasks. Source for Panel A: Rapp et al. (2019), https://doi.org/10.1016/j.foreco.2019.05.045. Source for Panel B: USDA Crop Production Survey (2023).

Table A1. Latent Class Estimates with Class-Specific Annual-Payment Coefficients

	Class 1 (status quo oriented)		Class 2 (diversification receptive)
Panel A. Choice Attribute Coefficients			
Diversification Intensity	−0.0212		−0.0096
	(0.0179)		(0.0089)
Increased Resilience	−0.0741		−0.0046
	(0.0583)		(0.0081)
Maple Yield Decline	0.0445		−0.0481**
	(0.0404)		(0.0190)
New Equipment Required	0.8291		0.1176
	(0.8830)		(0.3373)
Share of Peers Diversifying Sugarbushes	0.0198		0.0087
	(0.0169)		(0.0063)
Contract Length	−0.2437		0.0256
	(0.1561)		(0.0401)
Status Quo ASC	3.4082**		−1.1254
	(1.6450)		(0.8832)
Annual Payment	0.0009		0.0013*
	(0.0009)		(0.0008)
Difference in Status Quo ASC: Class 1 – Class 2		4.5336**	
		(1.8349)	
Difference in Annual Payment: Class 1 – Class 2		−0.0004	
		(0.0011)	
Panel B. Class Membership Class 1 (status-quo-oriented group) relative to Class 2			
Male	−0.4569		
	(0.7681)		
Age	0.0596***		
	(0.0177)		
Education	0.2153		
	(0.5394)		
Low risk preference	1.9349**		
	(0.9177)		
High risk preference	−0.0519		
	(0.6630)		
Timber-related income	1.4031**		
	(0.5900)		
Biodiversity protection	−1.8898***		
	(0.6953)		
Constant	−0.8894		
	(1.2065)		
Panel C. Model Statistics			
Posterior class share	84.68%		15.32%
Log likelihood		−157.01	
AIC		362.02	
BIC		489.44	

Notes: The dependent variable equals one for the selected alternative and zero otherwise. The model is estimated using the pre-information choice tasks (trials 1 – 3). Standard errors are reported in parentheses. Attribute definitions and units are provided in Table 1. All choice-attribute coefficients, including Annual Payment, are allowed to vary across classes. A test fails to reject equality of the annual-payment coefficients across classes (p = 0.688). The common-payment specification reported in Table 4 has lower AIC and BIC and is therefore retained as the preferred specification. The difference in the Status Quo ASC is calculated as the Class 1 coefficient minus the Class 2 coefficient using a post-estimation linear combination. Class labels are descriptive and reflect the principal statistically significant preference patterns within each class. Class-membership coefficients represent changes in the log odds of membership in Class 1 relative to Class 2, the reference class. Posterior class shares are averages of respondent-level posterior class-membership probabilities. AIC and BIC are calculated using estat ic for consistency with Table 4. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

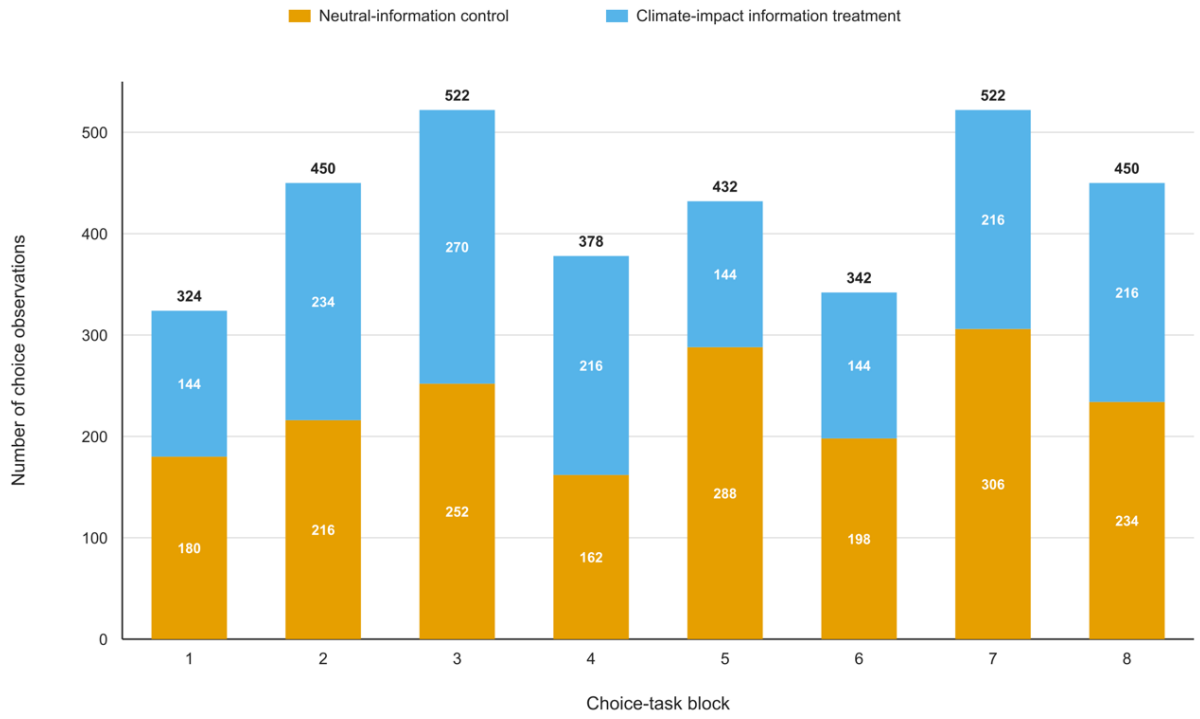


Figure A3. Distribution of Choice Observations Across Choice-Task Blocks and Experimental Groups

Notes: The figure reports the number of choice observations in each choice-task block, separately for respondents assigned to the climate-impact information treatment and the neutral-information control groups. Values within the bars indicate the number of choice observations by each experimental group; values above the bars indicate the total number of choice observations in each block.

Table A2. Information Treatment Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Average information treatment effects			Heterogeneity by prior climate-impact beliefs		
	Status quo ASC	Resilience	Resilience & yield	Full model	Belief × resilience	Belief × yield	Belief × res. & yield
Panel A. Choice Attribute Coefficients							
Diversification intensity	−0.0109*	−0.0109*	−0.0109*	−0.0109*	−0.0106*	−0.0109*	−0.0106*
	(0.0061)	(0.0061)	(0.0061)	(0.0061)	(0.0061)	(0.0061)	(0.0061)
Resilience	−0.0016	−0.0016	−0.0016	−0.0016	−0.0036	−0.0012	−0.0032
	(0.0048)	(0.0048)	(0.0048)	(0.0048)	(0.0053)	(0.0048)	(0.0053)
Yield loss	−0.0015	−0.0015	−0.0015	−0.0015	0.0002	−0.0044	−0.0020
	(0.0118)	(0.0118)	(0.0118)	(0.0118)	(0.0119)	(0.0120)	(0.0121)
New equipment	0.0672	0.0671	0.0669	0.0670	0.0905	0.0979	0.1003
	(0.2373)	(0.2373)	(0.2373)	(0.2372)	(0.2439)	(0.2414)	(0.2441)
Peer share	0.0048	0.0048	0.0048	0.0048	0.0051	0.0054*	0.0053*
	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)
Contract length	−0.0041	−0.0041	−0.0041	−0.0041	−0.0043	−0.0058	−0.0044
	(0.0249)	(0.0250)	(0.0250)	(0.0250)	(0.0249)	(0.0249)	(0.0249)
Annual Payment	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Status quo ASC	2.0283***	2.0295***	2.0321***	2.0302***	2.0801***	2.0489***	2.0797***
	(0.4474)	(0.4482)	(0.4487)	(0.4491)	(0.4602)	(0.4504)	(0.4583)
Panel B. Average Information Treatment Effects							
Diversification intensity × Info × Post				0.0162	0.0182	0.0175	0.0186
				(0.0118)	(0.0120)	(0.0117)	(0.0120)
Resilience × Info × Post		0.0168**	0.0151*	0.0154*	0.0022	0.0174**	0.0039
		(0.0082)	(0.0080)	(0.0079)	(0.0106)	(0.0080)	(0.0095)
Yield loss × Info × Post			0.0435*	0.0439**	0.0473**	0.0198	0.0343
			(0.0224)	(0.0221)	(0.0224)	(0.0325)	(0.0291)
New equipment × Info × Post				0.2479	0.3156	0.3660	0.3380
				(0.3888)	(0.4050)	(0.3915)	(0.4044)
Peer share × Info × Post				−0.0092	−0.0096	−0.0089	−0.0095
				(0.0072)	(0.0074)	(0.0073)	(0.0074)
Contract length × Info × Post				−0.0439	−0.0297	−0.0317	−0.0280
				(0.0507)	(0.0505)	(0.0504)	(0.0505)
Status quo ASC × Info × Post	0.1546	0.5993	0.9663*	1.0209	1.3176*	1.3457*	1.3198*
	(0.3829)	(0.4433)	(0.5149)	(0.7831)	(0.7958)	(0.7589)	(0.7881)
Panel C. Post-information Attribute Valuations							
Resilience				0.0102*			
				(0.0058)			
Yield loss				0.0214			
				(0.0161)			
Panel D. Interactions with Pre-treatment Climate-impact Beliefs							
Resilience × Belief					0.0100*		0.0081
					(0.0054)		(0.0054)
Resilience × Belief × Post					−0.0125***		−0.0104**
					(0.0045)		(0.0049)
Resilience × Belief × Info × Post					0.0303***		0.0257***
					(0.0107)		(0.0087)
Yield loss × Belief						0.0197*	0.0093
						(0.0118)	(0.0114)
Yield loss × Belief × Post						−0.0238**	−0.0106
						(0.0100)	(0.0103)
Yield loss × Belief × Info × Post						0.0575**	0.0222
						(0.0288)	(0.0237)
Attribute × Post included	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel E. Model Statistics							
Choice Observations	3420	3420	3420	3420	3384	3384	3384
Pseudo R-squared	0.5049	0.5064	0.5079	0.5100	0.5192	0.5140	0.5201
Log Pseudolikelihood	−620.08	−618.24	−616.29	−613.69	−595.85	−602.22	−594.76

Notes: Conditional logit estimates using three pre-information and three repeated post-information choice tasks; standard errors clustered by respondent in parentheses. Info equals one for the information-treatment group, and Post equals one for choice tasks completed after the treatment point. All specifications include attribute × Post interactions to absorb learning, fatigue, and other repeated-choice effects common to both groups, so the attribute × Info × Post coefficients measure treatment-induced changes in attribute preferences relative to the control group. Post-information valuations in Panel C are linear combinations of the corresponding baseline, attribute × Post, and attribute × Info × Post coefficients in Column (4). Belief is agreement that climate change will affect the productivity of the respondent's sugarbush during their lifetime (five-point scale), standardized to mean zero and unit standard deviation, so lower-order coefficients in Columns (5) – (7) are evaluated at mean belief; these columns use respondents with nonmissing beliefs. The Annual Payment coefficient is held constant across groups and periods. Attribute definitions and units are in Table 1. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

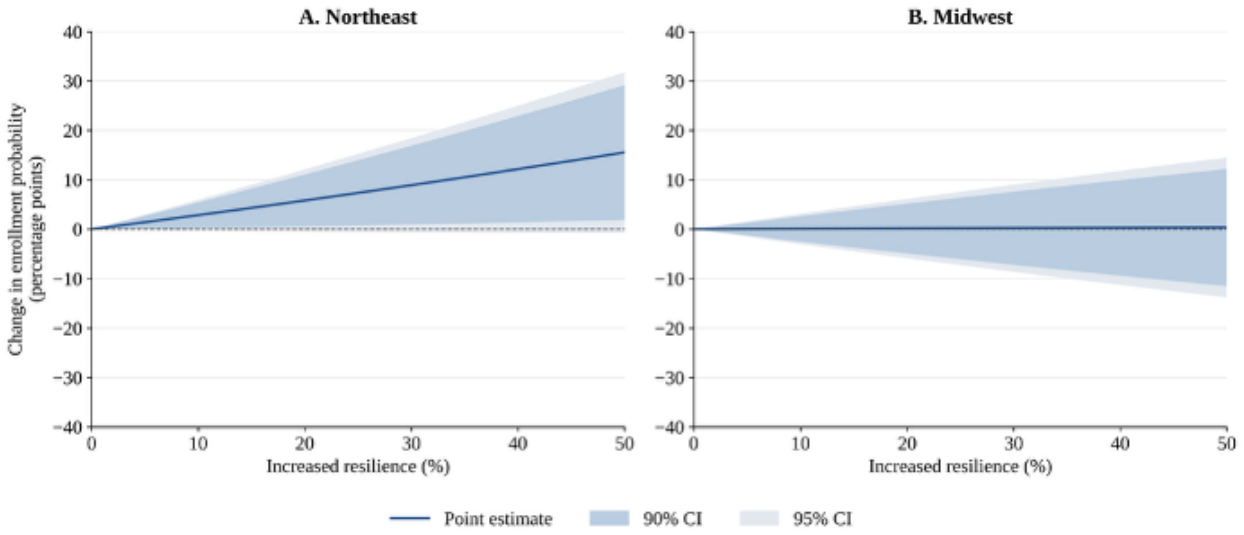


Figure A4. Information-induced resilience effects by region

Notes: Solid lines show the estimated change in enrollment probability attributable to the information treatment through the increased-resilience channel, separately for respondents in the Northeast (Panel A) and the Midwest (Panel B), as increased resilience rises from 0% to 50%. Estimates compare post-information choices with a counterfactual that excludes the resilience-related information effects while retaining the common post-task effects and holding other attributes at their reference levels. The Midwest receives the more severe projected decline in syrup production, whereas the Northeast accounts for most U.S. maple syrup production. The difference in information effects between regions is not statistically significant ($p = 0.25$). Shaded areas represent 90% and 95% confidence intervals.

Table A3. Conditional and Mixed Logit Estimates of Attribute Preferences

	(1) Conditional logit	(2) Mixed logit
Panel A. Mean preference coefficients		
Diversification Intensity	−0.0109*	−1.1289*
	(0.0061)	(0.6212)
Increased Resilience	−0.0016	−0.4585*
	(0.0048)	(0.2521)
Maple Yield Decline	−0.0015	−0.6360*
	(0.0118)	(0.3697)
New Equipment Required	0.0673	0.6025
	(0.2374)	(1.9598)
Share of Peers Diversifying Sugarbushes	0.0048	0.1621*
	(0.0031)	(0.0849)
Contract Length	−0.0041	−2.8774*
	(0.0250)	(1.5576)
Annual Payment	0.0001	0.0242*
	(0.0004)	(0.0133)
Status quo ASC	2.0271***	171.0091*
	(0.4419)	(92.7510)
Panel B. Random-coefficient standard deviations		
Diversification Intensity		1.3460*
		(0.7358)
Increased Resilience		1.1011*
		(0.6012)
Maple Yield Decline		2.4230*
		(1.3233)
New Equipment Required		11.1879*
		(5.9088)
Share of Peers Diversifying Sugarbushes		0.0287
		(0.0210)
Contract Length		5.3385*
		(2.9471)
Status quo ASC		216.2007*
		(117.6518)
Predicted status quo probability at reference levels (%)	79.1%	78.3%
Respondents	190	190
Choice Observations	1,710	1,710
AIC	621.89	430.83
BIC	665.44	512.49
Log likelihood	−302.94	−200.42

Notes: Coefficients are reported with standard errors in parentheses. Both models are estimated using the pre-information choice tasks (trials 1–3). Standard errors in the conditional logit model are clustered by respondent. In the mixed logit model, the choice-attribute coefficients and the status quo alternative-specific constant are specified as independently normally distributed random coefficients, whereas the annual-payment coefficient is fixed across respondents. The model is estimated by simulated maximum likelihood using 250 Halton draws. Among the alternative mixed logit specifications considered, the reported specification produced the lowest AIC and BIC. Panel B reports the estimated standard deviations of the random coefficients; statistically significant estimates provide evidence of unobserved preference heterogeneity. Because utility coefficients are identified only relative to the scale of unobserved utility, their raw magnitudes should not be compared directly across the conditional and mixed logit models. Monetary trade-offs are instead calculated as coefficient ratios relative to the annual-payment coefficient, which removes the common utility scale. The predicted status quo probability at reference levels is calculated with the systematic utilities of both program alternatives normalized to zero, thereby isolating the contribution of the status quo alternative-specific constant. For the mixed logit model, the probability is integrated over the estimated distribution of the random status quo constant. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

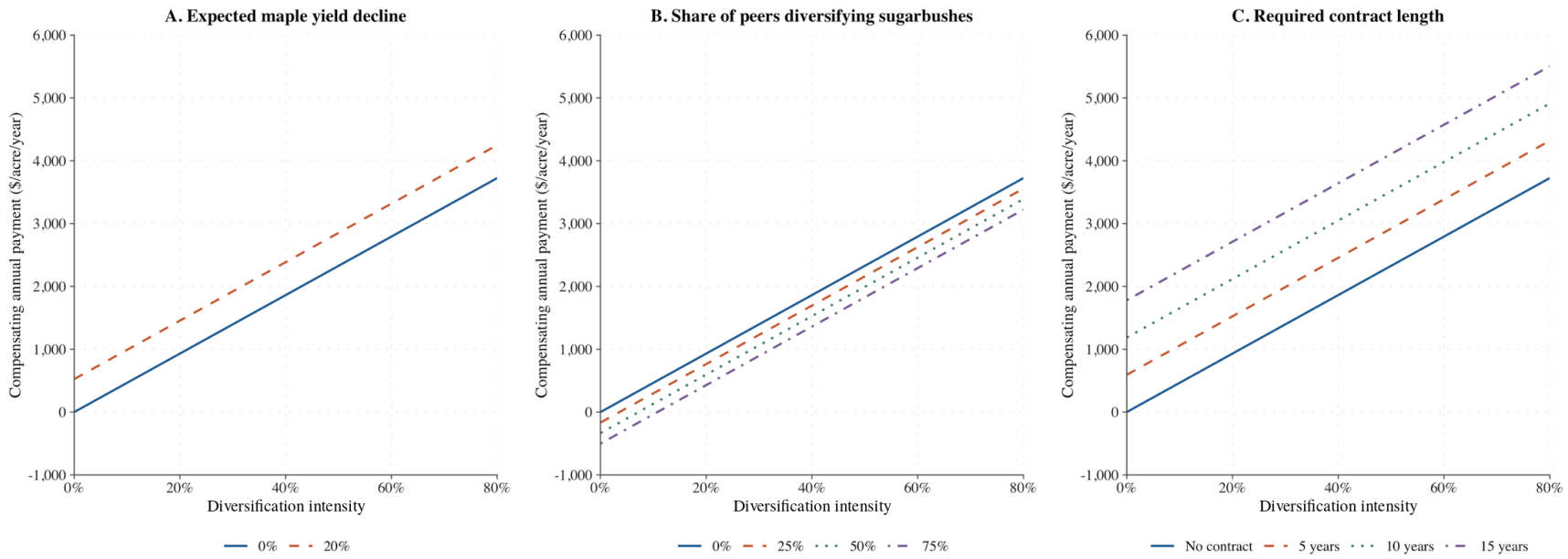


Figure A5. Model-Implied Compensating-Payment Schedules across Alternative Program Requirements

Notes: The curves report the annual payments required to offset the utility effects of increasing the required diversification intensity under alternative levels of expected maple yield decline, peer diversification, and contract length. The solid blue curve in each panel represents the corresponding benchmark level: no expected maple yield decline in Panel A, no peers diversifying their sugarbushes in Panel B, and no contract requirement in Panel C. All other program attributes are held at their benchmark levels. Estimates are derived from the pre-information mixed logit model using the mean attribute coefficients and the fixed annual-payment coefficient. The parallel curves reflect the linear and additive utility specification, under which each additional program requirement produces a constant payment shift across diversification levels. Curves report model-implied point estimates. Diversification intensities and annual-payment amounts exceeding the experimental range are extrapolations and should be interpreted accordingly.

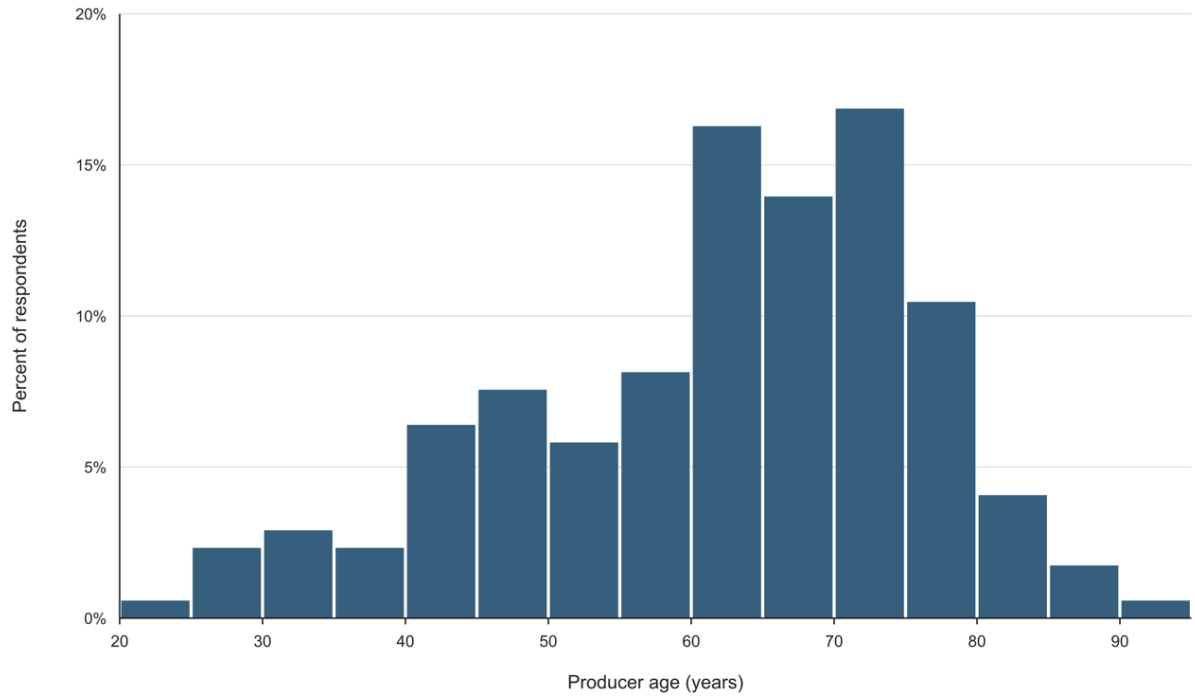


Figure A6. Distribution of Producer Age

Notes: The figure shows the distribution of producer age among respondents with nonmissing age information, using five-year intervals. The vertical axis reports the percentage of respondents in each age interval. The sample includes 172 respondents; 18 respondents with missing age information are excluded.