

Land Use on the Urban Fringe

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ABSTRACT

Due to their location on the urban fringe, many historically agricultural counties face development pressure from a spreading urban core. These local communities must contend with often conflicting objectives of providing economic development opportunities while at the same time protecting their county's natural resources. Land conservation policies incentivize landowners to keep land identified as critical environmental resources in their natural state. In this project, we analyze property-level administrative data to evaluate whether land conservation policies and neighbor land use patterns affect the probability of land parcel development. We find some evidence of the contagion effect and that the county's acknowledgment of Priority Conservation areas impacts development motivation.

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GENERAL AUDIENCE ABSTRACT

Communities on the "urban fringe", the transitional area where the town meets the county, are experiencing strong pressures to develop. The population has moved from the city center towards the suburbs for quieter, safer neighborhoods, better schools, and more outdoor amenities. Localities manage this growth while protecting their resources, such as natural land, by implementing conservation policies/preservation guidelines. In this project, we utilize data from Powhatan County to evaluate whether local conservation efforts and land use patterns affect the probability of land development. This is an important topic as local officials work to manage land resources where the development of the county's most valuable land would be difficult, if possible, to reverse.

Dedicated to Virginia Tech.

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List of Abbreviations

AFD Agricultural Forestall Districts

PCA Priotity Conservation Areas

Chapter 1

Introduction

1.1 Background

The trend of urbanization in the United States has been ongoing for several decades. Urbanization refers to the process by which a society becomes more urban or city-oriented. Not all parts of the United States are urbanizing at the same rate. The urban fringe, for instance, is developing faster than the average rate.^[9] The urban fringe is the transitional area between urban and rural areas. It is characterized by a mix of land uses, such as residential neighborhoods (the suburbs), commercial developments, and agricultural land. This area is in high demand because it offers affordable urban and rural life benefits.^[9] Increased development at the urban fringe may pose challenges due to increased resource demand, a strain on existing infrastructure and services, and environmental degradation. Therefore, many local governments strive to provide practical development guidelines that support economic development while protecting the community and environment. This paper evaluates the effect of county-level development strategies, existing land use patterns, and conservation efforts on land development.

1.1.1 Development at the Urban Fringe

The United States saw a net gain of over 44 million acres of developed land from 1982 to 2017, as shown in Figure 1.1.[19] This is due to various economic and cultural shifts. For example, the United States population is increasing by about 1 percent yearly due to high immigration, longer life expectancy, and high fertility rates.[9] Simultaneously, the average household size is dropping. These changes coupled together with shifting lifestyle preferences, economic opportunities, and technological advances have dramatically increased the demand for new housing, especially on the urban fringe.[9] For example, technological advances have enabled people to work remotely, decreasing the need for people to live close to their job. This residential growth can encourage further commercial, industrial, and infrastructural development. If this growth is channeled efficiently, these trends can spur economic benefits for communities on the urban fringe. However, if unchanneled growth can lead to "urban sprawl" a concern voiced by many across the US. [11]. "Urban sprawl" is a type of urban development characterized by low-density development in previously rural or undeveloped areas. This type of development is often characterized by a lack of planning or coordinated development, resulting in inefficient land use.

As cities and suburbs expand, they encroach onto agricultural and undeveloped land, converting it to residential, commercial, or industrial uses. Figure 1.1 shows that from 1982 to 2017, there was a loss of over 52 million acres of cropland in the United States.[19] Notably, much of the movement out of cropland is due to shifts in the agricultural sector. Agriculture shaped many American rural communities' culture, economy, and way of life. Two centuries ago, 30 percent of Americans lived on small and local farms and produced most of the nation's food.[14] However, industrialized agriculture has transformed farming and reshaped rural America. By 2020, the share of Americans living on farms fell to under 2 percent.[14] Industrialized agriculture is an approach to farming that emphasizes large-scale production,

efficiency, and technological innovation. Industrialized agriculture consolidated farm operations leading to a concentration of land ownership and a decline in rural populations. As a result, rural America is continuously becoming less agricultural, less remote, and more economically diverse.[2] While agriculture remains an integral part of the American economy by providing economic opportunity and stability for rural areas, it must continue to evolve and adapt to changing conditions and demands.

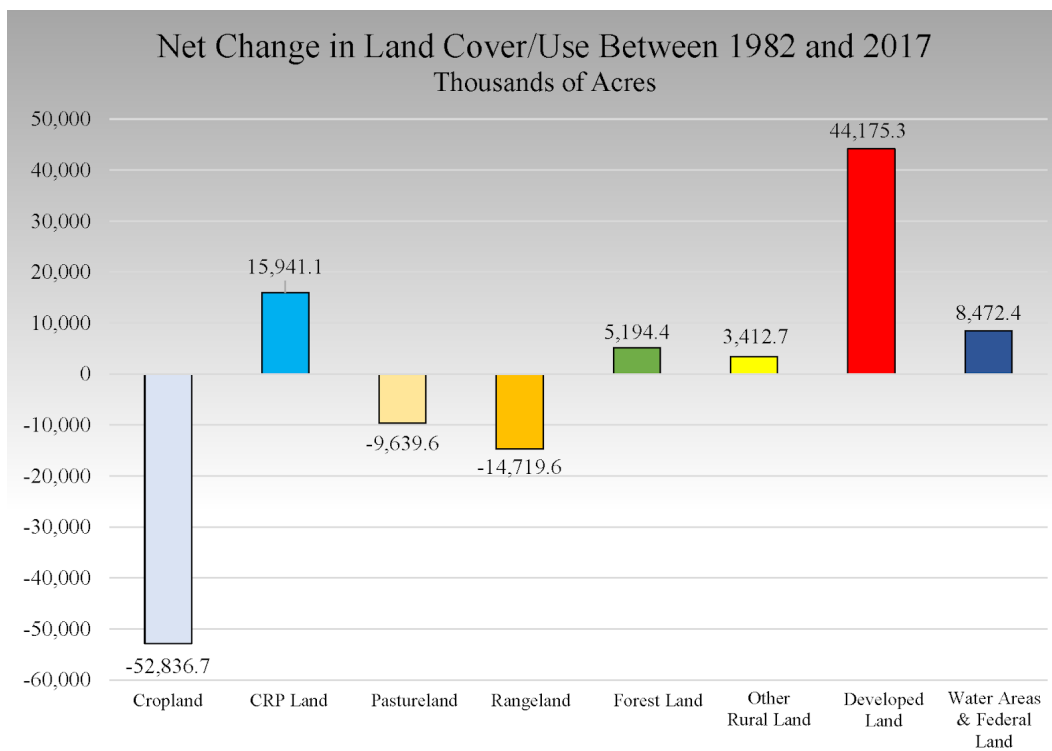


Figure 1.1: U.S. Department of Agriculture [19]

Land at the urban fringe is subject to high development pressure as national trends move towards increased urbanization and decreased cropland. Rational decision-making regarding land development at the urban fringe would lead to an optimal level of utility, or benefit, to the community. However, individuals tend to overlook the adverse effects land development could have on the community, environment, and soil quality. [3] The Regional Development

Theory explains that land use changes in a region reflect the efforts to utilize land resources optimally. However, rural development often results in decreased welfare for rural areas due to an "urban bias." [3] This could be explained by a drain of resources, natural beauty, and capital at the expense of the rural community.[3] Most local governments strive to provide practical strategic development guidelines to direct increasing development pressures and encourage efficient land use.

In the twentieth century, local governments have focused on protecting natural environments, and most localities have some form of policy designed to protect and conserve natural/agricultural land.[8] However, there are relatively few direct means for localities to constrain growth and direct its pattern. Local development planning and policy must efficaciously target their community's physical land and environmental health with programs that preserve the ecological health of their land.[4] Policy levers that directly affect local development patterns include zoning and tax incentives.

1.1.2 Powhatan County

This paper evaluates the effect of county-level development strategies and conservation efforts on land development on the urban fringe, specifically in the case of Powhatan County. Powhatan is a historically agricultural county located at the urban fringe of Richmond, Virginia. The county is experiencing high levels of growth and development, and due to the county's attractive character and proximity to the state's capital, these trends will likely continue.[20] Like many counties on the urban fringe, Powhatan is quickly transitioning to a more residential community. However, the county remains tied to its rural roots, which they intend to honor as development continues.[20]

Powhatan was established in 1777 in Virginia's Central Piedmont between Virginia's Coastal

Plain and the Blue Ridge Mountains. The country is approximately 20 miles from Richmond, VA, and 2 hours from Washington, D.C. The borders were last amended in 1850 and established the 272 square mile County of Powhatan; at this point, the county's population was 8,170.[20] The James River forms the northern border of Powhatan, which feeds the many creeks throughout the county. The economy was originally linked to river traffic and the cultivation of crops, timbering, and livestock production.[20]

The population declined to about 5,500 by 1950, followed by a dramatic, steady growth period. By 2000, the population was over 22,000.[20] From 2010 to 2020, approximately 300 new homes were approved for construction in Powhatan County per year.[20] As of 2017, less than 1 percent were employed in agriculture, forestry, fishing, hunting, and mining. However, according to the 2017 agricultural census, the total market value of agricultural products sold was \$11,249,000 dollars.[18] The main crops sold were forage (hay/haylage), and soybeans.[18] As of 2021, the total population of Powhatan County was up to 29,253, which is over a four hundred percent increase in less than a century.[6] The median income is just under a hundred thousand dollars, and over fifty percent of the population within Powhatan County is employed.[6] The top employment sectors are government, construction, and retail trade. Most workers commute to other localities, such as the City of Richmond, or other Richmond-adjacent counties, such as Henrico or Chesterfield.

Powhatan Counties roads are mostly rural, but the county has several well-maintained routes well-suited for travel. Virginia State Route 228 runs through the northeast corner of Powhatan County. This is a suburban belt route, bypassing Richmond, and is a primary state highway in Virginia. Additionally, U.S. Route 60 runs west to east through the county. Most of the development in Powhatan County occurs near these highways. Powhatan County outlines optimal future land use, depicted in Figure 1.2.[20] The designated growth areas are around these major roads, including the Courthouse Village, Route 60 Corridor East Area,

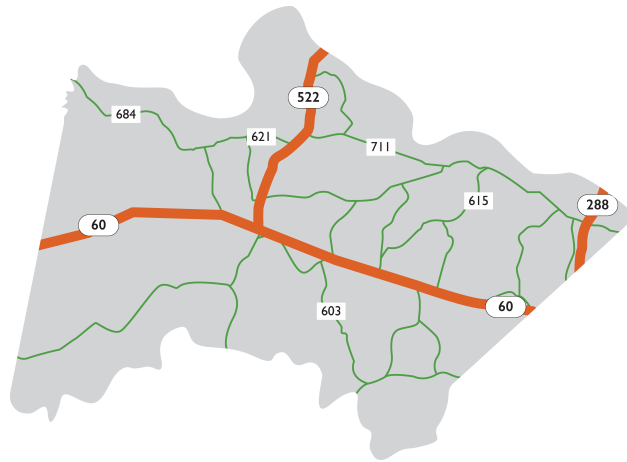


Figure 1.2: Powhatan County

and Route 711 Village. The Courthouse Village is located in central Powhatan along Route 60 and is the historical and government center for Powhatan County.[20] The Route 60 Corridor East Area is also along Route 60 and has "commercial nodes" with retail stores, restaurants, and other businesses.[20] This area can accommodate various development types, including industrial and commercial land uses. The final designated growth area is the Route 711 Village, along Route 288 and 711 in the county's Northeast corner. This area is mainly dedicated to economic opportunity and can accommodate extensive development.[20]

Like many urbanizing areas in Virginia, local officials have been grappling with constructing an efficient economic growth strategy while managing citizen complaints about the preservation/conservation of the county. The land-development process is often contentious and involves local officials, landowners, lawyers, neighbors, and residents, who either support or oppose additional development. The Planning Commission holds public hearings monthly to decide on citing specific development requests. The local officials in Powhatan have the ultimate power to accept, require modifications, or reject parcel-specific proposals and plans.[20] They rely on the County's Comprehensive Plan, which lays out guidelines on best supporting the community in Powhatan County.[20]

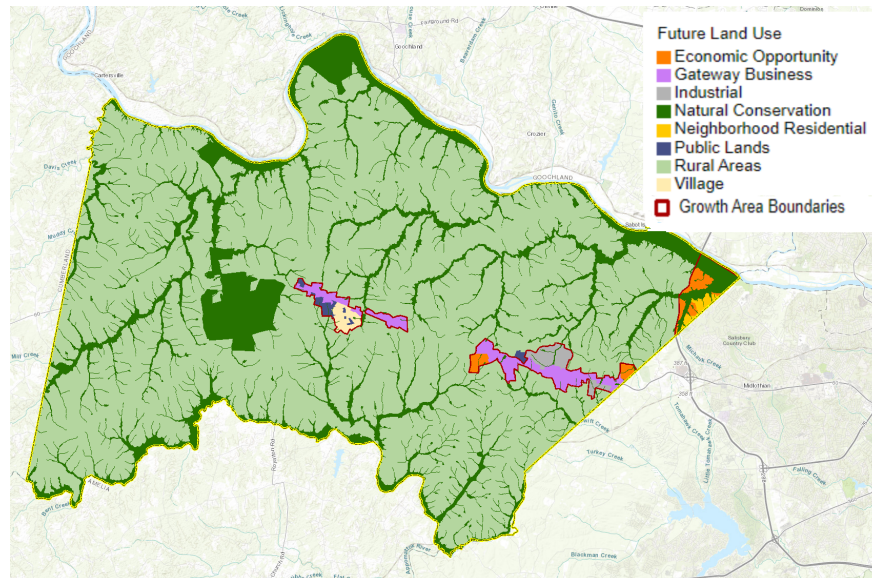


Figure 1.3: 2021 Countywide Future Land Use Plan

A fundamental goal and central theme of Powhatan County’s 2021 Comprehensive Plan is maintaining the county’s rural character and promoting a rural lifestyle. This involves preservation efforts, especially of ”signature” parts of the county.[20] These efforts include recognizing Priority Conservation Areas (PCA), protecting environmentally critical land, and utilizing the Agricultural/Forestal District (AFD) program. Figure 1.4 shows the three different types of conservation districts outlined in Powhatan County’s Comprehensive Plan.

First, the county recognizes ”Protected Lands.” These are ”critical environmental resources” such as wetlands, streams, and steep slopes.[20] If a parcel contains ”Protected Lands,” the landowner must adhere to the local, state, and federal regulations and protect these areas.[1] These lands, as designated, are ”un-build-able” and should be ”maintained in a naturalized, undisturbed state.” [20]

Second, the county recognizes Priority Conservation Areas (PCAs) as land that is critical to maintain with preservation/conservation efforts.[20] These areas include land adjacent to Protected Lands, wildlife habitats, sensitive soils, and any land the county deems vital for the

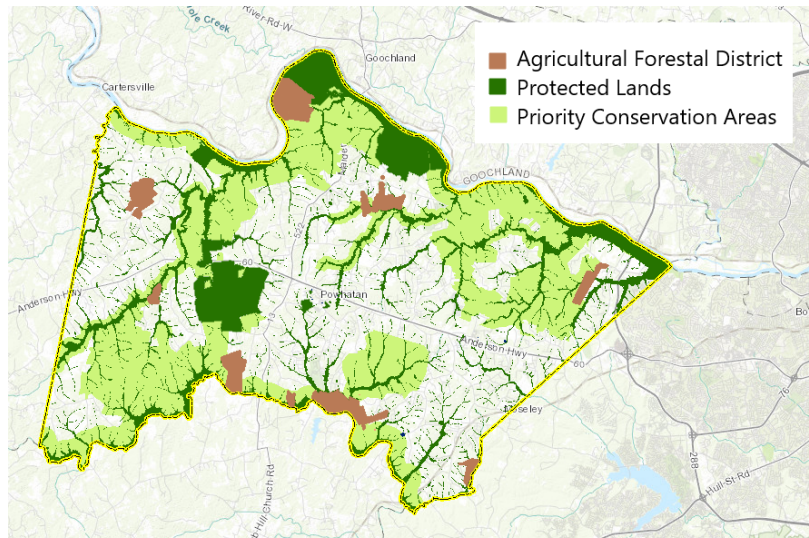


Figure 1.4: Land in Conservation By Program Type

county’s ecological health and natural beauty. PCAs consist of just under twenty percent of land in Powhatan County. While county officials review proposed land use changes of land that fall within Priority Conservation Areas, the County’s Comprehensive Plan lists (3) specific guidelines for PCAs. These are: (1) maintain vegetation buffers at least 200 feet in width around wetlands, rivers, and streams, (2) properties zoned Agricultural or Rural Residential should not be rezoned to a higher-intensity land-use class, and (3) residential development should have the most negligible impact on environmental resources.[20] The 2021 Comprehensive Plan also states that land use plans ”should be done to ensure that the character and land use patterns associated with these areas are protected in the future.”[20]

Finally, Powhatan County utilizes the Agricultural Forestal District (AFD) program. AFD is a voluntary program created in 1977 by the Virginia General Assembly to help localities, such as Powhatan, protect critical pieces of land. Landowners may opt to ”sell” the development rights of their land to Powhatan. In exchange, the land is taxed based on use rather than its market value. PCAs are a principal means for identifying which land should be

added to the AFD. The AFD program has been in Powhatan County's Comprehensive Plan for decades.[20] However, in the words of the Agricultural and Forestal District Advisory Committee, this is a "buried" program; despite being defined as a "prime land-use tool." [15] As of 2020, Powhatan County has approximately 5,640 acres of AFD land, depicted in Figure 1.5.

In October 2020, the AFD Advisory Committee prepared a review of Powhatan County's use of this program.[15] The committee acknowledged that external and internal pressures in Powhatan encourage land development. Nevertheless, citizens pressured the government to "keep us a rural, farming community," which resulted in the county utilizing the AFD program.[15] The committee explained that the tax incentive for including land in AFDs is insignificant. Thus, it does not affect real estate decisions.[15] This is because land in Powhatan County is already taxed based on its land-use classification; therefore, utilizing AFD is "redundant." [15] Nonetheless, the AFD Advisory Committee encourages the continuation of this program. They argue that its inclusion is necessary in response to the "heavy and continued pressure to develop farming/forest/open space into residential uses, with all the services and problems such usages bring." [15]

1.2 Literature review

The literature on land development is rapidly expanding. Land development largely affects ecosystem health. Therefore, land conservation efforts are primarily motivated by protecting the environment.[4] However, land conservation efforts also serve social and economic purposes. Bockstael (1999) explains that the environmental, social, and economic motives behind conserving land are so abundant and intertwined that they are inseparable.[4] This leads to the creation of many conservation efforts that are independent of one clearly de-

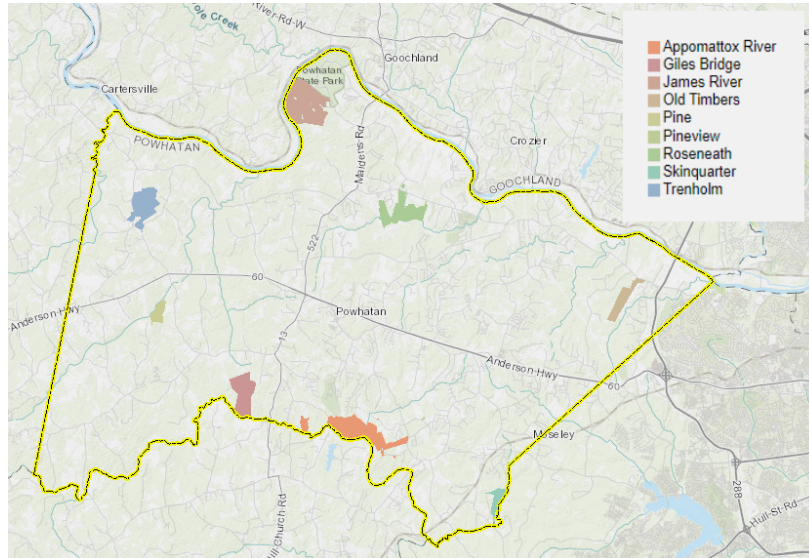


Figure 1.5: Land In Agricultural Forestal Districts

fined motive. Nevertheless, conservation policies that impact land development and broadly aim to preserve natural land are abundant.[4] Without clearly defined, independent motives, land conservation policy can have many environmental, social, and economic impacts. The literature analyzing these impacts is voluminous and rapidly expanding. [4]

The Capozza-Helsley (1989) land development model looks at the marginal value of land productivity based on the distance from the urban center.[7] This model shows that the productivity per unit land area under urban uses, such as housing or industry, is affected by its proximity to the urban center. This is due to decreased travel time, more access to a large labor force, and increased access to technology.[7] Irwin and Bockstael (2007) evaluated the pattern and evolution of urban sprawl.[10] Their findings contradict the Capozza-Helsley (1989) land development model, and note that the largest fragmentation increases occurred in areas far from urban centers. This is due to decreased travel time, more access to a large labor force, and increased access to technology which has led to a substantial increase in the amount and spatial extent of sprawl. Alastair McFarlane (2003) also concluded that land productivity is not consistently inversely related to distance.[12] Instead, speculation

and regulation impact land development decisions and urban sprawl's amount and spatial extent. [12]

Stavins and Jaffe (1990) evaluated factors that drive land-use changes; specifically, they measured the impact of federal actions on the development of wetlands in the Mississippi Valley.[16] The federal government protects this region's wetlands and provides public investments, such as flood control and drainage projects.[16] Stavins and Jaffe (1990) explain that land conservation may occur less often than is socially optimal, motivating these federal activities.[16] However, they conclude that the federal government's policy approach has contradictory effects and that their public investments are encouraging the development of the wetlands.[16] They concluded that public policy both encourages and discourages land development and that "the overall justification for these federal programs ought to be re-examined, and stringent tests of public need should be applied to both public and private actions." [16]

Lubowski (2008) investigated the influences of market and policy factors, specifically evaluating the effects of the Conservation Reserve Program (CRP).[11] This program utilizes yearly rental payments as an incentive to remove environmentally sensitive land from agricultural production and encourage landowners to improve the environmental health and quality of their land. Lubowski (2008) found that private land-use decisions depend on land quality and public policies.[11] However, they suggest the effect of the CRP program is limited and suggest more targeted policies would be needed to slow down or reduce urbanization on the urban fringe.[11]

Bockstael and Irwin (1999) outline how policies designed to affect the amount and pattern of land development in the U.S. are complex and indirect.[4] Additionally, they acknowledge that many land-use activities have spillover effects.[4] This entails interdependence within neighborhoods and affects individual choice.[5] Therefore, factors contributing to individual

choices can have expansionary effects.[13]

Cory and Willis (1985) also evaluate contagion externalities and the conversion of land at the urban fringe and find evidence that the development of acreage on the fringe encourages further development of proximate acreage. They argue that contagion effects must be included in the analysis to evaluate land conversion accurately. [8]

The existing literature evaluating the effect of policy on land conversion has been done, at best, at the county level. This is due to challenges with the granularity and precision of data.. Towe and Lawley (2013) were able to evaluate the contagion effect within neighborhoods at the individual level. They find strong evidence of social influences on decisions where a neighbor's behavior affects an individual's decision-making.[17] This analysis was done on the likelihood of an individual defaulting on their home loans.[17] This paper will build on the existing literature on the effect of conservation efforts on land development by utilizing parcel-level data. This will allow for a more precise analysis of the factors associated with land development, including the social influences of neighbor's behavior.

1.3 Project Outline

There is a significant literature base on the effects of conservation policy on land development. However, this type of analysis is limited at the parcel level. This project will build on the previously constructed models of land development and test which factors motivate land development in Powhatan County at the parcel level. In particular, this paper assesses the impact of conservation and preservation strategies on the motivation to develop land and the contagious effects of such policies. Powhatan County is a good case for empirically exploring this issue due to its location at the urban fringe of Richmond, its utilization of conservation efforts at the local level, and the availability of spatially explicit economic information.

A fundamental goal and central theme of Powhatan County is to maintain the county's rural character. The county implements preservation strategies; Powhatan County utilizes the Agricultural Forestal Districts (AFD) program and recognizes Priority Conservation Areas. The AFD provides tax incentives to landowners in exchange for keeping their land in an agricultural or forested state. This program is designed to preserve and protect important land. The county also acknowledges PCAs, recognized as land well-suited for inclusion in the AFD program. However, the AFD Advisory Committee acknowledges that there are no strong incentives for landowners to enter their land into AFD. Therefore, it is unlikely that the PCA land, which the county deems essential to preserve and protect, will be added to the AFD. Thus, the conservation of these lands relies on the land development guidelines given to PCAs. However, these guidelines are loose, and there is reason to question the ability of these guidelines to deter the loss of these critical pieces of land within the county.

Given the recognized importance of these areas and the uncertainty of the effectiveness of the current guidelines, it is essential to assess the impact of including land in Priority Conservation Areas on land conversion in Powhatan County. This would aid in understanding the development pressures on these lands and the strength of the current policies. This is an essential topic as local officials work to manage the high-demand land market where the potential development of the county's most valuable land would be difficult, if possible, to reverse.

This project analyzes a decade's parcel-level administrative data from Powhatan County to evaluate the factors associated with land conversion and agriculture loss. In particular, the effect of including land in Priority Conservation Areas will be measured. The county acknowledges that Priority Conservation Areas "should be protected in the future"; this statement calls attention to the desirability to protect this land but eludes to the uncertainty that the current guidelines provide adequate protection.^[20] Additionally, the literature shows

that for an accurate evaluation of preservation to be conducted, you must account for the contagion effect of development and preservation strategies. This project, therefore, assesses the impact of conservation and preservation strategies on land development while controlling for the contagion effects of such policies.

Chapter 2

Data

2.1 Administrative Tax Data

Powhatan County's administration collects tax data on each parcel/property within the county. The county uses in-house professional appraisers/assessors to perform the data collection. These assessors are responsible for visiting every parcel of land each tax year for general real estate reassessment. During this process, the assessors also view and verify the physical characteristics of each parcel. This reassessment information is then used to amend the county's administrative tax data. The Department of Information maintained the historic administrative tax data. For this project, they provided administrative tax data on each parcel/property within the county for each tax year from 2012 to 2021. The provided data included information on parcel shape, size, location, tax assessments, and information on the property owner.

The data-capturing methodologies were different each year. As such, there were areas where the historical parcel boundaries did not align precisely. Data cleaning and manipulation generated a panel that tracks the parcels through time (see Appendix [A.1](#)). This resulted in a balanced panel of $N = 15,478$ land parcels which we follow with $T = 4$ time periods from 2012 to 2021. The data is in 3-year increments: 2012, 2015, 2018, and 2021. The total number of observations across all years in the data is $n = 61,912$.

Virginia’s land use codes classify land into seven categories: Single Family Urban, Single Family Suburban, Multi-Family Residential, Commercial and Industrial, Agriculture/Undeveloped (20-99 Acres), Agriculture/Undeveloped (100+ Acres), and tax-exempt. Powhatan’s administrative tax data included land use codes using the same six categories as the state. However, they include subcategories of ”tax-exempt.” For example, Powhatan has unique codes for churches and cemeteries, however, these codes map into state ”tax-exempt” category. Other lands that fall into the ”tax-exempt” category are parcels with educational, governmental, or religious usages. Powhatan’s land use codes were condensed to match Virginia’s. Figure 2.1 shows the breakdown of land use in Powhatan.

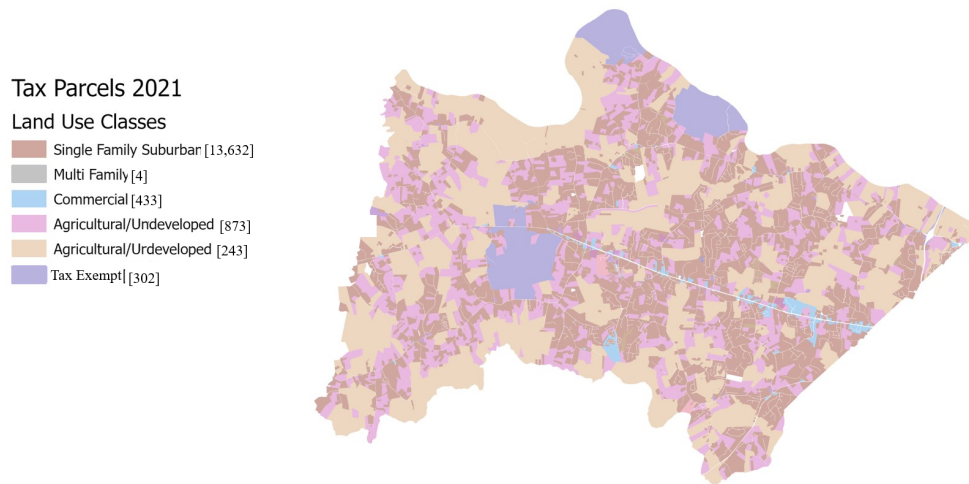


Figure 2.1: Land Use Classifications (2021)

The majority of land in Powhatan is residential. As Table 2.1 shows, just under 90 percent of the parcels are utilized for single-family suburban housing. Residential housing has, on average, about 4 four acres of land. This equates to less than one-third of the total acres in Powhatan County. Agriculture/Undeveloped (20-99 Acres) accounts for about six percent of parcels in Powhatan County and about a quarter of the total acres in Powhatan. The largest parcel is the Powhatan County Wildlife Management Area. This area is 4,200+ acres and is classified as tax-exempt. It is open to the public for fishing, hunting, hiking, and

other recreational activities. The second largest parcel is 2,900 acres, owned by Powhatan's Properties Land and Lumber LLC. This parcel is classified as Agriculture/Undeveloped (100+ Acres).

Table 2.1: Land Use Categories

Land Use Categories	Percent of Parcels
Single Family Suburban	86.71
Multi Family	0.01
Commercial/Industrial	2.68
Agriculture/Undeveloped 20-99 Acres	6.49
Agriculture/Undeveloped 100+ Acres	2.19
Tax Exempt	1.8

As described in Appendix A.1, there were 14,820 parcels recorded in Powhatan County in 2012. By 2021, there were 15,465 parcels. Given the different numbers of parcels by year in Powhatan County, creating a balanced data set required data manipulation. Therefore the numbers in Table 2.2 reflect parcel percentages based on the 2021 parcel boundaries. This is shown in Table 2.2. From 2012 to 2021, Powhatan County lost many agricultural/undeveloped parcels and gained many residential and commercial/industrial parcels. As shown in the table, single-family suburban residential land alone increased by 437 parcels from 2012 to 2021, a 3.4 percent increase. Additionally, commercial/industrial parcels gained 58 parcels for a 16.2 percent increase. Meanwhile, Agriculture/Undeveloped (100+ Acres) experienced a 49.4 percent decrease, losing 238 of the original 481 pieces of land. Agriculture/Undeveloped (20-99 Acres) land experienced a 24.5 percent decrease, losing 284 of the original 1,157 parcels.

Next, the land use categories provided in Powhatan County's Administrative Tax data were further collapsed and converted into a binary variable indicating if the parcel is in a developed or undeveloped state, as shown in Table 2.4. Parcels are assigned a zero if the land usage is agricultural/undeveloped. All other parcels, including residential, commercial/industrial, and tax-exempt land, are assigned one to indicate they are developed.

Table 2.2: Land Use Over Time

Land Use	2012	2015	2018	2021
Single Family Suburban	13,186	13,314	13,340	13,623
Multi Family	0	0	0	4
Commercial/Industrial	375	382	487	433
Agriculture/Undeveloped 20-99 Acres	1,157	1,106	994	873
Agriculture/Undeveloped 100+ Acres	481	403	375	243
Tax Exempt	279	273	282	302
Total	15,478	15,478	15,478	15,478

Table 2.3: Development Categorization

Land Use Categories	Development Stage
Single Family Suburban	Developed
Multi Family Residential	
Commercial/Industrial	
Tax Exempt	
Agriculture/Undeveloped 20-99 Acres	Undeveloped
Agriculture/Undeveloped 100+ Acres	

From 2012 to 2021, many parcels developed. The histogram in Figure 2.2 shows that there were 1,638 undeveloped parcels in 2012, making up 10.58 percent of parcels in Powhatan. By 2021, there were only 1,116, down to 7.21 percent of the total parcels. Even though undeveloped land is a relatively small percentage of the total acres in Powhatan, about half of the land in Powhatan is undeveloped. This is because developed parcels are typically much smaller than undeveloped parcels. On average, developed parcels are about five acres, and undeveloped parcels are just under a hundred acres.

2.1.1 Data Used for Analysis

This project aims to evaluate what motivates the development of undeveloped land. Of the 15,478 parcels of land in the data set, 14,110 were already developed in the first period ($t=2012$). These parcels remain developed throughout observation and do not enhance the

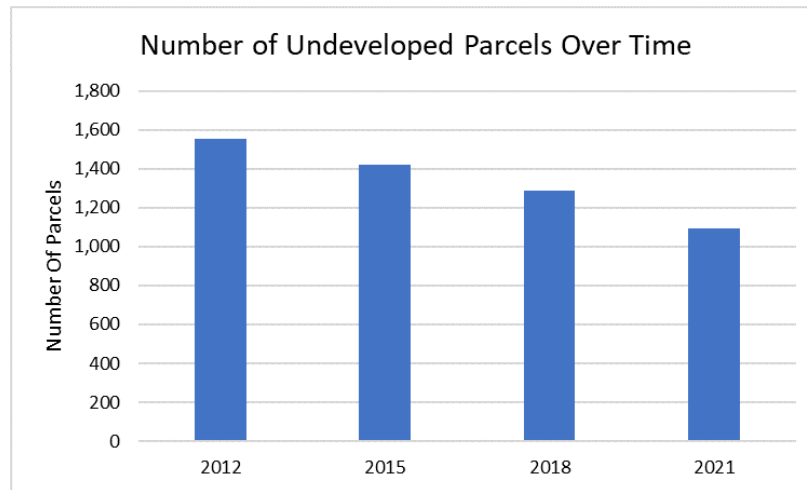


Figure 2.2: Undeveloped Parcels

analysis. Therefore, the parcels already developed in 2012 were dropped from the data set. Figure 2.3 depicts the Developed parcels dropped from the data set and the remaining undeveloped lots shown in yellow. This resulted in a balanced panel that tracks $n = 1,638$ parcels over the four panels from 2012 to 2021. The total number of observations that are in the analysis data set is $N = 6,552$.

Of the 1,638 parcels that were undeveloped in the first period (2012), 597 were developed by 2021. These 597 parcels are depicted in Figure 2.6. These parcels were originally agricultural/undeveloped and transitioned into residential, commercial, or industrial land.

Parcelization is dividing a large piece of land into small, individual parcels. This seems to be the type of development occurring in Powhatan county. Figure 2.5 provide a "blow up" of parcelization occurring in Powhatan. In this case, many large undeveloped plots of land (adjacent to each other) are being sold off and subdivided and converted into many single-family housing parcels.

The data is in 3-year increments, including data from 2012, 2015, 2018, and 2021. Of the originally undeveloped parcels, 36 percent will be developed by 2021. Table 2.4 shows the

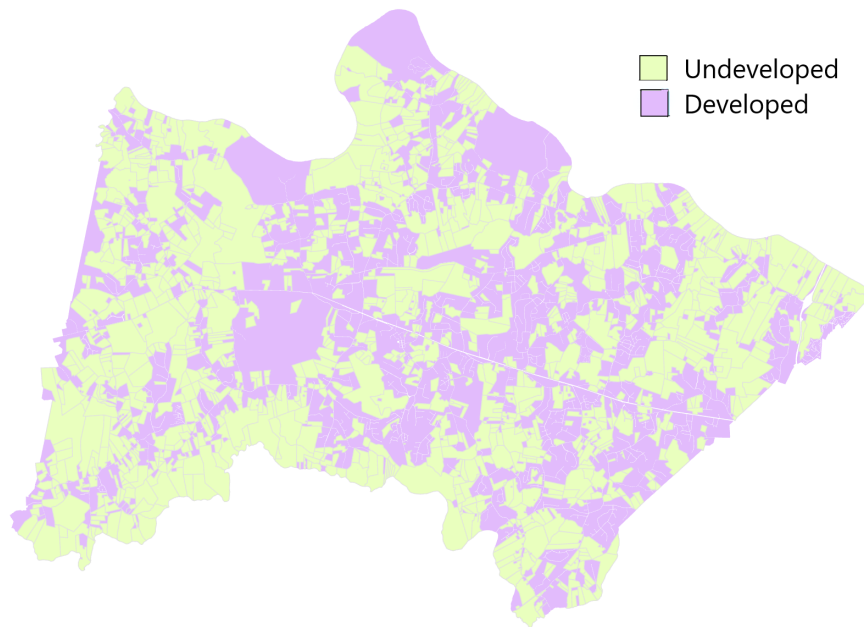


Figure 2.3: Developed Parcels (2012)

development status of the analysis data set over time. On average, 199 parcels were developed during each period.

Table 2.4: Undeveloped Parcels Over Time (Restricted Data Set)

Development Status	2012		2015		2018		2021	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Undeveloped = 0	1,638	1.00	1,501	0.91	1,302	0.79	1041	0.64
Developed = 1	0	0.00	137	0.09	336	0.21	597	0.36
Total	1638	1	1638	1	1638	1	1638	1

Before running regressions, year 2021 was dropped because of perfect collinearity. This resulted in a balanced panel w $N=4887$ parcels tracking over 3 time-periods (2015,2018,2021). We will continue to include 2012 data in the data discussion in order to accurately represent the years that the data describes.

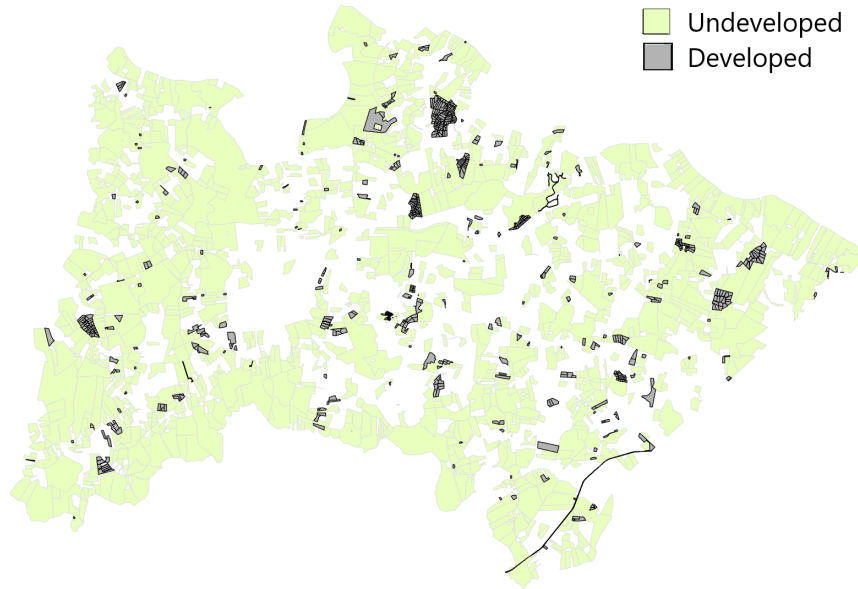


Figure 2.4: Parcels That Developed Parcels between 2012 and 2021

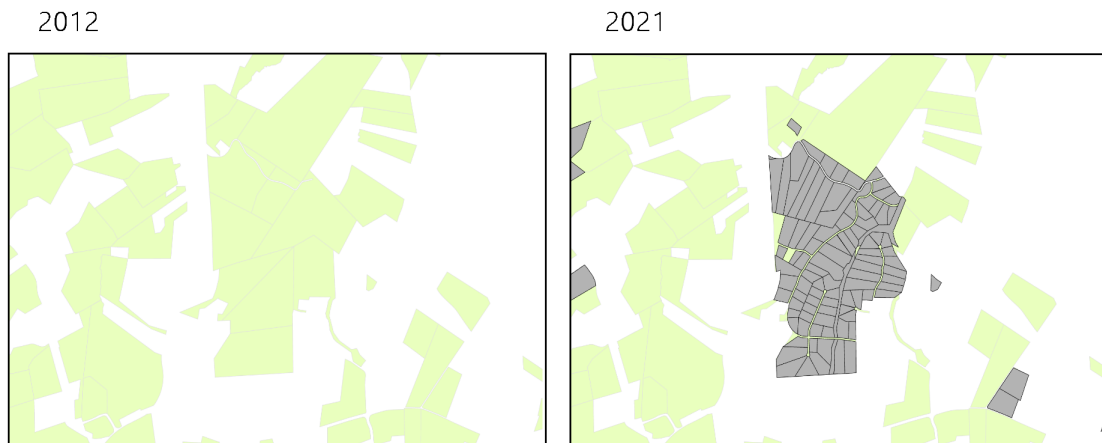


Figure 2.5: Developed Parcels (2012-2021)

2.2 Additional Variables

2.2.1 Conservation

Powhatan County's Department of Information Technology manages much of the county's data. Their Geographic Information System (GIS) Services division produces and maintains the county's geographical data. For this project, they provided data on Powhatan's conserved lands and preservation areas. In particular, they provided maps of Priority Conservation Areas, Protected Lands, and land in Agricultural Forestall Districts.

Over twenty percent of parcels in the final data set are completely within Priority Conservation Areas' bounds. This equates to, on average, 345 parcels a year within PCAs. These parcels were given a one ($PCA = 1$) if entirely within PCAs and a zero ($PCA = 0$) if they were not.

Of the 1,638 parcels in the final data set, there are 30 parcels included in the AFD program and five parcels entirely within the bounds of "Protected Land." Parcels in the AFD program and/or recognized as Protected Land cannot be developed. Therefore, these classifications are not included in the model.

2.2.2 Neighbors

To measure peer effect, information on the size, development status, and land-use classification for adjacent parcels is included in the data set. Parcel's neighbors were first identified using spatial analysis; a neighboring parcel is one where the boundaries touch at any point. On average, each parcel has 4.59 neighbors. Figure 2.6 shows how we determined neighbors based on contiguity. In our data we found that the minimum number of neighbors is one, and the maximum is 136. The parcel with the maximum number of neighbors is depicted in

Figure 2.6. It is an undeveloped piece of land in the center of a residential area. On average, 60 percent of each parcel's neighbors are developed, and 23 percent are within Priority Conservation Areas.

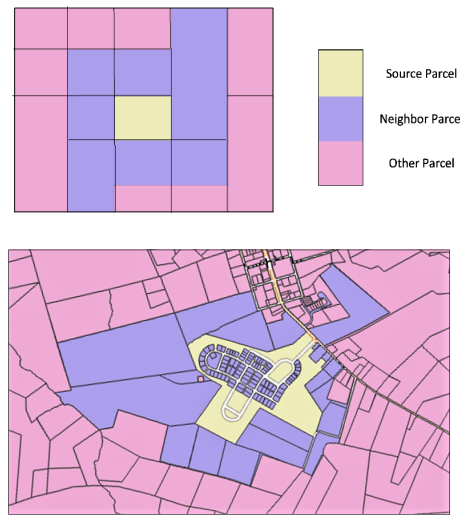


Figure 2.6: Adjacent Parcels

Data on each parcel's neighbors' conservation status, acreage, and land use were added to the data set. The variables created for each parcel include the total acreage of adjacent parcels, the percentage of developed neighbors, and the percent of neighbors in each of the three conservation classifications. For example, if one out of four of your adjacent parcels were included in the AFD, the variable (PercNbrAFD) would equal 0.25. Table 2.5 shows the descriptive statistics for the adjacency variables used in our model. On average, 61 percent of each parcel's neighbors are developed, 23 percent are in PCA, and under 2 percent are included in the AFD program.

Table 2.5: Descriptive Statistics - Neighbors

	Mean	SD
PercNbrDev	.607	.264
PercNbrPCA	.230	.340
PercNbrAFD	.017	.068
lnNbrAcreage	-1.570	1.381
<i>N</i>	6552	

2.2.3 Soil Quality and Crop Layer

Soil quality will affect not only the productivity of the land but could be factor to consider when making land use decisions. It is implausible that developed land can convert back to a natural state. Therefore, developing high-quality land is a practically irreversible decision.

The National Cooperative Soil Survey classifies soil based on its usefulness into eight classes. The original eight classifications were condensed into Good Agricultural Soil, Restricted Agricultural Soil, and Pasture, Rangeland, Wildlife. The Pasture, Rangeland, and Wildlife category comprises soil with severe limitations that are generally unsuited for cultivation. Under six percent of soil in Powhatan falls into this classification. Meanwhile, 31 percent is Good Agricultural Soil; this is the highest soil classification and therefore means the best land in the county. Powhatan County soil is mostly Class 2, defined as restricted but good agriculture solid where crops can be grown.

Table 2.6 shows how we reclassified the soil quality variable into three categories: Good, restricted, and pasture, etc.

The data set also includes crop data from the USDA National Agricultural Statistics Survey. The crop variable indicates which crop is most commonly found within each parcel of land. Approximately 85 percent of the parcels in the data set are Forested. The next most common

Table 2.6: Soil Quality Reclassification

Classification	Definition	Condensed Classification	Percent
1	soils have slight limitations that restrict their use	Good Agricultural Soil	29
2	soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.		
3	soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.	Restricted Agricultural Soil	66
4	soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, or forestland		
5	soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, or forestland	Pasture, Rangeland, & Wildlife	5
6	soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food		
7	soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.		

crop type is forages, with about 200 parcels annually. The third most common is row crops. There are, on average, 46 parcels a year growing row crops, which are typically considered to be high-value crops. Table 2.7 shows the condensed classification of this categorical variable.

2.2.4 Travel

Data from the Virginia Department of Transportation (VDOT) was used to record traffic volume and travel time to Richmond, Virginia. VDOT is responsible for building, maintaining, and operating the state’s roads, bridges, and tunnels. They also gather traffic data from sensors in or along streets, highways, and other sources. This data includes estimates of the average number of vehicles that traveled each segment of the road, and daily vehicle miles traveled for specific groups of facilities and vehicle types. This data provided the metric to understand the traffic volume of roadways in the county. Although Powhatan has no inter-states, the two-state routes that it does have can provide fast travel throughout the county. State Route 60, which runs horizontally through the county, holds much annual traffic.

Table 2.7: Crop Reclassification

USDA Classifications	Condensed Classifications
Developed/Open Space	Developed/None
Developed/Low Intensity	
Developed/Med Intensity	
Developed/High Intensity	
Dbl Crop WinWht/Soybeans	Double cropped
Grassland/Pasture	Forages
Alfalfa	
Other Hay/Non Alfalfa	
Deciduous Forest	Forested
Evergreen Forest	
Mixed Forest	
Shrubland	
Other Crops	Horticulture crops
Grapes	
Christmas Trees	
Barren	Other
Follow/Idle Cropland	
Corn	Row crops
Sorghum	
Soybeans	
Barley	Small grains
Winter Wheat	
Open Water	Water
Woody Wetlands	Wetlands
Herbaceous Wetlands	

2.2.5 Summary Statistics

For this project, Powhatan County provided both spatial data and historical administrative tax data. This was compiled with additional data sets from the Virginia Department of Transportation, USDA and additional public sources. Table 2.8 gives the description for all the variables used in our model as well as their sources. Additionally, table 2.9 gives description statistics for all the non-categorical variables used in our model.

Table 2.8: Variable Descriptions

Variables	Description	Type	Source
Developed	If ag/undeveloped land is developed	Binary	PC
PCA	Land is in Priority Conservation Area	Binary	PC
lnAcreage (Thsnds)	Logged total thousands of acres for parcel		PC
LiveIn	Owner's permanent address is in Powhatan, VA	Binary	PC
WaterFeature	Water feature in parcel	Binary	PC
Soil	Soil quality	Categorical	NCSS
Crops	Type of crop	Categorical	NASS
TrafficVolume	Traffic Volume	Categorical	VDOT
TravelTime	Travel time to Richmond	Categorical	VDOT
TaxAssessedValue	Real Tax Assessed Value parcel		PC
LnNbrAcreage (Thsnds)	Logged thousands of acres of adjacent parcels		PC
PercNbrDev	Percent of total adjacent parcels that are developed		PC
PercNbrAFD	Percent of total adjacent parcels that are in AFD		PC
PercNbrPCA	Percent of total adjacent parcels that are in PCA		PC
Year	Year		PC
CensusGroup	Census group	Categorical	USCB

VDOT-Virginia Department of Transportation, PC - Powhatan County,
 NASS - USDA National Agricultural Statistics Survey, NCSS - USDA National Cooperative
 Soil Survey, UCSB - United States Census Bureau

Table 2.9: Descriptive Statistics

	Mean	SD
Developed	.163	.369
PCA	.210	.407
lnAcreage (Thsnds)	-3.307	1.528
LiveIn	.600	.489
WaterFeature	.319	.466
TaxAssessedValue	4.942	6.488
PercNbrDev	.607	.264
PercNbrPCA	.230	.340
PercNbrAFD	.0171	.068
lnNbrAcreage (Thsnds)	-1.570	1.381

	Number	Percent
Crops		
Water	18	.28
Wetlands	35	.54
Double Cropped	13	.20
Forages	582	8.92
Forested	5,670	86.90
Other	19	.29
Row Crops	188	2.88
Soil		
Good	2,047	31.37
Restricted	4,090	62.68
Other	388	5.95
Travel Time		
Within 30 mins	191	2.93
Within 45 mind	2,147	32.90
Within 1 hr	2,407	36.89
Over 1 hr	1,780	27.28
Traffic Volume		
Lowest - 1	1,744	26.73
2	3,160	48.43
3	440	6.74
4	1,081	16.57
Highest - 5	100	1.53
<i>Total</i>	6525	100

Chapter 3

Methodology

We now move on to discussing our methodology and how it aligns with our research question. To review, we've discussed how communities on the "urban fringe", are experiencing strong pressures to develop. Localities manage this growth while protecting their resources, such as natural land, by implementing conservation policies/preservation guidelines. In this project, we utilize data outlined in the previous chapter to evaluate which factors, such as conservation efforts, affect motivation to develop land.

In this chapter, we will explain how we approached the research using Linear Probability Models. Then we will discuss alternative estimators such as Logit and Probit models. Finally, we will explain how our methodology contributes to the overall reliability of the research.

3.1 Model Development

Our analysis fits a latent variable framework because we are interested in the level of motivation to develop land denoted as *Developed**. This is an unobserved ("latent") continuous variable that drives development decisions. We hypothesize that the motivation to develop is affected by X - a vector of variables such as parcel characteristics, conservation policy, contagion effects, and tax-assessed value. The error term, (u) also known as the residual or disturbance, represents the unexplained variation in the dependent variable that is not accounted for by the independent variables.

$$\text{Developed}^* = X\beta + u \quad (3.1)$$

We do not observe motivation but instead, we observe whether a parcel of land is developed, or not, which we denote as *Developed*. so that,

$$\text{Developed} = \begin{cases} 0 & \text{if } \text{Developed}^* \leq A \\ 1 & \text{if } \text{Developed}^* > A \end{cases} \quad (3.2)$$

where A is the motivation to develop a threshold that needs to be exceeded to observe development of a land parcel. Since we do not observe A we can arbitrarily set it to zero so that,

$$\begin{aligned} P(\text{Developed} = 1|X) &= P(\text{Developed}^* > A|X) \\ P(\text{Developed} = 1|X) &= P(\text{Developed}^* > A|X) \\ &= P(X\beta + u > A) \\ &= P(u > -X\beta) \\ &= P(u \leq X\beta). \end{aligned}$$

This only holds if the error term(u) follows a symmetric distribution with zero mean. These probabilities can be determined by the appropriate assumption of a functional form: the identity function, logistic, or normal distribution which we denote as $F(X\beta)$ in equation 3.3:

$$P(\text{Developed} = 1|X) = F(X\beta) \quad (3.3)$$

Below I outline the methodology for using the identify function or Linear Probability Model,

then the non-linear Probit and Logit models that use the normal and logistic functions.

3.1.1 Specification 1: Linear Probability Models

Equation 3.3 is first implemented empirically using a linear probability framework and estimated using pooled ordinary least squares.

The base specification is Model (1.) and contains only the variable of interest, Priority Conservation Area, denoted as PCA in equation 3.4.

$$P(\textit{Developed}_{i,t} = 1|x) = \beta_0 + \beta_1 PCA_{i,t} + \epsilon_{i,t} \quad (3.4)$$

For the linear probability model, marginal effects can be interpreted as the coefficient on β_1 . So, for example, holding all factors constant, β_1 can be interpreted as the effect of a one-unit change in land in Priority Conservation Areas on the probability that a land parcel is developed. Multiplying the coefficient by 100 gives the percentage.

In model (2), we include the parcel characteristics recorded in the administrative tax data. This includes variables $\ln\text{Acre}$, WaterFeature , LiveIn , and TaxAssessedValue described in 2.8. First, we'll discuss the addition of a parcel acreage; this variable was measured in thousands of acres. The relationship between a parcel's development status and acreage may be non-linear. The effect of a relatively small parcel, let's say a one-acre parcel, increasing by one acre is greater than the effect of a larger acre, let's say a 200-acre property, increasing to a 201-acre property. Therefore acreage is logged. Model (2.) also controls for LiveIn , a binary variable indicating if the land owner lives in Powhatan, which could affect development motivation.

Model (2.) also adds a term to control for the tax-assessed value of each parcel. This value

was converted to the real price to control inflation in terms of 2021, using data from the Bureau of Labor Statistics using the following equation 3.5:

$$TaxAssessedValue_{2012} = TaxAssessedValue_{2012} \times CPI_{2021} \div CPI_{2012} \quad (3.5)$$

Land price is a primary motivator for land conversion. However, this variable is unobserved. Therefore, tax-assessed value is used as a proxy variable for land value. However, Powhatan bases its tax-assessed value on various factors, including size, location, and land-use classification. This explains a potential problem with the usage of this variable due to potential multicollinearity. Therefore, we analyzed the correlation coefficients to summarize the relationship between TaxAssessedValue and other variables in the model, see A.2 for the correlation matrix. Due to this potential multicollinearity, casual inferences will be avoided. Additionally, robust standard errors will be utilized to help avoid biased standard errors and misleading t-values. Model (2) is outlined in equation 3.6:

$$P(Developed_{i,t} = 1|x) = \beta_0 + \beta_1 PCA_{i,t} + \beta_2 \ln(Acre)_{i,t} + \beta_3 LiveIn_{i,t} + \beta_4 WaterFeature_{i,t} + \beta_5 TaxAssessedValue_{i,t} + \epsilon_{i,t} \quad (3.6)$$

The following specification estimated in equation 3.7 and which we call Model (3.) adds data on site-specification attributes. This includes the parcels' soil quality, crops, proximity to Richmond, and traffic volume. Traffic volume allows us to control proximity and connectivity. Soil quality can affect the productivity of the land; this is evidence that soil quality could be a factor considered when making land use decisions. Also, agriculture plays a pivotal role in Powhatan's economy. Therefore crop layer was added to the model. Finally,

traffic volume and travel time to Richmond were included in the model to control for the distance from both the county and city center.

$$P(\text{Developed}_{i,t} = 1|x) = \beta_0 + \beta_1 \text{PCA}_{i,t} + \dots + \beta_6 \text{TrafficVolume}_i + \beta_7 \text{TravelTime}_i + \beta_8 \text{Crop}_i + \beta_9 \text{Soil}_i + \epsilon_{i,t} \quad (3.7)$$

The following specification estimated in equation 3.8, which we call Model (4.), adds data on neighboring parcels. These variables account for the contagious nature of the land conversion process and conservation easements. First, the adjacent parcels' acreage is controlled for. The relationship between a parcel's development status and its neighbors' acreage is nonlinear, similar to a parcel's acreage. Therefore, the neighbor's acreage is logged. The percent of adjacent parcels in AFD and PCA were also included to account for the contagion effect of these conservation districts.

$$P(\text{Developed}_{i,t} = 1|x) = \beta_0 + \beta_1 \text{PCA}_{i,t} + \dots + \beta_{10} \ln \text{NbrAcreage}_{i,t} + \beta_{11} \text{PercNbrAFD}_{i,t} + \beta_{12} \text{PercNbrPCA}_{i,t} + \epsilon_{i,t} \quad (3.8)$$

Our final specification is outlined in equation 3.9 which we call Model (5.) we exploit the panel nature of the data set by including both time and district-level fixed effects. We also include an interaction term between time and spatial fixed effects to control for any unobserved variables within districts, over time.

$$P(\text{Developed}_{i,t} = 1|x) = \beta_0 + \beta_1 \text{PCA}_{i,t} + \dots + \beta_{13} \text{CensusGroup} * \text{Year}_{i,t} + \epsilon_{i,t} \quad (3.9)$$

3.1.2 Alternative Estimators: Logit and Probit Models

The linear probability model does not restrict the estimated response probabilities to lie between zero and one. Therefore, a linear probability model can result in predicted values outside the zero- one range. We also correct an inherent heteroskedasticity problem using White's correction. Nevertheless, we implement two additional empirical models: a Logit and a Probit to observe how robust our findings are to the estimator used.

To motivate this specification, we consider a more general version of equation 3.3

$$P(\text{Developed} = 1|X) = F(\beta, X) \quad (3.10)$$

where $F()$ F is the logistic function or the standard normal cumulative distribution function.

For shorthand purposes, let,

$$Z = \beta_0 + \beta_1 X_i + \dots + \beta_n X_n \quad (3.11)$$

A Logit model can be represented using the following formula:

$$P(\text{Developed} = 1|X) = \frac{\exp(Z)}{1 + \exp(Z)} \quad (3.12)$$

A Probit model can be represented using the following formula, where ϕ is the cumulative

distribution function:

$$P(\textit{Developed}^* = 1|X) = \phi(Z) \quad (3.13)$$

All three specifications: linear probability, Logit, and Probit were estimated and the results are presented and discussed in the next chapter. Note that with a non-linear model, the estimates of β cannot be interpreted as marginal effects. We, therefore, predicted the marginal effects at the mean of X and present these predicted values to allow comparison with the linear probability model. In addition, we used the delta method to estimate standard errors for the marginal effects.

3.1.3 Hypothesis Testing

We will be using hypothesis test to evaluate if there is any relationship between land in Priority Conservation Areas and motivation to develop. This is due to the possibility of a positive and negative relationship between land in PCA and motivation to develop. For example, being included in PCAs could establish enough regulatory guidelines that it restricts development. However, PCA could also encourage development since it categorizes the county's "attractive" and crucial land features. Therefore, I am using a two-sided hypothesis test to determine if there is a significant effect in either direction, either negative or positive.

The null hypothesis (H_0) is that there is no relationship between land in Priority Conservation Areas and motivation to develop. The alternative hypothesis (H_1) is that there is a relationship between the two variables.

The relevant hypothesis test is:

$$\begin{aligned} H_0 : \beta_1 &= 0 \\ H_1 : \beta_1 &\neq 0 \end{aligned} \tag{3.14}$$

I expect that we will reject the null hypothesis, in favor of the alternative, β_1 will not equal zero. This would indicate that the inclusion of land in Priority Conservation Areas has an effect on motivation to develop. We will be using a F-test for the OLS model and the Wald test for the probit model. Testing at the $\alpha = 0.05$ level.

Additionally, the literature shows that for an accurate evaluation of development to be conducted, you must account for the contagion or peer effect. This refers to the impact that a social network, in this case neighboring parcels, has on others' decisions. This project assesses the impact of the contagion effects on motivation to develop. Therefore, we use a likelihood ratio test to ensure that these variables belong in the model. The null hypothesis (H_0) is that variables on a parcel's neighbors (PercNbrAFD and lnNbrAcreage) have no significant effect on the dependent variable. While the alternative hypothesis (H_1) is that at least one of these variables has a significant effect. This effect can be positive or negative.

The relevant hypothesis test is:

$$\begin{aligned} H_0 : \beta_9 &= \beta_{10} = \beta_{11} = 0 \\ H_1 : \text{At least 1, } \beta_{9-11} &\neq 0 \end{aligned} \tag{3.15}$$

Due to the existing literature on peer effect in land development, I predict that I will reject the null hypothesis in favor of the alternative. We will be testing this at the $\alpha = 0.10$ level.

Chapter 4

Results

In this chapter, we present empirical implementations of the estimators outlined in Chapter 3. We start by presenting and discussing the Linear Probability Models. We then move to discuss the results from different estimators.

4.1 Linear Probability Models

Along with the dependent variable *Developed**, the primary variable of interest is PCA. This variable is defined in 2.9 as Priority Conservation Areas which are land the county deems important to preserve and protect. A simple one-variable model estimated using POLS is shown in Table 4.1, Model (1). Results of this model suggest that, with no other controls, land in PCA is associated with a 4.9 decrease in the probability of land being developed at the $\alpha = 0.01$ percent significance level.

Table 4.1, also shows regression results for alternative linear probability model specifications with varied control variables. As explained in Chapter 3, Model (2) adds additional variables to control for parcel characteristics. An F test of joint significance suggests that these additional variables significantly impact the dependent variable. Similar to Model (1), a parcel is less likely to be developed if it is within the bounds of PCA. Additionally, the parcel is less likely to be developed if the owner lives in Powhatan County or if the parcel contains a water feature. These effects are both significant at the $\alpha = 0.01$ percent significance level.

Table 4.1: OLS Regression Results

	Model 1	Model 2	Model 3
PCA	-0.049*** (0.010)	0.008 (0.007)	0.000 (0.007)
lnAcreage		-0.222*** (0.003)	-0.232*** (0.003)
LiveIn		-0.026*** (0.006)	-0.020*** (0.006)
WaterFeature		-0.014** (0.005)	-0.017*** (0.006)
TaxAssessedValue		0.016*** (0.001)	0.019*** (0.001)
Other Controls ^a		X	X
_cons	0.174*** (0.005)	-0.635*** (0.012)	-0.819*** (0.030)
<i>N</i>	6525	6525	6525
<i>R</i> ²	0.003	0.603	0.610
adj. <i>R</i> ²	0.003	0.603	0.609
F	21.983	1243.234	341.026

^a Soil Quality, Traffic Volume, Travel Time, Crop Layer

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The final specification presented in Table 4.1, Model (3), accounts for site-specific attributes of the parcel. A t-test of joint significance provides evidence that these variable impacts the dependent variable.

Two additional specifications are presented in Table 4.2. Model (4), accounts for the contagion effect by including PercNbrAFD, PercNbrPCA, and lnNbrAcreage, defined in Table 2.9. The literature shows that for an accurate evaluation of development, you must account for the contagion effect of development and preservation strategies. An F test was

conducted, the F value is 23.91, and the p-value associated with this value is 0.000. This provides evidence that at least one of the peer effect variables (PercNbrPCA, PercNbrAFD, lnNbrAcreage) significantly affects the dependent variable.

In Model (5), we control for interaction between year-fixed effects and census group-fixed effects. This accounts for differences across districts and time not observed in the data set. Again, a t-test of significance suggests the fixed effects enhance the model's fit.

In the next section, I compare models to see how robust the results are to estimators that are robust to outliers and heteroscedastic.

4.1.1 Comparison of Estimators

While we can correct the standard errors in the linear probability model, the Probit and Logit models do not violate the homoskedasticity assumption by construction. Table 4.3 shows OLS, Probit and Logit results with Model (5) controls. OLS assumes a constant marginal effect and the coefficients are equal to the marginal effects. The marginal effects for the Logit and Probit models need to be estimated at particular values of the variables – in this case, the mean. Table 4.3 shows the average marginal effects' sign and significance are inconsistent across the linear and non-linear models. As expected, there is consistency across the Probit and Logit models. Given these results, our explanation will be based on the Probit specifications.

4.1.2 Probit Model Results

Using the same latent variable model, the Probit model assumes the relationship between the independent and dependent variables is nonlinear and follows a cumulative normal dis-

Table 4.2: OLS Regression Results

	Model 4	Model 5
PCA	-0.006 (0.010)	-0.004 (0.009)
lnAcreage	-0.224*** (0.004)	-0.214*** (0.004)
LiveIn	-0.022*** (0.006)	-0.022*** (0.006)
WaterFeature	-0.016*** (0.006)	-0.029*** (0.006)
TaxAssessedValue	0.018*** (0.001)	0.018*** (0.001)
PercNbrAFD	0.264*** (0.048)	0.162*** (0.046)
PercNbrPCA	0.013 (0.013)	0.005 (0.013)
lnNbrAcreage	-0.014*** (0.003)	-0.008*** (0.003)
CensusGroupxYear FE		X
Other Controls ^a	X	X
_cons	-0.395*** (0.034)	-1.005*** (0.045)
<i>N</i>	6525	6525
<i>R</i> ²	0.612	0.660
adj. <i>R</i> ²	0.609	0.658
F	386.120	292.666

^a Soil Quality, Traffic Volume, Travel Time, Crop Layer
Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.3: Average Marginal Effects For 3 Estimators

	(1)	(2)	(3)
	OLS	Logit	Probit
PCA	-0.004 (0.009)	0.025*** (0.008)	0.020** (0.010)
lnAcreage	-0.214*** (0.004)	-0.125*** (0.005)	-0.129*** (0.005)
LiveIn	-0.022*** (0.006)	-0.006 (0.004)	-0.006 (0.005)
WaterFeature	-0.029*** (0.006)	-0.004 (0.005)	-0.008 (0.006)
TaxAssessedValue	0.018*** (0.001)	0.003*** (0.001)	0.004** (0.001)
PercNbrAFD	0.162*** (0.046)	0.039** (0.020)	0.061** (0.025)
PercNbrPCA	0.005 (0.013)	-0.021** (0.010)	-0.014 (0.012)
lnNbrAcreage	-0.008*** (0.003)	0.000 (0.002)	0.000 (0.002)
Other Controls ^a	X	X	X

^a Soil Quality, Traffic Volume, Travel Time, Crop Layer,

CensusGroupxYear FE

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

tribution. The model estimates the coefficients of the independent variables. We then use the model to estimate marginal effects for the average parcel and standard errors using the delta method. Table 4.4 shows the results for the estimated marginal effects.

As explained in Chapter 3, Model (1) is the base econometric model. Model (2) adds additional variables to control for parcel characteristics. A likelihood ratio test was used to evaluate the additional controls. The likelihood ratio chi-squared (χ^2) is 4692.47 with a p-value of 0.000. This provides significant evidence that the inclusion of the parcel characteristic variables significantly improved the fit of the model. Model (3) accounts for the parcel's site-specific attributes. A likelihood ratio test was used to evaluate the additional controls and provided evidence that these variables enhance the model's fit.

Model (4) accounts for the contagion effect by including PercNbrAFD, PercNbrPCA, PercNbrDev, and lnNbrAcreage, defined in Table 2.9. The literature shows that for an accurate evaluation of development, you must account for the contagion effect of development and preservation strategies. A likelihood ratio test was conducted, the χ^2 value for the contagion effect variables is 6.93, and the p-value associated with this value is 0.0740. This provides evidence, at the $\alpha = 0.10$ significance level, that adding these variables (PercNbrDev, PercNbrPCA, PercNbrAFD, lnNbrAcreage) improves the fit of the model. In Model (5), we control for interaction between year-fixed effects and census group-fixed effects, see A.3 for additional analysis of adding year and census group fixed effects. A likelihood ratio test was used to evaluate the additional controls and provides evidence that the interactive fixed effect is the best fit for the model.

In model (1), the base economic model, the effect of the Priority Conservation Area variable is statistically significant and shows that inclusion in PCA is associated with a 0.051 decrease in the probability of the dependent variable taking the value of one, $Developed^* = 1$. In other words, these results show a negative correlation between a parcel of land being included

in Priority Conservation Areas and being developed. In models, (2) through (5), the sign of the coefficients on this variable, PCA, flips. This indicates that, all else being equal, the inclusion in PCA is associated with an increase in the probability of being developed. Models (2) through (4) show no statistical significance at the $\alpha = 0.05$ level. However, in Model (5.), the effect of the Priority Conservation Area variable is statistically significant at the $\alpha = 0.05$ level. This shows that the inclusion in PCA is associated with a 0.020 decrease in the probability of the dependent variable taking the value of one, $Developed^* = 1$. In Model (5.) the likelihood ratio chi-squared (χ^2) of 4749.20 with a p-value of 0.000 tells us that our model as a whole is statistically significant; that is, it fits significantly better than a model with no predictors.

We will test the relevant hypotheses using the results from the Probit model with Model (5.) controls.

The relevant hypothesis is:

$$\begin{aligned} H_0 : \beta_1 &= 0 \\ H_1 : \beta_1 &\neq 0 \end{aligned} \tag{4.1}$$

The null hypothesis (H_0) is no relationship between land in Priority Conservation Areas and development motivation. The alternative hypothesis (H_1) is no relationship between the two variables. I reject the null hypothesis in favor of the alternative hypothesis that 1 does not equal zero at the $\alpha = 0.05$ percent level.

Additionally, we hypothesize:

$$\begin{aligned} H_0 : \beta_9 &= \beta_{10} = \beta_{11} = \beta_{12} = 0 \\ H_1 : \text{At least 1, } \beta_{9-12} &\neq 0 \end{aligned} \tag{4.2}$$

Table 4.4: Probit Regression Results - Average Marginal Effects

Table 4.5: Average Marginal Effects

	(1)	(2)	(3)	(4)	(5)
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
PCA	-0.052*** (0.012)	0.006 (0.004)	0.008 (0.005)	0.007 (0.008)	0.020** (0.010)
lnAcreage		-0.115*** (0.004)	-0.114*** (0.004)	-0.112*** (0.005)	-0.129*** (0.005)
LiveIn		-0.003 (0.005)	-0.001 (0.004)	-0.002 (0.004)	-0.006 (0.005)
WaterFeature		-0.010** (0.004)	-0.008* (0.005)	-0.007 (0.005)	-0.008 (0.006)
TaxAssessedValue		0.002* (0.001)	0.001 (0.002)	0.001 (0.002)	0.004** (0.001)
PercNbrAFD				0.072*** (0.020)	0.061** (0.025)
PercNbrPCA				0.001 (0.010)	-0.014 (0.012)
lnNbrAcreage				-0.001 (0.002)	0.000 (0.002)
CensusGroupxYear FE					X
Other Controls ^a		X	X	X	X
<i>N</i>	6,525	6,525	6,525	6,525	4,887

^a Soil Quality, Traffic Volume, Travel Time, Crop Layer

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The null hypothesis (H_0) is that the contagion effect variables (PercNbrDev, PercNbrPCA, PercNbrAFD, lnNbrAcreage) have no significant effect on the dependent variable. While the alternative hypothesis (H_1) is that at least one of these variables has a significant effect. A likelihood ratio test was conducted, the χ^2 value for the contagion effect variables is 6.93, and the p-value associated with this value is 0.0740. This provides evidence, at the $\alpha = 0.05$ significance level, that adding these variables (PercNbrDev, PercNbrPCA, PercNbrAFD, lnNbrAcreage) does not improve the fit of the model. Therefore, I reject the null hypothesis in favor of the alternative hypothesis that at least one of these variables has a significant effect at the $\alpha = 0.10$ percent level.

Chapter 5

Conclusion

This research is built on previously constructed land development models and aims to assess the impact of conservation and preservation strategies on the motivation to develop the land. This research is done at the parcel level in Powhatan County. In particular, we are analyzing the recognition of PCAs as well as the contagion effect of the AFD program. Landowners voluntarily enter the AFD program and receive tax breaks in exchange for the development rights of their property. Thus, land that remains in the AFD is not under development pressure. Parcels in PCA are recognized as land well-suited for inclusion in the AFD. These areas include critical wildlife habitat, old-growth woodlands, wetlands, sensitive soils, and other features which contribute to the ecological health and beauty of Powhatan County.[20]

The county deems Priority Conservation Areas essential to preserve and protect. However, the conservation of these lands relies on land development guidelines. These guidelines aim to protect and preserve these environmental resources.[20]. However, these guidelines are loose. Therefore, the analysis of PCAs on development motivation is essential in order to understand the risk of development on the county's critical land features.

This research shows there is a significant effect between being included in Priority Conservation Areas and the motivation to develop. This is true when controlling for all other variables, such as Tax Assessed Value, Proximity to Richmond, soil quality, and crop layer. The goal of PCA is to establish which parcels should be conserved. Therefore, finding a negative correlation between land included in PCAs and development motivation would be

optimal. In the case of negative correlation, it could be argued that the regulatory guidelines that come with being included in PCAs restricts development. However, we find a positive correlation between being included in PCA and development motivation. I will argue that this is a result of the loose regulatory guidelines. Additionally, I will argue that being included in Priority Conservation Areas indicates if a parcel is "attractive" and contains crucial land features. This recognition may inadvertently signal the land's value and increase demand which could further explain why we observe a positive association between inclusion in PCA and development motivation.

The County acknowledges that Priority Conservation Areas "should be protected in the future."^[20] However, these results provide uncertainty that the current guidelines provide adequate protection. This is critical because the potential development of the County's most valuable land would be difficult, if possible, to reverse.

Additionally, this paper aimed to assess the contagion effects of the county's preservation strategies. Previous literature established that impacts of contagion effects must be anticipated for an accurate evaluation of preservation to be conducted. This research align with this conclusion.

In conclusion, being included in PCA has an affect on parcel development. Additionally, there is an observed peer effect in land development. These conclusions have potentially strong policy implications and lead to interesting research questions. There is heavy pressure to develop farming, forest, and open space, to residential, commercial, or industrial land. With all the services, risks, and problems associated with uncontrolled growth, it is probable that local officials will continue to work to manage their land resources. This is especially true in regards to the county's most valuable land since it's development would be difficult, if possible, to reverse. With local officials working to slow down or direct urbanization on the urban fringe, more robust policy analysis is needed to ensure efficient and inclusive policy

effects.

Appendices

Appendix A

A.1 Data Cleaning

Powhatan County’s Department of Information collects geographic, property, and zoning data on each parcel/property within the County. The county provided Geographic Information System (GIS) maps and data for this project. The data is collected annually and contains information on parcel shape, size, area, and location as well as property lines, boundaries, zoning, and property assessments, as well as information on the property owner. My data is a balanced panel that tracks $N = 15,478$ panel members over $T = 4$ time periods from 2012 to 2021. The data is in 3-year increments, including data from 2012, 2015, 2018, and 2021. The number of observations in the dataset is $n = 61,912$. The administrative tax data provided by Powhatan County was spatial data for the 4 time periods of interest ($t = 2012, 2015, 2018, 2021$). To analyze the parcels over time, I had to merge the 4 data sets to create panel data. In 2012, there were 14,820 parcels recorded in Powhatan County. By 2021, there were 15,465 parcels. Given the different numbers of parcels by year in Powhatan County, creating a balanced data set requires data manipulation. Creating a balanced panel allows one parcel to be observed in every period. I had to apply methods to handle this unbalanced panel and reformat the data so that all 15,456 parcels could be tracked through the four time periods. First, I started by importing administrative tax data in 2021 and combined it with the 2018 data using the parcel’s record number. The parcel’s record number is a unique identifier (ID) for each piece of land consistent through the four time periods for 15,102 of the 15,456 parcels in 2021. Table 1 shows three parcels, $n=1,2,3$, with consistent

record numbers in 2018 and 2021. The parcels that could be tracked through time by record number/ID were saved.

Table A.1

ID (2018):	ID (2021):
1	1
2	2
3	3

After the 2021 data was combined with the 2018 data by record number, 419 parcels could not be tracked over time by record id. This could happen when a parcel’s ownership, usage, or boundaries change between the combined periods. For example, new parcels that split from a parent parcel were given a new record number. I will be using the term “parent parcel” to reference a piece of land in the base period ($t = n$) and the term “children parcel” to reference the same piece of land in a later period ($t = n + 1$). There were 55 parcels of land in 2018 whose record number/ID did not appear in the 2021 data set. The 355 parcels of land from the 2018 administrative data set could not be tracked forward to their children parcels. Therefore, I had to separate these parcels from the 2018 data set and spatially merge them with the 2021 parcels. The parcels whose record number was found in 2018 but not in 2021 were separated, and their location was used to merge them with the 2021 data spatially. This process tied these parcels to their children parcels in 2021. An example is an agricultural piece of land with a specified record number, say $n=4$ in $t=2018$. Between 2018 and 2021, this piece of land was split into two residential parcels, and they were given two new record numbers, say $n = 7, 8$. Spatially merging the 2018 lost parcels with the 2021 data allows us to track the parent parcel of the 2021, $n = 2$ and $n = 3$, residential parcels. The data set now includes: Additionally, there were 364 parcels whose record number in 2021 was not found in the 2018 data set; therefore, these pieces of land could not be tracked through time by record number. When 2018 and 2021 data were combined by record number, these 364

Table A.2

ID (2018):	ID (2021):
4	7
4	8

parcels from the 2021 administrative data set could not be tracked back to the parent. The parcels with a record number that was found in 2021 but not in 2018 were separated from the 2021 data set. These 364 2021 tax parcels were spatially joined with the 2018 parcels to locate their parent parcel. An example of this occurrence is two residential parcels $n = 5, 6$ that split off from a larger agricultural parcel say $n = 9$. The data set now includes the following: I then combined the parcels merged by record number with the spatially merged

Table A.3

ID (2018):	ID (2021):
5	9
6	9

data sets, cleaning out any duplicates.

Combined, the data set now include the following:

Table A.4

ID (2018):	ID (2021):
1	1
2	2
3	3
4	7
4	8
5	9
6	9

Finally,

A.2 Correlation Matrix

Correlation matrix testing for multicollinearity in Tax Assesed Value.

Table A.5: Correlation Matrix

	TaxAssessedValue	PCA	lnAcreage	WaterFeature	SoilQuality	Crops
TaxAssessedValue	1.00					
PCA	-0.05	1.00				
lnAcreage	0.61	0.05	1.00			
WaterFeature	0.12	-0.02	0.26	1.00		
SoilQuality	-0.03	0.01	-0.05	0.07	1.00	
Crops	0.09	0.03	0.29	0.05	-0.03	1.00

A.3 Probit - Fixed Effects

Probit marginal fixed effects results while moving from Model (4) controls to Model (5). Model (5) adds fixed effects. This table presents the results for Model (4) with no fixed effects, then testing the effects of adding year fixed effects, census tract fixed affects, then an interaction between year and census tract fixed effects.

Table A.6: Probit - Fixed Effects

	Model (4)	Year FE	Census FE	Model (5)
PCA	0.235 (0.202)	0.266 (0.226)	0.350* (0.198)	0.420* (0.221)
Year FE		X		
Census FE			X	
YearxCensus FE				X
_cons	-12.017*** (0.935)	-13.055*** (0.989)	-11.720*** (0.962)	-12.815*** (1.073)
<i>N</i>	4887	4887	4887	4887
r2_p	0.829	0.844	0.831	0.849
chi_2	348.91	332.09	369.76	413.43

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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