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Forested Farmland and Biofuel Production: Combining Spatial and Economic Data to Estimate the Impact of Land Use-Values on Forestation Rates

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State and national policies driving ethanol production in Pennsylvania and elsewhere in the United States have elevated corn prices and subsequently the amount of land devoted to growing corn. There are concerns this may have a negative impact on water quality and other ecosystem services, especially if land is converted from forest to corn production. Pennsylvania has experienced a net increase in forested farmland in recent years, but higher corn prices may slow down or reverse such a pattern. The overall benefit from expanding ethanol production has to take into account land-use changes that decrease forested land and therefore bear a cost of foregone carbon sequestration and water quality benefits. This paper utilizes land cover and soil maps to create spatially explicit variables to examine the pattern of forestation in a heavily corn producing region of Pennsylvania using multinomial logistic regression. Results are mainly consistent with expectations that land with the highest rents from corn production are least likely to become forested over the period, indicating that the framework developed has potential for further analyses pertaining to agricultural land-use.

Keywords and JEL codes (if available)

Introduction

The production and use of biofuels is a central element of national energy policy in the United States. The Environmental Protection Agency's Renewable Fuel Standard mandating the blending of ethanol in gasoline, along with subsidies for ethanol production and consumption have driven a massive expansion of ethanol production. Corn is the major feedstock for ethanol, and the increased demand to produce ethanol has led to a large increase in the amount of cropland devoted to corn. While there is substantial interest in Pennsylvania in the production of ethanol from corn, there is concern about the environmental impacts of increasing the amount of land in corn. One concern is the impact on water quality, as land in corn in a major source of nutrients and sediments entering Pennsylvania's streams and rivers. Another concern is the impact of conversion of forests to cropland. Pennsylvania's forested farmland area has been expanding for several years. From the years 1992 to 2007, wooded farmland increased by over 295 thousand acres (USDA, 2009). In contrast, from 1982 to 1992 wooded farmland decreased more than 312 thousand acres. Land enlisted for additional corn production could come from farmland that is currently forested reversing the recent trend of re-forestation, or, it could reduce the rate at which farmland is converting to forest cover. A loss of forest cover could influence the overall environmental impact of local ethanol production.

One issue to be considered when evaluating the impact of ethanol use on the environment is the level of Greenhouse Gas (GHG) emissions. Replacing fossil fuels with those derived from plants is a potential way to reduce GHG emissions because carbon dioxide is absorbed from the atmosphere as the plant grows via photosynthesis,

the same reason carbon dioxide in the atmosphere can be sequestered in forests. If biofuel production contributes to reducing forested land the overall benefits may be significantly diminished since a reduction of fossil fuel emissions is counteracted by a loss of carbon sequestration making the impact of biofuel production on land use important for realizing an overall reduction of Pennsylvania's GHG inventory (Rose, et al., 2005 p. 10).

A second set of concerns associated with conversion of forests to cropland is the impact on ecosystems. There are several benefits people enjoy from the open space and biodiversity associated with healthy ecosystems including the provision of fresh water, fiber, pollination, nutrient cycling, and recreation. In the United States, land use change has instigated the loss of open space and a decline in forest health and biodiversity largely on private lands (USDA Forest Service, 2008). Private forestland in Pennsylvania is going to experience economic pressure to produce biomass for ethanol production. If agricultural commodities, such as corn grain, are used as the primary source of biomass for ethanol production private forests on farmland may be the most influenced. Therefore, examining the forestation of farmland specifically is important for anticipating ethanol induced landscape change and associated environmental impacts.

This paper looks for whether land recently converting from farmland to forested land is more or less likely to be impacted by increasing corn prices due to ethanol production. Farmland initially used for cropland or pasture that has converted to woodland over the years 2000 and 2005 is isolated using spatial data on land use and land cover. The spatial and soil characteristics of such land are compared to those of land converting to some non-forested use, and to those of land remaining cropland or pasture.

Literature Review

Previous investigations into the relationship between government policy, agriculture, and forestation have found that when policy alters the relative returns from agriculture and forestry it can influence individual management decisions to achieve the desired aggregate result, such as an increase in environmental services. Alig, et al. (1998), for example, examined the economic and ecological consequences of changes in forest management policies in the Northern part of the United States. An increase in the returns to forestry relative to agriculture was found to boost biodiversity and wildlife habitat in the region through an increase in forestland. Plantinga (1996) shows that a reduction in milk-price-support policy increases forestation in Wisconsin by decreasing the returns to agriculture relative to forestry. Energy policy that subsidizes ethanol production may impact the amount of forestland in Pennsylvania indirectly by increasing corn prices. The subsequent reduction in environmental benefits provided by forested land could create a situation where 'land use decisions are affected by policies that have been designed to address completely different social concerns, but the consequences for land use change can be both unintended and severe' (Bockstael and Irwin, 1999 p.14).

Although this paper does not model changes in grain prices explicitly, there is considerable research indicating local, national and world grain markets are being influenced by biofuel policy. Expanding ethanol production is expected to increase total use of U.S. feed grains over the next several years to record highs, depleting carryover stocks of corn, and thus contributing to higher grain prices (Hoffman, et al., 2007). Ethanol production facilities can increase prices in the local corn markets where they are located (McNew and Griffith, 2005). McNew and Griffith looked at 12 ethanol plants

with an average annual capacity of 32.5 million gallons, finding the increase in local corn price averaged 12.5 cents per bushel. Tokgoz, et al. (2007) examine the impacts of expanding ethanol production on the long-term price for corn. Under current ethanol tax policy, holding the prices of crude oil, natural gas, and distillers' grains at current levels, the 'break-even' price for corn is $4.05 per bushel and corn-based ethanol production reaches 20 percent of projected U.S. fuel consumption by 2015 (31.5 billion gallons). This requires 15.6 billion bushels of corn, compared to 11.0 billion produced annually at present. A recent report from the Economic Research Service (Trostle, 2008) shows the rapid expansion of biofuel production contributed to the 60 percent increase in world food commodity prices over the last two years. Corn-based ethanol production in the U.S. has had a small effect on global markets historically, but Trostle (2008) posits that the rapid expansion over the past 5 years has changed the structure of the U.S. corn market such that the world's supply and demand balance for grains has been impacted. Given the U.S. is the world's largest corn exporter, higher prices caused by increased demand for corn in the U.S. has spilled over into world markets.

In addition to increasing domestic and world prices for corn and other food commodities, corn-ethanol production increases sensitivity to market shocks. Westcott (2007) explains that ethanol demand is relatively inelastic compared to other uses for corn such as for animal feed or to export, so overall corn demand is expected to become less elastic as ethanol production expands. Inelasticity of corn demand combined with low levels of carryover stocks means when a shock does occur a greater change in market prices will be needed to adjust uses and bring the corn market back into equilibrium, therefore increasing price volatility.

The goal of this paper is to anticipate the interaction of biofuel policy and land use change with respect to forestation on a relatively small portion of Pennsylvania, in order to capture the influence of 'locally specific processes' related to agricultural production in the region. The main research question addressed is whether a higher corn price from policy-driven biofuel production is likely to decrease the amount of forestland located in agricultural areas.

Conceptual Framework

There are several reasons farmland is converted to forest. Taking the Ricardian approach, farmland converts to forest when the rents earned on that land from some non-forested use, such as cropland, become relatively less than rents realized from a use including (or allowing for) the development of forest cover. It has been shown that forestry competes more directly with field crops as soil quality decreases (Plantinga, 1996). Over time, the relative prices for timber and other agricultural goods may fluctuate causing the land use shares of farmland to adjust in response. Since a higher level of productivity on a parcel of land increases the potential returns from field crops as commodities or animal feed, it makes intuitive sense that there should be a lower rate of conversion to forest on such land, given a change in relative prices.

In the case of Pennsylvania, timber production is not the only reason farmland becomes forestland. According to the 2002 Census of Agriculture, almost 14 percent of the over 1.5 million acres of farmland that is woodland in Pennsylvania is pastured (USDA, 2004). Therefore, some conversion may be due to natural regeneration of forest on land that may previously been used to grow corn, or rotated with corn and pasture, but

has converted to permanent pasture in the context of historically low corn (and thus feed) prices. Land with high productivity generates more output and will compete with purchased feed more vigorously, so it is expected that pasture becomes forested on land of lower quality.

Forestation could also occur naturally on abandoned farmland. The burden of real property taxes has been cited as a reason for the decrease in farms, since often ‘real estate’ taxes are based on the market value of land, not the amount earned from the land when used for agriculture, making the method of taxation a larger burden for farms than other businesses that don’t require such a large land base (Kelsey and Harper, 2001). To protect farmland loss Pennsylvania has a program called Clean and Green that values farmland for tax purposes based on the potential earnings from the land when used for agriculture or forestry instead of the land market value. However despite this measure residential development in a county or school district may increase the rate land is taxed to finance new roads, schools and other community services required from an increase in population (Kelsey and Harper, 2001) so taxes still contribute to farmland abandonment in some cases.

Government policy may motivate the establishment of forests on farmland as illustrated by Plantinga (1996) and Alig, et al. (1998) by either timber planting or natural reforestation. For example, the Conservation Reserve Program (CRP) is a voluntary program intended to encourage farmers to convert highly erodible cropland and environmentally sensitive land to vegetative cover like native grasses or trees. This protects long-term productivity while providing positive environmental externalities like improving water quality and establishing wildlife habitat (USDA, 2008). The Resource

Enhancement and Protection (REAP) program offered through the Pennsylvania Department of Agriculture offers tax incentives to agricultural producers to implement 'best management practices.' One such practice that is eligible is stream fencing with a 35-foot riparian buffer of either grass or trees (PADA, 2008). These programs allow landowners to capture 'conservation rents' so that there is a financial return associated with generating positive externalities on land like improving water quality, biodiversity or habitat. The returns to participating in government conservation programs relative to those possible from field crop production will also influence the spatial distribution of farmland that converts to forested cover, due to the higher conservation value placed on environmentally sensitive land next to streams and wetlands. A higher rate of forestation amongst sensitive land provides evidence that agricultural producers are successfully capturing rents associated with environmental services such land provides.

Conversion of farmland to forest cover can be conceptualized as a bid-rent function of the expected returns to field-crop production, pasture, timber production, and conservation. Farmland may also convert to a non-forested land cover category such as development, infrastructure, or otherwise. Taking a Ricardian approach, farmland will be put to the use providing the highest return relative to other potential uses. If ethanol production increases the price of field-crops, *ceteris paribus* the expected returns to crop production increase relative to other uses that allow for (woodland that is pastured), encourage (conservation), or require (timber production) the establishment of forest cover, as well as non-forested uses. Let the returns to crop production be defined as the unit price for output times the quantity produced less the costs of production.

$$R = pq - c(q) \tag{1}$$

Then the change in returns from a change in output price is

$$\frac{dR}{dp} = q + \left(p - \frac{dc}{dq} \right) \frac{dq}{dp} = q \qquad (2)$$

since the envelope theorem tells us when profits are maximized the marginal unit cost of production, $\frac{dc}{dq}$,-. , is equal to the unit price, *p*. Therefore the sensitivity of returns to crop production to changes in price will depend on soil productivity. Thus land capable of producing higher yields should experience more pressure to stay or convert to crop production than less productive land. Comparing the soil productivity of land remaining in cropland or pasture, converting to forest cover, and converting to non-forest cover should indicate whether ethanol production is likely to have a relatively strong impact on the rate farmland is converting to forest cover.

Data and Methodology

The data set is constructed using a combination of spatial land cover and soil data. Two raster digital data land cover maps covering different time periods are used to track the conversion of farmland to forest cover from one time period to the next. The initial data represents land cover observed over the years 1999 to 2002 (Warner, 2003), and the second land cover map the years 2003 to 2007 (Warner, 2008). These data sets were created through a mix of interpretation of remotely sensed data from satellite images taken at multiple dates to compensate for cloud cover interference, and ancillary data sources were used to assist with ambiguity about the density of urban areas and wetlands. Corn price in 2007 dollars per bushel in the first period (1999 to 2002) ranges from 2.52

to 3.42, with an average price of 2.92. During the second period (2003 to 2007) corn price ranges from 2.44 to 4.56 dollars a bushel in the year 2007, and an average price of 3.29. The corn price for each year in both periods is listed in Table 1 (National Agricultural Statistics Service, 2007).

The land cover data are in GRID format, meaning it is divided into uniform-size ‘gridcells.’ The size of the grid cells is 30 by 30 meters, or, about a quarter of an acre, with each classified as a single land use. The tracking of land use conversion using digital raster land cover data derived from satellite imagery has been used previously in a study tracking the pattern of conversion from non-urban to urban land under two different policy regimes in Maryland (Shen and Zhang, 2007). The approach in this study is similar, except that the unit of analysis, in this case raster grid cell, is significantly smaller (30 x 30 meters) than the Maryland study (100 x 100 meters). There is potential for misclassification in this type of data, particularly on the ‘fringe’ between different land cover categories, say forest and pasture, as well as between time periods. The land cover maps’ accuracy was not personally validated by ground truthing (visiting a sample of sites) so no knowledge of the amount of misinterpretation present in the published maps is known and should be considered when interpreting any results.

The dependent variable is categorical, and each grid cell is assigned an integer value corresponding to one of three possible outcomes for farmland when the land cover maps are compared. Farmland is defined as land designated as cropland or pasture in the initial land cover map. The first potential outcome is no change from the first to the second land cover map, indicating no conversion away from either crops or pasture, and is treated as the base outcome (Y = 0). The second possible outcome is defined as a

change from farmland to forest when the two maps are compared (Y = 1). Farmland that converts to any land cover classification other than forest or wetland falls into the third and final outcome category (Y = 2). The land cover data available only represents two periods in time, so the change from one period to another defines the dependent variable resulting in a static, rather than dynamic analysis. This means changes in prices over time can not be included to represent actual changes in the relative rents for different land use options. Instead, the characteristics of farmland that does not convert are compared to characteristics of farmland converting to forest and non-forest uses. The comparison is intended to determine 1) if land remaining as cropland or pasture tends to have different characteristics than land converting away, and, 2) whether farmland that has converted to forest cover specifically have different characteristics than farmland converting to non-forested cover.

Land with higher potential returns to crop production should be the most influenced by an increase in crop price, so an explanatory variable is included to compare this characteristic between the three potential outcomes. Assuming all farmers face the same output and input prices, the expected return to a piece of land will depend on its expected productivity. Therefore a measure of innate soil quality is used to capture variation across observations in the expected returns from agriculture. Soil maps generated from national soil surveys (USDA and Natural Resources Conservation Service, 2005) are used to provide each grid cell the most detailed soil classification available. In addition to spatially referenced soil maps, each county also has a National Soil Information System relational database containing a number of data tables associated with the soil series map units. The table ‘Nonirrigated Yields by Map Unit’ is used to generate the yields that can

be expected under a high level of management for a particular soil classification located in a particular county. The current feedstock for ethanol production in the region is corn so the representative corn yield in bushels of grain per acre is used (*yld)*.

The other explanatory variables are included to account for spatial characteristics associated with each observation that are likely to influence the observed outcome. The distance of each unit of farmland to the nearest body of water or wetland is included as an explanatory variable (*wtr*). This is to allow for ‘conservation rents’ that may be captured from land located close to water bodies or wetlands. Farmland located near rivers, streams or wetlands may qualify for enrollment in a government funded conservation program, increasing the likelihood that it is converted to forest cover compared to a unit of farmland far away from water even though both have the same soil productivity. The Euclidean, or, straight-line distance from water is calculated to the nearest meter in ArcGIS (ESRI) for each grid cell of farmland. The same procedure is carried out to calculate the distance to land already classified as forest in the first land cover map. The distance to the nearest forest is included as a variable (*frst*) to help control for the influence of natural forestation as well as the increased likelihood that ‘fringe’ land may be interpreted differently between the two data sets registering a land use change that may not have taken place. The statistical model takes the multinomial logit form with farmland unit i not converting as the reference category, and m = 1 or 2 corresponding to conversion to forest and non-forest respectively.

$$\ln \frac{P(Y_i = m)}{P(Y = 0)} = \alpha_m + \sum_{k=1}^{K} \beta_{mk} X_{ik} = Z_{mi} \qquad (3)$$

The model is run for five contiguous counties located in the southeastern part of

Pennsylvania: Lancaster, York, Cumberland, Franklin and Adams. The counties were selected for three reasons. First, there is a relatively high level of corn production compared to the rest of Pennsylvania. In the year 2006, these five (out of sixty-seven) counties were responsible for 29 percent of Pennsylvania cropland growing corn for grain (National Agricultural Statistics Service, 2007). Therefore, higher corn prices from ethanol demand are likely to influence agricultural land use decisions in this region. Second, the intensity of agriculture and location in the Chesapeake Bay Basin make the amount and location of forestland in these counties relevant for achieving environmental goals related to water quality as well as carbon sequestration, and wildlife habitat. Third, all counties in the study area are considered to be in the same regional timber market (Jacobson, 2008), and therefore face the same timber prices.

The overall pattern of the three possible outcomes for farmland in the study area shows the majority of observations remaining farmland, and those that do convert away from farmland are evenly split between forested and non-forested cover, or have a larger share going into forested cover. For three of the five counties 76 percent of farmland in the first land cover map remains farmland in the second, falling into the base outcome group. The remaining two counties, York and Adams, have 68 and 72 percent of observations falling into the base outcome category of remaining farmland. Adams has the highest percent of observations converting to forest cover (18), followed by York (16), Franklin (14), Lancaster (12) and Cumberland (12). York also has the largest share of observations converting to non-forest cover (16). Lancaster and Franklin both have 12 percent falling into the third outcome category, and Adams and Franklin have 10 percent each.

The average corn yield in bushels per acre ranges from 101 to 155 with the lowest in Adams and highest in Lancaster. Franklin, York and Cumberland have quite similar averages of 106, 112 and 117 bushels per acre respectively. The mean distance in meters from surface water amongst the counties is shortest in Adams (330), followed by Lancaster (378), York (401), Franklin (436) then Cumberland (530). Distance to established forest tends to be much shorter than distance to water, ranging from 78 meters in both Adams and Cumberland, to a maximum of 107 meters in Lancaster, with the remaining two counties averaging 80 (York) and 92 (Franklin) meters.

Results

The categorical dependent variable representing three possible outcomes for farmland (remaining farmland, converting to forest, converting to non-forest) is regressed on the three explanatory variables (corn yield, distance to water, distance to established forest) using the Multinomial Logit Model provided in the econometric software package Limdep developed by William H. Greene for each of the five counties separately. This results in five regressions and ten equations where $j = 1, 2, \ldots, 5$ counties.

$$Z_{mij} = a_{mj} + b_{1mj} yld_i + b_{2mj} wtr_i + b_{3mj} frst + e_{mij} \quad (4)$$

All estimated coefficients are statistically significant except for the constant term and coefficient for yield in the case of Franklin county, for the outcome Y = 2, or conversion to non-forest. One way to assess the model fit is to see how often it correctly assigns an observation to the appropriate outcome category. The model correctly classifies observations into the three categories 71 percent of the time for Cumberland County, 70 percent for Franklin, 67 for Lancaster, 63 for Adams, and 61 percent of the time for York. Another measure of model fit, is to compare the actual outcome with the

predicted probability of that outcome calculated using the coefficients obtained from estimating the model. The predicted probability is calculated using the estimated coefficients for the reference category as

$$P(Y_i = 1) = \frac{1}{1 + \sum_{h=1}^{M} \exp(Z_{hi})} \tag{5}$$

and for the other two categories,

$$P(Y_i = m) = \frac{\exp(Z_{mi})}{1 + \sum_{h=1}^{M} \exp(Z_{hi})} \quad . \tag{6}$$

Table 2 compares the observed outcome and predicted probability of that outcome for each county. In general, the model over-predicts the probability farmland remains farmland, and under-predicts the probability farmland converts to either forest or non-forest cover.

The estimated coefficients (Tables 3 through 7) indicate farmland converting to either forest or non-forest from farmland tends to be located closer to water and established forest than farmland remaining farmland. In Lancaster, York and Cumberland, farmland converting to forest cover has a lower corn yield than land remaining farmland, while farmland converting to some non-forested cover has a higher corn yield than land remaining farmland. The coefficients for Franklin follow the same pattern, except the coefficients for corn yield and the constant term are not statistically different from zero for the equation predicting the outcome of conversion to non-forest. The corn-yield-coefficient for Adams diverts from the pattern, in that farmland converting to forest cover tends to have a higher corn yield than land remaining farmland, as well as farmland converting to non-forest.

The partial derivatives of the predicted probabilities are computed holding all variables at their mean value and presented in Table 8. The table shows the marginal change in probability given a one unit (bushel or meter) increase in an explanatory variable holding all others at their mean value, a Z statistic calculated as the marginal change (Coefficient) divided by its standard error, and the elasticity of each variable for each possible category: not converting from farmland (Y=0), converting from farmland to forest (Y=1), or converting from farmland to non-forest (Y=2). Elasticity refers to the percentage change in probability based on a one percent increase in the explanatory variable (as opposed to a one unit change). If a one percent change in a variable changes the probability of an outcome by less than one percent, it is considered to be inelastic. Given a one percent change in a variable produces a change in the probability greater than one percent in is considered elastic.

The probability farmland does not convert (Y=0) is inelastic with respect to changes in all three explanatory variables (corn yield, distance to water, and distance to forest) in the case of all five counties. The probability farmland converts to forest (Y=1) is inelastic with respect to distance from water, but elastic with respect to distance from forest for all five counties. Elasticity of the probability of conversion to forest with respect to corn yield is of mixed magnitude with Lancaster and Cumberland counties showing elasticity, and the remaining three counties inelasticity. The most varied result is for the elasticity of the probability of conversion to some non-forested land cover to the variables. This is not surprising considering this outcome is aggregated from several possible land use conversions, and so may vary considerably from county to county. York is inelastic with respect to all three variables, Franklin and Adams are elastic only

with respect to distance from established forest, and Lancaster and Cumberland are elastic with respect to distance from forest and corn yield.

Discussion

The results indicate there is a difference in soil productivity between farmland converting to forest, and that converting to non-forest such that land cover change to forest has occurred mainly on farmland with relatively lower corn yields. In the case of increased corn price, the returns to corn production will experience a larger boost relative to alternatives on land that in recent history has not been converting to forest cover, suggesting there may not be a large impact on the rate of re-forestation. This may not hold for Adams County, where there is evidence of forestation of farmland with relatively high corn yields.

This result may also change if the energy crop assumed changes from corn to another crop, such as switch grass, that could alter the relative returns on traditionally low yielding land much more than the use of corn grain. If the transition to cellulose- derived ethanol leads to higher economic rents from growing perennial grasses on conventionally less productive farmland, in essence creating an ‘equalizing’ effect on returns to cropland across all soil qualities, there may be a more severe impact on the amount of forested farmland as the land previously competitive with forestry or conservation may now be more profitable in biofuel feedstock production. The ultimate impact on GHG emissions will depend on whether the reduction of fossil fuel use surpasses the decrease in carbon sequestration. Therefore a suggestion for further research is to compare the results of this analysis (assuming corn grain is used as feedstock) with a scenario in which the relative

rents from various sources of cellulose are compared. This research will be more realistic once there are ethanol production facilities actually using cellulose as a feedstock, so information on which sources of cellulose are technologically and economically viable in practice is available.

There does not appear to be a distinct difference between farmland converting to forest and non-forest in terms of its distance from water. This result may indicate that when land is taken out of crop production or non-forested pasture, the 'conservation rents' associated with foresting land close to surface water are either not being captured by land owners through government programs, or if so, the returns to conservation, relative to other non-forested choices such as development, are not large enough to actually influence the pattern of land cover change. However, this could be in part because distance was included as a continuous variable, and the actual relationship between conservation payments and location relative to water may be non-linear, such that it may loose significance after a certain distance.

Although there is a difference between farmland that does not convert, and farmland that does convert in terms of distance to forest, there does not appear to be a decided difference between farmland converting to forest and non-forest cover, indicating 'conservation rents' from contiguous forest cover may not be available to landowners or are not competing with non-forested uses to the point of influencing landscape change.

Further research needs to be carried out to test for spatial auto-correlation, or other problems associated with using an artificial boundary for the decision-unit of analysis that may create the impression of several independent decisions, when in fact they are a result of only one decision.

Tables

Table 1: Observed Prices and Feed Price Ratios

Year	State Corn Price	National Corn Price	Milk Feed Price Ratio	Hog Feed Price Ratio
1999	3.00	2.35	4.47	21.52
2000	2.52	2.24	3.67	28.04
2001	2.73	2.21	3.97	27.40
2002	3.42	2.45	3.00	18.32
Average	*2.92*	*2.31*	*3.78*	*23.82*
2003	3.34	2.56	2.94	18.71
2004	2.47	2.71	3.40	23.16
2005	2.44	2.08	3.44	26.86
2006	3.64	2.35	2.64	21.19
2007	4.56	3.39	2.81	13.80
Average	*3.29*	*2.62*	*3.05*	*20.75*

Table 2: Comparison of Observed Outcome and Predicted Probability of an Outcome Based on the Model

		Y=0	Y=1	Y=2
Lancaster				
	Outcome	0.7565	0.1216	0.1219
	Predicted Probability	0.8410	0.0929	0.0661
York				
	Outcome	0.6793	0.1616	0.1592
	Predicted Probability	0.7582	0.1269	0.1149
Cumberland				
	Outcome	0.7551	0.1226	0.1223
	Predicted Probability	0.8293	0.0910	0.0796
Franklin				
	Outcome	0.7639	0.1354	0.1006
	Predicted Probability	0.8281	0.0978	0.0741
Adams				
	Outcome	0.7187	0.1800	0.1013
	Predicted Probability	0.7668	0.1527	0.0805

Table 3: Coefficient Estimates, Lancaster County

Observations	134588		
Restricted Log Likelihood Function	-97422.68		
Chi Squared	22572.54		
Prob[ChiSqd> value)	0		
	Coefficient	b/St.Er.	Mean of X
Characteristics in numerator of Prob[Y = Forest]			
Constant	1.7871	29.885	
Forest	-0.0153	-77.166	107.44
Water	-0.0009	-22.510	377.51
Yield	0.0129	-32.488	154.85
Characteristics in numerator of Prob[Y = Not Forest]			
Constant	-1.2116	-16.420	
Forest	-0.0146	-77.217	107.44
Water	-0.0020	-44.758	377.51
Yield	0.0088	18.682	154.85

Table 4: Coefficient Estimates, York County

Observations	114094		
Restricted Log Likelihood Function	-96950.95		
Chi Squared	18042.7		
Prob[ChiSqd> value)	0		
	Coefficient	b/St.Er.	Mean of X
Characteristics in numerator of Prob[Y = Forest]			
Constant	0.4166	9.114	
Forest	-0.0231	-92.564	79.92
Water	-0.0006	-15.669	400.52
Yield	-0.0007	-2.060	111.89
Characteristics in numerator of Prob[Y = Not Forest]			
Constant	-0.2720	-5.863	
Forest	-0.0144	-69.491	79.92
Water	-0.0014	-35.910	400.52
Yield	0.0039	10.393	111.89

Table 5: Coefficient Estimates, Cumberland County

Observations	80836		
Restricted Log Likelihood Function	-58717.33		
Chi Squared	16178.87		
Prob[ChiSqd> value)	0		
	Coefficient	b/St.Er.	Mean of X
Characteristics in numerator of Prob[Y = Forest]			
Constant	1.5337	26.454	
Forest	-0.0253	-63.547	77.75
Water	-0.0010	-28.945	529.94
Yield	-0.0105	-20.933	117.29
Characteristics in numerator of Prob[Y = Not Forest]			
Constant	-0.9879	-13.348	
Forest	-0.0292	-68.700	77.75
Water	-0.0012	-36.041	529.94
Yield	0.0139	22.400	117.29

Table 6: Coefficient Estimates, Franklin County

Observations	131008		
Restricted Log Likelihood Function	-92694.3		
Chi Squared	19522.54		
Prob[ChiSqd> value)	0		
	Coefficient	b/St.Er.	Mean of X
Characteristics in numerator of Prob[Y = Forest]			
Constant	0.9508	26.674	
Forest	-0.0159	-77.835	91.93
Water	-0.0011	-32.870	436.21
Yield	-0.0092	-28.076	105.88
Characteristics in numerator of Prob[Y = Not Forest]			
Constant	***0.0057***	0.136	
Forest	-0.0210	-81.635	91.93
Water	-0.0010	-27.875	436.21
Yield	***-0.0002***	-0.658	105.88

Table 7: Coefficient Estimates, Adams County

Observations	85832		
Restricted Log Likelihood Function	-66772.98		
Chi Squared	10862.99		
Prob[ChiSqd> value)	0		
	Coefficient	b/St.Er.	Mean of X
Characteristics in numerator of Prob[Y = Forest]			
Constant	-0.4778	-9.660	
Forest	-0.0205	-75.421	77.81
Water	-0.0003	-7.228	330.71
Yield	0.0057	13.953	100.62
Characteristics in numerator of Prob[Y = Not Forest]			
Constant	-0.7577	-12.342	
Forest	-0.0179	-54.570	77.81
Water	-0.0010	-16.725	330.71
Yield	0.0037	7.211	100.62

Table 8: Partial Derivatives of Probabilities with Respect to the Vector of Characteristics Computed at the Mean Value

	Variable	Coefficient	b/st. er.	Elasticity
Lancaster				
Prob(Y=0) = .820				
	Constant	-0.0384	-4.94	
	Forest	0.0022	124.92	0.2896
	Water	0.0002	45.24	0.104
	Yield	0.0003	5.31	0.0507
Prob(Y=1) = .088				
	Constant	0.1536	32.69	
	Forest	-0.0011	-91.02	-1.3578
	Water	-0.6147	-17.91	-0.2629
	Yield	-0.0011	-34.71	-1.9513
Prob(Y=2) = .092				
	Constant	-0.1152	-18.96	
	Forest	-0.0011	-87.1	-1.2853
	Water	-0.0002	-43.91	-0.6786
	Yield	0.0008	21.73	1.4272
York				
Prob(Y=0) = .726				
	Constant	-0.0077	(-1.05)	
	Forest	0.0037	116.47	0.403
	Water	0.0002	34.54	0.1198
	Yield	-0.0004	-6.07	-0.0565
Prob(Y=1) = .124				
	Constant	0.0503	10.48	
	Forest	-0.0022	-108.12	-1.4489
	Water	-0.3904	-9.43	-0.1264
	Yield	-0.0002	-3.99	-0.14
Prob(Y=2) = .151				
	Constant	-0.0425	-7.38	
	Forest	-0.0014	-58.87	-0.7505
	Water	-0.0002	-35.09	-0.4729
	Yield	0.0005	10.99	0.3902
Cumberland				
Prob(Y=0) = .830				
	Constant	-0.4506	-6.22	
	Forest	0.0038	110.04	0.3595
	Water	0.0002	42.69	0.1063
	Yield	-0.0002	-2.83	-0.0246
Prob(Y=1) = .088				
	Constant	0.1302	29.41	
	Forest	-0.0018	-72.28	-1.6111
	Water	-0.0001	-26.45	-0.4658
	Yield	-0.0009	-23.66	-1.2594
Prob(Y=2) = .082				
	Constant	-0.0852	-15.25	
	Forest	-0.002	-84.86	-1.9175
	Water	-0.0001	-33.35	-0.5785
	Yield	0.0011	24.29	1.6068

Table 8 Continued

	Variable	Coefficient	b/st. er.	Elasticity
Franklin				
Prob(Y=0) = .816				
	Constant	-0.086	-19.14	
	Forest	0.0026	121.66	0.3037
	Water	0.0002	40.34	0.0889
	Yield	0.0009	20.69	0.1103
Prob(Y=1) = .110				
	Constant	0.0933	27.69	
	Forest	-0.0014	-80.43	-1.1637
	Water	-0.0001	-31.3	-0.414
	Yield	-0.0009	-28.65	-0.8709
Prob(Y=2) = .073				
	Constant	-0.0073	-2.56	
	Forest	-0.0013	-96.56	-1.6308
	Water	-0.0001	-24.6	-0.3664
	Yield	-0.0001	2.23	0.0833
Adams				
Prob(Y=0) = .759				
	Constant	0.1065	13.74	
	Forest	0.0035	97.41	0.3675
	Water	0.0001	14.67	0.04978
	Yield	-0.0009	-14.08	-0.1219
Prob(Y=1) = .151				
	Constant	-0.051	-8.19	
	Forest	-0.0024	-82.45	-1.2328
	Water	0	-4.99	-0.0676
	Yield	0.0007	13.27	0.4607
Prob(Y=2) = .090				
	Constant	-0.0555	-11.17	
	Forest	-0.0012	-51.94	-1.028
	Water	-0.0001	-16.21	-0.3065
	Yield	0.0002	5.467	0.2542

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