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Adoption of Warm Season Grasses by Beef Cattle Producers in the Fescue Belt

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Cattle producers in the Fescue Belt predominantly rely on cool-season grass (CSG) pastures. Supplementing CSGs with warm-season grasses (WSG) can provide economic and environmental benefits. We elicit Tennessee cattle producer willingness-to-adopt WSG using data from a hypothetical choice experiment that offered a monetary incentive to establish WSG pasture. A novel double-hurdle regression with Student-*t* errors was estimated using a Bayesian Hamiltonian Monte Carlo procedure. About 66% of participants were willing to convert 14%–21% of their pasture acres to WSG depending on the incentive amount. A $95/acre incentive is estimated to convert 7,631 acres to WSG, costing $0.77 million.

Key words: cost share, double hurdle, Hamiltonian Monte Carlo, normal mixture model, pasture, Student-*t* error

Introduction

The Fescue Belt spans 35 million acres of 15 states in the Southeastern United States and is home to about 40% of U.S. cow–calf operations (U.S. Department of Agriculture, 2019). Cattle production in this region primarily comprises forage-based grazing systems that rely on tall fescue (*Schedonorus* spp. (Schreb.) Dumort) for pasture and hay. Tall fescue is a perennial cool-season grass (CSG) desirable for cattle production because it is adaptable, easy to establish, and persists under adverse conditions (Stuedemann and Hoveland, 1988). However, susceptibility to fescue toxicity and slow growth during the summer months—tall fescue's growth occurs mainly from late February or early March to May and from late September to November (Wolf, Brown, and Blaser, 1979)—present challenges for continuous grazing of tall fescue pasture (Roberts and Andrae, 2004; Volenec and Nelson, 2007; Looper et al., 2010).

The objective of this study is to determine producer willingness to adopt (WTA) warm season grass (WSG) in the Fescue Belt using data from a 2018 survey of Tennessee beef cattle producers. The survey included a choice experiment to elicit producer responsiveness to a hypothetical monetary incentive encouraging the adoption of WSG. Producer WTA and the number of pasture acres producers were willing to convert to WSG are modeled as a two-tiered decision using a double-hurdle regression. The procedure used to estimate the double-hurdle models is novel in that

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the second-stage outcome equation is modeled as a normal mixture model with Student-t_v errors. Specification of the error distribution this way admits individual-specific effects due to unobserved heterogeneity in the second-stage acreage conversion decision.

Program participation (i.e., producer WTA) and participation intensity (i.e., the scale of WSG adoption measured as pasture acres converted to WSG) are conditioned on producer perceptions of, or experience with, WSG systems; farm business characteristics; operator demographics; and previous changes in pasture and herd management plans made by producers during prolonged drought periods. Understanding the factors that influence beef cattle producer willingness to establish and manage WSG pasture and responsiveness to monetary incentives could inform the design of programs that encourage the use of best pasture management practices and the adoption of practices adapted to warmer and drier climates.

Pasture Management in the Fescue Belt and Warm Season Grasses

Pasture management strategies commonly used by Fescue Belt producers that address low forage productivity during the summer include reducing stocking rates and providing cattle with supplemental feed (Kallenbach, 2015). Another approach is to diversify planted forages with WSG, which extends grazing days into the summer months (Kallenbach, 2015; Mullenix and Rouquette, 2018). Several WSG species are suitable for the Southeastern United States, including native perennials such as switchgrass (*Panicum virgatum*), big bluestem (*Andropogon* spp.), and Indiangrass (*Sorghastrum* spp.); nonnative perennials like Bermudagrass (*Cynodon* spp.); and annuals such as crabgrass (*Digitaria* spp.). These forages break dormancy in late March or early April, grow from mid-May through midsummer, and go dormant in October. Supplementing fescue grazing systems with WSG can produce positive weight gains for stocker cattle (Burns and Fisher, 2013; Lowe et al., 2015; Lowe II et al., 2016; Backus et al., 2017; Boyer et al., 2020b) and moderate the effects of drought and reduce summer heat risk (Brown, 1999). Rotating cattle onto WSG pasture during the summer could also reduce overgrazing, improve water quality, and lower soil erosion rates (Moore et al., 2004; Muir, Pitman, and Foster, 2011; Byrnes et al., 2018; Stanley et al., 2018).

The benefits of augmenting CSG forage systems with WSG are balanced by significant establishment and maintenance costs, which may explain the limited use of WSG in the Southeast (Taylor, 2000; Keyser et al., 2021). WSG can be difficult to establish. No grazing or hay production should be expected during the establishment year while root systems develop (Burns and Fisher, 2013). Further, most perennial WSG do not reach full yield potential by the second year (Burns and Fisher, 2013). Thus, converting pasture acres to WSG requires producers to invest 1–2 years of capital, labor, and other opportunity costs. Integrated CSG and WSG systems may also require producers to implement rotational grazing and follow rigid herbicide and fertilizer management plans that may incur additional labor, managerial, chemical, and forage costs (Gillespie et al., 2008).

Working land conservation programs (e.g., the Environmental Quality Incentive Program (EQIP), Grassland Reserve Program, and Wildlife Habitat Incentive Program) provide financial and technical assistance for adopting new forage species or rehabilitating pasture (Ryan and Marks, 2005; Lambert et al., 2007; Harper et al., 2015). For example, the Natural Resource Conservation Service's EQIP Practice 512 provides technical and financial support to help producers manage summer forage, reduce soil erosion, and enhance water quality (U.S. Department of Agriculture, National Resource Conservation Services, 2011). An EQIP 512–type program could be implemented to reduce or offset the costs producers might incur establishing and managing WSG. Previous studies have found that the likelihood of producers voluntarily adopting best management practices increases as financial assistance increases (e.g., Cooper, 2005; Lichtenberg, 2004; Ma et al., 2012; Jensen et al., 2015). However, to our knowledge, no previous research has investigated beef cattle producer willingness to adopt WSG given a monetary incentive.

Methods and Procedures

We model producer adoption of WSG as a two-tiered decision. Discrete choice models are frequently used to analyze farmer decision making and rely on McFadden's (1974) random utility maximization framework (e.g., Vanslembrouck, Huylenbroeck, and Verbeke, 2002; Wossink, 2003; Cooper, 2005; Defrancesco et al., 2008). We use this approach to model the two-tiered decision-making process for determining voluntary program participation, followed by participation intensity measured as pasture acres converted to WSG.

Participation Decision

Producers adopt WSG when the expected utility from adoption exceeds that from a business-as-usual forage management plan. Producers adopting WSG are willing to convert pasture acres to WSG up to the point at which the marginal utility of conversion equals the marginal conversion costs. Indirect utility from net returns earned by producers is assumed to be linear in arguments with a systematic and a stochastic component:

$$v_i(\bar{\pi}_i; \mathbf{z}_i, \varepsilon_i) = v(\bar{\pi}_i; \mathbf{z}_i) + \varepsilon_i, \tag{1}$$

where ε is a stochastic, unobserved component of utility, $\mathbf{z}$ are producer attributes and farm business characteristics, $\bar{\pi}$ are net returns from raising cattle on pasture, and i indexes producers.

Indirect utility for producers who do not adopt WSG is $v_{i0}(\mathbf{z}_i, \bar{\pi}_i; acres_i = 0) + \varepsilon_{i0}$, with ε_{i0} a random disturbance. When producers accept an incentive to convert pasture acres to WSG, their indirect utility is

$$v_{i1}(\mathbf{z}_i, \bar{\pi}_i + \pi_i^* + c_i;\ acres_i > 0) + \varepsilon_{i1}, \tag{2}$$

where c is an incentive, π_i^* the producer's expectation of net returns to WSG absent the incentive, and ε_{i1} a random disturbance.[1] Note that $\pi_i^* < 0$, otherwise WSG would have already been adopted. The combined terms $\pi_i^* + c_i$ are the indifference price, which is the lowest amount at which a producer is willing to adopt WSG (Cooper, 2005). Like utility, the indifference price is unobserved. A hypothetical monetary incentive is used in this study to elicit the indifference price at which a producer adopts WSG.

Survey respondents likely had little information on which to base expectations of the effects of WSG adoption on the profitability of their cattle operations. The practice is relatively new to producers in the region; there have been, to our knowledge, no published studies of the effects of WSG adoption on profitability, and the survey provided no information on such effects. Had such information been available, it could have been included in the survey as a common basis from which respondents could estimate how WSG adoption might influence the profitability of their individual operations. Net returns from WSG would depend on calving season, herd size, water sources, rotational grazing constraints, and annual weather conditions. We take an empirical approach and model π_i^* as a producer-specific random effect in the participation model to proxy a focal point for expected net returns.

The producer converts pasture to WSG forage when the utility of doing so exceeds the utility of not adopting WSG. Indirect utility is parameterized as a linear function of its systematic and stochastic components. Indirect utility for the producer refusing the incentive is

$$v_{i0} = \mathbf{z}_i \boldsymbol{\alpha}_0 + \bar{\pi}_i \cdot \alpha_\pi + \varepsilon_{i0}, \tag{3}$$

where $(\boldsymbol{\alpha}_0, \alpha_\pi)$ are utility weights associated with producer attributes and net returns, respectively. For the producer who accepts incentive c and converts pasture acres to WSG, indirect utility is

$$v_{i1} = \mathbf{z}_i \boldsymbol{\alpha}_1 + (\bar{\pi}_i + \pi_i^* + c_i) \cdot \alpha_\pi + \varepsilon_{i1}, \tag{4}$$

[1] We thank an anonymous reviewer for suggesting this approach.

with $\pi_i^* < c_i$; otherwise, equation (3) applies. The likelihood that a producer accepts the offer balances on the difference in utility under each state and the indifference price. This difference is a latent variable, v^*, observed as a probability, such that

$$(5)\quad \begin{aligned} v_{i1} - v_{i0} &= \boldsymbol{z}_i(\boldsymbol{\alpha}_1 - \boldsymbol{\alpha}_0) + \alpha_\pi \cdot (c_i + \pi_i^*) + (\varepsilon_{i1} - \varepsilon_{i0}) \\ \implies v_i^* &= \boldsymbol{z}_i\boldsymbol{\alpha} + \alpha_\pi \cdot (c_i + \pi_i^*) + \varepsilon_i \\ \implies \Pr[acres_i > 0] &= F_\varepsilon[-\varepsilon_i < \boldsymbol{z}_i\boldsymbol{\alpha} + \alpha_\pi \cdot c_i + \alpha_\pi \cdot \pi_i^*)], \end{aligned}$$

where F_ε is a cumulative distribution function for the error term ε and $\varepsilon \sim (0, \sigma_\varepsilon^2)$.

Assuming the random disturbances are standard normal distributed and after normalizing equation (5) by the standard error of the random term, then $\varepsilon_{i1}/\sigma_\varepsilon = \varepsilon_{i1} \sim \mathcal{N}(0,1)$ and $(\boldsymbol{\alpha}/\sigma_\varepsilon, \alpha_\pi/\sigma_\varepsilon)$. Let $\boldsymbol{x}_{i1}$ include farm and operator characteristics with the corresponding (normalized) utility weights $\boldsymbol{\beta}_1 = \boldsymbol{\alpha}/\sigma_\varepsilon$ and $\alpha_\pi^* = \alpha_\pi/\sigma_\varepsilon$. The probability a producer accepts the offer to convert pasture acres to WSG is then

$$(6)\quad \Pr[acres_i > 0] = \Phi(\boldsymbol{x}_{i1}\boldsymbol{\beta}_1 + \alpha_\pi^* \cdot c_i + \alpha_\pi^* \cdot \pi_i^*),$$

where $\Phi(\cdot)$ is the cumulative density function (CDF) of the standard normal distribution.

Participation Intensity

The second hurdle explains participation intensity in terms of the pasture acres converted to WSG (*acres*), given that the producer accepted the incentive. Let $\boldsymbol{x}_{i2} = [\boldsymbol{z}_{i2}, c_i]$ include operator and farm business characteristics and the incentive, with corresponding parameters $\boldsymbol{\beta}_2 = [\boldsymbol{\alpha}_2, \alpha_A]$. The pasture acres a producer is willing to convert to WSG, given that the incentive offered is equal to or exceeds the producer's indifference price, is

$$(7)\quad acres_i = \boldsymbol{x}_{i2}\boldsymbol{\beta}_2 + \varepsilon_{i2} | -\varepsilon_{i1} < \boldsymbol{x}_{i1}\boldsymbol{\beta}_1 + \alpha_\pi^* \cdot c_i + \alpha_\pi^* \cdot \pi_i^*,$$

where ε_{i2} is an *i.i.d.* error term with an expected value of 0.

We introduce producer heterogeneity into the acreage conversion decision (equation 7) by estimating individual-specific error variances. Under this assumption, the data model for participation intensity admitting heterogeneity is

$$(8)\quad acres_i | acres_i > 0 \sim \mathcal{N}(\boldsymbol{x}_{i2}\boldsymbol{\beta}_2, \sigma_i).$$

The heterogeneity terms are proportional to a scaling factor common to all producers, $\sigma_i \propto 1/\omega$, with respect to a producer-specific scale parameter, h_i, and a global scale parameter, ω, meaning $\sigma_i = h_i \cdot \omega$. When the local scale parameters are $h_i^2 \sim \Gamma^{-1}(\nu/2, \nu/2)$ with ν degrees of freedom, then the acreage response equation is a t_ν-distributed normal mixture model with heteroskedastic errors (Gelman et al., 2013).

Bayesian Estimation of the Double-Hurdle Model with Student-t Errors

Producer preferences for accepting an incentive and subsequently planting pasture to WSG are modeled using a truncated normal hurdle regression, which is often called a double-hurdle regression. Cragg (1971) introduced the double-hurdle regression as an alternative to Tobin's (1958) censored regression. Cragg's procedure models the likelihood that an agent undertakes an action (i.e., accepting an incentive), followed by the decision maker's subsequent effort committed to the activity (i.e., enrolling acres) as being determined by two distinct underlying processes.

We estimate the parameters of the two-tiered decision using Bayesian methods. Previous studies have used Bayesian methods to estimate Cragg's model under the assumption of homoskedastic errors for the second hurdle (Holloway, Barrett, and Ehui, 2005). This approach considers the parameters of interest (e.g., $\boldsymbol{\theta} = [\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \alpha^*_\pi]$) to be unknown random variables rather than fixed parameters to be estimated. The posterior density of the likelihood function is derived from the double-hurdle model's sample log likelihood. The sample log likelihood of Cragg's double-hurdle model is (Wooldridge, 2010)

(9)
$$\begin{gathered} \ln p\left(acres_i|\boldsymbol{\theta}, \alpha^*_\pi, \pi^*_i, \omega, \boldsymbol{x}_{i1}, \boldsymbol{x}_{i2}, acres_i > 0\right) = \\ 1\left[acres_i = 0\right] \ln \Phi\left(-\boldsymbol{x}_{i1}\boldsymbol{\beta}_1 - \alpha^*_\pi \cdot c_i - \alpha^*_\pi \cdot \pi^*_i\right) \\ +1\left[acres_i > 0\right] \ln \Phi\left(\boldsymbol{x}_{i1}\boldsymbol{\beta}_1 + \alpha^*_\pi \cdot c_i + \alpha^*_\pi \cdot \pi^*_i\right) \\ +1\left[acres_i > 0\right]\left(\phi\left[\left(acres_i - \boldsymbol{x}_{i2}\boldsymbol{\beta}_2\right)/\omega\right] - \ln \omega - \ln \Phi\left[\boldsymbol{x}_{i2}\boldsymbol{\beta}_2/\omega\right]\right), \end{gathered}$$

where $\phi(\cdot)$ is the normal probability density function. Producer-specific expectations on net returns to WSG are modeled as truncated normal random effects with a common scale parameter and an upper bound of c_i, $\pi^*_i \sim \mathcal{N}^{c_i}(0, \sigma_{\pi^*})$.

Using $p(\nu)$ as the prior distribution for the degrees of freedom hyperparameter, ν, and applying Bayes's rule, the joint posterior density of Cragg's log likelihood with heteroskedastic errors is

(10)
$$\begin{gathered} p(\boldsymbol{\theta}, \omega, \alpha^*_\pi, \pi^*_i, \sigma_{\pi^*}, \nu, h_i|acres_i) \propto p(acres_i|\boldsymbol{\theta}, \alpha^*_\pi, \omega, \pi^*_i, \sigma_{\pi^*}, \nu, h_i) \cdot \\ p(\boldsymbol{\theta}, \alpha^*_\pi|\omega, \pi^*_i, \sigma_{\pi^*}, \nu, h_i) \cdot p(\omega|\pi^*_i, \sigma_{\pi^*}, \nu, h_i) \cdot p(\pi^*_i|\sigma_{\pi^*}, \nu, h_i) \cdot p(\sigma_{\pi^*}|\nu, h_i) \cdot p(h_i|\nu) \cdot p(\nu). \end{gathered}$$

We use the weakly informative normal prior for the main-effect parameters of the adoption/participation intensity equations, $p(\boldsymbol{\theta}) \sim \mathcal{N}(0, 10)$, which suggests our null hypotheses for these parameters are 0. A Gamma(a, b) prior was used for the global scale parameter and the π^*_i's scale parameter, $[p(\omega), p(\sigma_{\pi^*})] \sim \Gamma\left(2, \frac{1}{10}\right)$ (Gelman et al., 2013).

A proper prior is required for the local scaling factors because the individual-specific effects, h_i, are equal to the number of observations (Gelman et al., 2013). The prior distribution for the local scaling parameters is the inverse-Gamma, $p\left(h^2_i\right) \sim \Gamma^{-1}(\nu/2, \nu/2)$, with a Gamma prior for the degrees of freedom hyperparameter, $p(\nu) \sim \Gamma(2, \frac{1}{10})$.

Hamiltonian Monte Carlo Sampling

R-Stan was used to conduct the sampling procedure (Stan Development Team, 2020). A no-U-turn sampler Hamiltonian Monte Carlo (NUTS-HMC) procedure was used to estimate the posterior distributions of each model's parameters (Gelman et al., 2013).[2] The NUTS-HMC sampler reduces Markov Chain dependency in parameters more rapidly than the Gibbs or Metropolis–Hastings accept/reject algorithms (Homan and Gelman, 2014).

We ran four chains with a warm-up period of 10,000 iterations and an additional 10,000 iterations to generate four sets of posterior distributions. Every tenth sample was retained, resulting in 4,000 parameter samples. Chain convergence was verified using Gelman and Rubin's (1992) diagnostic. Gelman–Rubin diagnostics approaching 1 indicate that a parameter's chain is stationary.

Producer Response to the Incentive

The marginal effects of the double-hurdle model are derived from the conditional and unconditional predictions of pasture acres converted to WSG. The conditional acres only apply to respondents who accepted the incentive, while the unconditional estimate generates *ex ante* predictions for all respondents. The conditional estimate of acres converted is (Burke, 2009)

(11)
$$E\left(acres_i|acres_i > 0, \boldsymbol{x}_{i2}\right) = \boldsymbol{x}_{i2}\boldsymbol{\beta}_2 + \omega \cdot \frac{\phi\left(\boldsymbol{x}_{i1}\boldsymbol{\beta}_1 + \alpha^*_\pi \cdot c_i + \alpha^*_\pi \cdot \pi^*_i\right)}{\Phi\left(\boldsymbol{x}_{i1}\boldsymbol{\beta}_1 + \alpha^*_\pi \cdot c_i + \alpha^*_\pi \cdot \pi^*_i\right)}$$

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[2] R-Stan code for these models is available from the corresponding author.

and the unconditional estimate is

$$(12) \qquad E\left(acres_i|\boldsymbol{x}_{i1},\boldsymbol{x}_{i2}\right) = \Pr\left[acres_i > 0\right] \cdot E\left(acres_i|acres_i > 0,\boldsymbol{x}_{i2}\right).$$

Calculation of the marginal effects for the participation decision follows the usual procedure for probit regressions (Wooldridge, 2010). Marginal effects for the Blundell–Meghir and bivariate hurdle models follow Mutlu and Gracia (2006). We report the unconditional marginal effects for the WSG supply equations (i.e., $\partial E(acres_i|\boldsymbol{x}_{i1},\boldsymbol{x}_{i2})/\partial x_{ij}$). The elasticity of participation with respect to the incentive is calculated as $\partial \Pr(acres_i > 0)/\partial c \times c/\Pr(acres_i > 0)$. The elasticity of pasture acres enrolled with respect to the incentive is calculated as $\partial E(acres_i|\boldsymbol{x}_{i1},\boldsymbol{x}_{i2})/\partial c_i \times c_i/E(acres_i|\boldsymbol{x}_{i1},\boldsymbol{x}_{i2})$.

Data

Data were collected from a 2018 survey of Tennessee beef cattle producers. A list of 7,433 beef cattle producers affiliated with the Tennessee Agricultural Enhancement Program (TAEP) was obtained from the Tennessee Department of Agriculture. The TAEP offers cost shares to livestock and other agricultural producers to support long-term investments on Tennessee farms (see https://www.tn.gov/agriculture/farms/taep.html). The list frame may be biased toward producers who are more amenable to participating in a state or federally managed cost share program. This bias may be exacerbated by the requirement that livestock producers must complete educational programming to qualify for the program's highest cost share rates. There were 5,825 email addresses associated with the list of producers.

Qualtrics (Provo, UT) was used to administer the survey. Administration of the survey occurred in three phases. First, producers received invitations to participate in the survey. Email invitations were sent on March 2, 2018. The email invitation was followed by a reminder email 2 weeks later. Individuals unaffiliated with an email address were mailed a postcard invitation. The emails and postcard included a URL link to the survey, along with information about the survey's purpose. On April 8, the University of Tennessee Human Dimensions laboratory began contacting nonrespondents to administer the survey over the phone. The overall response rate was 30%, with 1,385 responses to the online survey and 367 responses to the phone survey.

This research focuses on the subgroup of 458 respondents who had not previously used WSG. Producers who indicated they already managed WSG pasture did not participate in the choice experiment. The first section of the survey contained questions about livestock and forage production, livestock numbers, rotational grazing practices, and owned and leased pasture acres. The second section included a choice experiment to elicit respondent willingness to adopt WSG. Five incentive levels were randomly assigned across surveys. To limit respondent confusion, the WTA question was framed in terms of the producer's share of the costs of converting pasture to WSG, net of the hypothetical incentive. For example, producers were asked if they would convert pasture acres to WSG if *their* share of the cost were \$35, \$70, \$105, \$145, or \$175 per acre (see the appendix for an example). Assuming an annual conversion cost of \$200/acre (Lowe II et al., 2016), the cost shares incentives are equivalent to \$165, \$130, \$95, \$65, and \$25 per acre. The range was based on a previous study conducted by Keyser et al. (2021) in 2012. Keyser et al. asked Tennessee producers to state an estimated cost of establishing a WSG. Respondents indicated costs between \$25/acre and \$175/acre. Also, 88% of producers said they would not be willing to spend more than \$125/acre to establish WSG. We established our cost share payments based on this information.

Follow-up questions included asking respondents about their concerns over establishing WSG and the expected effects of WSG on their operations. All respondents were asked about their supplemental feeding practices, the impact of drought on their operation, sources of livestock drinking water, and opinions about the importance of risk management and drought contingency planning. The final section of the survey focused on producer demographics.[3]

[3] A copy of the survey instrument is available from the corresponding author.

Explanatory Variables

Research exploring the factors influencing farmer adoption of best management practices focuses on farm and farmer characteristics. Factors such as operator age, educational attainment, farm size, information resources, managerial ability, input costs, farmer perceptions of stewardship, and government policies or incentives influence technology adoption to varying degrees (e.g., Lambert et al., 2007; Kim, Gillespie, and Paudel, 2008; Jensen et al., 2015).

While these and similar variables are included in the participation decision, some are excluded from the intensity equation for statistical and theoretical reasons. Hurdle models can include the same covariates in both tiers, but this practice is discouraged. If the participation and intensity equations share the same covariates, then the participation/outcome equations are identified only by the model's nonlinearity (Wooldridge, 2010).

From a theoretical standpoint, we exclude operator demographic characteristics from the intensity equation because we consider the acres converted to WSG to be a production decision variable most likely influenced by economic considerations, including the hypothetical incentive offered (Jensen et al., 2015). We first discuss the variables included only in the participation equation, followed by the variables common to both hurdles.

Participation Equation

Producer characteristics included as control variables in the participation equation are operator age, education, the respondent's planning horizon, and the respondent's engagement with Extension. Table 1 reports definitions and descriptive statistics for these variables.

Operator Characteristics

Producer age (*age*) is expected to be negatively associated with the decision to convert pasture acres to WSG. Older farmers tend to have shorter planning horizons and are therefore less likely to adopt new practices (Roberts et al., 2004). Younger farmers, on the other hand, may have a longer planning horizon and more willing to experiment with new forage species or forage management practices that could increase weight gain.

Producers with higher levels of educational attainment are more likely to adopt relatively complex practices (Walton et al., 2008). Likewise, we expect producers with a college degree (*coll*) to be more willing to accept the offered incentive and convert pasture acres to WSG.

Respondent intention to pass the farming operation to a family member after retirement may implicitly extend that producer's planning horizon and thus positively influence willingness to participate in stewardship practices (Claytor et al., 2018). A dummy variable (*pfo*) equaling 1 if the respondent intended to pass the farm to a family member, and 0 otherwise, is included in the participation equation. This variable is hypothesized to correlate positively with the participation decision.

Attendance at Extension field days or workshops (*atte*) is also hypothesized to be positively correlated with willingness to adopt WSG. Previous studies have found that producers who use information from Extension may be more likely to adopt new technologies (Walton et al., 2008).

Producer attitudes play an important role in adoption decisions (Baumgart-Getz, Prokopy, and Floress, 2012). Respondents who believe the survey results will actually influence policy design may be more likely adopt or pay more for profarm programs (Herriges et al., 2010). Respondent confidence that the survey would influence farm programs in Tennessee (*conf*) is expected to correlate positively with willingness to convert pasture acres to WSG forage.

Table 1. Descriptive statistics (*N* = 458)

Variable	Label	Mean	Std. Dev.	Min.	Max.
Incentive ($/acre)	*incent*	96.38	49.53	25	165
Survey mode (1 = email)	*ss*	0.67	0.47	0	1
Total pasture acres	*acret*	144.95	160.11	7	1,453
Would change					
Pasture productivity (1 = increase)	*wcppi*	0.83	0.38	0	1
Forage quality, livestock health, & nutrition (1 = increase)	*wcfqlhi*	0.79	0.41	0	1
Flexibility in managing pasture and grazing (1 = increase)	*wcfmi*	0.61	0.49	0	1
Number of water sources used (1 = increase)	*wcwsi*	0.14	0.34	0	1
Management burden (1 = increase)	*wcmbi*	0.37	0.48	0	1
Time and effort concern of adoption (scale of 1–3)	*paco*	2.15	0.64	1	3
Times of converted or renovated pasture (scale of 1–4)	*ccrs*	1.57	0.85	1	4
Age (years)	*age*	54.21	13.23	18	84
College (1 = yes)	*coll*	0.50	0.50	0	1
Pass to family member when retired (1 = yes)	*pfo*	0.77	0.42	0	1
Field days or Extension workshops attended (scale of 1–5+)	*atte*	2.22	1.16	1	5
Confidence of survey influence (scale of 1–3)	*conf*	2.07	0.53	1	3
Total household income (scale of 1–7)	*tinc*	3.74	1.83	1	7
% of income from farming (scale of 1–5)	*fainc*	1.69	1.05	1	5
Purchased pasture insurance (1 = yes)	*pins*	0.15	0.36	0	1
Stocking density animal units/acre)	*stod*	0.69	0.53	0.07	8
Rotate frequency (scale 1-4)	*rotsfr*	2.02	0.88	1	4
Fertilizer management (1 = used)	*ferm*	0.84	0.36	0	1
Tested soil (1 = used)	*ts*	0.59	0.49	0	1
Sprayed to control weeds (1 = used)	*scw*	0.77	0.42	0	1
Percentage of municipal water	*pmw*	15.47	29.56	0	100
Percentage of days on hay during summer	*dhs*	1.00	3.00	0	30
Action taken					
Bought hay to feed livestock (1 = yes)	*bhfl*	0.51	0.50	0	1
Supplemented water source (1 = yes)	*sws*	0.34	0.48	0	1
Shipped livestock for custom grazing elsewhere (1 = yes)	*slcg*	0.05	0.21	0	1
Sold livestock (1 = yes)	*sl*	0.58	0.49	0	1

Farm Business Attributes

Farm business attributes included in the participation equation focus on earned income and risk management. Household income (*tinc*) is a proxy for farm capital and thus expected to be positively correlated with willingness to adopt WSG. Higher incomes suggest a greater capacity to absorb establishment costs and bear additional risk (Tey and Brindal, 2012). Similarly, the share of income derived from farming (*fainc*) is expected to be positively correlated with willingness to enroll acres in the hypothetical program. Producers reporting a greater share of income from farming are hypothesized to have relatively lower opportunity costs (Lambert et al., 2017) and therefore lower resistance to the extra managerial attention associated with the adoption and use of WSG.

The purchase of pasture, rangeland, and forage insurance (*pins*) may indicate that a producer is relatively risk averse and thus willing to adopt practices believed to moderate risk. On the other hand, converting pasture acres to WSG could be viewed as a risky investment. It is therefore uncertain how this variable will influence acreage conversion to WSG.

Total pasture acres (*acret*) managed by the producer is expected to be positively correlated with willingness to convert pasture acres to WSG. Typically, farm size positively correlates with the adoption of novel agricultural technologies because larger operations are able to spread the fixed costs of adoption over more acres (Mazorra, 2001; Damianos and Giannakopoulos, 2002).

Pasture Management Practices

Pasture management practices included in the participation equation are stocking density and whether the producer practiced rotational grazing, fertilized pastures, tested pasture soils, or used herbicides on pasture to manage weeds. Additional questions on pasture management practices focused on modes of providing cattle with drinking water and the days cattle were on hay during summer months.

Stocking density (*stod*) is expected to increase producer willingness to participate in the hypothetical program. Stocking density was calculated as animal units per acre of pasture, calculated using Claytor et al.'s (2018) method.

The frequency with which producers rotated livestock through paddocks (*rotsfr*) is expected to be positively correlated with willingness to adopt WSG. Rotation frequency signals greater ability to practice rotational grazing, which is likely a requirement for integrating WSG into CSG forage systems. Other research finds that producers believe rotational grazing extends grazing days (Gillespie et al., 2008; Ward et al., 2008), but grazing studies have found modest benefits in terms of better cattle health or performance from rotational grazing (Briske et al., 2008; Hawkins, 2017).

Producers who applied fertilizer to their pasture (*ferm*), conducted a soil test to manage pasture fertility (*ts*), or sprayed herbicide to control weeds (*scw*) in 2017 are expected to be more willing to convert pasture acres to WSG. Cattle producers who had recently engaged in these practices presumably manage their pasture more intensively and thus would be more likely to consider diversifying their forage resources.

A greater number of days cattle are on hay (*dsh*) implies greater potential for supplemental feed cost reduction associated with WSG adoption. On the other hand, days on hay could also imply a greater capacity and/or willingness to feed animals hay and thus less of a need to supplement CSG production with WSG during the summer. Boyer et al. (2020a) found that beef producers in Tennessee rarely feed hay in the summer. Therefore, the most likely result may be that the number of days on hay will have little or no effect on willingness to adopt WSG.

Adaptive Practices

Producer experience with adaptive herd and pasture management strategies was also included in the participation equation. Conversion of pasture acres to WSG may increase the resiliency of CSG grazing systems to drought. The extent to which a producer's operation has been affected by drought could influence their perception of WSG as an alternative or supplement to fescue-dominant pastures.

Producers were asked how they changed their pasture management practices during the most recent drought they could recall. Producers who purchased hay to supplement forage (*bhfl*), supplemented their cattle's main water source (*sws*), used municipal utilities to water cattle (*pmw*), shipped livestock for custom grazing elsewhere (*slcg*), or thinned the herd through market sales (*sl*) are expected to more to be willing to adopt WSG.

Variables Common to the Participation and Intensity Equations

Farm business and pasture management variables, farm household characteristics, and operator attributes common to the participation and intensity equations include (i) respondent perceptions of how the conversion of pasture to WSG would change their current pasture management systems, (ii) the total number of pasture acres managed by the respondent, and (iii) the respondent's survey mode. A dummy variable indicating whether respondents finished the survey online or over the

Table 2. Incentives, Participation, and Pasture Acres Converted to Warm Season Grass

Incentive	$25	$60	$95	$130	$165
Survey data					
Adopters	57	53	65	54	71
Average pasture acres converted	31	27	30	43	33
Average of total pasture acres operated	153	138	136	163	141
Model estimates					
Adopters[a]	279	293	308	321	334
Average pasture acres converted (unconditional)[b]	20	22	25	28	31

Notes: [a] Calculated as the sample size (458) multiplied by the probability of accepting the incentive (equation 6).
[b] Unconditional acres calculated calculated using equation (12).

phone (*ss*) is used to control for survey mode effects. The amount of the cost share incentive (*incent*) is expected to positively affect both program participation and participation intensity.

Research on best management practice adoption commonly examines the effects of farm and farmer characteristics on adoption. Less attention has been given to producer perceptions of how practice adoption would affect profitability and other aspects of the operation. Producers who believed WSG adoption would increase pasture productivity (*wcppi*); forage quality, livestock health, and nutrition (*wcfqlhi*); and flexibility in managing pasture and grazing (*wcfmi*) are expected to be more willing to adopt WSG and to convert relatively more pasture acres to WSG.

Compatibility with the respondent's current managerial practices is measured by producer perceptions of whether WSG adoption would require increasing livestock access to water (*wcwsi*) or would increase managerial burden (*wcmbi*), along with the producer's previous experience replanting pasture with a different forage (*ccrs*). Additional managerial burden or capital expenses associated with converting pasture acres to WSG may discourage producers from adopting WSG or reduce the number of acres converted to WSG. Conversely, previous experience with replanting forage on pasture may reduce the time required to learn how to establish WSG. Producers who were more concerned about the time and effort needed to replace CSG forage with WSG (*paco*) are expected to perceive WSG adoption as relatively complex and thus less willing to adopt WSG and willing to convert fewer acres of pasture to WSG species.

Results and Discussion

Mean respondent age was 54 and respondent mean annual household income was $92,000. On average, respondents owned 99 head of livestock and managed 145 pasture acres. About 50% of respondents had a college degree or equivalent. According to the 2017 U.S. Census of Agriculture, the average age of principal producers in Tennessee was 59. On average, operators managed 68 acres of pastureland (U.S. Department of Agriculture, 2019). In 2017, Tennessee residents had a mean annual household income of $68,386, and 26% of Tennessee residents had a bachelor degree or higher (U.S. Census Bureau, 2017). Thus, the reported sample had higher levels of educational attainment than the state's general population.

Table 2 shows that 66% of respondents (n = 300) accepted the offered incentive. A total of 9,823 in-sample acres were converted. Averaged across the five incentive levels, respondents converted 22% of their pasture acres to WSG (32 acres).

Model Statistics

The posterior log likelihood of the double hurdle was $-2,616$ (Table 3).[4] The degrees of freedom parameter, ν, was 20.51, suggesting moderate error variance heterogeneity with respect to the acreage conversion decision. Homoskedastic errors would correspond with a degrees of freedom parameter value of $\nu \approx 100$, while evidence of strong heterogeneity would correspond with a parameter value of $\nu \approx 2$. The scale parameter for the indifference price was 18.12, suggesting that π^* varied considerably across the sample. Minimum and maximum π^* were -165 and 204, respectively.

The Gelman–Rubin statistics were equal to 1 (to three decimal places), indicating convergence of the respective parameter chains. The posterior distributions of the double hurdle were used to calculate the marginal effects of the covariates on the participation decision and participation intensity. We discuss the marginal effects with 90% highest posterior density intervals (HPDI) that exclude 0. The discussion reports the mean of the marginal effect's posterior distribution along with the lower 5% and upper 95% HPDI bounds.

Model Estimates

Respondents who completed the survey online were 0.07 (0.01, 0.12) (mean, followed be lower 5% and upper 95% bounds in parentheses) more likely to accept the hypothetical incentive (Table 4). However, respondents who completed the survey by phone were willing to convert 3.66 (1.65, 5.77) more acres to WSG than respondents who completed the survey online. There are any number of possible reasons why survey mode might affect responses. One possibility is that respondents who completed the survey online (without having to be called) may have been more predisposed to completing the survey because they were more interested in WSG. Thus, the difference in WTA between the two modes could reflect a response bias. If so, then the survey results may overestimate willingness to adopt WSG among Tennessee cattle farmers since survey nonrespondents may be less interested in adopting WSG. On the other hand, if mode is correlated with interest, it is surprising that response by phone was negatively correlated with participation intensity.

Producer and Farm Operation Characteristics

Producers who believed WSG would increase forage quality and livestock health and would provide them additional flexibility with respect to pasture and grazing management were 0.10 (0.03, 0.18) and 0.06 (0.01, 0.11) more likely to accept the incentive and participate in the WSG program, respectively. Thus, while respondents may be inexperienced with converting CSG to WSG species, there appears to be an expectation that the practice would improve their operation. Improvement in forage quality and increased managerial flexibility were attractive features of WSG associated with its adoption, but these same qualities were negatively associated with pasture acre conversion to WSG (Table 4).

Producers who believed that WSG adoption would increase managerial commitments were -0.03 (-0.06, -0.01) less likely to accept the incentive and adopt WSG. Conversely, conditional on accepting the conversion incentive, this characteristic was positively associated with acres converted. However, concerns over the time and effort required to establish WSG were negatively associated with CSG pasture conversion (-3.58 acres). Producers who relied on municipal water for their livestock were less likely to participate in the WSG program. Those who would accept the incentive are expected to convert about one-half an acre less of pasture to WSG. This finding may reflect additional perceived costs not covered by the incentive with respect to retrofitting current watering systems.

[4] We considered Mutlu and Gracia's (2006) bivariate double-hurdle and Blundell and Meghir's (1987) double-hurdle specifications. The models failed to converge.

Table 3. Hamilitonian Markov Chain (HMC) Posterior Summary: Participation and Pasture Acres Converted to Warm Season Grass (WSG)

		Participation				WSG Acres			
Variable	**Label**	**Mean**	**Std. Dev.**	**Lower 5%[a]**	**Upper 95%**	**Mean**	**Std. Dev.**	**Lower 5%**	**Upper 95%**
Constant	*constant*	−1.3091	0.5932	−2.2686	−0.3664	10.4291	6.6486	−0.3212	20.9881
Incentive ($/ac)	*incent*	0.0024	0.0013	0.0003	0.0046	0.0953	0.0298	0.0479	0.1435
Survey mode (1 = email)	*ss*	0.3003	0.1462	0.0665	0.5387	5.8989	3.1653	0.8451	10.8868
Total pasture acres	*acret*	0.0001	0.0005	−0.0006	0.0009	0.0970	0.0086	0.0837	0.1111
pasture productivity (1 = increase)	*wcppi*	0.1370	0.2037	−0.1775	0.4747	0.7340	4.2979	−6.0750	7.7100
forage quality &livestock health & nutrition (1 = increase)	*wcfqlhi*	0.3903	0.1719	0.1173	0.6703	4.3529	4.0368	−1.9765	10.8415
flexibility in managing pasture and grazing (1 = increase)	*wcfmi*	0.3119	0.1502	0.0754	0.5485	3.4527	3.3855	−1.8477	8.8204
number of water sources used (1 = increase)	*wcwsi*	−0.0053	0.2019	−0.3339	0.3250	7.8498	4.0848	1.2678	14.3884
management burden (1 = increase)	*wcmbi*	−0.2574	0.1459	−0.4860	−0.0201	−7.3276	3.1059	−12.3394	−2.4685
Time and effort concern of adoption (scale 1-3)	*paco*	0.0018	0.1021	−0.1625	0.1608	−8.2246	2.3284	−12.0981	−4.5775
Times of converted or renovated pasture (scale 1-4)	*ccrs*	−0.0097	0.0816	−0.1442	0.1197	0.7316	1.7238	−2.0574	3.4794
Age (years)	*age*	−0.0071	0.0053	−0.0159	0.0012				
College (1 = yes)	*coll*	0.0310	0.1457	−0.2071	0.2637				
Pass to family member when retired (1 = yes)	*pfo*	0.2042	0.1596	−0.0522	0.4520				
Field days or Extension workshops attended (scale 1-5)	*atte*	0.1214	0.0587	0.0284	0.2156				
Confidence of survey influence (scale 1-3)	*conf*	0.0378	0.1237	−0.1630	0.2326				
Total household income (scale 1-7)	*tinc*	0.0034	0.0388	−0.0598	0.0669				
% of income from farming (scale 1-5)	*fainc*	0.0359	0.0648	−0.0651	0.1399				
Purchased pasture insurance (1 = yes)	*pins*	0.0270	0.1897	−0.2807	0.3208				
Stocking density animal units/acre)	*stod*	0.3536	0.1783	0.0794	0.6436				
Rotate frequency (scale 1-4)	*rotsfr*	0.1044	0.0786	−0.0248	0.2298				
Fertilizer management (1 = used)	*ferm*	0.2456	0.1854	−0.0443	0.5489				
Tested soil (1 = used)	*ts*	−0.0112	0.1414	−0.2359	0.2169				
Sprayed to control weeds (1 = used)	*scw*	−0.0737	0.1636	−0.3347	0.1891				
% of municipal water	*pmw*	−0.0066	0.0022	−0.0102	−0.0030				
% of days on hay during summer	*dhs*	0.0311	0.0208	−0.0018	0.0648				
bought hay to feed livestock (1 = yes)	*bhfl*	0.1721	0.1374	−0.0426	0.3955				
supplemented water source (1 = yes)	*sws*	−0.2927	0.1435	−0.5225	−0.0596				
shipped livestock for custom grazing elsewhere (1 = yes)	*slcg*	0.0467	0.3043	−0.4382	0.5244				
Sold livestock (1 = yes)	*sl*	0.1419	0.1425	−0.0852	0.3617				
σ		21.2397	0.7701	20.0414	22.4785				
ν		20.7539	14.2748	4.3325	46.8284				
σ_{π^*}		18.1217	12.2222	2.8315	41.7129				

Notes: $N = 458$. Posterior log likelihood is $-2,616$. [a] Lower and upper bounds of the 90% highest posterior density intervals of the distribution.

Table 4. Posterior marginal effects

		Participation Decision (accept offer)			Pasture Acres to Warm Season Grass (WSG)[a]		
Variable	**Label**	**Marginal Effect**	**Lower 5%[a]**	**Upper 95%**	**Marginal Effect**	**Lower 5%**	**Upper 95%**
Incentive ($/acre)	*incent*	0.0008	0.0001	0.0015	0.0658	0.0352	0.0959
Survey mode (1 = email)	*ss*	0.0661	0.0130	0.1196	−3.6645	−5.7727	−1.6463
Total pasture acres	*acret*	3.9e−5	−0.0002	0.0003	0.0437	0.0336	0.0543
Would change							
Pasture productivity (1 = yes)	*wcppi*	0.0376	−0.0470	0.1339	−1.4289	−5.2611	2.4038
Forage quality, livestock health, nutrition (1 = yes)	*wcfqlhi*	0.1019	0.0273	0.1790	−4.5378	−7.5259	−1.5267
Flexibility in managing pasture and grazing (1 = yes)	*wcfmi*	0.0616	0.0130	0.1110	−2.9847	−5.1681	−0.7819
Number of water sources used (1 = increase)	*wcwsi*	−0.0004	−0.0152	0.0138	−0.4808	−1.1354	0.1597
Management burden (1 = increase)	*wcmbi*	−0.0295	−0.0563	−0.0019	2.1313	0.9281	3.3196
Time and effort concern of adoption (scale of 1–3)	*paco*	0.0005	−0.0530	0.0525	−3.5786	−5.9625	−1.3308
Times of converted or renovated pasture (scale of 1–4)	*ccrs*	−0.0031	−0.0469	0.0393	0.2230	−1.6185	2.0286
Age (years)	*age*	−0.0023	−0.0051	0.0005	−0.0714	−0.1608	0.0140
College (1 = yes)	*coll*	0.0049	−0.0339	0.0421	−0.1571	−1.3486	1.0652
Pass to family member when retired (1 = yes)	*pfo*	0.0512	−0.0142	0.1164	−1.6485	−3.7816	0.4566
Field days or Extension workshops attended (scale of 1–5)	*atte*	0.0383	0.0080	0.0685	1.2150	0.2490	2.1874
Confidence of survey influence (scale of 1–3)	*conf*	0.0280	−0.1016	0.1645	−0.8899	−5.2426	3.1413
Total household income (scale of 1–7)	*tinc*	0.0051	−0.0683	0.0838	−0.1765	−2.7337	2.2483
Percentage of income from farming (scale of 1–5)	*fainc*	0.0198	−0.0374	0.0784	−0.6523	−2.6068	1.2127
Purchased pasture insurance (1 = yes)	*pins*	0.0011	−0.0142	0.0153	−0.0393	−0.5376	0.4988
Stocking density (animal units/acre)	*stod*	0.1116	0.0241	0.2051	3.5375	0.7562	6.5343
Rotate frequency (scale of 1–4)	*rotsfr*	0.0329	−0.0088	0.0735	1.0419	−0.2809	2.3275
Fertilizer management (1 = used)	*ferm*	0.0683	−0.0134	0.1570	−2.2052	−5.0699	0.4280
Tested soil (1 = used)	*ts*	−0.0018	−0.0443	0.0428	0.0589	−1.4043	1.4575
Sprayed to control weeds (1 = used)	*scw*	−0.0172	−0.0803	0.0501	0.5592	−1.6399	2.6030
Percentage of municipal water	*dhs*	0.0098	−0.0008	0.0205	0.3116	−0.0244	0.6528
Percentage of days on hay during summer	*bhfl*	0.0280	−0.0077	0.0654	−0.8740	−2.0378	0.2390
Action taken							
Bought hay to feed livestock (1 = yes)	*sws*	−0.0315	−0.0572	−0.0055	1.0209	0.1766	1.8368
Supplemented water source (1 = yes)	*slcg*	0.0006	−0.0077	0.0081	−0.0202	−0.2882	0.2682
Shipped livestock for custom grazing elsewhere (1 = yes)	*sl*	0.0265	−0.0168	0.0692	−0.8657	−2.2452	0.5456

Notes: [a] Unconditional marginal effects; $\frac{\partial E(acres_i|\mathbf{x}_{i1},\mathbf{x}_{i2})}{\partial x_{ij}}$.

[b] Lower and upper bounds of the 90% highest posterior density intervals of the distribution.

Respondents who attended relatively more Extension events were more willing to accept the incentive and to convert more pasture acres to WSG (Table 4). For each additional Extension event attended, respondents were 0.04 (0.01, 0.07) more likely to accept the hypothetical incentive, and those who did were willing to convert an additional 1.22 (0.25, 2.19) acres.

Stocking density (measured as animal units per acre) was positively correlated with willingness to accept the incentive and convert pasture acres to WSG. For a one-animal-unit-per-acre increase in stocking density, respondents were 0.11 (0.02, 0.20) more willing to accept the incentive to adopt WSG and willing to convert an additional 3.54 (0.78, 6.53) acres (Table 4). The positive relationship between grazing intensity and WSG adoption may suggest that producers value WSG as a means of reducing overgrazing on their CSG pastures during the summer.

Actions taken to mitigate the effects of drought on the operation affect the likelihood of accepting the incentive and also pasture acres converted to WSG. Producers who responded to drought by supplementing their water sources were −0.03 (−0.06, −0.01) less likely to participate in the hypothetical program. However, for producers who employed this strategy during drought would convert 1.02 (0.18, 1.83) acres of pasture to WSG. Other drought-adaptive practices were not associated with the adoption decision or acres converted to WSG.

Incentive to Convert Pasture to Warm Season Grasses

The effect of the incentive on the participation decision was positive and significant (Table 4). In elasticity terms, a $10/acre increase in the incentive increased the probability of participating in the program by 1.2% (0.10%, 2.4%). Thus, while producers appear to respond positively to the incentive, overall response is inelastic. The size of the incentive was also positively correlated with the number of acres respondents were willing to convert to WSG. All else equal, a $10/acre increase in the incentive would increase the number of acres adopters were willing to convert by 3.2 (1.7, 4.7) acres.

Evaluated at the lower and upper bounds of the incentive ($25/acre and $165/acre, respectively) and calculating the unconditional acres converted to WSG using the model estimates, producers would convert 14% (low end) to 21% (high end) of their total pasture acres to WSG (Table 2).

Producers were not particularly responsive to a cost share incentive supporting the conversion of pasture acres to WSG species. This lack of responsiveness suggests either that the primary barrier(s) to adopting WSG may not be financial or that the salience of the incentive is limited by the scant information producers have on the net returns to WSG adoption. Producers may be unconvinced of the benefits of converting a share of their CSG pasture to WSG species due to the concept's relative novelty among the region's beef cattle operators. Nonetheless, the prospect of converting portions of CSG pastures to WSG species in anticipation of longer, drier summer months associated with climate change is an enticing option for producers considering expanding their management options to include adaptive pasture management practices.

Conclusions

Supplementing CSG in the Fescue Belt could enhance the resiliency and profitability of the region's livestock operations. Warm-season grasses could compensate for the reduced productivity of CSG during the summer months, enhancing resilience to drought and disease. The conversion of a share of the region's CSG to WSG could also enhance wildlife habitat, prevent sediment loss, and increase water quality. However, prior studies suggest that the utilization of WSG in the region is low.

This research elicited the willingness of cattle producers in Tennessee to adopt WSG in a hypothetical choice experiment, conditioned on farm operator and business characteristics. A double-hurdle regression with Student-*t* errors was used to estimate producer willingness to adopt WSG and the pasture acres they would convert to WSG. Producers would convert 14%–21% of their pasture acres to WSG, depending on the level of the incentive. At the median incentive of of \$95/acre, 17% of the 44,592 pasture acres operated by respondents could be converted to WSG.

One potential shortcoming of this study is the lack of consideration of the benefits WSG can provide to cattle producers in drought. In addition, the study did not consider how the adoption of WSG would fit into a risk-averse producer's portfolio, despite recent work showing the adoption of WSG can reduce exposure to production risk (Boyer et al., 2020a).

An additional research limitation is that we could not include any information to respondents on the expected monetary benefits they might receive from increased forage productivity and reductions in supplemental feed costs during the summer months. The diversity of operations in the study region in terms of scale and land resources makes it difficult to make accurate generalizations across the population of operations about WSG profitability. To address this shortcoming, we introduced individual-specific random effects into the participation decision to control for the lack of a common anchor for net returns to WSG.

Another important caveat is the sample of producers who participated in the survey. Producers who participate in the TAEP self-select into this program for different reasons. It may be that these persons would be more likely to participate in this hypothetical program compared to the population of producers who do not participate in the TAEP. While the survey response rate was high, the findings most likely only generalize to TAEP producers.

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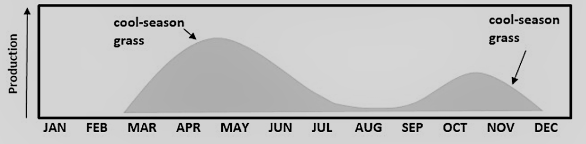
Appendix A: Choice Screen with Costs

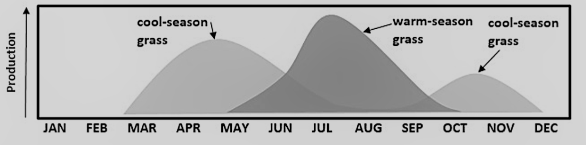
CHOICE QUESTION

Since cool-season grass growth slows during the summer, livestock producers could plant warm-season grasses to increase forage production and limit over-grazing during the summer.

Cool Season Forage Production:



Cool & Warm Season Forage Production:



Suppose there was a voluntary cost-share program for planting warm-season grasses. To qualify for the program, livestock producers would have to: (1) Plant a warm-season grass; (2) Document the number of acres planted, along with seeding rate and planting date; and (3) Collect and use data from soil tests to manage fertilizer applications.

Would you participate in this program if **your share** of the costs of planting a warm-season grass was **$xx per acre**? (xx = 35, 70, 105, 140, 175)?

○ No, I would not participate

○ Yes, I would participate and plant a warm-season grass

How many acres of warm-season grass would you plant?

Acres ☐