Land-Use Change and Carbon Sequestration in the Forests of Ohio, Indiana, and Illinois: Sensitivity to Population and Model Choice.

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ABSTRACT

This study develops a model of land use change in the Midwestern states of Ohio, Indiana, and Illinois. Given the emergence of spatial econometrics, three models are compared to assess the sensitivity of the estimates to alternative assumptions about the distribution of the errors. Projections of future land use change are then developed, and the results are compared across different assumptions about population growth and models. We then estimate carbon sequestration potential in the region and compare the costs of different programs across the population assumptions and the alternative models. Different assumptions about population growth and error terms do not appear to affect the carbon sequestration cost estimates.

INTRODUCTION

In recent years, a number of authors have suggested that forests could provide an alternative for storing carbon and thereby mitigating potential climate change (Sedjo, 1989; Parks and Hardie, 1995; IPCC, 1996; Adams et al., 1999; Plantinga et al., 1999; Stavins, 1999). The costs of carbon sequestration in these studies have generally ranged from $20 to more than $100 per ton. This fairly wide range of cost estimates is derived from differences in the carbon storage potential across forest types in different regions, as well as differences in opportunity costs of removing land from agricultural production. In addition, some studies predict higher costs simply because they discount future carbon flows (see Plantinga et al., 1999 and Stavins, 1999).

Given the wide differences in the costs of carbon sequestration shown in the literature, it is useful to take a closer look at some of the factors that may affect these costs. Plantinga et al. (1999) suggest that land opportunity costs are one of the most important factors affecting carbon sequestration costs, and anything that raises these opportunity costs should have a fairly large effect on the overall costs of a program. For example, in regions where economic growth increases the conversion of land from rural to urban uses, the costs of sequestration could be high. This study explores how carbon sequestration costs vary with different future projections of population growth.

Carbon sequestration costs are explored with an econometric model of land use in Midwestern counties of Ohio, Indiana, and Illinois, following Hardie and Parks (1997) and Plantinga et al. (1999). Given the emergence of the literature on spatial econometrics (see Anselin, 1988), we test for the presence of spatial autocorrelation in the estimated models. Spatial autocorrelation could be important if, for instance, there is some unobserved relationship between the policies in two nearby counties. If these unobserved factors are related to the errors (i.e. they are correlated), then the standard errors for the parameter estimates could be biased. We thus develop three alternative specifications for our area-base model of the Midwest, given different assumptions about the form of the spatial relationships between county level observations. Estimates of future land use areas and carbon sequestration costs are then developed and compared across the alternative models.

MODEL AND DATA

This paper develops an area base model similar to Hardie and Parks (1997) and Plantinga et al. (1999) to estimate the share of land usage in forest, agriculture, and urban uses in the Midwestern US states of Ohio, Indiana, and Illinois. Each share of land usage can be expressed as multinomial logistic function with explanatory variables such as forest rent, crop rent, urban rent, distance to the nearest city, population density, land quality indices, and dummy variables for specific years (See Table 1). The functional form of a multinomial logistic function is following

$$P_j = \frac{e^{b_j X}}{1 + \sum_{j=1}^{m-1} e^{b_j X}}, \ j = 1,,, m-1 \qquad (1)$$

The left hand side is the proportion of land allocated to j usage and X is the vector of independent variables and β is the vector of coefficients to be estimated. To have an estimatable functional form, this model can be expressed by log of proportions in different land uses such as

$$\ln\left(\frac{p_j}{p_m}\right) = bX + u_i \ , \qquad (2)$$

where u_i is assumed to be an independently and identically distributed, normal error term. Because the errors could display heteroskedasticity, we adopt White's suggestion to correct the covariance matrix (White, 1980).

In addition to heteroskedasticity that may occur as a result of the log transformation in (2) or as a result of the underlying data, one must carefully consider other problems that could arise with the errors in equation (2). One problem may be the presence of spatial autocorrelation or omitted variable bias. For instance, the errors of two counties next to each other may be more closely related than the errors of two counties that are further apart. Alternatively, some unobserved factors that affect the proportion of land uses in different counties could be omitted, but correlated with error u_i. The correlation with the error term can bias estimates of the standard errors. With county level data, such unobserved factors could relate to policy variables that are similar across counties, or it could be related to economic growth. For instance, economic growth in one county could raise prices in that county, causing potential new migrants to move to nearby counties where land prices are lower (Hsieh, 2000).

Despite the growth of the literature on spatial econometrics, relatively few studies have attempted to apply the techniques to forestry and land-use change (Sohngen, 2000). For policy purposes, it would be useful to know if the techniques can help make better predictions of future land use change. We thus test spatial dependency using following functional form,

$$Y = rWy + Xb + u \qquad (3)$$

The left hand side is the dependent variable as before, W is an n-by-n weight matrix (where n is the number of observations) that defines spatial dependency among observations, and X is the set of independent variables. The coefficients to be estimated are β and ρ. The weight matrix is chosen arbitrarily, although there have been many studies investigating the optimal choice of weight matrices (Cliff & Ord, 1982; Upton and Fingleton, 1985; Anselin, 1988). After testing a range of alternatives, we chose the 45 arc distance criteria and row standardized weight matrix as defined by *SpaceStat*. On average, each county has 8 counties for its neighbors by 45 arc distance.

An alternative method for capturing spatial effects is to utilize a fixed effects estimator, which recognizes that certain observations behave similarly (see Case, 1992). For example, one might expect that land at the urban rural fringe in our sample would have higher levels of opportunity costs than land further from cities. One would then want to treat these counties differently from rural counties, by using a fixed effects estimator. With a fixed effects estimator, the error terms are specifically assumed to be correlated with the terms in X. We explored a number of alternative fixed effects, but settled on population density for this study. This makes some sense if counties closer to cities behave differently from rural counties. We rank each county in our dataset by population density and then use dummy variables to represent the quintiles (See Table 1).

Data used in this study was obtained from various sources. County level land-use share data is from the NRI database for 1982, 1987, and 1992 (total 283 counties). The NRI samples fixed plots on the landscape at five-year intervals. Estimates from these sample plots are aggregated to the county level for our model. Land rental values are estimated from other data sources for forest, crop, and urban. Following Plantinga et al.

(1999), population density (DENS) is used as a proxy for urban land values. It is assumed that higher density increases development forces so in turn increase the opportunity cost of maintaining other land uses. The total area of each county is from NRI data and total population is from the Bureau of Census data for the same period of time (1982, 1997, and 1992).

Forest rent (FORENT) is estimated as the discounted net present value of timber revenue per acre. Yield functions for each of the major species in each county are weighted by the proportion of the species in each county, using USDA Forest Service Forest Inventory and Analysis data. Regional timber price are used in Ohio and Illinois (OASS, 1999 and IASS, 1999) although only state level data is available in Indiana (Hoover, 2000). Land rents for forestry are obtained with the Faustmann formula (Johansson and Logfren, 1985), assuming interest rates are 5 %. Land is assumed to be naturally regenerated, an assumption we suspect is true for most land that converted from agriculture to forestry in this region over the time period investigated.

In previous research, agricultural rents (CRENT) have been estimated with a number of different approaches, such as farm revenues and costs (Stavins and Jaffe 1990, Parks and Murray 1994, Hardie and Parks 1997), ratio of income from competing land use (Alig 1986, Alig et al. 1988), prices of commodities from agriculture (Lichtenberg 1989, Wu and Brorsen 1995), and revenues less costs as calculated from farm budgets (Plantinga et al. 1999). In this study, annual revenue above variable cost is used as the estimate of the value of cropland. Crop budgets obtained from the Cooperative Extension Services of the three states are used to estimate these values for four major crops produced in the region: corn, wheat, soybean, and oats. Crop yield for each county is estimated from USDA Agricultural Census (USDA 1999). Price information is obtained from USDA data base system (USDA 2000). County level estimates of crop rents are then determined by weighting the returns for each crop in a county by the number of acres in the crop in the county for each period.

We control for land quality with two additional variables LCC and AVLCC. There are eight land capability classes in the NRI data that is assessed by slope, soil texture, soil depth, effects of past erosion, permeability, water holding capacity, and type of clay minerals. Land in the first four classes is most suitable for common field crops, forest trees, and range plants (USDA, 1961). Consequently, LCC is the proportion of land in each county in the first four classes. AVLCC is average class (weighted by area) in each county. Note that higher AVLCC implies lower quality land.

Distance form the nearest city (DISTANCE) is also used in the models. Similar to the population density variable, this variable is expected to capture a component of urban land use demand, although it is likely to play a different role than population density. We also include dummy variables for years in most models estimated below. This amounts to estimating a fixed effects model in our panel of data over 3 periods. The fixed effect model accounts for a number of factors that are unobserved in each county, but which are expected to remain the same over the time period. Examples of these types of variables might be lakes and streams, or large capital investments like timber mills. A dummy variable is also used for first and last years in our analysis (1982 = D82 and 1992 = D92).

ESTIMATION AND RESULT

The observations for the three time periods are pooled, and fixed effects are used for two of the years. The results for three alternative models are presented in Table 2. The Base Model does not correct for spatial effects, but it does correct for the presence of heteroskedasticity with White's consistent estimator of the variance-covariance matrix (White, 1980). The remaining heteroskedasticity does not bias the estimates, but it could underestimate the variance in the model, potentially biasing our tests of significance (Greene, 1997).

The Fixed Effects Model (FE Model) incorporates the fixed effects based on population density in each county, and the spatial model accounts for a specific form of heteroskedasticity, namely spatial autocorrelation. The estimated coefficients in each of the models generally show expected signs and are significant. Higher forest rent reduces the proportion of agricultural land to forestland (A/F equation) and urban land to forestland (U/F equation). Higher crop rent increases the proportion of agriculture to forestland (A/F) and urban to forestland (U/F). Population density (DENS) shows expected sign in the U/F equation, but in the A/F equation, higher population density reduces the ratio of agricultural land to forestland. This suggests that population seems to prefer agricultural land for development purposes. One explanation for this is that forestland is more expensive to develop, so that most development occurs on agricultural land rather than forestland. Similar results can be found from one previous study, which explains that counties with higher population also have higher rate of forestland (Parks and Murray, 1994), but they suggest that the results is coincidental.

A higher value for the land quality classification (AVLCC) reduces the proportion of land in agriculture; thus lower land quality reduces the proportion of agriculture.

Alternatively, a higher proportion of high quality agricultural land increases the proportion of agricultural to forestry land, and it reduces the proportion of urban to forest land (although it is insignificant in all three models). Distance to the nearest city reduces the proportion of agricultural and urban land to forestland. The result for urban land probably reflects the fact that most population centers in this region are located in agricultural regions rather than forested regions.

The dummy variables in the fixed effects model are significant only for the most populated counties in the A/F equation, where the highest levels of population density significantly reduce the proportion of agricultural to forest land. One explanation is that most development occurs on agricultural land rather than on forestland, perhaps due to costs. Alternatively, when population density grows around cities, it may induce a shift of agricultural land to forestland as farmers move away from the region. Most of the dummy variables are significant in the U/F equation, and they decline towards 0 for lower population densities. As expected, the ratio of urban to forestland is generally higher for more populated counties. The fixed effects reduce the scale of the density variable in both equations, although we note the fixed effects are correlated with the density variable.

The spatial model and the base model display different significance levels for a number of variables. This could reflect correlation between the error term and unobserved or omitted variables in the base model, or it could just reflect a nuisance (spatial autocorrelation). However, we note that significance levels change mainly for the two variables reflecting suburbanization, i.e. DISTANCE and DENS become insignificant in the A/F equation. This suggests that our hypothesis above that population prefers agriculture land relative to forest-land could be over-stated. In contrast, the coefficients for forest rents and crop rents remain significant, and the coefficients are virtually the same. This provides some measure of confidence for hypothesis tests about the effects of forest and crop rents on the decision to hold land in agriculture and forestry. The results of the spatial model support Parks and Hardie (1994) who suggest that the relationship of forestland to suburbanization is coincidental. Suburbanizing trends affect mainly the level of urban to forest and agricultural land, however, the decision to maintain land to agriculture or forestry depends mainly on land rents (and consequently land quality).

PROJECTING LAND USE AND CARBON SEQUESTRATION

These regression results are interesting, but our main interest is to explore whether different estimation methods or population growth predictions affect future carbon sequestration and carbon sequestration costs. We begin by using the models to predict future land use in the region between 2000 and 2040. Although our regressions only cover the period 1982 to 1992, we obtain an expected value for the year 2000 using actual price data from that year, and we use that year as our base. As the new NRI data for 1997 becomes available for counties, the results will be updated. Two scenarios of population growth are developed to test the sensitivity of carbon sequestration costs to population. The first scenario assumes that population growth occurs uniformly across the states. The second scenario places all the population growth in suburban counties around metropolitan areas, while allowing population to decline in rural areas. For Ohio, metropolitan areas are Columbus, Cleveland, Cincinnati, Dayton, Akron, Toledo, and Pittsburgh (some eastern counties in Ohio are suburbs of Pittsburgh). Suburb areas are counties neighboring counties for these cities. For Indiana, cities are Indianapolis, Evansville, Fort Wayne, South Bend, Gary, Chicago, Cincinnati, and Louisville. For Illinois, cities are Chicago, Springfield, Peoria, Rockford, and St. Louis. Both scenarios assume the same total level of population growth in the entire region, but they allocate the growth differently across counties. The total population growth from 2000 to 2040 is projected to be 26% in Ohio, 31% in Indiana, and 22% in Illinois (Department of Commerce, 1995).

This baseline scenario assumes that timber stumpage prices rise at 0.6% per year. Cropland rental rates are assumed to rise at 2% per year. Two sources of information were used to develop these crop rent predictions for major crops in this region, FAPRI (2000) and USDA (2000). These studies predict increases in crop rents of 2% to 4% per year. We use this lower value as our baseline assumption for crop rents. Other variables such as distance and soil quality are expected to be same over the years.

Land use projections are shown in Table 3. In general, forestland and agricultural land are projected to decrease over this period of time and urban area is expected to increase. Interestingly, the S*uburban population growth* scenario predicts larger changes than the *Uniform population growth* scenario. If population growth occurs mainly in regions that are already more heavily populated, we predict that more land is used per person. The base model projects the smallest amount of forestland loss over the period, 776 to 1,071 thousand acres, while the largest forestland loss is projected by spatial model under *Suburban population growth* scenario (1,323 thousand acres lost).

The projections of total urbanization are remarkably similar across the three modeling approaches. However, the models make different predictions about how much of this land comes from crops versus forests. The base and fixed effects models predict that the largest share of losses arises from cropland, while the spatial model places more of the losses in forestland. Recall that the spatial model suggests that the most important effect on the decision to maintain land in crops or forests relates to land values. All other things equal, forest rents tend to be lower, and the spatial model predicts that urbanization occurs on the lowest quality land first (generally forestland).

Carbon in forests is calculated using estimates from Birdsey (1990). Stocks in trees and the forest floor and understory are estimated. Little is known about the dynamics of carbon storage in forest soils either when afforestation or deforestation occur, so we ignore soil storage for this analysis. We also ignore changes in carbon that occur when forests are managed but the land use remains the same. Active harvesting and management occurs throughout the region, so this would be expected to bias the baseline estimates. However, our policy mechanism is chosen to be revenue neutral for timber harvests, so we do not expect this to bias the estimates of carbon gains (which are focused on land use changes rather than forest management). Because forestland is predicted to shift to urban uses over the next 40 years, aboveground carbon storage is predicted to decline from approximately 523 million tons in 2000 to 491 million tons in 2040, or a loss of 32 million tons. The base and fixed effects models suggest less forest loss, and consequently more carbon storage than the spatial model: 32.8 and 34.4 million tons lost for the base and fixed effects models respectively, and 41.1 million tons lost for the spatial model.

A number of different policies have been suggested to get landowners to sequester additional carbon in forestry. Van Kooten et al. (1995) suggests that forestland owners be paid while they sequester carbon as trees grow, but that they are taxed when they harvest forests or convert land to some other use. Stavins (1999) uses a similar approach in that he suggests that landowners be subsidized for converting agricultural land to forests and that they be taxed for converting forestland to agriculture or development. Sohngen and Mendelsohn (2001) rent forest carbon. Landowners are paid rent when they hold carbon in trees and they are not paid rent when they do not hold carbon in trees. We use this rental concept in this analysis. Landowners are assumed to be paid carbon rent for holding land with trees.

We make a number of simplifying assumptions for this model. First, although policy-makers may be interested in only paying for new and additional carbon, we rent all forestland acres, whether they are new acres or old acres. From an efficiency standpoint, this makes no difference for the total amount of carbon sequestered, although it could have large effects on who the beneficiaries of a carbon policy are. Second, we also choose rental payments arbitrarily for this analysis, although they can in principle be related to the marginal costs of carbon abatement in the energy sector (see Sohngen and Mendelsohn, 2001). Third, we assume that rental rates are constant over time, although it is likely that sequestration rental prices will increase over time as the marginal damages from climate change increase (see Nordhaus and Boyer, 2001). Finally, we do not discount carbon in this paper. Discounting carbon quantities without regard to prices ignores the potential change in the value of carbon sequestration over time. Instead, we are most interested in the total amount of carbon that can be stored above baseline in the year 2040, and the costs of achieving these tons of sequestration.

We explore the differences in carbon sequestration costs for the three different models and the alternative population growth assumptions. Three carbon sequestration scenarios that target 10, 20, and 50% increases in carbon sequestration above the baseline in 2040 are considered. Rental payments that provide this amount of carbon by 2040 are used in each scenario. The 10% gain is roughly 49 million additional tons of carbon, the 20% gain translates into roughly 98 million additional tons of storage, and the 50% gain translates into roughly a 244 million ton gain by 2040.

The land use changes implied by these alternative policies for the year 2040 are shown in Table 4. The 10% gain in carbon can be obtained with 1.0 million additional acres of forestland, while the 20% gain requires approximately 2.0 million additional acres of forestland to forests, and the 50% gain requires 4.8 million more acres of forestland, or approximately 36% more forestland. The programs focus heavily on reducing deforestation rather than afforestation, so it takes less land proportionally to attain a higher proportion of carbon gain. However, additional afforestation causes larger cropland losses and more urbanization. Our model predicts that when urbanization occurs on cropland, more acres are used per person than when urbanization occurs on forestland. Raising forest rents steals some cropland, but it has the secondary effect of shifting some urbanization to cropland, which in turn uses more land than it otherwise would have used. Carbon sequestration programs, thus, could exacerbate farmland losses.

The costs of these programs are compared in Table 5. Across the three models, the costs are quite similar for a small program, although they appear to diverge for larger programs. The base model predicts the smallest overall costs. The costs do not appear to differ much depending on the population growth assumed. Larger population growth in the suburban areas suggests lower overall costs in general. This makes sense, given that most programs will likely focus on rural areas where opportunity costs are lowest. We do not predict marginal costs for this paper, however average costs may be of some interest. Average costs are approximately $14 per ton for the small scenario and $16 per ton for the large scenario. On an annual basis, these estimates suggest approximately 1 – 6 million metric tons of sequestration is possible per year over 40 years for $14 to $16 per ton. These appear fairly low compared to the results suggested by other authors (Plantinga et al., 1999; and Stavins, 1999), but we note that these are average costs and not marginal costs, and we have not discounted the costs. They are broadly consistent with the costs suggested by Adams et al. (1999), who suggest that for $9-$21 per ton, we could obtain an annual flux of 16 –73 million metric tons across the entire US.

CONCLUSION

This paper investigates the land usage trend in the Midwestern US; Ohio, Indiana, and Illinois. Data on land use trends and economic variables for each county in these three states was collected for the years 1982, 1987, and 1992. Three different econometric models were estimated and projections were obtained by two different assumptions on population growth from year 2000 to 2040.

Our estimated results are as expected: forest rents increase the area of forestland, crop rents and urban rents act increase the area of crops or urban land. Higher quality of land relates positively to cropland. Higher population density increases the proportion of forest to agricultural land, suggesting that most development occurs on cropland.rather than forestland. However, the statistical significance of this result is not consistent across the three models tested. That is, in the spatial model, the significance of this result disappears.

Overall, the results do not change dramatically when spatial dependence is explicitly modeled with either fixed effects or direct spatial dependence. The most important effects of the spatial dependence and fixed effects models occur in the equations that consider urban uses. This suggests that there could be unobservable or unexplained processes that could be causing omitted variable bias in the standard errors; however, these affect mainly urbanization process. They do not appear to be affecting the decision to hold land in forests versus agriculture. Given that carbon policies are likely to focus on rural regions, ignoring spatial models is not likely to dramatically change estimates of the costs of carbon sequestration.

The projections of land use change suggest losses of both forestland and agricultural land with the expansion of urban land by the year 2040. Interestingly, the suburban growth scenarios predict more loss of farm and forest land than the uniform growth scenarios, implying that when growth occurs in urban areas, it consumes more land than when growth occurs in suburban areas.

The total stock of carbon in forests in the region is decreasing over time. Policies to sequester 10 – 50% more carbon than the baseline by 2040 are explored. The costs appear fairly high, however, the average costs of attaining this carbon are not dramatic. Our results suggest lower costs of sequestration than others have predicted in general, although we note that we do not discount carbon and we consider average, not marginal costs. Because the programs focus on reducing deforestation for urban uses, and on afforestation, it takes less than 10% more forestland to create 10% more carbon sequestration. Reducing deforestation can also provide carbon more quickly than can afforestation. However, reducing deforestation comes with a potential anciallary cost; it increases cropland losses at the expense of urbanization. This makes some sense because our results suggest that if urban uses convert cropland, they use more acres than if they convert forestland. By locking up forestland for sequestration, carbon programs may unintentionally lead to additional cropland losses to urbanization.

Table 1. Definition of variables

Variables	Definition
CONST	Constant term
FORENT	Forest rent
DISTANCE	Minimum Distance from major cities to the center of each county
DENS	Total population divided by total area in each county
LCC	The ratio of the first two highest land class
AVLCC	Average land class in each county
D82	Dummy variable for 1982 data
D92	Dummy variable for 1992 data
Crent	Crop rent obtained by budget information
D1	Dummy for the counties that population density is upper 20%
D2	Dummy for the counties that population density is between 40%~ 21%
D3	Dummy for the counties that population density is between 60%~41%
D4	Dummy for the counties that population density is between 61%~80%
Rho	Coefficients for the weight matrix in Spatial model.

Table 2. Estimation result of each model

	Base Model		FE Model		Spatial model	
Regression	A/F	U/F	A/F	U/F	A/F	U/F
CONST	4.905	1.274	5.046	0.748	4.653	1.450
FORENT	-0.051**	-0.004	-0.050**	-0.012	-0.048**	-0.006
DISTANCE	-0.003**	-0.009**	-0.004**	-0.007**	-0.003	-0.008**
DENS	-0.004**	0.015**	-0.002*	0.008**	-0.003	0.015**
LCC	0.917**	-0.054	0.842*	-0.006	0.864	-0.134
AVLCC	-1.088**	-0.796**	-1.110**	-0.727**	-1.063**	-0.791**
D82	-0.063	-0.162	-0.046	-0.316**	-0.042	-0.151
D92	0.032	-0.118	0.069	-0.351**	0.027	-0.122
CRENT	0.005**	0.002	0.005**	0.003*	0.005**	0.003
D1	-	-	-0.324**	1.251**	-	-
D2	-	-	-0.106	0.791**	-	-
D3	-	-	0.015	0.516**	-	-
D4	-	-	-0.011	-0.047	-	-
Rho	-	-	-	-	0.0821	0.1484**

*; Significant under 1%

**; Significant under 5%

Table 3. Land use projections (000 acres)

	2000	2010	2020	2030	2040	Net change
Base Model						
Uniform						
Forest	14538	14495	14420	14177	13762	-776
Crop	49099	48767	48432	48257	48251	-848
Urban	7017	7391	7802	8219	8641	1624
Suburban						
Forest	14538	14454	14313	13982	13467	-1071
Crop	49099	48580	48022	47614	47391	-1708
Urban	7017	7620	8319	9058	9796	2778
FE Model						
Uniform						
Forest	14322	14261	14168	13907	13474	-848
Crop	49312	48950	48582	48356	48273	-1039
Urban	7019	7442	7904	8391	8907	1888
Suburban						
Forest	14322	14211	14062	13741	13246	-1076
Crop	49312	48781	48258	47892	47673	-1639
Urban	7019	7661	8334	9021	9735	2716
Spatial model						
Uniform						
Forest	14722	14621	14480	14159	13657	-1065
Crop	48918	48672	48434	48368	48477	-441
Urban	7008	7354	7733	8120	8513	1505
Suburban						
Forest	14722	14587	14392	13995	13399	-1323
Crop	48918	48508	48070	47782	47672	-1246
Urban	7008	7552	8185	8870	9576	2568

Table 4: Land-use change by 2040, relative to the baseline (000 acres)

Uniform population growth scenario				Suburban population growth scenario			
Base Model	Small	Medium	Large	Base Model	Small	Medium	Large
Forest	986	1972	4870	Forest	968	1922	4749
Crop	-1421	-2840	-7000	Crop	-1407	-2788	-6863
Urban	435	868	2130	Urban	438	866	2114
Fixed Effects Model				Fixed Effects Model			
Forest	983	1932	4807	Forest	966	1906	4722
Crop	-1286	-2518	-6194	Crop	-1272	-2499	-6120
Urban	302	585	1386	Urban	304	591	1397
Spatial Model				Spatial Model			
Forest	984	1927	4725	Forest	960	1870	4620
Crop	-1377	-2691	-6559	Crop	-1357	-2636	-6463
Urban	393	763	1831	Urban	397	766	1841

Table 5. Net Present Value of total cost of carbon sequestration
(1992, billion dollars)

	Small (10%)	Medium (20%)	Large (50%)
Uniform population growth			
Base Model	0.682	1.413	3.838
FE Model	0.710	1.416	3.812
Spatial Model	0.727	1.469	3.935
Suburban population growth			
Base Model	0.685	1.406	3.816
FE Model	0.707	1.410	3.792
Spatial Model	0.724	1.454	3.924

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