Forest Policy and Economics 184 (2026) 103711

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Does the public value ecosystem services secured by pine savanna restoration and bobwhite management on private lands?

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ARTICLE INFO

Keywords:
Colinus virginianus
Endangered and threatened species
Gopher tortoise
Groundwater recharge
Hybrid mixed logit model
Non-market valuation
Private lands conservation programs
Scenic open space

ABSTRACT

Private land stewardship in the southeastern United States is crucial to attain pine savanna restoration and conservation of the threatened northern bobwhite (*Colinus virginianus*). Both government and privately funded conservation efforts secure numerous ecosystem services, including groundwater recharge, scenic open spaces, and biodiversity. Yet, we have incomplete information on whether the public values these ecosystem services. From June 15th to July 19th, 2022, we administered stated preference choice experiment surveys to 770 members of the public in Alabama, Georgia, Florida, and South Carolina to ascertain if the public values ecosystem services provided by pine savanna and bobwhite conservation. We analyzed data using hybrid mixed logit models. Respondents positively valued recovery of threatened bobwhite and gopher tortoise populations and high levels of groundwater recharge and scenic open space. Respondents with higher moral obligations to prevent land use conversion (personal norms, awareness of consequences, and ascription of responsibility related to conservation) were more likely to support allocation of taxes to pine savanna restoration on private lands. Respondents' moral obligation to prevent land use conversion was positively correlated with their engagement in outdoor recreational activities. Our findings indicate that the public values pine savanna and bobwhite conservation efforts on private lands in the Southeast, and that outreach related to pine savanna restoration efforts should appeal to people's moral obligation to support conservation of biodiversity, habitat restoration, and the provision of ecosystem services.

1. Introduction

Global environmental change (i.e., climate change, species invasions, land-use change) is driving the loss of ecosystems and biodiversity (Mantyka-Pringle et al., 2012). Savannas are highly vulnerable to global environmental change, particularly the mesic savannas of North America, which are dominated by longleaf pine (*Pinus palustris*). Until recently, these longleaf pine savannas were undervalued and inappropriately managed because their ecological value was not recognized (Pau et al., 2023). Although pine savannas were once dominant across the southeastern United States (hereafter, Southeast), 96% of these savannas have been converted to other land uses (e.g., urban development, crop production) or severely degraded by fire suppression (Noss et al., 2015; Peet et al., 2018). Remaining southeastern pine savannas mostly occur within the Coastal Plain region (Fig. 1; Peet et al., 2018; Platt, 1999). Conserving and re-establishing pine savanna landscapes is essential because they provide numerous ecosystem services, including native plant species richness, conservation of imperiled species, groundwater recharge, and open space (Dixon et al., 2022). Pine savannas are composed of multiple species of pine in the overstory, including loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus chinate*), and longleaf pine, with a diverse understory of native grass, shrub, and forb species (Robertson et al., 2021). Pine savannas provide habitat for an array of species of concern, including northern bobwhite (*Colinus virginianus*; hereafter bobwhite), gopher tortoises (*Gopherus polyphemus*), red-cockaded woodpeckers (*Leuconotopicus borealis)*, and indigo snakes (*Drymarchon couperi*). Bobwhite and gopher tortoise populations have declined by over 84% in the Southeast, closely mirroring the loss of native grasslands and pine savannas (Hermann et al., 2002; United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), 2022). Groundwater recharge is particularly important for the Floridan Aquifer, which provides fresh drinking water

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https://doi.org/10.1016/j.forpol.2026.103711
Received 12 June 2025; Received in revised form 30 November 2025; Accepted 12 January 2026
Available online 22 January 2026

to millions of Alabama, Florida, and Georgia residents (Dixon et al., 2022; Fleckenstein, 2018). Open space preservation is a key component of conservation efforts by land trusts in the United States (Cho et al., 2008; Kline et al., 2004).

Conservation and restoration of native habitat and biodiversity on private lands are important to restoring ecosystem function and securing human wellbeing (Barbedo et al., 2014), especially in the Southeast where private lands conservation efforts may not adequately protect vulnerable species (Jenkins et al., 2015). Private landowners play a critical role in protecting and restoring pine savannas, since they own 86% of forested land in the Southeast (Wear and Greis, 2013). There is a tradition of private landowners managing pine savannas for game species in the Southeast, in particular bobwhite. From the 1880s to the 1930s, wealthy families bought large tracts of land in the Coastal Plain region to create bobwhite hunting estates (hereafter, bobwhite properties; Dixon et al., 2022). Bobwhite properties situated in northern Florida and southwestern Georgia (the Red Hills region, ~280,000 ha of private land) contain the highest densities of wild bobwhite in the Coastal Plain region (2.2–6.6 birds/ha; Sisson et al., 2017), owing to substantial private investment (~$154/acre/year; ~$381/ha/year) in habitat restoration and management of wild bobwhite (Nimlos et al., 2023). Although owners of bobwhite properties play an important role in conserving pine savannas, engaging other landowners who manage agricultural or forestlands is important because these lands are often under intensive production and typically offer little suitable habitat for bobwhite (Dixon et al., 2022). Accordingly, the United States Department of Agriculture (USDA) offers technical assistance and financial incentives to landowners to conduct land stewardship activities that restore pine savannas and recover bobwhite and native wildlife populations (United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), 2022). The USDA aims to restore seven million acres of grasslands and pine savannas over five years (2022 to 2026) through the Northern Bobwhite, Grasslands, and Savannas Framework for Conservation Action (https://www.nrcs.usda.gov/programs-initiatives/working-lands-for-wildlife/northern-bobwhite). In 2024, the USDA Natural Resources Conservation Service (NRCS) dedicated $13 million through the Northern Bobwhite Pilot Project to incentivize landowners to manage working lands for early successional habitat.

No research has been conducted on whether the public values pine savannas in the Southeast or supports the allocation of tax dollars to bobwhite conservation. It is important to understand these public preferences because tax dollars are used to finance conservation programs (Oluoch et al., 2021). Better understanding of public preferences also assists natural resource managers and government agencies in determining the structure and size of incentives that should be provided to landowners who conserve ecosystem services (Browning et al., 2024; Costanza et al., 2014). Accordingly, we designed a survey to determine whether the public supports the allocation of tax dollars to conservation programs that restore and conserve supporting ecosystem services (pine savannas), regulating ecosystem services (groundwater recharge), cultural ecosystem services (scenic open spaces), and imperiled species (bobwhite and gopher tortoise populations) on private lands in the Southeast. We focused on gopher tortoise conservation because the gopher tortoise is an endemic keystone species that is also a suitable umbrella species for habitat conservation plans in the Southeast (Johnson et al., 2017). The gopher tortoise is an ecosystem engineer that constructs burrows that benefit >350 commensal species (Johnson et al., 2017). We administered the survey to members of the public in Alabama, Florida, Georgia, and South Carolina, four states in which private landowners secure biodiversity and ecosystem services by managing their properties for bobwhite (Nimlos et al., 2023).

Based on the norm activation model (Schwartz, 1977), we hypothesized that individuals' personal norms, awareness of consequences, and ascription of responsibility would influence their willingness to pay a tax to support pine savanna restoration and bobwhite conservation on private lands. Personal norms are feelings of moral obligation to engage in pro-environmental behaviors (Bronfman et al., 2015; de Groot and Steg, 2009), including funding conservation programs. Raymond and Schneider (2014) found that members of the public with a personal norm against extinction felt morally obligated to support policies that protect endangered species on private lands. Awareness of consequences encompass individuals' understanding of the adverse environmental or social consequences of not engaging in pro-environmental behaviors

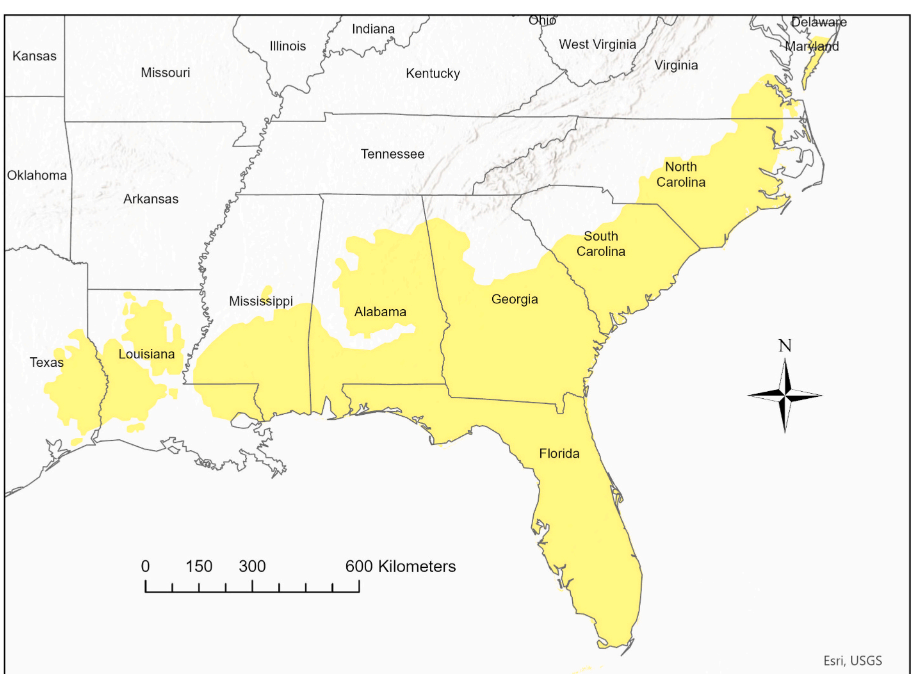

Fig. 1. The historic range (pre-European settlement) of pine savannas in the southeastern United States (indicated in yellow). GIS data retrieved from Peet et al. (2018). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Bronfman et al., 2015; Schwartz, 1977; Steg and de Groot, 2010), whereas ascription of responsibility encompasses individuals' sense of responsibility for the negative consequences of not engaging in pro-environmental behaviors (de Groot and Steg, 2009). Individuals with higher awareness of consequences, ascription of responsibility, and personal norms are more likely to engage in pro-environmental behaviors (Park and Ha, 2014; Ünal et al., 2018; Zhang et al., 2018). We predicted that individuals with higher awareness of consequences of habitat loss and ascription of responsibility and personal norms to contribute to conservation outcomes would be more likely to support bobwhite and pine savanna conservation programs. Consistent with the larger literature, we also predicted that individuals' environmental knowledge would influence their beliefs and norms related to stewardship and conservation actions, and hence their willingness to support bobwhite and pine savanna conservation programs. Knowledge about environmental problems, including strategies to address environmental problems, may result in willingness to take action (e.g., willingness to support conservation programs; Jensen, 2002).

People use, value, and access ecosystem services differently based on their socio-demographic characteristics (Daw et al., 2011; Lau et al., 2019). Consistent with prior research, we predicted that individuals who identify as female (Pienaar et al., 2019) or white (Sharma and Kreye, 2022), younger individuals (Watkins and Poudyal, 2021) and individuals with higher incomes or education levels (Ressurreição et al., 2012) would be more likely to support the allocation of taxes to conservation programs. Finally, we predicted that individuals who identify as progressive in their political orientation (Jo et al., 2021) and who participate in outdoor recreation (e.g., hiking; Dhakal et al., 2012) would be more likely to support conservation programs. We predicted hunters would support programs that improve habitat for game populations, although hunters may be less likely to support programs that increase populations of predators that impact game species (Hanley et al., 2010).

2. Methods

2.1. Survey design

We administered online stated preference choice experiment (SPCE) questionnaires to ascertain (1) whether the public values ecosystem services secured by pine savanna restoration, and (2) if the public would be willing to pay taxes to finance land stewardship that supports bobwhite. Prior to presenting respondents with SPCEs, we informed respondents that private lands are critical for the conservation of wildlife and habitat with 80% of all wildlife habitat in the United States (US) occurring on private land (see the Supporting Information). We further informed respondents that wildlife habitat often occurs on agricultural, ranching, and timber lands (hereafter, agricultural lands), but that urban development is resulting in the conversion of habitat to housing. Survey respondents were informed that private agricultural lands help to purify and secure water supplies through groundwater recharge. Specifically, we explained that groundwater recharge is a process by which rainfall is filtered by the soil and flows into groundwater (such as wells), thereby providing drinking and irrigation water. This written explanation was accompanied by a diagram showing how water filters underground for different land uses, and how water is then used by people living in cities (Fig. 2). As a measure of respondents' environmental knowledge, we asked if they were previously aware that 80% of wildlife habitat in the US occurs on private lands (yes = 1, no = −1), and wetlands, forests, and agriculture help replenish groundwater (yes = 1, unsure = 0, no = −1 for each land use). We generated a measure of respondents' stated environmental knowledge by summing their responses to the knowledge questions because these items were categorical variables.

Respondents then received information about bobwhite and gopher tortoises, including that both species are currently listed as threatened. We presented images of these species and explained that both species benefit from pine savanna restoration and stewardship. Respondents were informed that if species populations increased to the level that they were no longer at risk of extinction in the Southeast, then they would be considered recovered. We also presented images of wetlands and pine savannas on bobwhite properties. Based on Nimlos et al. (2023), we informed respondents that it costs landowners ~$170/acre/year to manage their lands primarily for bobwhite, owing to the costs of labor and habitat management, predator trapping, and property taxes. As a precursor to the SPCEs, we informed respondents that the federal government uses taxes to help finance private lands stewardship programs.

Respondents were then presented with SPCEs, in which they were asked whether they would vote in favor of collecting additional tax dollars to finance land stewardship on bobwhite properties. Survey

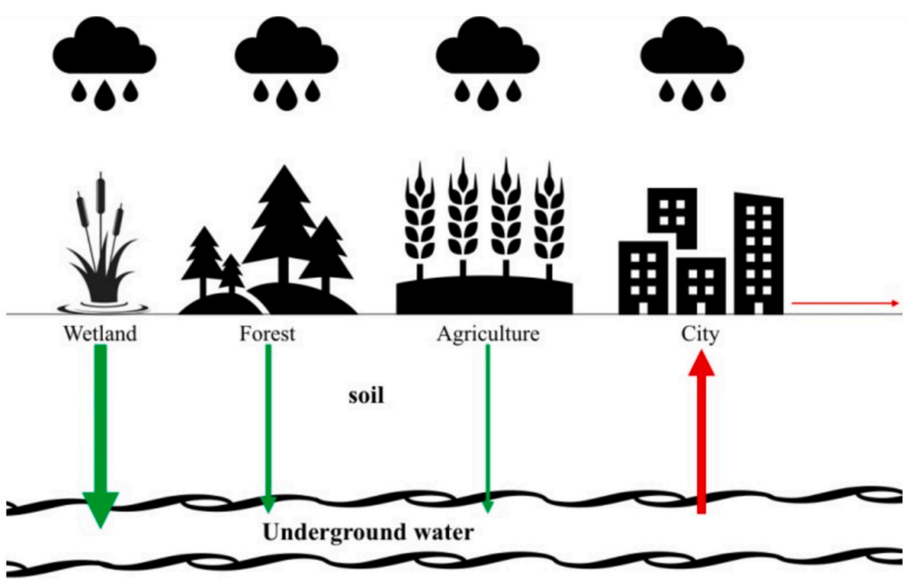

Fig. 2. Illustration of groundwater recharge presented to survey respondents. Green arrows denoted groundwater recharge and the red arrow denoted water extraction. The width of the arrows captured the volume of water flowing into or out of aquifers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

respondents chose between different programs that varied in levels of groundwater recharge, scenic open space, the conservation status of bobwhite populations, the conservation status of gopher tortoise populations, and taxes required to finance stewardship actions. We informed respondents that stewardship actions would result in bobwhite populations (BOBWHITE) and gopher tortoise populations (TORTOISE) being listed as 'threatened' or 'recovered' (Fig. 3), although we did not specify how long population recovery would take or the probability of species recovery. Here, BOBWHITE and TORTOISE are attributes with two levels, namely 'threatened' and 'recovered'. Respondents were also informed that land stewardship actions would determine whether groundwater recharge (RECHARGE) and scenic open space (SCENIC) were 'low', 'medium', or 'high' (i.e., three attribute levels). We explained that if respondents voted for programs to finance bobwhite management and land stewardship then they would pay an annual tax for the next 10 years (TAX) of $25, $50, $75, or $100 per household (i.e., four attribute levels). Although we recognize that bobwhite management may jointly produce increased bobwhite and gopher tortoise populations, scenic open space, and groundwater recharge, it is unlikely that the public understands that land stewardship may result in joint production of these ecosystem services. Thus, we assumed that we did not violate separability of attributes and levels in designing the SPCEs.

We further explained that if respondents chose not to pay increased taxes, they were choosing that the government should not help finance pine savanna and bobwhite conservation, which could result in land use conversion to urban development. We explained that land use conversion increases the likelihood that bobwhite and gopher tortoise populations will decline, while also reducing groundwater recharge and scenic open space. Following this information, we asked respondents to consider different conservation program options that varied in ecosystem services provided and tax payments. Each SPCE contained two conservation program options (or profiles). Respondents could select a preferred conservation program, or they could choose to "opt-out", i.e., they could choose to not pay a tax that supports land stewardship on bobwhite properties (Fig. 4). Following the SPCEs, we asked respondents to indicate how confident they were that their choices reflected what they would actually pay in taxes (10-point scale, not at all confident = 1, very confident = 10). To test for protest responses, we asked respondents who chose the opt-out for all four SPCEs to indicate their reasons for choosing not to pay additional taxes to finance land stewardship on properties managed for bobwhite. Protest responses reveal that respondents' evaluation of choice sets do not reflect their true preferences (Mitchell, 2013). For example, respondents may value the conservation of ecosystem services on bobwhite properties and would be willing to fund conservation programs, but they select the opt-out because they object to federal taxes. SPCEs may fail to determine the true economic value of attributes if protest responses are retained in regression analysis (Meyerhoff and Liebe, 2008).

We used SAS statistical software to generate the D-efficient design (prior parameters set equal to zero) to minimize the standard error of the estimated model parameters. The D-efficiency for our survey was 99.92. The D-efficient design contained 16 SPCE questions, which were divided into four blocks of four SPCE questions (i.e., we generated four survey versions that differed in which SPCE questions were presented to respondents; Table S1). Respondents were randomly assigned one of the SPCE blocks.

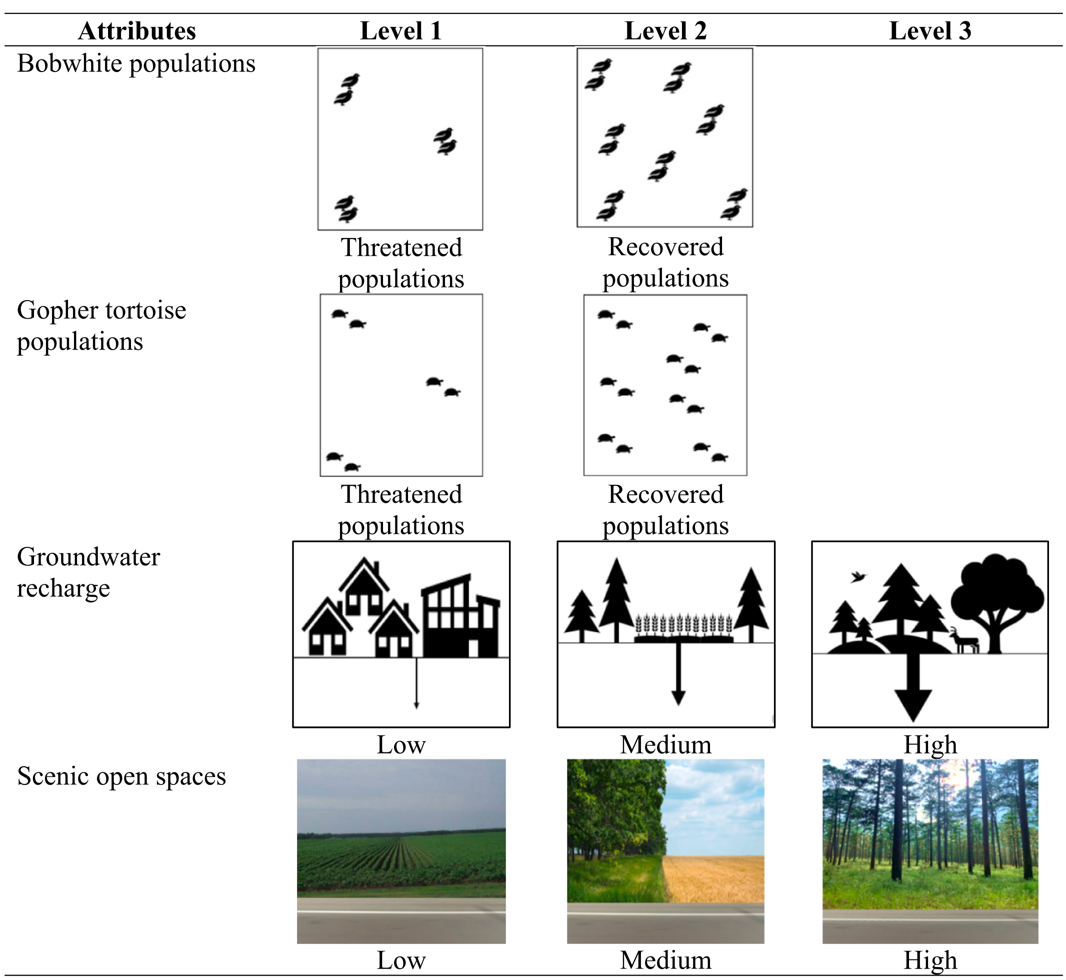

Fig. 3. Images used in the questionnaire to describe each attribute level for the stated preference choice experiments (SPCEs).

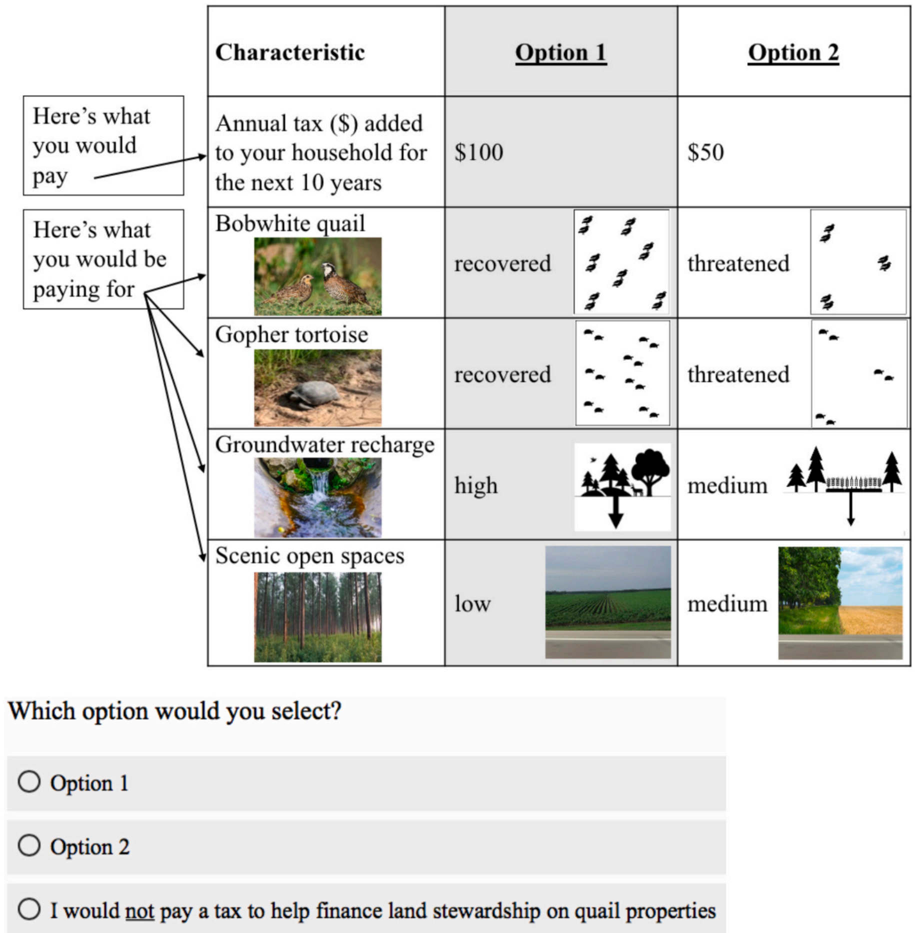

Fig. 4. An example of a stated preference choice experiment (SPCE) question.

To measure respondents' awareness of consequences of habitat loss, we asked them to indicate their level of agreement (strongly disagree = −2, disagree = −1, neither disagree nor agree = 0, agree = 1, strongly agree = 2) with three statements: 'loss of habitat on private land will be fatal to wildlife conservation'; 'if we don't act now we will lose all wildlife habitat to development'; and 'the threat of urban development to habitat has been exaggerated'. We elicited respondents' ascription of responsibility to contribute to conservation outcomes by asking their level of agreement with the following three statements: 'it is my responsibility to help finance wildlife conservation on public land'; 'it is my responsibility to help finance wildlife conservation on private land'; and 'every citizen must take responsibility for helping the environment'. To measure respondents' personal norms to contribute to conservation outcomes, we asked their level of agreement that they 'feel morally obligated to pay a tax that supports wildlife conservation', 'taxes that protect the environment are a waste of taxpayer's dollars', and 'wildlife conservation is important to [them]'. Finally, to ascertain how socio-demographics influenced respondents' preferences for conservation programs, we elicited respondents' gender, age, education, ethnicity, income, political orientation (extremely liberal = −3, moderate = 0, extremely conservative = 3), and participation in recreational activities.

2.2. Survey implementation

Prior to finalizing the questionnaire, we conducted pretests with individuals from our target population (Alabama, Florida, Georgia, and South Carolina residents) and researchers at the University of Georgia who specialize in social sciences or game management. The Institutional Review Board at the University of Georgia reviewed the research materials and protocol and declared the study to be non-human subjects research (PROJECT00005461). Nonetheless, we presented respondents with informed consent before they agreed to participate in the survey so that respondents understood how information would be used and that they could exit the survey at any time without penalty.

Owing to the concentration of bobwhite properties in the Red Hills region, we stratified our sample so that 60% of respondents resided in Florida (30%) and Georgia (30%), with the remaining respondents residing in Alabama (20%) and South Carolina (20%). In addition to state quotas, we used US Census (2020) data on age (75.6% of individuals aged ≤65 years), gender (51.5% female), and ethnicity (25.8% African American, 11.7% Hispanic/Latino) across Alabama, Florida, Georgia, and South Carolina to obtain a representative sample. We paid Qualtrics Research Services to recruit individuals to participate in the study. Qualtrics Research Services administered the online questionnaire from June 15 to July 19, 2022.

2.3. Analysis of the stated preference choice experiment (SPCE) questions

We analyzed the SPCEs using a hybrid mixed logit (HMXL) model, which combines the mixed logit model (Revelt and Train, 1998) with the multiple indicators and multiple causes (MIMIC) model (Jöreskog and Goldberger, 1975). The HMXL model allowed us to measure whether respondents' socio-psychological traits influenced their preferences for conservation programs, while controlling for potential measurement error and endogeneity issues (Daly et al., 2012; Hess and Stathopoulos, 2013). The HMXL model incorporates a discrete choice model, a measurement component, and a structural component.

2.3.1. Discrete choice model

Economic theory assumes that, when presented with a choice, respondents select the option that generates the greatest level of satisfaction (maximizes utility) after rationally comparing all options (McFadden, 1973). Following McFadden (1973), the utility (U_{ij}) that individual i derives from each choice set (or profile) j in the SPCE is given by:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \mathbf{X}_{ij}\boldsymbol{\beta}_i + \varepsilon_{ij}$$

where V_{ij} is the systematic (observed) component of the utility function, ε_{ij} is a random error (iid extreme value), $\mathbf{X}_{ij}$ is a matrix of the attributes and attribute levels of the conservation programs, and $\boldsymbol{\beta}_i$ is a matrix of estimated individual-specific coefficients. The mixed logit model allows for preference heterogeneity by relaxing the assumption that $\boldsymbol{\beta}$ are fixed across respondents. Within the HMXL model, random parameters are also a function of individual-specific latent variables ($\mathbf{LV}_i$), which measure respondents' socio-psychological traits, such that:

$$\boldsymbol{\beta}_i = \boldsymbol{\beta}_i^* + \mathbf{LV}_i\boldsymbol{\gamma}$$

where $\boldsymbol{\gamma}$ is a matrix of estimated coefficients and $\boldsymbol{\beta}_i$* has a multivariate normal distribution with a vector of means ($\boldsymbol{\beta}^{\mathbf{M}}$) and a covariance matrix to be estimated (Budziński and Czajkowski, 2022).

For our analysis, V_{ij} took the form:

$$\begin{aligned} V_{ij} =& \beta_{0i} + \beta_{1i}\text{BOBWHITE}_{ij} + \beta_{2i}\text{TORTOISE}_{ij} + \beta_{3i}\text{MEDIUM RECHARGE}_{ij} \\ &+ \beta_{4i}\text{HIGH RECHARGE}_{ij} + \beta_{5i}\text{MEDIUM SCENIC}_{ij} \\ &+ \beta_{6i}\text{HIGH SCENIC}_{ij} + \beta_{7i}\text{TAX}_{ij} \end{aligned}$$

where β_{0i} was the alternative specific constant (ASC) associated with choosing not to finance land stewardship (conservation program was selected = 0, respondent chose opt-out = 1), BOBWHITE$_{ij}$ was the conservation status of bobwhite populations (binary coded as threatened = 0, recovered = 1), TORTOISE$_{ij}$ was the conservation status of gopher tortoise populations (threatened = 0, recovered = 1), and TAX$_{ij}$ was the annual tax that households would pay for the next 10 years ($0, $25, $50, $75, $100) depending on whether respondents chose the opt-out or conservation program j. We binary coded the attribute levels for groundwater recharge and scenic open space, such that medium (MEDIUM RECHARGE$_{ij}$, MEDIUM SCENIC$_{ij}$) and high levels of these attributes (HIGH RECHARGE$_{ij}$, HIGH SCENIC$_{ij}$) were coded as 1 when presented in the SPCE. The baseline levels for BOBWHITE$_{ij}$ and TORTOISE$_{ij}$ were 'threatened', the baselines levels for RECHARGE and SCENIC were 'low', and the baseline level for TAX$_{ij}$ was $0 – associated with choosing not to finance conservation on bobwhite properties (i.e., the opt-out). Following Budziński and Czajkowski (2022), the conditional probability of respondent i selecting conservation programs $\mathbf{CP}_i$ for T_i choice tasks was given by:

$$\Pr\left(\mathbf{CP}_i|\mathbf{X}_i, \boldsymbol{\beta}_i^*, \mathbf{LV}_i, \boldsymbol{\gamma}\right) = \prod_{t=1}^{T_i} \frac{e^{\mathbf{X}_{ijt}\boldsymbol{\beta}_i}}{\sum_{k=1}^{J} e^{\mathbf{X}_{ikt}\boldsymbol{\beta}_i}}$$

2.3.2. Measurement component

Consistent with the norm activation model, we incorporated a latent variable '*moral obligation to prevent land use conversion*' (a psychological variable that cannot be directly measured) in the HMXL. We measured respondents' moral obligation to prevent land use conversion by analyzing responses to the l indicator statements (I_{il}) pertaining to awareness of consequences of habitat loss, ascription of responsibility to support conservation actions, and personal norms to support conservation actions. Each observed indicator was treated as an ordered categorical variable with a probit link to the underlying continuous individual-specific latent psychological variable, moral obligation to prevent land use conversion ($\mathbf{LV}_i$). In addition, we assumed that the indicator variables were influenced by respondents' stated environmental knowledge (KNOW) and political orientation (POLITICS; Ben-Akiva et al., 2002):

$$\mathbf{I}_i^* = \mathbf{LV}_i\boldsymbol{\lambda} + \mathbf{P}_i\boldsymbol{\alpha} + \boldsymbol{\eta}_i$$

$$I_{il} = m \text{if} \tau_{l,m-1} < I_{il}^* \leq \tau_{l,m}, m = -2, \ldots, 2$$

where $\boldsymbol{\lambda}$ is a matrix of coefficients (factor loadings) of individual specific latent variables $\mathbf{LV}_i$, $\mathbf{P}_i$ includes respondents' stated environmental knowledge and political orientations, $\boldsymbol{\alpha}$ are coefficients to be estimated, $\tau_{l,m}$ are item-specific thresholds, and the error term $\eta_{li} \sim$ N(0,1) (Budziński and Czajkowski, 2022; Czajkowski et al., 2017).

2.3.3. Structural component

We measured respondents' moral obligation to prevent land use conversion as a function of their socio-demographic characteristics ($\mathbf{SD}_i$):

$$\mathbf{LV}_i = \mathbf{SD}_i\boldsymbol{\theta} + \xi_i$$

where $\boldsymbol{\theta}$ is a matrix of coefficients and ξ_i is a normally distributed error term. Specifically, we estimated respondents' moral obligation to prevent land use conversion as a function of their gender (female = 1, male or non-binary = 0), age (years), education (years), income ($'000), race (African American or Black = 1, other races/ethnicities = 0), engagement in bird watching (BIRD$_i$), hiking (HIKE$_i$), fishing (FISH$_i$), or hunting (HUNT$_i$, days per year), and state of residence (Alabama [AL], Florida [FL], Georgia [GA], South Carolina [SC]):

$$\begin{aligned} \mathbf{LV}_i =& \theta_1\text{GENDER}_i + \theta_2\text{AGE}_i + \theta_3\text{EDUCATION}_i + \theta_4\text{INCOME}_i + \theta_5\text{RACE}_i \\ &+ \theta_6\text{BIRD}_i + \theta_7\text{HIKE}_i + \theta_8\text{FISH}_i + \theta_9\text{HUNT}_i + \theta_{10}\text{AL}_i + \theta_{11}\text{FL}_i \\ &+ \theta_{12}\text{GA}_i + \theta_{13}\text{SC}_i + \xi_i \end{aligned}$$

We omitted a constant from the estimated structural regression model, in order to avoid the dummy variable trap associated with including binary variables for each state of residence in the model.

2.3.4. Model estimation

We jointly estimated the measurement and structural components of the HXML in lavaan using the Weighted Least Squares Mean and Variance adjusted (WLSMV) with theta parameterization estimation method (Rosseel, 2012; Rosseel et al., 2025). We fit a confirmatory factor analysis (CFA)/MIMIC model to estimate the factor loadings of the indicator variables, and we fixed the variance of $\mathbf{LV}_i$ to identify the scale of the latent variable. After fitting the CFA, we estimated individual-specific latent factor scores $\widehat{\mathbf{LV}_i}$ using lavaan's regression-based factor score estimator. We normalized the latent factor scores (mean = 0, standard deviation = 1) in order to attain identification of the HXML model (Daly et al., 2012).

The HXML model was estimated using the BGW algorithm (Bunch et al., 1993) and the *Apollo* package in R version 4.4.2 (500 Sobol draws per respondent; Hess and Palma, 2019, 2025). The coefficients for the attribute levels were estimated as:

$$\boldsymbol{\beta}_i = \boldsymbol{\beta}^{\boldsymbol{M}} + \boldsymbol{\upsilon}_i\boldsymbol{\sigma} + \widehat{\mathbf{LV}}_i\boldsymbol{\beta}_{LV}, \boldsymbol{\upsilon}_i \sim \mathbf{N}(0, 1)$$

where $\boldsymbol{\beta}^{\mathbf{M}}$ are mean coefficients, $\boldsymbol{\sigma}$ are standard deviations of the random coefficients, and $\boldsymbol{\beta}_{\mathbf{LV}}$ capture how respondents' moral obligation to prevent land use conversion shifted their preferences for conservation program attributes. As such, we tested for pure heterogeneity of preferences ($\boldsymbol{\beta}^{\mathbf{M}}$, $\boldsymbol{\sigma}$) and systematic preference heterogeneity related to respondents' moral obligation to prevent land use conversion ($\boldsymbol{\beta}_{\mathbf{LV}}$). We considered a coefficient statistically significant if $p \leq 0.05$.

Because we assumed a normal distribution for the tax coefficient, we used a negative-tax conditioning approach when estimating marginal willingness to pay (WTP) for the conservation program attributes. For each Monte Carlo draw, we retained the tax coefficient only if it was negative and sufficiently bounded from zero ($\beta_i^{\text{tax}} < -0.001$). We discarded WTP draws associated with non-negative tax coefficients or tax coefficients that were near zero. To estimate WTP distributions, for each of S = 10,000 draws we 1) sampled $\upsilon_{is}^{\text{tax}}$ and computed β_{is}^{tax}, incorporating $\widehat{LV_i}$, 2) sampled υ_{is} and β_{is} for each attribute incorporating $\widehat{LV_i}$, 3) applied negative-tax conditioning to β_{is}^{tax}, and 4) computed WTP_{is} for retained draws.

Prior to estimating the HMXL models, we recoded respondents' selection of conservation programs based on their confidence in their responses. If respondents stated that their confidence in their responses to the SPCEs was ≤6, then we recoded their responses as selection of the opt-out. Researchers commonly use this certainty correction to reduce hypothetical bias in choice experiments, which is the discrepancy between hypothetical preferences for a conservation outcome and actual preferences for conservation (Morrison and Brown, 2009; Poe et al., 2002).

We also used timers during survey implementation to ensure respondents did not speed through the SPCEs. We removed respondents from the survey who answered the SPCEs in <5 seconds. To eliminate protest responses, we removed respondents who stated that they had selected the opt-out for all SPCEs because they did not want to pay more taxes, did not consider it their responsibility to pay for conservation on private lands, disapproved of government funded subsidies for conservation, or did not trust private landowners to use the subsidy to engage in conservation actions.

3. Results

We surveyed 770 members of the public living in Alabama (*n* = 138, 17.9%), Florida (*n* = 217, 28.2%), Georgia (*n* = 241, 31.3%), and South Carolina (*n* = 174, 22.6%; response rate of 23%). The largest share of respondents were male (*n* = 426, 55.3%) and identified as white (*n* = 557, 70.1%; Table S2). Respondents' median age range was 45–64 years, their median annual household income was $25,000–$49,999, and their median education level was some college. Although the largest share of respondents selected that they were moderate in their political orientation (*n* = 260, 33.8%), remaining respondents skewed conservative (*n* = 342, 44.4%). Most respondents participated in birdwatching (*n* = 471, 61.2%), fishing (n = 471, 61.2%), and hiking (*n* = 651, 84.5%), but only 165 respondents (21.4%) hunted. Our sample underrepresented females (44.0%), African Americans (22.5%), and Hispanics (4.7%).

Most respondents were previously aware that wetlands (*n* = 466, 60.5%), forests (*n* = 459, 59.6%), and agriculture (*n* = 429, 55.7%) help replenish groundwater, but were not aware that the majority of wildlife habitat occurs on private lands (*n* = 547, 71%; Table S3). Only 149 respondents (19.4%) were previously aware of all statements used to measure environmental knowledge. The median stated knowledge score was 2 (0.30 ± 2.93, range: −4 to 4). In total, 607 respondents (78.8%) stated that the costs of bobwhite management were higher than they expected.

3.1. Hybrid mixed logit model

Respondents were approximately evenly split across the four survey versions (26.2% of respondents received survey version 1, 24.7% received version 2, 25.2% received version 3, and 23.9% received version 4). Only 80 respondents (10.4%) selected the opt-out for all four SPCEs presented in the survey. Respondents who elected not to pay towards stewardship programs on bobwhite properties most commonly indicated they did not want to pay more taxes (n = 55), they could not afford to pay additional taxes (*n* = 38), and it was not their responsibility to pay for conservation on private lands (*n* = 28; Table S4). We considered that 69 respondents had provided protest responses, and they were omitted from the hybrid mixed logit analysis.

On average, respondents agreed that development threatens wildlife habitat on private land, which is fatal to wildlife conservation, wildlife conservation was important to them, citizens are responsible for helping the environment, it was their responsibility to help finance wildlife conservation on public land, and they felt morally obligated to pay a tax that supports wildlife conservation (Table S5). The measurement analysis for the HMXL model indicated that these items were significantly related to the latent variable, thereby confirming that the latent variable (LV) measured respondents' moral obligation to prevent land use conversion (Table 1). Confirmatory factor analysis further indicated that responses to the indicator items were driven by an underlying latent psychological variable (comparative fit index (CFI) = 0.968, Tucker-Lewis index (TLI) = 0.991, root mean square error of approximation (RMSEA) = 0.066, standardized root mean squared residual (SRMR) = 0.057) and Cronbach's alpha (0.839) suggested that there was a high level of internal consistency between the indicator items. Responses to all indicator variables were influenced by respondents' political orientation. Individuals who identified themselves as politically conservative more strongly agreed that the threat of urban development to habitat has been exaggerated and that taxes that protect the environment are a waste of taxpayer's dollars, which is consistent with lower moral obligation to prevent land use conversion. By contrast, respondents' stated environmental knowledge only influenced their level of agreement that wildlife conservation was important to them.

The structural component of the HMXL model indicated that respondents did not demonstrate different moral obligation to prevent land use conversion based on their gender, age, education, household income, or engagement in hiking and hunting. However, respondents who identified as African American or Black demonstrated lower moral obligation to prevent land use conversion. Respondents who more frequently engaged in fishing or bird watching demonstrated higher moral obligation to prevent land use conversion.

On average, respondents preferred that pine savannas are restored and are not converted to intensive land uses (β^{M} = −7.745), although respondents demonstrated preference heterogeneity with respect to land use conversion (σ = 19.925). Respondents who demonstrated stronger moral obligation to prevent land use conversion preferred that pine savannas are restored (β_{LV} = −14.199). Respondents were homogeneous in their preference for bobwhite recovery (β^{M} = 1.513, σ not significantly different from zero). Respondents also preferred recovery of gopher tortoise populations (β^{M} = 1.120), although respondents were heterogeneous in the strength of their preference for gopher tortoise recovery (σ = 1.093). Respondents' moral obligation to prevent land use conversion was positively associated with their preference for recovery of bobwhite (β_{LV} = 0.397) and gopher tortoise populations (β_{LV} = 0.266). On average, respondents preferred medium (β^{M} = 0.714) and high groundwater recharge (β^{M} = 1.444), although they demonstrated preference heterogeneity – with a subset of respondents deriving disutility from medium (σ = 1.116) and high groundwater recharge (σ = 1.453). Respondents were homogeneous in their preference for high scenic open space (β^{M} = 1.240), but they exhibited preference heterogeneity for medium open space (σ = 0.871). Respondents' preferences for groundwater recharge and scenic open space did not vary according to their moral obligation to prevent land use conversion. On average, respondents preferred to pay lower taxes when financing conservation programs (β^{M} = −0.856). However, respondents demonstrated preference heterogeneity with respect to tax payments (σ = 1.987). Respondents with stronger moral obligation to prevent land use conversion were less sensitive to tax payments (β_{LV} = 0.655).

3.2. Marginal willingness to pay

We retained 66.0% of tax draws when estimating marginal WTP. On average, respondents placed highest value on recovery of bobwhite populations ($75.65) and high groundwater recharge ($73.43; Table 2). On average, respondents' welfare would be reduced if pine savannas are not conserved or restored (negative marginal WTP associated with the ASC). As expected, the value that respondents placed on each of the

Table 1
Hybrid mixed logit model.

Measurement component[a]			
Indicator variables	LV	Environmental knowledge	Political orientation
Loss of habitat on private land will be fatal to wildlife conservation	0.923** (0.073)	−0.021 (0.020)	−0.113** (0.038)
If we don't act now, we will lose all wildlife habitat to development	1.138** (0.085)	−0.019 (0.021)	−0.182** (0.039)
The threat of urban development to habitat has been exaggerated	−0.607** (0.050)	0.008 (0.017)	0.169** (0.031)
It is my responsibility to help finance wildlife conservation on public land	1.073** (0.069)	0.037* (0.021)	−0.218** (0.038)
It is my responsibility to help finance wildlife conservation on private land	0.964** (0.074)	0.012 (0.019)	−0.061 (0.034)
Every citizen must take responsibility for helping the environment	1.144** (0.082)	0.039 (0.022)	−0.184** (0.042)
Wildlife conservation is important to me	1.611** (0.121)	0.056* (0.028)	−0.189** (0.049)
I feel morally obligated to pay a tax that supports wildlife conservation	1.380** (0.097)	0.029 (0.024)	−0.212** (0.043)
Taxes that protect the environment are a waste of taxpayer's dollars	−0.753** (0.062)	0.020 (0.019)	0.222** (0.034)

Structural component	
Socio-demographic variables	**θ**
Gender (female = 1)	0.034 (0.083)
Age (years)	<0.001 (0.002)
Education (years)	0.008 (0.020)
Income ($'000)	0.003 (0.002)
Race (African American/Black = 1)	−0.272** (0.098)
Recreational activities[b]:	
Bird watching (days per year)	0.001* (<0.001)
Hiking (days per year)	<0.001 (<0.001)
Fishing (days per year)	0.004** (0.001)
Hunting (days per year)	0.008 (0.007)
State of residence:	
Alabama	0.475** (0.163)
Florida	0.546** (0.160)
Georgia	0.496** (0.156)
South Carolina	0.590** (0.157)

Discrete choice model			
Program attributes	**Main effects**		**Interactions**
	β^{M}	σ	β_{LV}
ASC	−7.745** (1.584)	19.925** (3.113)	−14.199** (2.210)
Bobwhite recovered	1.513** (0.199)	0.768 (0.406)	0.397** (0.141)
Gopher tortoise recovered	1.120** (0.151)	1.093** (0.259)	0.266* (0.112)
Medium groundwater recharge	0.714** (0.153)	1.116** (0.320)	0.186 (0.145)
High groundwater recharge	1.444** (0.233)	1.453** (0.331)	0.192 (0.142)
Medium scenic open space	0.271 (0.148)	0.871* (0.411)	−0.085 (0.145)
High scenic open space	1.240** (0.202)	0.656 (0.369)	0.146 (0.138)
Tax[c]	−0.856** (0.229)	1.987** (0.419)	0.655** (0.219)
Log-likelihood	−1655.17		
AIC	3358.34		
N	701		

Note: Parameter estimates for HMXL models in which we used more stringent criteria for determining whether responses should be coded as selection of the opt-out (confidence levels of 7 and 8) are presented in the supplementary materials. See Table S7.
[*] significant at $p \leq 0.05$; ** significant at $p \leq 0.01$.
[a] The estimated ordered logit threshold parameters are reported in the supplementary materials. See Table S6.
[b] Frequency with which respondents engaged in activity. Coded as never = 0, yearly = 1, every six months = 2, monthly = 12, weekly = 52, and daily = 365.
[c] We scaled tax payments by dividing TAX by 100.

Table 2
Posterior marginal willingness to pay (WTP) for each attribute, stratified by latent variable (LV) groups indicating low, medium, or high moral obligation to prevent land use conversion.

	Median	Moral obligation to prevent land use conversion[a]		
		Low	Medium	High
Bobwhite recovery	75.65	49.71	82.05	141.51
Gopher tortoise recovery	55.29	35.51	57.59	95.27
Medium groundwater recharge	33.34	22.54	36.34	56.94
High groundwater recharge	73.43	54.01	74.56	107.60
Medium scenic open space	14.38	18.13	13.39	10.85
High scenic open space	64.32	51.86	66.45	100.47
Conversion of pine savannas to high intensity land uses	−225.84	337.04	−357.30	−1555.08

Note: Median WTP estimates that were generated by HMXL models in which we used more stringent criteria for determining whether responses should be coded as selection of the opt-out (confidence levels of 7 and 8) are presented in the supplementary materials. In total, 64% of tax draws were kept when generating these WTP measures. See Table S8.
[a] Median WTP are reported for each level of moral obligation to prevent land use conversion.

conservation program attributes increased as their moral obligation to prevent land use conversion increased, with the exception of medium groundwater recharge. Only respondents with low moral obligation to prevent land use conversion derived welfare from allowing pine savannas to be converted to other land uses.

3.3. Limitations

Despite using best practices in developing the survey and analyzing our data, there are several limitations associated with SPCEs. Although we used a certainty-6 correction, there is a risk of hypothetical bias in our findings, which occurs when respondents make different decisions during the study than they would in a real situation (Escribano et al., 2021). Adjusting the confidence level that we used to correct for measurement bias didn't substantially change our findings related to respondents' preferences for bobwhite and gopher tortoise recovery, groundwater recharge, and scenic open space (Table S7), but did result in more conservative WTP estimates (Table S8). Second, it is possible that respondents experienced cognitive burden when completing the SPCEs, which might reduce their choice consistency (Louviere, 2001). We attempted to reduce cognitive burden by only including four SPCEs in each questionnaire, and we included timing checks for how long respondents took to complete the SPCEs to remove participants who sped through the SPCEs. Presenting respondents with the cost per acre for pine savanna restoration and bobwhite management may have caused them to anchor their responses on this cost estimate, thereby resulting in biased willingness to pay estimates (Lemos et al., 2022). We used a normal distribution to specify the tax coefficient because the lognormal distribution inflated the standard deviation coefficients in the mixed logit estimation, which in turn inflated the WTP estimates. We also discarded 34% of tax draws when estimating WTP to ensure that WTP estimates were not inflated. This suggests that a subset of respondents disregarded the tax attribute when responding to the SPCEs. The D efficient design is more robust when prior parameters are not set to zero (Walker et al., 2018). Finally, we cannot confirm that our results can be generalized to other ecosystem services or residents living in other states outside of our study area.

4. Discussion

In the US, government agencies have invested substantial resources in incentivizing private landowners to restore pine savannas and grasslands and conserve bobwhite (Burger et al., 2019; United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), 2022). Private landowners who value bobwhite hunting also invest substantial private funds in restoring pine savannas to support high densities of wild bobwhite for hunting (Nimlos et al., 2023). Both tax-funded conservation programs and private investment in bobwhite management secure biodiversity (e.g., bobwhite, gopher tortoises, red-cockaded woodpeckers, native grasses and forbs) and ecosystem services (groundwater recharge, scenic open spaces), while also increasing the landscape's overall resilience to climate change (Dixon et al., 2022; United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), 2022). We examined whether the public values pine savanna restoration and bobwhite management on private lands. Our analysis suggests that members of the public residing in Alabama, Florida, Georgia, and South Carolina recognize the benefits of pine savanna and bobwhite conservation on private working lands. Respondents tended to positively value the cultural, supporting, and regulating ecosystem services provided by pine savanna restoration and land stewardship on bobwhite properties, which also indicates that the public values ecosystem services provided by privately financed bobwhite properties. However, a subset of respondents preferred not to pay taxes towards conservation programs even though we informed them that failure to finance conservation programs could result in conversion of bobwhite properties and working lands to urban development.

Consistent with prior literature (López-Mosquera and Sánchez, 2012; Ressurreição et al., 2012; Obeng and Aguilar, 2018), our findings demonstrated that respondents' beliefs and norms pertaining to conservation were correlated with their willingness to support stewardship programs. Respondents' preferences for species recovery and continued funding of pine savanna restoration programs were influenced by their moral obligation to prevent land use conversion, which encompassed their awareness of consequences of habitat loss, ascription of responsibility to support conservation actions, and personal norms to support conservation actions. We found some evidence that knowledge of the role of private lands in securing species habitat and ecosystem services was correlated with personal norms to prevent land use conversion. Public support for tax-funded conservation programs and bobwhite properties may be increased by educating the public about the conservation benefits associated with pine restoration and bobwhite management, highlighting ecosystem services that the public values highly (e.g., species habitat, water quality; Castro et al., 2016), and enhancing personal norms to support conservation initiatives (Obeng and Aguilar, 2018).

Contrary to our prior expectations, respondents' moral obligation to prevent land use conversion was not correlated with their gender, age, education, income, or hunting effort. Rather, respondents who actively engaged in fishing or bird watching demonstrated higher moral obligation, while respondents who identified as African American or Black or were politically conservative demonstrated lower moral obligation to prevent land use conversion. Individuals who frequently engage in outdoor activities may value potential cultural, aesthetic, and recreational benefits associated with pine savanna restoration (e.g., improved fishing quality, potential birdwatching opportunities, scenic views). However, hunters may not expect that they can access private lands to hunt (Poudyal et al., 2008). Our prediction that females would be more likely to support pine savanna restoration and bobwhite conservation was based on evidence that females demonstrate higher levels of environmental concern (Gifford and Nilsson, 2014; McCright and Xiao, 2014) and are more likely to support conservation of imperiled species (Liordos et al., 2017) and ecosystem services (Pienaar et al., 2019). However, there is growing evidence that females, African Americans, and older individuals are less likely to benefit from open spaces and outdoor recreation, often owing to personal safety and money, time, and transportation constraints (Ghimire et al., 2014) – which may help to explain our results. Although African Americans have a rich outdoor heritage, collective memories of racial discrimination have generated ambivalent views among African Americans about open spaces and wildland conservation (Johnson and Bowker, 2004). We note that the areas in which pine savanna restoration is being funded are also associated with plantations, slavery, and segregation (Porter, 2011). It is therefore not surprising that African American respondents were more likely to disagree that they have a moral obligation to support pine savanna and bobwhite conservation in the Southeast.

Our finding that politically conservative individuals disagreed with the statements that we used to measure moral obligation to prevent land use conversion is concerning because the Southeast has the most conservative political ideology in the US, and there is growing distrust of science and government (McNeal et al., 2014). One potential means to elicit the support of politically conservative individuals is to highlight that pine savanna restoration can help to secure the economic and cultural heritage of agricultural communities and prevent conversion of working lands to urban development. In Alabama, citizen groups have garnered public support for conservation efforts by using populist sentiment to frame wilderness preservation in terms of ancestral and cultural heritage, rather than protection of endangered species or undisturbed areas (Walton and Bailey, 2005).

Although no prior studies have estimated marginal WTP for bobwhite or gopher tortoise recovery, our findings are consistent with other valuation studies pertaining to the conservation of ecosystem services in the Southeast. Dahal et al. (2018) estimated that residents of coastal cities in Alabama and Mississippi were willing to pay $80.52 to $162.14 per household to preserve open space, which is consistent with our finding that respondents were willing to pay $51.86 to $100.47 for high scenic open space – depending on their moral norms to prevent habitat conversion. Furthermore, Klizentyte et al. (2025) found that Florida and Georgia residents were willing to pay $104.75 annually to ensure that water from the Upper Floridan Aquifer remains secure for future use, which is consistent with our finding that respondents were willing to pay $54.01 to $107.60 for high groundwater recharge – depending on their moral norms to prevent habitat conversion.

Although respondents were heterogeneous in their support for allocating tax dollars to pine savanna restoration and bobwhite conservation, our findings that the public valued the ecosystem services provided by these conservation efforts suggest that agencies should continue funding these programs. Our WTP estimates suggest that the value that the public derives from pine savanna restoration and bobwhite conservation exceeds the costs of these conservation efforts. The historical range of the northern bobwhite is so expansive that pursuing conservation goals for this species could result in collateral benefits to hundreds of other wildlife species and support the provision of ecosystem services (United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), 2022). Our findings further suggest that, in general, the public are supportive of bobwhite properties if they understand the conservation outcomes associated with land stewardship on these properties. Thus, the argument could be made that tax dollars should also be allocated to non-profit organizations that assist landowners in restoring and managing pine savannas, in addition to state wildlife agency efforts. Future research should explore how the public values other ecosystem services provided by pine savanna restoration. Additionally, future research should assess the opportunity costs of pine savanna restoration and bobwhite management, examine how opportunity costs vary spatially, and evaluate whether conservation incentives are sufficient to offset these opportunity costs. Lastly, future research should examine private landowners' barriers to engaging in pine savanna restoration and bobwhite management on their properties and how wildlife agencies can recruit more landowners to manage their land for wildlife habitat.

CRediT authorship contribution statement

Nicole M. Nimlos: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Elizabeth F. Pienaar:** Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **James A. Martin:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Funding for this work was provided by the Warnell School of Forestry and Natural Resources at the University of Georgia.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2026.103711.

Data availability

Deidentified data that support the findings of this study are available on Zenodo at https://doi.org/10.5281/zenodo.18262137.

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