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**Estimating Soil Loss Abatement Curves with Primary Survey Data and Hydrologic
Models: An Empirical Example for Livestock Production in an East Tennessee Watershed**

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Abstract

Government subsidy programs incentivize livestock managers to adopt best management practices (BMPs), such as rotational grazing, water tank systems, stream crossings, and pasture improvement to prevent or reduce soil erosion. This paper addresses the challenge of integrating socio-economic data on BMP adoption behavior with hydrologic/biophysical models to analyze the association between incentives, BMP adoption, and changes in soil erosion rates. Using primary survey data of livestock producers in an East Tennessee watershed, this research estimates willingness to adopt BMPs among livestock producers. The propensity to adopt one or multiple management technologies, given an incentive, is estimated with a multivariate probit regression. The likelihood producers adopt one or a combination of practices is then integrated into the Soil and Water Assessment Tool (SWAT) hydrologic model to generate soil loss abatement curves for the watershed. Abatement curves specific to each hydrologic response unit (HRU) comprising the watershed are estimated and then aggregated to determine an aggregate abatement curve for the watershed. Based on the abatement curves, HRU are ranked according to cost efficiency.

Key words: willingness to adopt; best management practices; sedimentation; abatement curve; hydrologic model

JEL Classification: Q52

Introduction

Overgrazing and poor pasture management affect erosion, water quality, and soil fertility. Grazing activities on pastureland are positively correlated with increased levels of soil loss and sedimentation (Burt, 1981; Pimentel et al., 1995; Knowler and Bradshaw, 2007; Smith et al., 2014). Reductions in soil depth decrease soil productivity leading to runoff and sedimentation (Pimentel et al., 1995). Sedimentation, in turn, stresses aquatic plants and other organisms (Clark, 1985). The United States (U.S.) government has primarily relied on regulatory approaches to address water pollution from point sources, but agencies favor voluntary approaches to reduce pollution from non-point sources, such as grazing lands. A typical voluntary approach for reducing non-point source pollution is to offer incentives to landowners and agricultural producers to install structures and/or adopt best management practices (BMPs) that lower emissions. Programs targeting sedimentation include the Environmental Quality Incentives Program (EQIP), managed by the U.S. Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS). EQIP provides producers incentives of 50% to 75% of start-up costs of installing and implementing BMPs (for example, installing fencing for rotational grazing) (Jensen et al., 2015). The Tennessee Healthy Watershed Initiative (THWI), a program managed by the Tennessee Department of Environmental Conservation (TDEC), also provides producers with incentives to adopt practices to reduce soil erosion and sedimentation.

Federal programs designed to moderate soil loss could benefit from information on producers' willingness to adopt (WTA) best management practices to reach groups of cattle producers more likely to participate in BMP programs. The effect of BMPs on soil loss is specific to the physical characteristics of farm parcels and the hydrology of watersheds. For instance, the slope gradient, land use, and soil type affect soil erosion rates differently (Bhattarai

and Dutta, 2007). Incorporating land parcel topography in policy decisions may facilitate the optimal distribution of incentives to producers who manage livestock on highly erodible land (HEL) or other sensitive land. Also, a BMP's soil loss abatement potential may be more accurately characterized if the estimate accounts for features specific to the watershed. More specifically, estimating the marginal abatement costs associated with individual parcels and their landowners is important to identify where programmatic expenditures could have the greatest marginal impact on sedimentation. With additional information about producer incentives to adopt specific practices, state and federal agencies could more effectively determine the financial incentive levels needed to meet and sustain local water quality objectives. Supplementing hydrologic models with primary survey data on adoption behavior could provide important information for to strategically recruiting producers into programs designed to improve water quality.

This paper focuses on the adoption and effect of best management practices by livestock operators in the Oostanaula Creek Watershed (OCW) in Southeastern Tennessee. Until May 2015, the OCW did not meet ambient water quality standards largely due to high sedimentation levels (TDEC, 2014). The approximately 18,000 ha of the OCW stretches across McMinn and Monroe counties in Southeastern Tennessee. The watershed is a tributary of the Hiwassee River, which begins in northern Georgia and flows through North Carolina and Tennessee, eventually joining the Tennessee River. Pasture-beef operations are the primary agricultural land use in the watershed.

The BMPs analyzed in this study are:

1. Rotational grazing. This practice is similar to prescribed grazing (NRCS practice # 528).

Rotational grazing partitions pasture into smaller areas with paddocks. Cattle are rotated

between paddocks to replenish forage after providing some time for vegetation regrowth.

Rotational grazing improves pasture quality, water quality, and livestock health (USDA-NRCS, 2009).

2. Pasture improvement, or conservation cover (NRCS practice # 327). This set of practices also moderates soil loss and sedimentation. Pasture improvement is achieved by planting vegetation or grasses that provide shade and soil cover (Lambert et al., 2014; Ritter, 2012).
3. Water tanks (NRCS practice # 614). Permanent or portable tanks provide drinking water for cattle. Water tanks are usually necessary if rotational grazing is adopted because the livestock do not have direct access to water sources when confined to paddocks (USDA-NRCS, 2009).
4. Stream crossings (NRCS practice #578). Stream crossings provide firm footing for cattle to cross streams. A stream may be covered with coarse gravel for livestock to safely cross while discouraging them from congregating in the stream (Hoormand and McCutcheon, 2014). Cattle crossing streams on a solid footing are less likely to erode banks and disturb the stream bottom.

Methods

This study evaluates the effect of incentives on BMP adoption among livestock producers in the Oostanaula Creek Watershed and quantifies the reduction in soil loss from grazing on pastureland attributable to BMP adoption. Producer characteristics and farm attributes determine the probability of BMP adoption. The adoption of any one of the four BMP technologies may be correlated with adoption of others. A producer's characteristics, whether observed or unobserved, may affect the likelihood he/she will adopt a set of BMPs as well as affect the choice of BMP if willing to adopt. Controlling for slope and soil type is also necessary given that

erosion, for any particular land use or any particular change in land use (i.e., adoption of a BMP) is a function of slope, soil texture, structure, permeability and organic matter characteristics (USDA-NRCS, 1996; Ritter, 2012). Therefore, the marginal costs of controlling soil erosion also differ across slope and soil types.

Survey

A survey of beef cattle producers in Oostanaula Creek and surrounding watersheds was conducted in 2011 and 2013 to determine producer WTA for four BMPs: pasture improvement, alternative water sources for cattle (i.e., installing water tanks), stream crossings, and rotational grazing. The survey followed Dillman's Tailored Design Method in which a booklet-type questionnaire, introductory letter, return postcard and return stamped envelope were mailed to potential respondents (Dillman, 2000). There were four sections in the survey. The questions in the first section, "Your Farm Operation," focused on producer and operational characteristics, and the value placed on objectives related to BMPs (e.g., improving forage quality, providing cattle access to a year-round supply of clean drinking water).

The second section, "Best Management Practices (BMPs)," asked producers if they have had previous experience with the BMPs and four questions asking whether he/she would accept a hypothetical cost share for the adoption of a BMP. There were 4^7 possible combinations of cost share amounts offered for the BMPs and 49 versions of the survey. The SAS procedure PROC OPTEX was used to determine an efficient subset of combinations in the experimental design (SAS version 9.2). The cost share values were randomly assigned across BMPs and the survey sample. An estimation of cost of implementation and maintenance for each practice, based on

NRCS estimates, was provided with the proposed cost share incentive rate which ranged from 50% to 125% of a base cost reported by NRCS (Lambert et al., 2014).

Questions in the third section, “Your Opinions,” explored respondent perceptions of local water quality and causes of water quality degradation. The fourth section, “Information About You” included demographic questions about producers (e.g., total household income, off-farm income, age, gender, education, family size). Description and mean values of the variables analyzed are included in Table 1.

Survey responses of livestock producers were collected through two survey waves; Wave 1 was sent by mail in March 2011 to 1,480 owners of 1,736 unique (agricultural) land parcels located in the portions of Oostanaula Creek (McMinn County) and the five surrounding watersheds: Sweetwater, Mouse Creek, Middle Creek, Pond Creek and Lower Chestuee Creek. The second wave was sent in February 2013 to 3,678 unique owners of 4,720 agricultural parcels located in Bradley, McMinn and Monroe Counties (Figures 2 and 3) (Lambert et al., 2014). The surveyed land parcels cover approximately 57% of the OCW, and approximately 36% of the OCW and surrounding watersheds.

The sample was collected using addresses from publicly available tax parcel information, which includes the physical addresses and land use classifications of land parcels (Clark, Park, and Howell, 2006; Lambert et al., 2014). Respondents without cattle were excluded from the analysis so the study population only includes cattle producers ($n = 261$).

Parcel/Typography Layers

Parcels were mapped with Geographical Information System (GIS) software (Srinivasan, Arnold and Jones, 1998). Using the “Zonal Statistics as Table” tool, each land parcel was

assigned one slope category based on the slope classification that makes up the largest surface area on the parcel (Figure 4). The majority slope category was generated using a GIS digital elevation map (DEM). The slope categories were calibrated with the “Slope” tool in GIS. Slope categories were designated to 0-2%, 2-8%, 8-16%, and $\geq 16\%$.

Similarly, each parcel was assigned one soil type category based on the soil type that constitutes the largest surface area of that parcel (Figure 5). The majority slope per parcel was calculated based on the USDA-NRCS’ digital general soil map of the United States (STATSGO), which is an inventory of soil pattern areas in the United States (USDA-NRCS, 2015).

Hydrologic Modeling of BMP Impacts

The Soil and Water Assessment Tool (SWAT) is a modeling framework used to quantify and predict the impacts of land management practices on water, sediment, and agricultural chemical yields in watersheds. SWAT is a product of modeling efforts conducted by the USDA’s Agricultural Research Service (Arnold et al., 2012). SWAT is a physically-based simulation model developed to simulate land-management and rainfall-runoff processes with a high level of spatial detail by separating land into sub-basins based on soil type, slope, land use and management practices which are referred to as Hydrologic Response Units, or HRUs (Gassman et al., 2007). The baseline soil loss was estimated with SWAT assuming no BMPs were adopted. The baseline soil loss is contrasted with the estimated soil loss level with full adoption of a BMP.

Multivariate Probit Regression

A multivariate discrete choice regression is used to model the BMP adoption decision. The regression determines if the decision to adopt multiple BMPs is influenced by the incentive level offered, holding other economic variables, operator characteristics, and managerial preferences constant. Personal attributes include age, gender, and education. Farm managerial characteristics include acres owned, stocking density, acres farmed as a percent of acres owned, pasture as a total share of acres, whether the producer plans on passing on the farm to family members, and if the BMPs are in use on the land already. Economic variables include household income and the BMP cost share incentives. Landscape features include slope and soil type (from STATSGO data) and property-assessed land value. It is hypothesized that the decision to adopt a set of BMPs is influenced by a monetary incentive level.

The empirical model is:

$$y_{ij}^* = x_i \beta_j + \sum_{j=1}^4 \alpha_j c_{ij} + u_{ij}, y_{ij} = \begin{cases} 1, & y_{ij}^* > 0 \\ 0, & y_{ij}^* \leq 0 \end{cases} \quad (1)$$

where y_{ij}^* is the probability of adopting BMP j , given the incentive levels offered for each BMP. The subscript i indexes producers, j indexes technologies, x are exogenous variables, c is the cost share level, α is the coefficient associated with a cost share, and u is an error vector with the $j \times j$ correlation matrix R . The errors are assumed to be $\sim MVN(0, R)$.

For estimation and simulation purposes, the adoption of a BMP is transformed to a (-1, 1) indicator variable:

$$q_{ij} = 2 * y_{ij} - 1 \quad (2)$$

where $q_{ij} = 1$ if $y_{ij} = 1$ and -1 if $y_{ij} = 0$.

Analysis of BMP Adoption and Soil Erosion Abatement

The main objective of this research is to generate an abatement curve to measure the cost of reducing soil erosion through the adoption of BMPs. It is hypothesized there are soil loss abatement curves associated with individual HRUs. The individual curves can be aggregated to generate a soil loss abatement curve for the entire watershed. HRU curves similar to Figure 6 could be used to estimate an aggregation of many curves to a single sedimentation abatement curve.

The log likelihood function for the system is estimated with simulated maximum likelihood. The parameter estimates maximize the log likelihood function:

$$\max_{\beta, R} \ln L = \sum_{i=1}^n \ln \Phi_4(q_{ij} \cdot x_{i, RG} \beta_{RG}, q_{ij} \cdot x_{ij} \beta_{SC}, q_{ij} \cdot x_{ij} \beta_{PI}, q_{ij} \cdot x_{ij} \beta_{WT}, Q \cdot R) \quad (3)$$

where Φ_4 is the standard normal multivariate cumulative distribution function; i.e., the probability of adopting the specified BMP scenario. β is a vector of regression coefficients, x for each of the BMPs, and $Q \cdot R$ is the matrix of the $q_{ij} \cdot \rho_{ij}$ combinations.

Estimation of Soil Loss Abatement Levels

Soil loss is predicted to be inversely related to the cost share level per BMP. Therefore, we expect the soil loss abatement curve to be downward sloping. The soil loss abatement curve

corresponds with the probability of adopting each of the BMPs with SWAT at different cost-share levels and for each HRU (Arnold et al., 2012).

The probability of adopting each BMP by representative producers in an HRU, or $\Phi_{4,h}$, is calculated as:

$$\Phi_{4,h} = \frac{1}{N_h} \sum_{i \in h} \Pr[S] \quad (4)$$

where the probability i indexes a subset of producers within each HRU, h . S is a technology scenario, N_h is the number of HRUs in the watershed, and \Pr is the conditional probability of its adoption. Equation (4) was used to estimate the sediment load in tons per day:

$$\bar{\delta}_h = \Phi_{4,h} * \delta^1 + (1 - \Phi_{4,h}) * \delta^0 \quad (5)$$

rearranged:

$$\bar{\delta}_h = \delta_h^0 + \Phi_{4,h} \cdot \delta_h^1 - \Phi_{4,h} \cdot \delta_h^0 \quad (6)$$

$$\bar{\delta}_h = \delta_h^0 + \Phi_{4,h} \cdot \Delta\delta_h^1 \quad (7)$$

where δ_h^1 is tons of soil loss per day estimated from SWAT after BMP adoption for the number of acres in each HRU; δ_h^0 is the sediment load with non-adoption estimated from SWAT in each HRU; and $\bar{\delta}_h$ is the expected soil loss in tons per day per HRU at a given cost share level. The right hand side of equation (5) has two parts. First is the product of the probability of BMP

adoption (the predicted coverage of BMP adoption) and soil loss with BMP adoption over the entire HRU. The second is the product of the probability of BMP non-adoption and the estimated soil loss with non-adoption across the entire HRU. The result of equation (5) is the expected amount of soil loss over the HRU. The progression from equation (5) to equation (7) shows that the expected amount of soil loss per day is the soil loss without any adoption (δ_h^0) added to the product of the probability of BMP adoption (assumed to be coverage of adoption) and the change in soil loss from non-adoption to BMP adoption across the entire HRU:

$$\Phi_{4,h} \cdot \Delta\delta_h^1.$$

The change in soil loss from non-adoption to adoption of BMP(s) is expected to yield a negative value. Soil loss abatement curves similar to figures 1 and 2 will be generated with equation (7).

The soil loss abatement is estimated by simulating the adoption of one BMP at a time. Simulating the adoption of each BMP successively is a logical first step in determining abatement patterns given the literature on the typical sequence in technology change adoption. For instance, adoption of pasture improvement is often considered a “gateway” to other BMP adoption. It follows that estimating a sedimentation abatement curve first with pasture improvement and then with other BMPs like rotational grazing is a likely order of events.

For example, to model the probability of adoption for rotational grazing,

$$\Pr[Y_{iRG} = 1, Y_{iPI} = 0, Y_{iSC} = 0, Y_{iWT} = 0] \quad (8)$$

$$= \Phi_4(q_{RG} \cdot x_i\beta_{RG}, q_{PI} \cdot x_i\beta_{PI}, q_{SC} \cdot x_i\beta_{SC}, q_{WT} \cdot x_i\beta_{WT}, Q \cdot \bar{R}) \quad (9)$$

Monte Carlo Simulation of Abatement Curves

Monte Carlo analysis is used to estimate adoption probabilities given parameter uncertainty. The parameters $\theta^* = (\beta, R)$ are drawn from the multivariate normal distribution to simulate the probability of the producers' decision to adopt BMP combinations.

$$\theta^* \sim MVN(\theta, cov(\theta)).$$

For $m = 1$ to 10,000 iterations:

1. Draw θ^* in which

$$\theta_m^* = \theta + C\eta_m \quad (10)$$

where C is the lower triangular matrix Cholesky decomposition of the covariance matrix, and η is a $\sim N(0,1)$ random variable drawn for replicate m .

2. Calculate the linear predictor, z^*

$$z_{ij} = q_j \cdot x_i \cdot \beta_j \quad (11)$$

$$3. \text{ Determine } \Phi_4(q_{RG} \cdot x_i \beta_{RG}^*, q_{PI} \cdot x_i \beta_{PI}^*, q_{SC} \cdot x_i \beta_{SC}^*, q_{WT} \cdot x_i \beta_{WT}^*, Q \cdot \bar{R}) \quad (12)$$

where $Q \cdot \bar{R}$ is the matrix of the $q \cdot \rho_{ij}^*$ combinations.

4. Calculate the change in sedimentation given the recalculated simulated adoption probabilities.

Preliminary Results and Discussion

To demonstrate the proof of concept, a simulation was conducted with fictional soil loss data to estimate what the soil loss abatement curves may look like with the adoption of rotational

grazing. There are 4 slope categories and 18 soil types in the dataset, generating 72 possible slope-soil type combinations. Of the 72 possible combinations, there were 36 unique majority slope and soil type combinations on respondents' parcels.

Econometric Results

The model yields a Wald Chi-Squared test value of 69.67% ($P < 0.00$) indicating that we may reject the H_0 that all of the coefficients in the model are equal to zero. The pseudo R^2 value is 0.17. The mean VIF value is 1.14 indicating that collinearity is not impacting the standard errors. A likelihood ratio test yields a value of 185.53 ($P < 0.00$). Therefore, we may reject the H_0 : the observed outcome was nearly as likely to occur with the nested model as compared to the observed model. An increase in one dollar per foot of the cost share for stream crossing increases the likelihood of adoption by 25%, significant at the 5% level. An increase in one dollar per acre of cost share for rotational grazing increases the probability of adopting rotational grazing adoption by 2%, ($P = 0.10$). Soil loss will be inversely related to the cost share level per BMP, and therefore that the soil loss abatement curve will be downward sloping.

Older producers are less likely to adopt water tanks and rotational grazing at the 1% and 5% level of significance, respectively. An increase of one year in age decreases the probability of adopting rotational grazing by approximately 1.8% and decreases the probability of adopting water tank systems by about 3.4%. Acres owned decreased the likelihood of adoption for stream crossing adoption by approximately 18% per 100 acres and by 20% for water tank system implementation per hundred acres. Both results were significant at the 1% level. Being college educated increased the probability of adopting stream crossing by 34.4% at a 10% level of significance. Stocking density has a positive effect on willingness to adopt water tanks but had a

negative impact on the likelihood of producers adopting rotational grazing (5% and 1% significance level respectively). The negative impact on rotational grazing adoption is likely due to the labor involved in rotating a large number of cattle between paddocks. If a producer is currently using pasture improvement, he/she is more likely to adopt all of the BMPs in the survey. The results corresponding to pasture improvement use are consistent with the literature in which using pasture improvement may be a first step, or “gateway” to using other BMPs (Lambert et al., 2014; Knowler and Bradshaw, 2007). The next step will be to generate soil loss estimates with SWAT for different BMP use scenarios. The econometric analysis of the survey data will then be combined with the soil loss estimates to generate the abatement curves similar to Figure 6.

Linking the probability of adoption to the predicted reduction in soil loss is necessary to determine the cost of sediment abatement, sustainable soil use and healthy watershed maintenance. It is expected that there will be a higher return on payment if geologic and biophysical factors are taken into account when developing cost-share payment schemes. Producers who work on high-impact HRU areas may be targeted for cost-share opportunities. Policymakers implementing programs like EQIP and THWI may use the estimated soil loss abatement curves as an aid in analyzing different scenarios. The scenarios include estimating 1) the total programmatic cost to reach a total maximum daily load (TMDL), a regulatory requirement for maximum levels of soil loss in water bodies; In the absence of a TMDL, estimating 2) the soil loss level for each cost-share incentive value provided by a BMP program, 3) the most economically efficient combination of BMP incentive values, or 4) soil loss reduction potential given a BMP program budget constraint.

Table 1. Description of variables and mean values

Variable	Description	Mean Value	Min. Value	Max. Value
<i>Cost Share Variables</i>				
p_rg	rotational grazing cost share (\$/acre)	27.4	16	40
p_sc	stream crossing cost share (\$/sq. ft.)	3.35	1.94	4.84
p_wt	water tank cost share (\$/water tank)	1361.58	767	1917
p_pi	pasture improvement cost share (\$/acre)	218.8	127	317
<i>Producer Characteristics</i>				
age	age in years	61.21	30	91
male	male = 1	0.91	0	1
college	has a college degree = 1	0.42	0	1
passon	plan to pass farm to a family member	0.89	0	1
tenure	total acres owned as a share of total acres farmed	1.42	0.4	21.67
<i>Farm Characteristics</i>				
acown	total acres owned (per 100)	1.66	8	1600
spast	pasture as share of total acres owned	72.14	11	100
stockden	stocking density (number of cattle per acre)	0.89	0.05	103.33
landval	appraised land value/acres owned	3623.69	0	37458.33
slope_maj*	slope category (%) with largest surface area	2.66	1	4
<i>Current use of BMPs</i>				
use_pi	current use of pasture improvement practices (yes = 1)	0.69	0	1
use_sc	current use of stream crossings (yes = 1)	0.3	0	1
use_rg	current use of rotational grazing (yes = 1)	0.6	0	1
use_wt	current use of water tanks (yes = 1)	0.46	0	1
<i>n = 261</i>				

* Slope categories include 0-2%, 2-8%, 8-16% and +16%

Table 2. Effect of Variables on BMP Adoption

Variable	Effect on Adoption			
	WT	RG	SC	PI
<i>Cost Share Variables</i>				
p_rg	0.01	0.02*	-0.01	0.01
p_sc	0.11	0.13	0.25**	0.07
p_wt	0.00	0.00	-0.00	-0.00
p_pi	0.00	0.00	0.00*	0.00
<i>Producer Characteristics</i>				
age	-0.03***	-0.02**	-0.01	-0.01
male	-0.04	-0.35	-0.02	0.10
college	-0.05	0.04	0.34*	0.20
passon	0.22	0.25	0.38	0.75***
tenure	0.00	-0.02	-1.36	0.05
<i>Farm Characteristics</i>				
acown	0.20***	0.08	0.18***	0.00
spast	0.00	-0.00	0.00	-0.00
stockden	0.30***	-0.03**	0.09	0.01
landval	0.00	0.00	-0.00	0.00
slope_maj*	0.23**	0.07	0.06	-0.01
<i>Current use of BMPs</i>				
use_pi	1.00***	0.514**	0.55**	0.76***
use_sc	0.05	0.01	0.48**	-0.15
use_rg	-0.01	0.29	0.01	-0.52**
use_wt	-0.21	-0.13	-0.54***	0.06
<i>n</i> = 261				
LL _{UR} = -458.765				
LL _R = -551.53				
*p<0.10, **p<0.05, ***p<0.05				

13. Suppose you were offered the bundle of BMPs at the cost shares listed below. Which BMPs would you adopt?

Assume that you may adopt as many as you would like. Please consider all costs and benefits, including the time required to establish and maintain each BMP. Estimated establishment costs are provided for each BMP. Your costs might be higher or lower.

BMPs and Cost Share Amounts	How many acres or units would you adopt?	Would not adopt
Pasture Improvement Cost share you would receive = \$ _XXXX_ per acre Estimated establishment cost = \$253.33 per acre	_____ acres	<input type="checkbox"/>
Waterer Cost share you would receive = \$ _XXXX_ per waterer Estimated establishment cost = \$1,533.33 per waterer. (You would be responsible for getting water to the waterer)	_____ waterer(s)	<input type="checkbox"/>
Stream Crossing Cost share you would receive = \$ _XXXX_ per square foot Estimated establishment cost = \$3.87 per square foot	_____ square foot	<input type="checkbox"/>
Rotational Grazing Cost share you would receive = \$ _XXXX_ per acre Estimated establishment cost = \$32 per acre	_____ acres	<input type="checkbox"/>

14. How certain are you of your responses to Question 13 above?

Not At All Certain	Somewhat Certain	Certain	Very Certain	Extremely Certain
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

15. How confident are you that responses to this survey will influence the design of programs that support BMP adoption by cattle producers?

Not At All Confident	Somewhat Confident	Confident	Very Confident	Extremely Confident
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

16. Do you think the adoption of these BMPs on your farm would have a noticeable effect on water quality in the streams near your farm?

☐ Yes
☐ No

Figure 1. Survey questionnaire detailing binary choice with cost-share levels randomized across BMPs and respondents

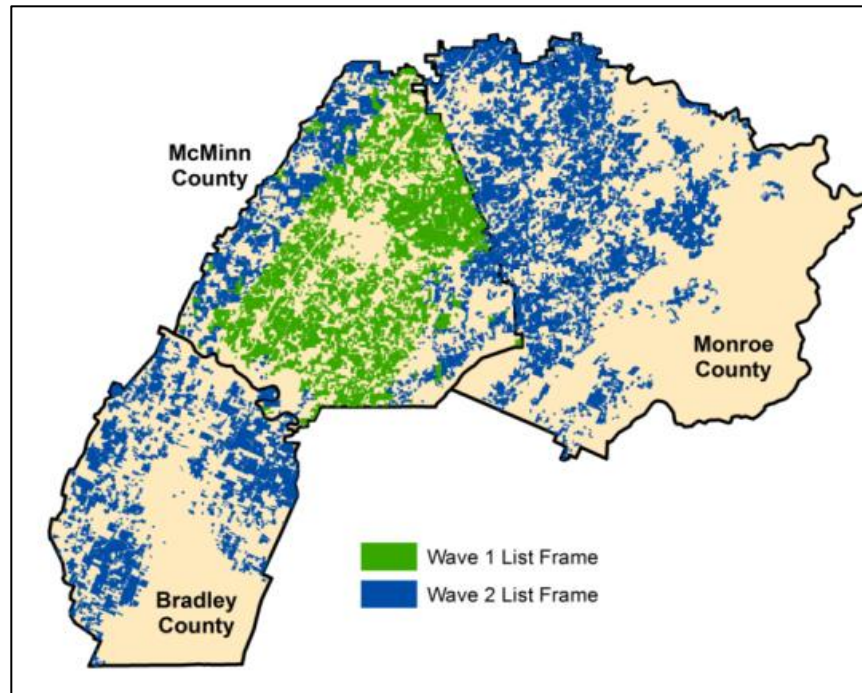


Figure 2. Wave 1 and Wave 2 parcels in Bradley, McMinn, and Monroe Counties

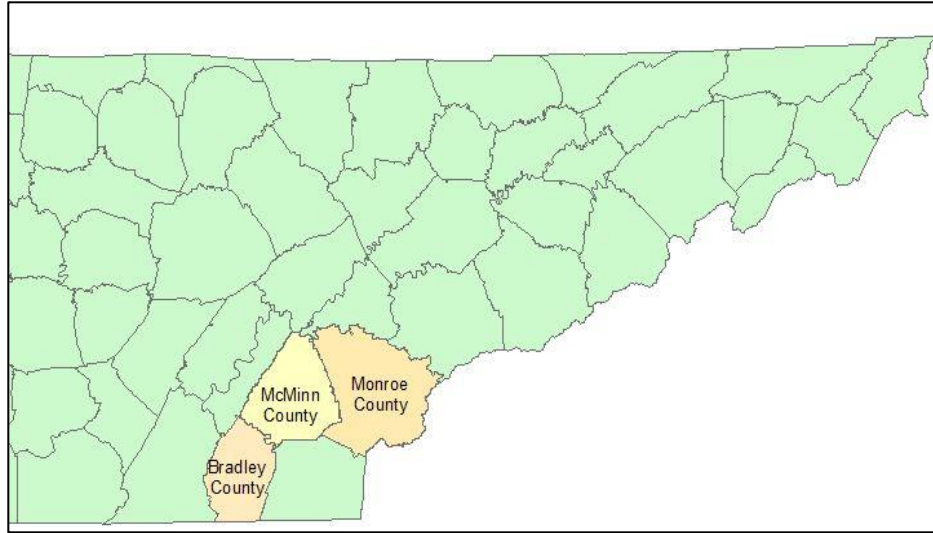


Figure 3. Situation of Bradley, McMinn and Monroe Counties in Southeastern Tennessee

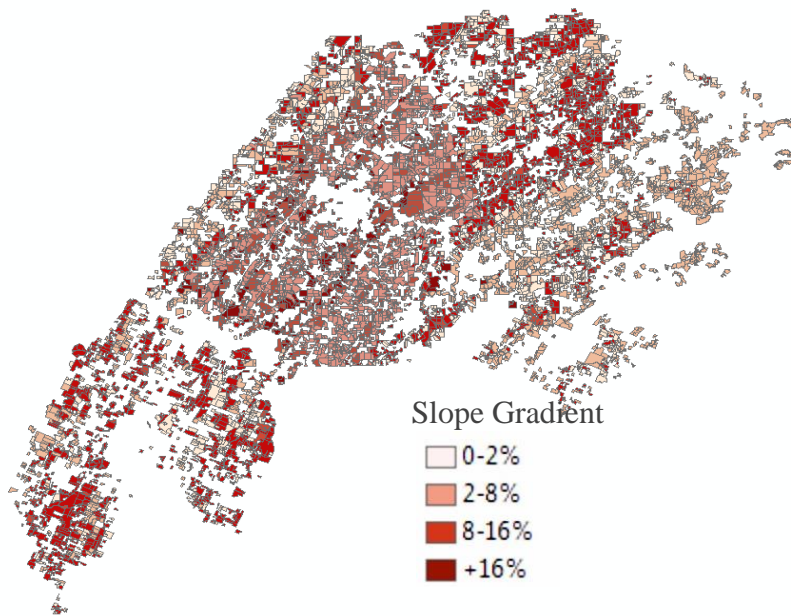


Figure 4. Surveyed land parcels by majority slope category

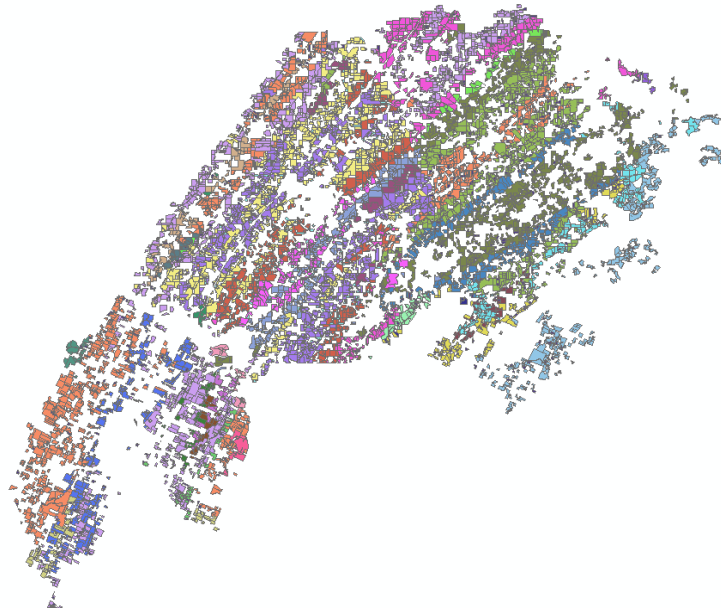


Figure 5. Surveyed land parcels by majority soil type

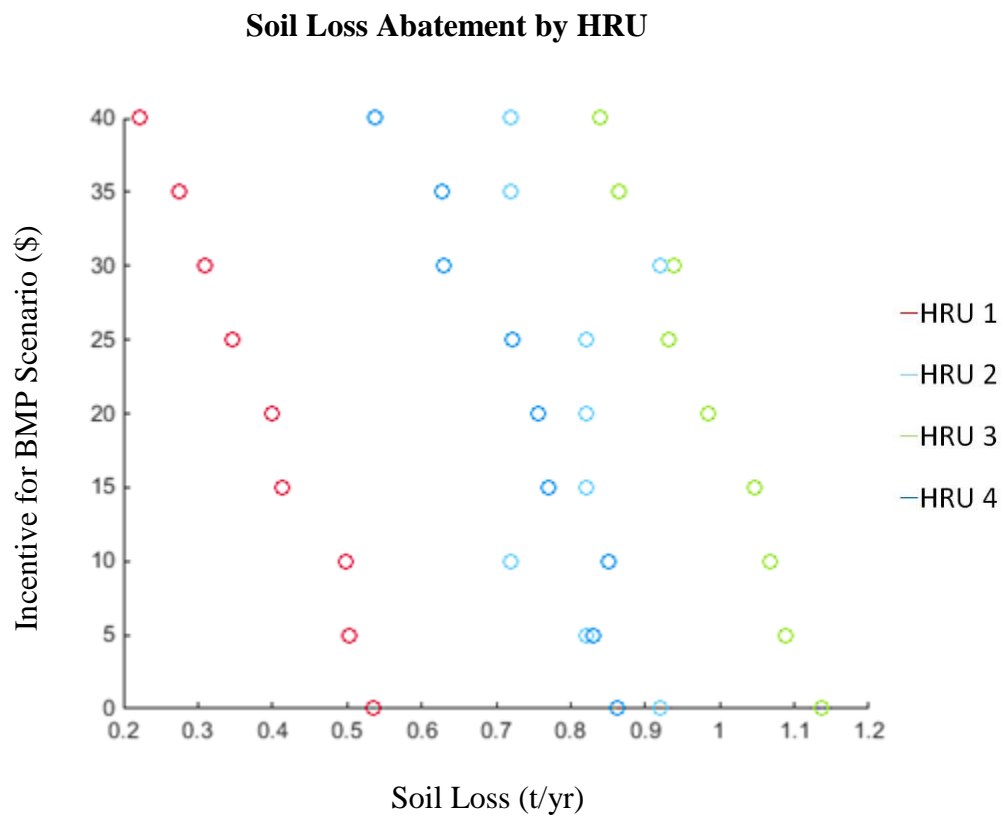


Figure 6. Simulated example of soil loss abatement curves by HRU

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