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Fringe Benefits

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Abstract
This study tests the hypothesis that increased rugosity (the ratio between urban perimeter and farmland area) of the rural-urban fringe allows farms to create greater value for their regions through greater access to urban markets. Findings show that increased rugosity is not associated with farmland loss despite correlating with greater population growth. Rugosity is, instead, associated with higher agricultural sales per acre and more farm-to-city networks. Using the urban interface as a variable to understand farm production and stabilization, this paper includes a spatial statistical analysis of county-level metro-area farm products, farmland loss, and demographics in relation to the concentricity of urban morphology in the United States. Four case studies reveal spatial and social network patterns of direct farm sales and donations of raw product. Farm-to-city market director interviews ground-truth these farm-city functions in relation to county and state-level policies that govern urban and farmland morphologies and function.

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FRINGE BENEFITS

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FRINGE BENEFITS

DEDICATION

To Leif, who has been with me since the beginning of this process. I look forward to many more years of making sense of the world together. Love, momma.

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ABSTRACT

FRINGE BENEFITS

Catherine Brinkley

Professor Thomas Daniels

This study tests the hypothesis that increased rugosity (the ratio between urban perimeter and farmland area) of the rural-urban fringe allows farms to create greater value for their regions through greater access to urban markets. Findings show that increased rugosity is not associated with farmland loss despite correlating with greater population growth. Rugosity is, instead, associated with higher agricultural sales per acre and more farm-to-city networks. Using the urban interface as a variable to understand farm production and stabilization, this paper includes a spatial statistical analysis of county-level metro-area farm products, farmland loss, and demographics in relation to the concentricity of urban morphology in the United States. Four case studies reveal spatial and social network patterns of direct farm sales and donations of raw product. Farm-to-city market director interviews ground-truth these farm-city functions in relation to county and state-level policies that govern urban and farmland morphologies and function.

Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. Introduction

Many people perceive a need to protect peri-urban farming because it operates with high resource efficiency on prime agricultural soils and produces local food and valuable ecological services. In the US, metropolitan statistical areas have more total prime agricultural soils than do rural areas (USDA, 2007). Prime farmland produces the highest agricultural yields with minimal inputs of energy, water and economic resources, and farming it results in the least damage to the environment. Metropolitan area farms account for 91% of all fruits, nuts and berries production; 78% of vegetables, 67% of dairy, and 54% of poultry and eggs production though these "urban influenced counties" contain only 20 percent of the total U.S. farmland (2007 Census of Agriculture, USDA Economic Research Service). Internationally, peri-urban commercial farming plays a significant role in food security for developing countries and is in the direct path as rapidly developing cities expand (FAO, 1999). As the world population continues to grow and become more urban, concerns will increase about adequate food supplies and healthy metro areas, necessitating more attention to preserving valuable peri-urban farming areas while considering how to grow urban areas in conjunction (Brouwer and McCarl, 2006).

Scholars have thoroughly documented the tensions brought by urban growth that intrudes into farmland. While many planners argue that in order to preserve financially active center cities and control sprawl (low-density development), planners must carefully guide urban land use in surrounding rural areas (OECD, 1979; Daniels, 1999; Rusk, 1999). Others, especially city managers and developers act differently, pushing development onto inexpensive fringe land. Because most urban centers are sited on fertile agricultural land in coastal plains or river valleys, when they expand they convert prime farm land to building sites (Bogue, 1956). Moreover, new urban settlements often consider nearby farming practices as unwanted nuisances. While also picturesque, farms can be associated with noise, dust, and odors causing conflicts and legal battles between farmers and non-farm neighbors (Lopez et al, 1988; Schwab 1998; Kim, Goldsmith, and Thomas 2009). With this line of thought, planners seek to minimize the interactions between rural farming land-uses and urban uses, calling for buffer zones between urban and farmland uses and concentric urban edges that minimize conflicting land-use abutments.

In the recent decades, to limit urban development on farmland and rural-urban tensions, planners gave considerable attention to managing a compact urban morphology with distinct separations between urban and farm lands (Daniels, 1997; Furseth and Lapping, 1999). Noting the friction between farm and urban communities, planners have developed tools to maintain farm and urban land function through growth management practices. These practices take two principal forms: formal mandatory regulation including urban growth boundaries, urban limit lines, annexation limits, and agricultural zoning; and less formal voluntary efforts, featuring the purchase and donation of development rights to public agencies and private land conservancies. While not explicitly stated, many of these policies do not seek to intentionally increase the rural-urban interface nor interlace rural and urban lands but seek to keep urban and farm lands separate and even buffer their interfaces.

Only recently have scholars noted some of the benefits peri-urban farming for nearby urban areas. In addition to food production, peri-urban farms have adapted ancillary programs for energy, waste management, recreation, and education to remain financially solvent near expanding metro areas (Brinkley, 2012). Farmland also provides non-market benefits to urban areas through amenity values of open space and rural character, slowing suburban sprawl, increasing wildlife habitat, and enabling such important ecosystem functions such as groundwater recharge (Gardner 1977; Wolfram 1981; Fischel 1985; McConnell 1989; Bromley and Hodge 1990; Nelson 1992; Kline and Wichelns 1998; Duke and Aull-Hyde 2002). Farmland proximity to urban areas can increase urban access to these ecosystem services. Considering the impact of rural-urban proximity as a landscape issue necessitates attention to three dimensional consideration of form and function, not only proximity of the land uses. Considering farmland as a valuable ecosystem capable of correcting for urban deficits in clear air, clean water and recreational opportunity, planners have yet to study the impact of weaving these complimentary land-uses together to maximize abutment.

Regrettably, many planners guide urban morphology without understanding fully how its form impacts peri-urban farm functions *or* urban functions (Irwin and Nickerson, 2003; Bergstrom and Ready, 2009). This work will analyze urban form as it relates to the function of peri-urban farm services. The underlying assertion tested in this research is that urban areas that are more physically intertwined with their peri-urban farmlands will collaborate more, resulting in both an increase in the farm amenity services and decreased rates of urban sprawl as the surrounding farmlands are valued for the amenities they provide. This study tests the novel hypothesis that the greater farm-urban interface, the greater urban and farm value generation through proximity of amenity destinations, decreased sprawl, social networking around local food, and organic infrastructure services that connect cities to their hinterlands.

This hypothesis about form and function is explored through the ecological concept of rugosity (Figure 1), the measurement of a functional surface's boundary with an environment through which it absorbs nutrients or exudes waste. In ecology, the measurement of a coral reef's rugosity (exterior roughness) is useful as an indicator of surface area available for nutrient transport. Similarly, the rugosity of the seafloor may indicate the amount of habitat available for colonization by benthic organisms. In this study, the rugosity of an urban area in relation to farmland may indicate the amount of farm-city interactions, where more urban rugosity indicates greater farm-city collaboration. Testing different measurements of rugosity against U.S. county datasets, rugosity is related to demographics, farm product, and farmland loss. Farm-city program coordinator interviews and planning document review reveal how land-use planning controls the urban morphology and impacts rural-urban collaborations.

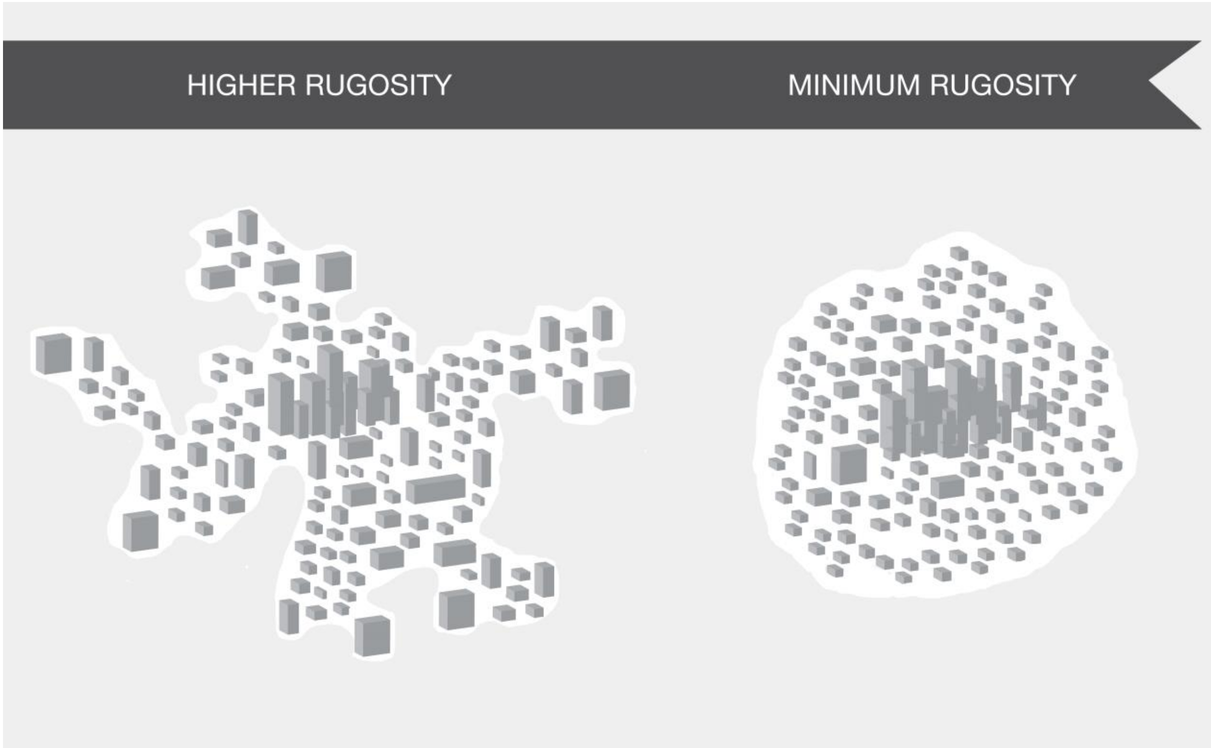

Figure 1. Rugosity Visualization. Higher rugosity (left) and minimum rugosity (right) for the same urban area (shown in white with simulated buildings) as compared to the rural area (shown in gray). Higher urban rugosity can be achieved by maximizing the interface between rural areas and natural/rural lands through implementation of greenbelts, green wedges, and wildlife habitat corridors. Higher densities on the urban interface will also increase the functional rugosity of the urban area. Image courtesy of Elizabeth Brinkley.

CHAPTER 2. Rugosity Derived from Spatial Ecological Theory

The rugosity theory of urban growth has antecedents in some of the more modern spatial ecological theories and the study of landscape ecology. Landscape ecology links growth and shrinkage of organism colonies to resource feedback loops that subsequently influence the landscape and evolutionary trajectories of those particular colonies as they co-evolve with their ecosystem (Wu & Loucks 1995). City morphology in relation to surrounding ecosystems is similarly being studied since the late 1980s when Forman and Godron (1986) published their seminal text on landscape ecology, bridging spatial ecology scientific interests — typically focused on heterogeneity in ecosystems — with more anthropocentric scientific traditions of geography, landscape architecture, and planning, rooted in the long history of human-based landscape alteration.

The subsequent study of urban morphology and spatial ecologies are made up of several ecological theories. Holling (1992) proposes that organisms and even communities of organisms have evolved physical and behavioral characteristics to exploit the environmental texture of their landscape in the same way that many resources have shaped city growth and form. Urban historian, William Cronon, has neatly summarized how transit lines and crop production has impacted the size and function of various cities (Cronon, 1991). Similarly, Holling's textural discontinuity hypothesis (TDH) posits that because resource distribution is discontinuous across landscapes, colonies, like cities should reflect this pattern and exhibit discontinuities consistent with the changes in the scale of resource availability. Ecosystems and city systems often form specific spatial patterns in response to their environments and available resources (Marshall, 1997; Milne et al., 1992; O'Neill et al., 1991). The concept of rugosity can be thus used to explain ontologically how and why cities form certain morphologies in response to their resources. Yet, because urban morphologies are as much a consequence of as an influence on their resources, the rugosity could also explain the efficient uptake and use of resources, such as farmland amenities. To this end, the concept of rugosity may also be useful in guiding urban growth to take better advantage of local ecosystem services.

The concept of rugosity is also closely related to the study of landscape spatial heterogeneity (Turner 2005). Considering urban or agricultural land-uses as patches on a landscape, the form, critical mass, and relationship of patches of different land uses or ecosystems to one another has been shown to influence individual patch survival while also influencing the larger network of patch composition (Cushman *et al.* 2010). Landscape concepts regarding loss and fragmentation of vegetation cover around the world have become fundamental to understanding the carbon cycle, and predicting the consequences of global climate change (Houghton 1995). In their quest to understand ecosystem patch survival, scientists are developing a unified framework to understand the dynamic flows of materials between urban and farmland ecosystems such as water, nutrients, and chemicals, both in time and space (Costanza *et al.* 2002). The ideas can be applied in suggesting strategies for managing the flows of desirable and undesirable materials between landscapes to influence soil fertility and erosion, or nutrient cycling and pollution. In the following study, farm networks for raw product sales or services are processes that may arise from or be affected by particular patch configurations. Understanding such farm-to-market sales data requires the consideration of continuous environmental gradients that would explain soil quality and potential products produced on the farm as well as purchasing power and consumer demand in nearby urban areas.

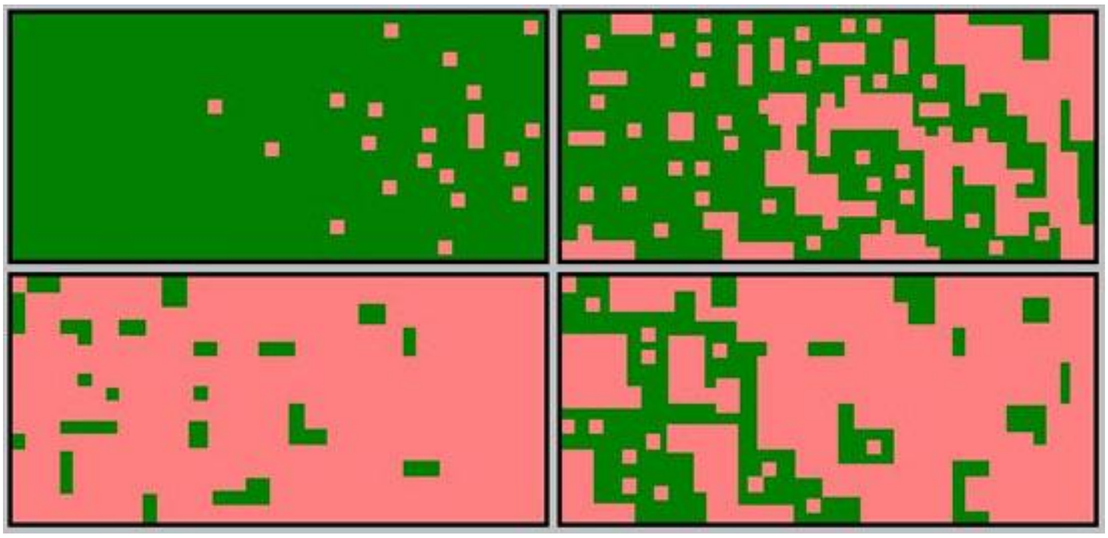

Figure 2. Fragmentation process of farmland (green) by urban (pink) invasion. Fragmentation can be summarized in several different phases. Clockwise, from the upper left panel: (a) perforation (initial small openings), (b) dissection (larger intrusions of change, often along physical features), (c) dissipation (spread and coalescing of alteration), and eventually, (d) shrinkage (reduction of patch size), and attrition (loss of patches).

The development and dynamics of spatial heterogeneity in landscapes is a central theme of ecological studies, especially the effects of conversion of natural ecosystems into human dominated systems such as agricultural or urban land use. As a habitat is altered in a landscape (e.g., farmland to urban land-uses in Figure 2) both the composition (farmland area) and the configuration (spatial pattern of patches) change. This conversion is called fragmentation (Figure 2). Certain patch configuration encourage further fragmentation and degradation of material flow. In biological systems, variation in configuration has a lesser effect compared to critical mass, except at very low proportion of patch composition in the landscape (Fahrig 1997). In this sense, rugosity of urban areas may play a lesser role in farmland loss than the critical mass of farmland retention and the availability of farm support services for machinery, feed and seed, processing, and transportation. Nonetheless, such ideas have practical consequences for the conservation of farmland and engendering of farm networks. Namely, will protection of a Single Large patch of farmland or Several Small patches (the SLOSS tradeoff; Simberloff and Abele 1976) have equivalent effects on economic farm survival? Similarly for cities, the question arises, should planners promote a single large city or multiple small villages, and how connected should these urban systems be with each other and with nearby landscapes, like farmland?

More recently, these spatial ecology theories have been infused with resilience theories that predict colony survival, with correlations to firm or farm survival. The theory of island biogeography predicts that larger and less isolated islands will contain more species than smaller, more isolated islands. The larger islands will be more resilient in the face of catastrophic events because there are more species available to find niches and repopulate the space. This theory is similar to agglomeration economy theories, where larger cities command more economic draw, more diverse job markets, and greater population growth. This concept is also found in studies on the necessary critical mass of farmland to retain agricultural firms or produce diverse marketing opportunities. This is not to say that a single species cannot dominate an island and decrease resilience just as single, large firms in a city make the city vulnerable to that singular market, or larger, homogenous farming operations are vulnerable to the vagaries of a single product market.

In relating spatial ecology to the ebb and flow of changing landscapes, metapopulation theory recognizes that local populations of organisms undergo periodic colonization and extinction, but that these local populations are linked to other populations nearby by migration. Hence, the collection of local populations, termed the metapopulation, can persist indefinitely if rates of local population extinction are balanced by rates of colonization from surrounding populations. This is similar to urban agglomeration economies, where small firms may 'go extinct' to be replaced by new firms in the succession of businesses so long as a healthy re-populating climate exists and there are policies to ensure new firm propagation. These theories speak to the importance of critical mass of diverse land-uses be that urban-based firms or agricultural firms, for which knowledge networks engender propagation and continued agricultural health even as some farms turn over to development and some vacant lands turn over to food production.

Figure 3. Visualization of Rugosity. The red line on the outside is the measure of the length of the rural-urban interface. Added to this, one can measure the density of fringe development and the contiguity of surrounding farmland.

These theories have been further connected to spatial planning with advances in the accessibility of computing, remotely sensed satellite and aerial imagery, development of geographic information systems (GIS, ARC/INFO was first released in 1982), and spatial statistical methods (Fortin & Dale 2005). In that sense, the development of rugosity theory furthers the ecological parallels and can be spatially tested across a national dataset to explain if an urban area's form has correlates with the function of surrounding farmland as ecological theories would predict. The theory of rugosity, or functional barriers, as it applies to urban morphology contains three main principles:

1. interface exposure, the amount of farmland that is in contact with urban areas (see Figure 3)

2. interface intensity, density of resources or development on the interface (see Figure 1)
3. patch contiguity, the connectivity or fragmentation of agricultural or urban land-uses

Only the length of the urban interface as it relates to farmland area or urban area will be statistically tested in this dissertation due to lack of a national dataset for urban density, density of farm services. Patch contiguity is partially explored in the 30 case studies and in-depth 4-county case studies.

CHAPTER 3. Methodology

The research is divided into two discrete phases: national statistical correlations and case studies. The first phase of the study is a descriptive and quantitative analysis of national farmland data at the county-level to find metropolitan-area counties with high dollar farm output, and select case studies from this data based on rural-urban rugosity and farm production. The second phase of the research aims to contextualize rugosity findings in local policy and farm land functionality.

National Scan

The national scan and statistical regression allows a spatial and temporal look into the association between land in farms, the value of agricultural production, and urban morphology. A national scan of counties in the continental United States identifies associations between rugosity, population change (2000-2010), metropolitan farm output and acreage at the county level over a ten year period (1997-2007). Counties are pre-screened to have the following criteria: metropolitan statistical area inclusion and annual agricultural production over $50 million. The pre-screening method allows the researcher to tailor findings to peri-urban farming counties that still have consequential farming operations. This national scan will identify if rural-urban rugosity is associated with farmland acreage stabilization or high value per acre farm production.

Three calculations of rugosity are explored against the national census and agricultural data set for appropriateness. Rugosity is measured as the urban area perimeter, concentricity of the urban perimeter, and the ratio of farmland the urban perimeter. These rugosity calculations are spatially joined by county with USDA amenity scores, U.S.D.A. Agricultural Census data (1997, 2002, 2007), U.S. Census data (2000, 2010), and 2004 County Typology codes.[1] State-fixed effected are controlled for by relating county variables to their state. As a result, significant statistical inferences can be made in relation to each rugosity reading to develop an appropriate measurement.

Descriptive Statistics and Spatial Multivariate Regression

I employed a combination of exploratory (spatial) data analyses and spatial econometric techniques using several statistical software packages (R, GeoDa and excel). Descriptive statistics and bivariate analyses were computed first, to explore the relationships between each of the explanatory variables and the dependent variable *y* (i.e. farmland loss or rugosity measurements). Multivariate models were then applied, with the aim of examining the relative importance of the explanatory variables for the spatial variation in farmland loss (at the scale of counties). To improve the statistical inference process, special attention was paid to multicollinearity, spatial heterogeneity (i.e. heteroskedasticity and/or structural instability) and spatial autocorrelation.

[1] An area's economic and social characteristics have significant effects on its development and need for various types of public programs. To provide policy-relevant information about diverse county conditions to policymakers, public officials, and researchers, ERS has developed a set of county-level typology codes that captures differences in economic and social characteristics. The 2004 County Typology codes classify all U.S. counties according to six non-overlapping categories of economic dependence and seven overlapping categories of policy-relevant themes. The economic types include farming, mining, manufacturing, services, Federal/State government, and unspecialized counties. The policy types include housing stress, low education, low employment, persistent poverty, population loss, nonmetro recreation, and retirement destination. In addition, a code identifying counties with persistent child poverty is available

State and regional control variables were created to control for fixed effects that could be due to specific policies or geographies in each state. By obtaining multiple observations from each state and looking at the effect of rugosity within each county, the state fixed-effects model removes the effect of state-level omitted variable bias.

The following correlation statistics were conducted on the county shapefiles: mono-variate spatial autocorrelation, bi-variate correlation, and multi-variate spatially weighted regression in GeoDA with controls for state-based effects. The pearson correlation product for every set of variables measures the extent to which two variables "vary together." These correlations were used to identify variables that track together and to limit using co-linear variables in the regression model created in the subsequent sections. A paired t-test assuming unequal variances was used on 118 counties paired based on statistically similar population and farm acres, but significantly statistically different measures of rugosity.

For planning, and particularly the study of urban morphology, place-based effects matter in crafting policy and explaining farming patterns. For this reason, spatial multi-variate regression in GeoDa 0.9.5-i (Anselin, 2003b) was used to confirm associations found in the descriptive correlation statistics.

Top 30 Counties with the Most Non-Concentric Urban Areas

To identify if rugosity is a byproduct of specific land-use planning tools or goals, the top 30 counties with the most non-concentric urban areas are analyzed for state and county-level growth management policies and their effectiveness. These counties are analyzed based on satellite imagery of land typologies bounding the UA to ascertain if certain bounding land-uses influence rugosity. Land-use governing policies are analyzed through review of state planning support, county comprehensive plans, county zoning ordinances, and acres preserved by farmland preservation programs. Like surrounding land-use, preserved farms would also act as hard boundaries for UA. Secondary literature and studies were used where found to explore the extent to which county-level planning was effective.

Case Studies on Rugosity and Farmland Loss: four counties

Case studies have three goals: 1) To verify national quantitative findings about the form of urban morphology and its impacts on farmland function; 2) To explain planning contexts for creating urban form and farmland functionality; and 3) To tease apart the impact of rugosity and planning practice on farmland loss. I employed an embedded multi-case study in four counties: high rugosity and high farmland loss; high rugosity and low farmland loss; low rugosity and high farmland loss; and low rugosity and low farmland loss. Cases were chosen based on proximity to similar markets with similar farm acreages, and statistically dissimilar rugosity across all three measurements (UA perimeter, concentricity, and farmland rugosity). Counties were selected from the national sample with the criteria of being located in Metropolitan Statistical Areas as defined by the 2000 Census with annual agricultural production over $50M as defined by the 1997 Agricultural Census.

The case study has three components:

1. County context: geography, demography, growth management policies, number of farms, and a map of rugosity.
    a. State-level plans, mandates, and enabling legislation
    b. County-level plans and ordinances
    c. Farmland preservation and grassroots farmland protection in the county
    d. Scholarly literature evaluating policy success in each county

2. Farm services within each county are compiled, categorized, and analyzed for typology. Types of farm services may include agricultural tourism, farmers markets, Community Supported Agriculture, or waste management. A map of farm services between individual farms and markets is created for each of the four case study counties. This map will help evaluate the distance between collaborating farms and urban areas, direction of farm service movement, and geographical patterns of farm service typologies. See appendix for IRB-approved recruitment letter and farm/market questionnaire.
3. The context for creating and maintaining farm services is noted in program director interviews. Information on federal, state and county-level programs operating within each county is gathered through a web search and interviews with experts. Program directors and coordinators are invited for a semi open-ended interview to explore the context surrounding each collaboration project and policies that encourage or discourage each farm-city collaboration/network. See appendix for IRB-approved interview recruitment letter and questions.

Agricultural Farm-to-Market Network Mapping

This phase of research quantifies the function of farmland in relation to urban morphologies by mapping farm first point of sale/donation for raw product and services (composting and school visits) to customers, institutions, and distributors. Immediate farm marketing channels are the simplest and most transparent part of the food system: products go straight from producers to users, and money or goodwill travels back in the other direction via direct, personal interactions with the farmer. To explore if these direct relationships are geographically bounded, first point of sale or donation, direct-farm service networks are extrapolated in Gephi and mapped over urban and farmland morphologies so that network direction, average distance, and magnitude can be derived for each category of farm-network in relation to landscape patterns.

Farm-to-market data was scrapped from farm websites listings on googlemaps, county farm listings, local harvest, and buyer associations (see appendix). Study county farmers were queried with an electronic questionnaire through email and/or facebook to identify their products and direct sale/donation markets (wholesalers, CSA member zipcodes, restaurants, institutions; see appendix). Markets were confirmed through an email and/or facebook inquiry, which asked them to identify other direct sale farms in a double verified snow-ball sampling technique (see appendix for email format). Market and farm locations were geocoded by latitude and longitude based on the exact address. Farm and market addresses were geocoded for longitude and latitude using iTouchMap (http://www.itouchmap.com/latlong.html) which verified farm or retail location with satellite imagery. Location was triangulated using the aerial view from google maps, aerial view from itouchmap, and farm webpages to confirm the geographical coordinates and ascertain if the wholesale/retailer is located on a farm and would therefore be considered a farmgate. CSA member purchases were coded at the zipcode level to protect client confidentiality. This technique allowed the researcher to capture direct farm networks within, moving into or going from study counties.

Farm networks for direct food sales and ancillary farm services originating or ending in case study counties were mapped and analyzed for distance, direction, type, number, and social network neighbors using Gephi and a custom-made program created by Jonas Persson. Using the 'geolayout' in Gephi, this map of networks was projected with mercurial projection over a map of remote-sensed urban areas and farmland based on USDA remote sensing satellite imagery data (cropscape, http://nassgeodata.gmu.edu/CropScape/).[2] Farmland data is available as Geotiff files, which are raster data. The cultivated crop mask data layer has a 30 meter spatial resolution and covers the continental United States. Because the remote sensing farm data are too detailed for analysis, they were amended for a coarser estimate. Using geoprocessing in the Spaital Analyst toolbox, I selected 'generalization' with a 'majority filter = 4' such that the kernel of the filter would represent four direct orthogonal neighbors, each representing 30 square meters of remotely sensed farmland. This changes the resolution of farm data to 90 sq meters and removes farm data that does not have four orthogonal neighbors. From this estimate of farm parcel

[2] Remote sensing farmdata is based on Cropland Data Layers from 2012. The crop mask data layer and collection methodology are available for download at http://www.nass.usda.gov/research/Cropland/Release/.

location, I could calculate the overlap with UA to determine how accurate each land description was. I could also overlay the Gephi geospatial network information to ascertain where networks were located in relation to satellite imagery of farmland and urban areas.

This research served as background case research for the interviews and helped the researcher to understand the social networks surrounding direct food sales and ancillary farm-city programs. For example, some counties may rely more on farmgate sales over CSAs. These farm-networks could influence land-use or be a product of local farm policies. Knowledge of farm networks helped the researcher orient interview questions about particular types of farm services in each study county.

Interviews

The third phase relates county-level program data to network analysis, to draw growth management and policy-based conclusions for future work. The third phase draws from 30 minute semi-open-ended program-director interviews from farm service umbrella groups (Buy Fresh, Buy Local; Agricultural Extension Office; County Planning Departments; Farm Bureaus, see appendix for list of interviewees) to assess farm program establishment, extent, longevity, context, and product for the four case study counties (see appendix for interview format). All interviews were conducted by phone with the exception of those in Chester County, which were conducted in person. Planning policies that enable or hinder farm-city collaborations are identified in each county. Data are triangulated with web-based and printed material from each program and county to draw growth management and policy-based conclusions for future work.

CHAPTER 4. Deriving Rugosity from Planning Theory, History and Practice

Urban and agricultural land value theories have not yet been married to create a unifying theory of how cities grow within their regions. Scholarly research has focused on the standard Von Thünen model of higher land values clustering in the center of urban areas, with land values tapering off steadily the further parcels are from the center. Data-driven models, however, have not supported these theories (Heikkila et al, 1989; Boyle and Kiel, 2001; Thorsnes, 2002; Bourassa et al, 2004; McConnell and Walls, 2005). Meta-analyses of peri-urban amenity values show an uptick in price per square-foot for housing and land values on the fringe indicated non-theorized value and desirability of the urban-rural fringe (Bergstrom and Ready, 2009). These findings suggest that land and housing near more rural or scenic areas can command higher prices than certain inner neighborhoods and suburbs.

Reframing urban history with attention to urban effects on peri-urban farmland situates a growing city, not in a vacuum of land values, but in its region. To understand growth, one must understand the economic dynamics, demographic changes, and planning regimes of rural areas. This research suggests that the theory of bid-rent models should be adjusted to account for the desirability to live near the fringe; likewise, planning theory should acknowledge this recurrent phenomenon, which has been a factor in the United States becoming a Suburban Nation with more of its population in suburbs than in central cities or rural areas combined. With this new understanding of high land values on the fringe, cities can be better fitted with growth management strategies that optimize fringe access by maximizing the rural-urban interface in combination with land preservation policies to minimize unwanted concentric growth or urban growth over prime, high-value farm and scenic lands.

Combining urban and rural development theory gives rise to a new growth management paradigm most akin to the ecological concept of rugosity, the relationship between a functional surface and the environment through which is absorbs nutrients or exudes waste. Cities, much like living organisms, uptake nutrients, produce products, and exude waste. In ecology, the measurement of a coral reef's rugosity (surface to area ratio) is useful as an indicator of surface area available for nutrient transport. The rugosity of the seafloor may indicate the amount of available habitat available for colonization by benthic organisms. Similarly, the rugosity of an urban area in relation to farmland may indicate the amount of functional interface available for farm-city ecosystem service and market interactions, where more urban rugosity indicates greater farm-city collaboration.

Urban Theory

The current understanding of planners who manage urban growth systems is derived largely from central place theory and data-driven empirical testing of this theory through spatial analysis. Johann Heinrich Von Thünen is commonly cited as the founding father of central place theory, though, in fact, his 1826 model was designed to explain the allocation of agricultural uses. Von Thünen defines the bid-rent curve as the maximum profit the land would generate if it were devoted to the highest economic activity. The "highest and best use" principle is found in property appraisals for taxation purposes. Agricultural land use generally rank low in land value per acre, and because urban land use is often considered the 'highest and best' use of land, this can result in pressure to valorize peri-urban farmland for its development potential and not agricultural productivity. Peri-urban farms may be subject to high property taxes in the absence of use-value assessment.

In central place theory, land rent is a function of distance from the city center, with the basic assumption that the farther away from the city, the greater the transportation costs. Higher-valued land uses would be more economically profitable, and could afford to locate closer to the central market at the city core, thereby saving on transportation costs. In terms of agriculture, cash crops are, therefore, located closer to their markets at the city core, and the uncultivated wilderness furthest from the city has a bid-rent value of zero reflecting its lack of marketable use. In the Von Thünen bid-rent model, land values are driven by the demand to be close to central markets and limited by the profit return from production minus the cost of transportation.

Von Thünen's model has served as the basis for the monocentric models of city development and agglomeration economies (Marshall, 1890; Hoover 1936 and 1948), elaborated upon by Alonso (1964), Mills (1967) and Muth (1969). Later urban theorists focused, not on agricultural goods, but on residential, commercial and industrial land uses, to explain how high bid-rent prices are located closer to the city center where a denser population drives higher demand for products in terms of jobs and retail. Harris and Ullman (1945) later suggested a model where cities expand, not around one single central business district, but around several amenity nuclei (Ricardo, 1911) and transportation routes (Hoyt, 1939), though these theories also suggested a tapering off of urban densities similar to what is broadly proposed by the Andres Duany transect models (Duany and Talen, 2002), which have been widely adopted by practicing planners.

The underlying assumption by proponents of these models is that population density dictates land values and location of services (Alig et al., 2004). As such, urban theorists began to focus on population dynamics as the driver of land values. The question of whether a city is capable of growing in population, physical space or economy has been the subsequent source of debate. Production specialization, infrastructure endowment, central location, or agglomeration economies have alternatively been emphasized as driving forces of urban population growth (Short, 2006).

Unable to satisfactorily explain urban growth drivers, theorists have insisted on dissolving cities from their regions in favor of a globalized view of what powers urban growth. Amin and Thrift note that the ‘‘city's boundaries have become far too permeable and stretched, both geographically and socially, for it to be theorized as a whole'' (2002, p. 8). More recently, urban theorists have sought to tie city growth to a global network of cities, noting that urban rates of expansion are tied to city interconnectedness within the global network of city economies (Hawley, 1968; Pred, 1973; Smith and Weller, 1977; Castells, 1996; Leamer and Storper, 2001). Sassen (2001) conceptualizes the city as a collection of intersecting, globally-reaching flows not a bounded metropolis. In this theory, cities are specialized economically to play unique functions in a global economy, and their growth is tied to how successfully they export their products to the global market. Contrary to expectation, specialization appears to play a limited role in urban growth (La Gory and Nelson, 1978). Social and cultural geographers like Sassen (2001) and Amin and Thrift (2002) argue for new ways of thinking about the drivers of urban growth, though they neglect to look for these drivers in the immediate regional surroundings of cities.

With a few exceptions, urban theorists have yet to situate the city in its region in any meaningful way (Jacobs, 1984). What unites the above urban theories represents a significant diversion from Von Thünen's early model, where land value is based on the potential agricultural use of immediate rural lands- factors of soil quality, terrain, transportation modes and markets. By not acknowledging the potential economic worth of rural amenities, these urban theories have failed to ground themselves in a regional context. This oversight is particularly puzzling given the acknowledgement of amenity value in natural landscapes (Richardo, 1911; Bergstrom and Ready, 2009). Some scholars even go so far as to diagnose sprawl and amenity valuation as an artifact of artificially low property taxes that do not encourage land conservation, but prioritize development potential and land speculation (Gihring, 1999).

In sum, urban theorists have been loath to consider the linkages between rural and urban land as important in generating value or growth. "Whereas agricultural land is an independent production unit, where rent is set according to the plot's own characteristics, land in the city has its usefulness and rent largely determined by its linkages with, and access to, other land, buildings and urban facilities" (Kivell, 1993, p. 30). This quote points out two major oversights: agricultural land value *is* determined by linkages to markets, *and* urban theorists have largely looked inward at urban land values, ignoring the linkages with rural lands. Urban theorists' ignorance about rural development and the silo-ing of urban theory contributes to general confusion over explaining the current trends in land values and growth, where lands further from the urban core are more highly valued than expected (Figure 4).

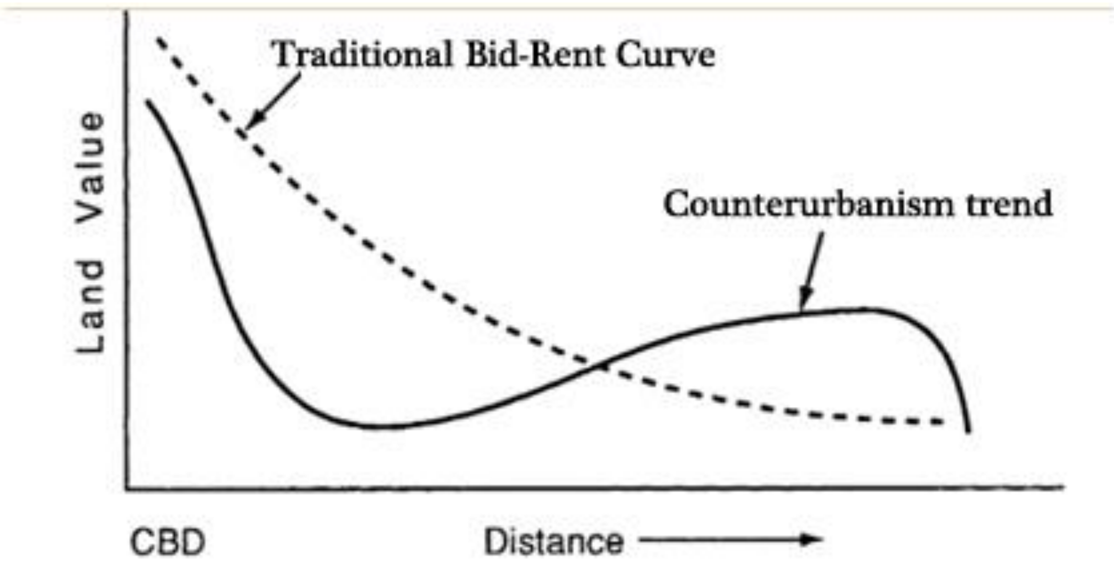

Figure 4. Land value as a function of distance from the center city. Notice that the counterurbanism trend reflects a higher than anticipated land value for fringe settlements. Many such graphs use population density in exchange for land value with similar findings that show a preference for fringe growth patterns.

Urban History

Often, these theoretical inclinations manifest in professional planning and its history, which has sought explanatory frameworks for understanding how and why people choose to live together in cities (see Mumford, 1961 and Short, 2006). Planning theory and history fetishize dense urban agglomerations, and largely neglect the phenomenon of choosing rural landscapes (Wellman, 1974; Graham and Marvin, 2001; Amin and Thrift, 2002; Audirac, 2002). Considering settlement patterns broadly as three patterns: urban, suburban or rural; the U.S. had a majority rural population until 1920. Briefly from 1920-50, the majority of Americans lived in cities as compared to suburbia or rural areas, and from then on suburbia took over as the dominant settlement trend (U.S. Census 1920, Nechyba and Walsh, 2004). Despite only briefly having a majority of the population in cities, Peter Hall's (1989) classic summation of planning history couches professional planning in terms of a series of "City" movements. Ironically, these movements which seek to glorify the city, simultaneously point to the unhealthy urban environment of cities as causes for both urban renewal and urban dispersion, the latter of which is represented by the preference for suburban living since 1950.

The urban–rural dichotomy is deeply ingrained in current planning systems, though it was not as evident at the birth of the profession. President Roosevelt's 1909 Commission on Country Life, an early federal attempt at policy recommendations for urbanization, suggested an urban land-use pattern that would benefit expanding urban and rural areas alike by preserving natural scenery in strips alongside urbanizing areas. The Commission asserted that, "this in no way interferes with the agricultural utilization of the land, but rather increases it. The scenery is, in fact, capitalized, so that it adds to the property values and contributes to local patriotism and to the thrift of the commonwealth" (United States Commission on Country Life, 1909, p. 53). In the absence of such a national policy of compact urban development in close proximity to working farmland, urban development proceeded haphazardly, devaluing both the urban core and the rural farm areas. Already at the Third National Planning Conference (1912), Mr. J Randolph Coolidge Jr. noted the "problem of the blighted district" in inner cities, neatly examining how the city's downtown area devalues without continual upkeep while people relocate at the fringe where new development is serviced by modern infrastructure (p. 100-12). Coolidge heralded the coming of the suburb in relation to the decline of the city and consumption of scenic, rural lands. Turn of the century planners identified the desirability and profitability of fringe development, along with a suitable landscape treatment that would benefit cities and farmland. Planning took another route, allowing and sometimes advocating for low density ex-urban growth.

Data-driven models on the location of urban growth have shown that ex-urban areas, those located well outside established urban and suburban boundaries, have witnessed the largest population growth since 1960 (Lamb, 1983; Nelson, 1992; Fulton et al., 2001; Heimlich and Anderson, 2001; Theobald, 2001; Davis et al 2004; Berube et al., 2006; Brown et al., 2005, p 1855-71). Ex-urban communities are heterogeneous landscapes made up of farms, suburban-style subdivisions, large-lot residential developments, commercial centers, and undeveloped open spaces (Nelson, 1992; Daniels, 1999; Green et al, 2005). Absolute numbers also show a preference for growth in fringe counties while urban areas decline. As a result of the lack of cohesive planning theory for the process of urbanization, a new model of urban expansion is needed to explain the current phenomenon of decentralization, disinvestment in center cities, and amenity valuation of open lands.

Farmland loss is not simply a matter of market preference and depressed agricultural values, but is also subject to the vagaries of public policy. Local government investment in pro-growth development via sewer and water extension line subsidies contributes to sprawl (Daniels, 1998). If counties are pro-growth, more urban expansion can be expected. Loudon County, Virginia and Montgomery County, Maryland across the Potomac River offer a prime example of similar land topologies, development pressures, and different local government emphases on growth with resulting differences in farmland loss and urban development. Researchers have shown that agricultural use-value taxation of land has worked to keep down the holding costs for farmers and land speculators until land values rise and the owners are willing to sell the land for a non-farm use (Daniels and Bowers, 1997). The property tax savings to the farmer are in effect capitalized into the value of the farmland for eventual sale for non-farm use. These market manipulations further distort of the bid-rent curve.

The extreme dispersion of urban land-use patterns, as they have become unhinged from public transportation systems and bounding parameters of high value crops has eluded planning theorists. To be fair, the lowest densities of urban development were never the concentration of urban theorists. Perhaps this is why metropolitan theorists fail when they try to model the drivers and limits of ex-urban growth where commuting can be extreme, and residential location decisions are driven by ‘‘unpriced spatial influences’’ (Anas et al. 1998, p. 1451) including environmental amenity and lifestyle—not house prices, workplace accessibility and rational economic choice. As a result of the lack of cohesive planning theory for the process of urbanization, a new model of urban expansion is needed to explain the current phenomenon of decentralization, disinvestment in center cities, and amenity valuation of open lands.

Rural Development Theory

Rural development theory- particularly as it pertains to fringe development and growth management- is a relatively new field covering the outgrowth of urban areas into farmlands (Van der Ploeg et al, 2000). Prior to the recent phenomenon of urban sprawl, rural development theory was most concerned with migration of rural people to the city, as well as community and economic development to improve the standard of living in small towns that were predominantly engaged in foodstuff production. In the United States, rural policy has been dominated by farm policy.

Johann Heinrich Von Thünen, the founding father of urban theory, is also the founding father of rural development (Sinclair, 1967). The Von Thünen model predicts the form of peri-urban agriculture with the following results:

1. Dairying, with its highly perishable product- milk, lies closest to the urban center, since dairy products must get to market quickly.
2. Timber and firewood, produced for fuel and building materials, are planted in the second ring as they are heavy and expensive to transport into the city.
3. Transportation costs of crops are less high, therefore the third zone consists of extensive fields crops such as grain. Grains last longer than dairy products and are much lighter than fuel, reducing total transport costs; they can be located further from the city.

4. Ranching is located in the outermost productive ring because animals can be driven into the city for butchering.
5. The final ring consists of wilderness with no marketable activities. This land has a null value in the bid-rent model correlating to the lack of use one can extract from the property due to the exorbitant cost of transporting the product.

Since Von Thünen created his models, there have been significant changes in transportation, energy supply, and tax policy. As transportation becomes less expensive, the Von Thünen model retains its layers, but becomes spread out over more space, pushing the rings further from the city. One could argue that transportation costs have become so inexpensive that any resemblance of rings of production has decayed into a nebulous haze. Advancements in refrigeration, pasteurization and preservation have also enabled food to come from further away, removing the necessity for proximity to urban markets (Cronon, 1991). As energy supply has changed from renewable, locally produced sources, such as timber, to oil and power generation plants, the need to have timber near cities also became obsolete. The mortgage interest deduction and property tax deduction distort the bid rent curve in favor of those looking to move to the fringe. While farmers do see a premium payment from direct sales and benefit from large markets (Gale, 1997), the theoretical Von Thünen city has become unbounded, divorced from surrounding, competing agricultural land interests and subject only to the real estate market in housing, commercial property, office space, and industry. The limiting factor to urban expansion in Von Thünen's model is the value of the inner most ring of high value crops. If the crops fetch lower prices than residential housing markets, agricultural land-uses will be replaced with urban land-uses.

Following Von Thünen's early work, Hart (1998) sought to explain the dynamics of urbanization on rural development. Hart used the imagery of urbanization creating "bow waves" that spread into agricultural buffer zones on the rural-urban fringe (1976, 1991). He defined peri-urban agriculture as "the zone of intensively cultivated, high-priced agricultural land that always remains in front of the expanding urban edge. The high price and the intensive cultivation of the agricultural land in the bow wave stem entirely from location, not from any inherent quality of the soil. The agricultural activities of the bow wave simply move farther out when the land is converted to urban use, as inevitably it will be" (Hart, 1998:328). This wave shapes the land rents, quantity, commodity type, and organization of agricultural production (Heaton, 1980; Audirac 1999). It also shifts production away from livestock and grains to horticulture and intensive crops, such as fruits and vegetables.

According to many data-driven models, the Von Thünen/Hart model holds merit (Barnard and Lucier 1998; Furuseth and Pierce 1982; Heimlich 1988; Heimlich and Anderson 2001; Otte 1974; Vesterby and Krupa 1993, 2001; Thomas and Howell, 2003). Cities are bound by suburbs which eventually are bounded by high value cropland and dairies. Metropolitan Statistical Areas (MSAs), defined by the Bureau of the Census, contain 20 percent of U.S. land area and 83 percent of the U.S. population (Bureau of the Census, GARMS, 2010). MSAs are the modern stand-in for Von Thünen's singular urban center. In 2007, MSAs contained 30% farms by number, which produced 40% of all farm assets though they accounted for only 18% of all farmland by acre (Agricultural Census, USDA, 2007). Metropolitan counties lead other counties in sales of high-value crops such as cotton, fruits, vegetables, and nursery/ greenhouse products. Fringe metro counties also ranked first in poultry, dairy, and other livestock product sales (Von Thünen’s first ring). Conversely, nonadjacent non-metro counties, led in sales of grains, cattle, and hog products (Von Thünen’s third and fourth rings). Thus, the highest value crops are located closest to their urban markets, as Von Thünen predicted. Most importantly, when the values of these crops are high enough, they can deter residential development (Fulton et al., 2001; Butler and Maronek, 2002; Thomas and Howell, 2003; Angel and Sheppard, 2005). In essence, the agricultural sector is behaving as theorists predicted in relation to urban areas even with advancements in transportation and energy; it is, instead, urban theory which needs readjusting.

Theory of Rural-Urban Transition

The dynamics of rural-urban change fall into two paradigms: rural people move into cities, or urbanites encroach upon rural lands. Numerous studies have covered the rural-to-urban migration of human capital, which ultimately diverts land and other natural resources from agriculture, negatively impacting family farm survival (Albrecht et al, 1990; Bradshaw and Muller 1998). These studies are primarily concerned with rapid urbanization in developing countries as rural dwellers flock to the cities in hopes of a higher quality of life (van der Ploeg, 2000). More recently, the latter proposition has become the dominant theory of urbanization in developed countries as more urbanites move to rural areas and convert farmlands to urban uses.

As urban development has engulfed rural communities, two theories of who populates the fringe have been posited. Heimlich and Andersson (2001) suppose that people move even farther from cities in search of less expensive land for housing. Isserman (2001) also viewed this "metropolitanization" of rural America as being due to the competitive advantages that rural areas afford in abundant, inexpensive land and job growth that has outpaced urban America since 1969. This notion suggests that relatively low-income people who cannot afford life in the city move into the rural areas, and that the high-value crop land is competing with poor or middle-class residential development.

On the other hand, numerous scholars have supposed that rural immigrants are, in fact, the wealthiest of urbanites. Living beyond the edge of the city is a premium lifestyle. Forty-five percent of people living in medium to large cities wanted to relocate to a rural or small town setting 30 or more miles from the city (Brown et al., 1997). Those who can afford the commute and resettlement costs become what many scholars refer to as rural gentrifiers (Phillips, 1993; Ghose, 2004; Nelson et al, 2010). This theory is lent credence by the observation that the flow of wealthy urbanites into rural communities closely follows economically prosperous periods (Champion, 1988; Fuguitt, 1985; Fuguitt and Beale, 1996; Johnson, 1999). Wealthy individuals and business owners, previously unable to choose a rural residence due to job clustering in cities or the costs of commuting, can act on their rural preferences and become agents of gentrification. In *City of Quartz* (1992), Davis relates how the conservation movement in California was led by the wealthy, who had settled along the coast long before the expansion of Los Angeles. Rural gentrification has been tied to economic reorienting to the service sector, an aging population, the rise of leisure and concurrent proliferation of second homes, dissatisfaction with suburban living, and the pursuit of a perceived higher quality of life available in the countryside (Vias and Nelson, 2006; Nelson et al., 2010). In this model, where high-income rural immigrants move to the countryside, the buffer of high-value crops is competing with the deep-pockets of the wealthiest urbanites as they seek rural residential land.

To add to the complexity, agricultural theorists note that low-wage service workers are also drawn to rural areas. Just as the gentrification by highly skilled professionals in global cities has stimulated parallel flows of low-wage, typically immigrant, labor (Sassen, 2006), rural gentrification by affluent baby boomers has drawn low-wage largely Latino workers to the same sets of destinations (Nelson et al, 2010). The uptick in housing and land-values caused by speculation in the face of rural gentrification threatens not only high-value crop lands, but also forces low-wage supporting service workers to commute from distant locations where they can afford housing. Indeed, this is often the strongest critique of growth boundaries: such tactics enable the wealthy to live in idyllic surroundings and perpetuate conversion of other rural lands for the supporting service sector (Downs, 2004; Anas and Rhee, 2006 and 2007).

Joining Rural and Urban Theory

There is a fifth dynamic at play in the fringe. In the face of the four largely pro-urban dynamics (rural retreat, middle-class urbanism advance, rural gentrification, and low-wage rural immigration), agriculture has adapted to urbanization in a way that counters the more general trends in the agricultural sector. Work by Heimlich and Anderson (2001) posits that Hart's "bow wave" (1998) is not necessarily pushing agriculture further from urban areas so much as it is transforming the agricultural products as it passes. Agricultural economists note that agricultural sales per acre increase in response to exurbanization to offset conversion of land and as a result of access to new urban markets (Butler and Maronek, 2002; Thomas and Howell, 2003).

Conversely, Heimlich and Barnard (1997) find that urban environments influence agricultural lands by increasing the prices for labor, land and other primary inputs while also promoting more regulations (such as environmental protection) and access to direct-sale markets. Farmers overcome these costs, taking advantage of the new opportunity to work 'urban jobs' by converting to part-time or recreational farming (Heimlich and Barnard, 1997). Small, labor-intense metropolitan farms no longer provide the main income of the family but give generous returns on minimal investment when compared to conventional farming. Producing more dollar-value per acre, peri-urban farms also retain a greater number of farmers. Isserman (2001) found that metropolitan counties have retained 81 percent of their farmers and farm employees from 1969 to 1997, compared to rural counties' retention of 71 percent.

Farms near urbanized areas produce more valuable products on less land with more diverse ownership and greater farmer retention (Heimlich, 1988; Heimlich and Brooks, 1989; Barnard and Heimlich, 1993; Heimlich and Barnard, 1992, 1997; Heimlich and Anderson, 2001). Adaptive farming is characterized by intensive cultivation of niche products with a high added value; farms are small and are unlikely to expand. Peri-urban farmers, unlike traditional farmers, do not necessarily require more land, less labor, scale opportunities, or specialization (Belleti et al., 2003). Instead, adaptive farmers seek to market themselves, while diversifying and intensifying production of value-added commodities and services (Van der Ploeg, 2000) in what has come to be known as pluriactive (Jervell, 1999) or multifunctional farming (Jervell et al, 2008; Renting et al, 2009; Zasada, 2011). Barnard and Heimlich (2003) and Van der Ploeg and Roep (2003) suggest that the increasing pressure to adapt results in incentives to develop new activities and valorize the multifunctional nature of farms, such as pick-your-own fruits and agritourism activities. The demand for non-commodity farm functions is the highest in urban regions. These new services and products are not measured in traditional agricultural censuses, leading an undervaluation of the products of peri-urban farms (Brinkley, 2012).

To understand the velocity of Hart's "bow wave" on agricultural transformation, one must understand the drivers and limits to urban expansion. Land-use change is partly driven by population growth, increases in income and wealth, and preferences for housing and lifestyles. The disproportionate growth of ex-urban areas, however, is most neatly summed up as a response to poor quality of life in cities, a desire to be near natural landscapes, and depressed farmland prices (Thurson and Yezer, 1994). Counter-urbanism theory (Berry, 1976) has sought to correlate exurban growth with inferior central city services, including lower quality public schools (Bayoh et al., 2006), and higher crime rates (Cullen and Levitt, 1999). Regional economic factors like increased income (Margo, 1992) and decentralization of employment centers (Thurston and Yezer, 1994; Glaeser et al., 2001) also drive ex-urbanization. This notion of anti-urbanism has its root in urban theorists' fear of the ills of congestion on people (Wirth, 1938; Mumford, 1961) and goods (Newman and Thornley, 2005). In this sense, the limits to urban growth are the drivers of ex-urban growth.

Likewise, the drivers of exurban growth are the limits to urban growth. Amenity migration and residential preference studies have billed the drivers of exurban growth as the draw of natural landscapes over the dystopian visions of inner-city life. Theobald (2005, p 32) recognizes that exurbanites often locate ''adjacent to or nearby 'protected' lands meant to conserve natural resources and biodiversity.'' The poor quality of life in cities can drive people to exurbia just as the amenities of exurbia can draw people from the city.

In order to allow urban out-growth into rural land areas, farm prices must be lower than development prices. Pyle (1985) found that the construction of exurban homes is correlated to depressed agricultural markets. In many metro counties, the value of farmland for farming is less than the value of farmland for development. The exception is vineyard land in Sonoma and Napa Counties. More general, international studies (Angel et al, 2005; Sheppard, 2011) found that high agricultural rents deterred sprawl. In other words, low agricultural land rents allow urban settlements to propagate.

Conversely, the limits to exurban growth are often the drivers of urban growth. Exurban growth is minimized when urban areas with a high quality of life draw and retain more residents. Many of the recent calls to create livable, urban communities- are couched as antecedents to "sprawl." Regulations that limit exurban growth are also necessary to retain successful, dense urban areas. A few planners (Daniels and Bower, 1997) have long championed regulations and financial incentives to curtail exurban growth and revitalize urban areas through a combination of zoning, growth boundaries, and farmland preservation. Many European countries have developed strict farmland development regulations to promote domestic food security and ensure dense, urban settlement patterns (Lapping, 1980). The high cost of fuel is also a commonly regulated commodity that influences land-use and promotes dense urban settlement patterns (Shepardson et al, 2011).

The environmental and social ramifications of rural gentrification have created crises and conflict for many farming communities (Taylor, 2011) as well as the low-wage, commuting workers (Nelson et al, 2010), and the first wave of rural gentrifiers who exhibit NIMBYism (Daniels, 1999 and 2004). For both the low-income and wealthy rural gentrifiers, there has long been a warning about the ills of an exurban lifestyle. Already in the 1950s, scholars forewarned the consequences of exurban living: constant debt, physical fatigue of commuting, and dissonance between the dream of country living and the labor of its reality (Spectorsky, 1955; Riesman 1957; Frumkin, 2002).

In a broader sense, the dangers of exurban living are not limited to the exurbanites themselves. Rural communities, highly productive farmland, and the best-use of resources are sacrificed in the pursuit of good country living. Rural land is more than null-value wilderness waiting for development; it is a working landscape of functioning farms and forests that serve both economic, historic and environmental purposes (Brinkley, 2012). The danger of exurban growth, however, is not to food production as is commonly posited by groups like the American Farmland Trust, with its slogan "No Farms, No Food." Urban growth may reduce production of some high-value or specialty crops, but will not harm food or fiber production overall (Heimlich and Anderson, 2001). The danger of exurban expansion hinges more upon the stresses of commuting for individual's mental and physical health (Frumkin, 2002), non-resilient exurban areas subject economically to the fluctuations in gas and oil price shocks, and inefficient land use patterns that result in a loss of economic and environmental opportunities between the rural-urban continuum (Brinkley, 2012).

Adjusting Planning Theory

Agriculture has adapted to urbanization in a way that counters the more general trends in the agricultural sector. Why then, shouldn't fringe urbanism counter more general urban trends? What repels urbanites from the city draws them to the fringe. Many urban theorists are reluctant to identify this trend, instead viewing ex-urbanization's break-away from traditional agglomeration centers as inevitable as cities reach their optimal size and more density results in congestion (Howard, 1902; Kotkin, 2005).

Only recently have planners acknowledged that nearly all urban places are expanding (Sheppard, 2011), and that there is relatively little advantage to establishing alternative self-contained communities that serve a specialized niche regionally (Florida, 2005) as these breakaway communities will eventually be engulfed by the new megacities (Sorensen and Okata, 2010). In a study of 40 urban areas in France and Japan, Eaton and Eckstein (1997) found that urbanization had similar growth rates across cities of different sizes ('parallel growth'), rather than either an increase in the population of larger cities relative to other cities ('divergent growth') or of the growth of smaller cities relative to larger cities ('convergent growth'). Thus, the real challenge is how to grow urban areas within their regions in a sustainable fashion, not a focus on gaining competitive advantages amongst other city cohorts or retaining an optimally sized urban area.

Currently, metropolitan regions are competing internally and externally for wealth and political power. The flight from cities has created suboptimal settlement patterns in the suburbs and exurbs that do not allow maximal wealth generation or use from the land. Cities are competing with their hinterlands, and regions are needlessly devaluing both their natural resources and agglomeration economies by pitting urban areas against rural areas. If planners are to face the facts, they must admit that the fringe is a desirable development site and adjust planning practices and theory accordingly (Sies and Silver, 1996). If access or proximity to open space at the urban periphery is an important amenity, then urban residents will have an incentive to build at the periphery. This may give rise to market failure because new construction will not internalize the loss of the value of open space for existing residents, nor the costs of center city depopulation. To add to this, many counties have tax policies that favor building on the fringe with lower property taxes, abatements for new construction, and subsidized new schools, sewer and water lines. Planners, therefore, must supply the market with development near intact natural resources in such a way that the center city is not devalued. In order to arrive at a mutually beneficial growth management strategy, planners must brave the theoretical divide between urban and rural development.

In light of the discovery that people want to live on the fringe, near farmland and natural amenities, it may be desirable for urban regions to maximize their connections to fringe areas by increasing the functional rural-urban interface. The challenge to planners is how to phase compact, contiguous development outward over time and how far. This strategy can be pursued only if it will not invite further sewer and water line extensions into the countryside or engender leap-frog development.

Rugosity is a measurement commonly used in ecology to capture a surface-to-area ratio where the surface is a functional barrier between two mediums with competing but complimentary needs. In the context of the rural-urban fringe, rugosity is a measure of the interface between urban and rural areas (see Figure 1). If an urban area is considered as an organism, the urban perimeter would be the functional surface through which a city absorbs a host of vital nutrients such as food, recreational services, and ecological benefits (Brinkley, 2012). Conversely, farmland can be viewed as the organism which operates through the functional surface of the urban perimeter to gain access to markets, labor, and culture. Densely developing land in fingers with preserved farm and natural lands on the buffer would maximize urban rugosity and the functionality of the rural-urban interface.

Planning on the Fringe

Planning scholars have made considerable headway in assessing planning tools and their use in fringe communities (Daniels and Bowers, 1997; Daniels 1998). These scholars have noted that the fringe is a desirable development location and that peri-urban farms are particularly vulnerable to the types of low-density, suburban and ex-urban developments proposed on the fringe. In organizing fringe communities for planning, these authors propose three main strategies for rural communities: 1) pro-growth; 2) balanced growth; and 3) no- or slow-growth. Each growth paradigm has complimentary, tested and proven tool kits for success, such as urban growth boundaries or purchase of agricultural conservation easements. The consensus amongst all of these growth paradigms is that leap-frog development should be avoided. Contiguous development is the preferred urban growth paradigm. High rugosity settlements could similarly follow high-, low- or no-growth paradigms with contiguous development to avoid leap-frog patterns. Unlike the accepted model of concentric low-density urban growth, high rugosity developments should use less farmland for development as their fringe development is made of high density development as opposed to low density, suburban development. Rugosity would not stop the bow wave of development, but it would slow it and capture more value in farmland and urban areas per acre.

Traditional and innovative land-use planning tools may also be used with high rugosity urban morphologies. One of the most popular mechanisms for farm land protection in the United States is to purchase agricultural conservation easements (PACE) also known as the Purchase of Development Rights (PDR) from landowners. PACE programs can be leveraged at any government level and even by private or non-profit organizations. The purchase permanently restricts the type and amount of development that can occur on that farm land in the future regardless of changes in ownership of the property. Government farmland conservation programs that apply this mechanism can use it in with Transfer of Development Right (TDR) programs. By targeting desirable ACEs to maximize rugosity, conservation programs can adjust development patterns, form large contiguous areas of protected farmland to provide social and ecological benefits, potentially boost farm-to-market networks and farm viability, and reinforce other planning measures to shape urban growth, such as urban growth boundaries. These conservation activities have a positive impact on the rate and probability of farm land being preserved, block development in unsuitable areas, maintain rural amenities near urban residents, and control growth patterns (Liu and Lynch, 2006; Lynch and Liu, 2007; Stoms et al., 2009; Daniels, 2010). Planners operationalizing rugosity theory need make only small adjustments to the deployment of PACE programs, which would still aim to protect culturally or ecologically sensitive land, but would encourage a greater rural-urban fringe.

To ascertain if communities desire high rugosity development, or if this development would save taxes or further add value to the land, planners may test varying degrees of proposed rugosity with cost-efficiency studies. Planners may also choose to levy farmland protection programs after conducting a cost-benefit analysis, cost-effectiveness analysis, or cost-utility analysis. These frameworks evaluate and prioritizing conservation parcels based on economic outcomes. The methods differ slightly in advantages and applications (Hughey, Cullen and Moran, 2003). A cost-benefit analysis measures preferences for an array of policy options expressed as an individual's willingness to pay for the change (benefit) or to avoid the change (cost). The analysis measures whether a benefit outweighs its cost by taking the ratio of benefit to cost to determine the return on investment. This method would capture community desire for rugosity. The problem with this analysis is that measuring nonmarket values is challenging and there is considerable criticism of the assumption that aggregate social well-being can be expressed as the simple sum of the well-being of individuals (Krupnick, Kopp and Toman, 1997). Conversely, a cost-effectiveness analysis (CEA) focuses on nonmonetary outcomes and seeks the least costly means by which to achieve the given policy goal. A cost-utility analysis measures the proposed cost of retaining or implementing a given utility. In each case, these cost analysis can be adjusted to note the desirability for a fringe lifestyle, a personal preference that is often conflated in studies with low-density development, single-house dwelling, low taxes, or new schools. As the principle of rugosity implies, it is possible and even desirable to have a high-occupancy condominium located on the rural-urban fringe and linked with already existing urban utility infrastructure. In this case, the natural or farmland viewshed can be further valorized with inclusion of public bike lanes or other recreational opportunities that do not interfere with farmland function.

While planners have developed an effective toolkit to manage and deploy development, they struggle with distinct disadvantages particular to fringe communities, making growth management and farmland protection difficult. Many counties in the United States lack enabling legislation to plan and may rely on fragmented local, municipal governments. Where there is enabling legislation, planning may not be mandatory and could be considered a costly unnecessary expense. Often times, municipal governments lack regional visions for planning or funding to carry out the necessary studies and gauge community support. To that end, fringe communities often have limited financial and human resource support for planning. Even where a municipality has community support, planning expertise, and adequate funding to plan, municipalities and counties may be limited by the state property rights and compensation legislation to land owners. These drawbacks often result in the reluctance of local governments to authorize land-use controls, relying on developer-driven demand and welcoming pro-growth strategies.

In the cases where rural planners cannot plan to manage growth or protect farmland, many scholars worry that high rugosity growth will engender more farmland loss as the nuisances of farmland more readily abut burgeoning developments. This thesis will test this concern empirically, but the theory of rugosity also recognizes that developments occur more densely near farmland amenities, and that the more people accommodated in desirable, dense, fringe developments, the less low-density sprawl patterns. To this end, high rugosity development caters to NIMBYism and could curry more political favor in keeping the scenic views over natural lands and farmland while allowing dense, contiguous development nearby.

Of course, many urban developments do not abut farmland, are encrusted in suburbs or abut natural landscape features. This dissertation will only explore the influence of rugosity on peri-urban farmland, the protection of which is a top priority for many rural planners. To this end, encouraging rugosity on the fringe can be applied to suburban developments as easily as urban developments using the main three concepts of contiguous (non-patchy) urban development, high-density fringe development, and increased urban-rural interface.

Taking the Rugosity Theory Further

This new theory of city development takes into account measures to maximize urban rugosity in order to maximize the interaction between urban and rural/natural environments for the synergies that exist between these two regions. This combined rural-urban theory not only explains the current phenomenon of decentralization, disinvestment in center cities, and amenity valuation of open lands, but opens predictions for future land-use models that would allow for urban expansion, farmland adaptation, and increased rugosity between rural-urban boundaries to maximize the value generation of collaboration. This study has devised methods to quantify rugosity of urban areas in the United States and test its effects on farmland function as a first step in challenging the dominant planning history and theory of concentric, tapering density urban growth.

CHAPTER 5. Measuring Rugosity and its Influence

The theory of rugosity contains three main principles of landscape texture: interface exposure, interface intensity (density of resources or development on the interface), and patch contiguity. The literature indicates that patch contiguity is the most important for farmland survival, but interface intensity and interface exposure may play equally important roles in farmland retention and preservation of agricultural supporting services. Future studies should address these measures in relation to each other and potential trade-offs for nearby development. Only the length of the interface will be tested in this dissertation through three alternate measurements: urban area perimeter length, concentricity, and urban interface in relation to farmland area. The measurements of rugosity are tested for significant correlation with county-level census and agricultural data.

National correlation findings will identify if rural-urban rugosity is associated with farmland acreage stabilization or high value per acre farm production for peri-urban farms. In the United States, urban-influenced agriculture is broadly considered as farmland within a Metropolitan Statistical Area (MSA). MSAs are defined by the U.S. Office of Management and Budget as geographical regions with a relatively high population density at their core and close economic ties throughout the area. They are comprised of a core county of with a city of 50,000 or more people and adjacent counties with more than 20,000 people that have strong economic ties to the core county. Most farmland preservation literature further demarcates peri-urban agriculture by the value of production, including only counties with annual sales greater than $50 million in farm products (American Farmland Trust, Farming on the

Edge). An initial scan of U.S. counties yielded 483 counties involved in peri-urban agriculture with these specifications (see Figure 6).

Counties are pre-screened to have the following criteria: metropolitan statistical area inclusion and annual agricultural production over $50 million. The pre-screening method allows the researcher to tailor findings to peri-urban farming counties that still have consequential farming operations. Statistical regression on rugosity, population change (2000-2010), metropolitan farm output and acreage at the county level over a ten year period (1997-2007) gives both a spatial and temporal look into the association between land in farms, the value of agricultural production, and urban morphology.

The county-level unit of analysis is rich in context. The county is often the framework for many farming outreach organizations: the Farm Bureau and other farmer organizations with county-level offices and memberships, the county Soil and Water Conservation District, county offices of USDA's Farm Service Agency, Natural Resources Conservation Service, and the land-grant university's Cooperative Extension Service. The countywide landscape plays host to a variety of conflicts critical to the survival of peri-urban agriculture, including municipality and county government competition over control of undeveloped land and infrastructure, and also, exurbanite households fighting with nearby farmers over farming practices. Moreover, the US provides a wealth of county-level agricultural data gathered by the federal government's Census of Agriculture. Conducted every fifth year, this census allows comparison of several measures of agricultural activity per county from 1997 to 2002 and 2007 editions. After the National Agricultural Statistics Service took over responsibility for the Census of Agriculture from the Commerce Department in 1997, sampling procedures changed so that more farm operations were included than possible under previous procedures. For this reason, agricultural census data is only comparable from 1997 and onward, limiting more retrospective analysis. National regression data is based only on 1997, 2002, and 2007 data to assure uniformity in collection method.[3] In future studies, remote sensing information for farmland and crop type will yield more accurate information as the definition of agricultural land in the census is based on sampling of "potential" farmland.

Determining a Rugosity Measurement

The granularity of the rugosity measurement is based on the outline of U.S. census blocks. Urban Areas (UA) in the United States are defined by the U.S. Census Bureau as contiguous, densely settled census block groups (BGs) and census blocks

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[3] The Census of Agriculture is conducted every five years by the National Agricultural Statistics Service (NASS), a branch of the United States Department of Agriculture (USDA). NASS has conducted the Census since 1997. Previously, the Census was conducted by the U.S. Bureau of the Census. In one form or another, there has been an agricultural census conducted periodically in the U.S. since 1840. According to NASS, the Census of Agriculture "is a complete count of U.S. farms and ranches and the people who operate them. The Census looks at land use and ownership, operator characteristics, production practices, income and expenditures and many other areas." Data is published for the nation, states, certain territories, and all U.S. counties. The USDA defines a farm as any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the relevant census year. This definition has changed nine times since 1840. From 1959 to 1974, the definition included both farm size and sales volume, with two different sales volume thresholds based on two farm size classifications (farms of 10 acres or more and farms of less than 10 acres). The current definition was adopted after 1974 and has no farm size requirement (http://www.agcensus.usda.gov/Help/FAQs/General_FAQs/index1.asp). Data points for farms that generated energy or electricity, farms that marketed products through community supported agriculture (CSA), and revenue from agritourism were collected only in 2007. All data points and their definitions can be found at http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usappxb.pdf

that meet minimum population density requirements (1000 people /sq mi or 390 ppl/km^2), along with adjacent densely settled census blocks with a density of at least 500 people/sq mi (190 ppl/km^2) that together encompass a population of at least 50,000 people. UAs are delineated without regard to political boundaries. An UA serves as the core of a metropolitan statistical area. This study uses the perimeter of Census 2000 Urbanized Areas (UA) as the basis of measuring the rural-urban interface and for calculations of rugosity. The dataset covers the 50 States plus the District of Columbia within United States.

Geographical Information Systems and the ArcMap tool were used in calculating county rugosities. I converted the UA polygons to lines using the "polygon to line" conversion tool in ArcInfo, and clipped where they intersected county boundaries using the using the Geoprocessing “clip features” tool. Using “field calculation” tool under the “table” view, I created a new field and summarized the **UA perimeter** lines in each county. The UA perimeter within each county is used for two alternate measurements of rugosity as follows:

*Concentricity of urban areas***:** measures rugosity as a function of urban area, where the urban perimeter is the functional perimeter. To calculate non-concentricity, I used the urban area within each county to calculate the potential perimeter if that area had been perfectly concentric (concentric perimeter=2*pi*sqrt(area/pi)). The actual UA perimeter length was divided by the calculated concentric perimeter to find the degree to which each urban area exhibited non-concentric morphology = UA perimeter/(SQRT(UA area/3.14)*2*3.14). A score of 1 indicates a perfectly concentric urban area.

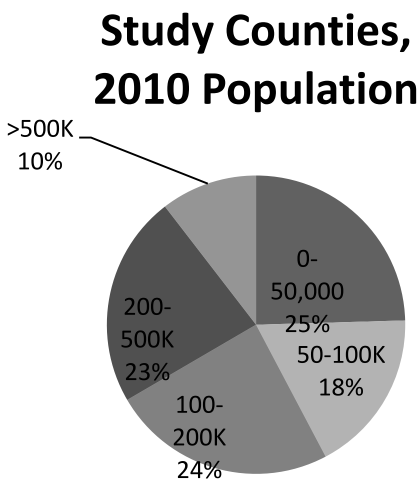
Farm rugosity: measures rugosity as a function of farmland where the urban perimeter is the functional interface. Ratio of farm acres to urban interface= UA perimeter/(1997 farmland acres)

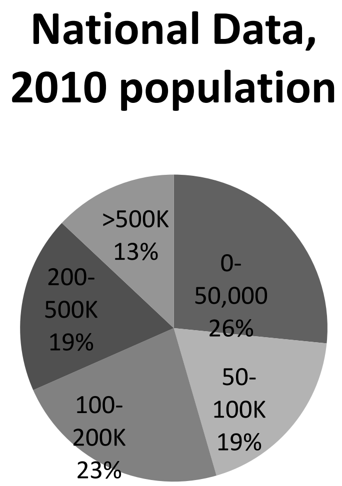
These three rugosity measurements are used in subsequent statistical correlations to understand significant relationships and determine a meaningful rugosity measurement for interface length. The thickness, or density, of farmland amenities or development on this interface is not tested in this dissertation. The patchiness, fragmentation, and contiguity of the rugosity concept is explored in the 30 case and four-county case study section but not in empirical statistical regressions.

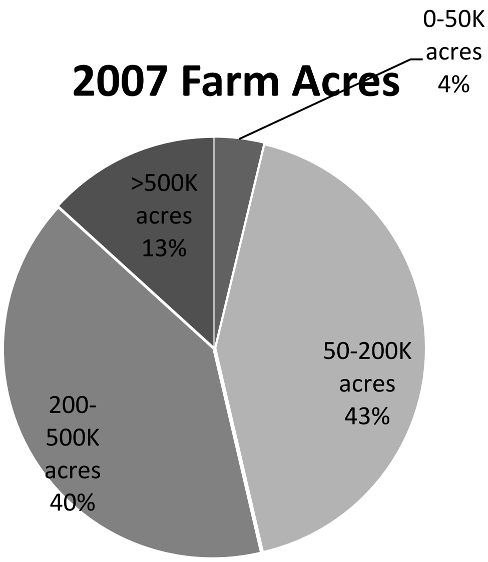
Agricultural Production across the U.S.

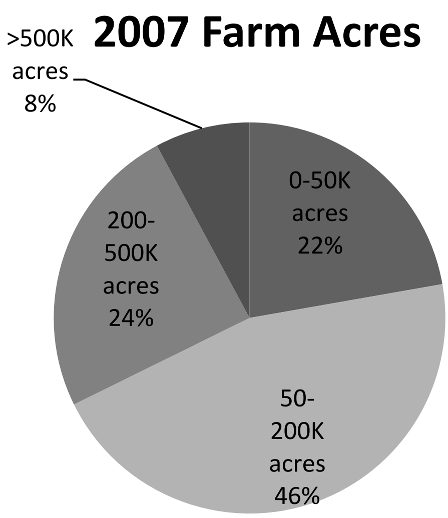
The national scan was selected from the 3143 counties in the continental United States based on the following criteria: a county must be in a 2000 Census defined MSA, intersect a 2000 Census defined Urban Area, and have total 1997 US Agricultural Census commodity sales over $50M. There were 1184 counties in MSAs, of which 1130 border an urban area, and 483 of these have agricultural sales over $50M. These 483 counties (Figure 6) represent a collection of counties engaged in peri-urban agriculture. Study counties had similar population and agricultural production breakdown profiles to the national dataset, but differed in that they did not capture many of counties with less than 50,000 acres (nearly 25% of US counties).

Roughly half of the counties in the US were excluded on the basis on less than $50M in yearly agricultural sales. The 483 counties were used in subsequent correlation, t-test and spatial multivariate regression analyses.


Study Counties, 2010 Population
>500K 10%
0-50,000 25%
50-100K 18%
100-200K 24%
200-500K 23%


National Data, 2010 population
>500K 13%
0-50,000 26%
50-100K 19%
100-200K 23%
200-500K 19%


2007 Farm Acres
0-50K acres 4%
50-200K acres 43%
200-500K acres 40%
>500K acres 13%


2007 Farm Acres
>500K acres 8%
0-50K acres 22%
50-200K acres 46%
200-500K acres 24%

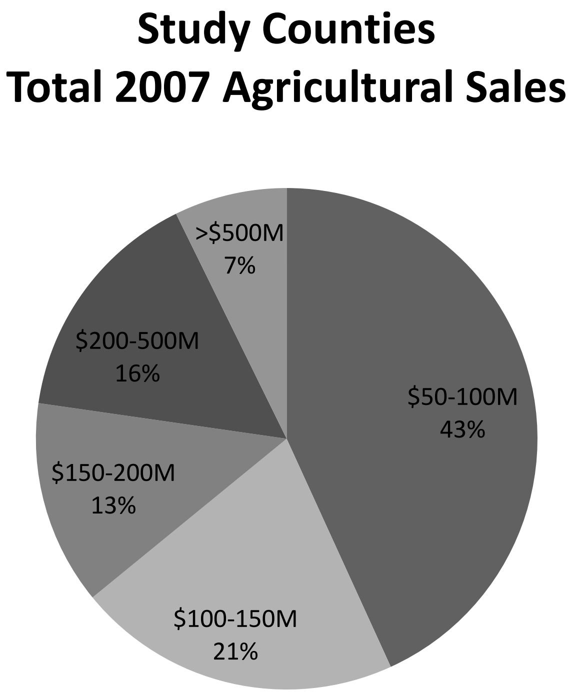


Figure 5. National scan county agricultural demography comparisons.

According to the 2007 agricultural census, MSA area farms account for 39% of all farm sales and 41% of all farms, though they occupy only 24% of all farmland. They account for 43% of all crop sales (65% of all vegetable sales, 80% of all fruit sales) and 32% of all livestock sales (46% dairy, 31% poultry, 17% hog). For the selected study counties, the figures are even more impressive. According to the 2007 agricultural census, study counties account for 34% of all farm sales and 26% of all farms, though they occupy only 15% of all farmland. They account for 39% of all crop sales (61% of all vegetable sales, 78% of all fruit sales) and 27% of all livestock sales (44% dairy, 26% poultry, 15% hog). By these measures, metropolitan area farms produce more value with less land than the national average and are more likely to focus on vegetable and fruit production than the average farm.

Counties Selected for National Scan

Figure 6. Counties used in the national scan. Larger states with the more total counties had more counties represented in the national scan: California (33), Texas (33), Indiana (32), Illinois (30), Michigan (23) Wisconsin (22) and Florida (20) had the most county representation. 2000 county populations ranged from 6,500 people in Carson County, Texas to 9.5 million in Los Angeles County, California.

Farm product, price, and area is highly heteroskedastic (not normally distributed) and spatially auto-correlated. Fruit and vegetable production in 2002 showed statistically significant spatial-auto clustering (Moran's I <.001), concentrating largely in California and Florida. Animal agriculture production occupied other geographically distinct areas of the county (Figure 7).

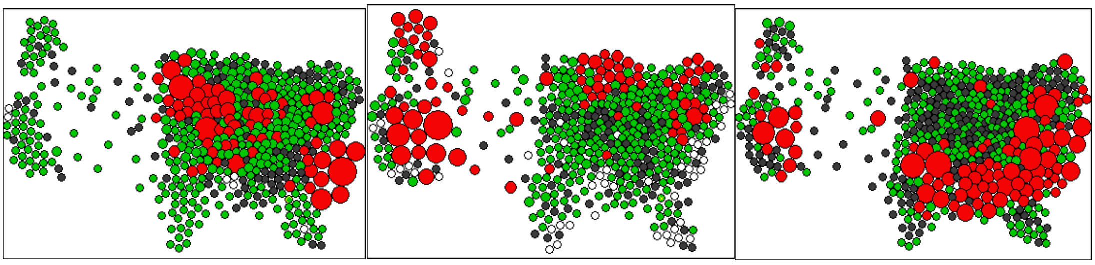


Figure 7. Animal agriculture clustering in high sales volume counties. Counties showed statistically significant spatial auto-correlation for 2002 hog production (far left Midwest and North Carolina), dairy (center California, Upper Midwest, and the Northeast), and poultry (far right South and Southeast) sales revealing the degree of spatial clustering of these industries. Red (high outliers in sales), Green (normal), Black (negative spatial correlation).

Surprisingly, over 25% of the study counties gained farmland from 1997 to 2007, with Weld County, Colorado gaining the most at nearly 200,000 acres. On the other hand, Kern County and San Bernardo County, California saw a loss of nearly half a million acres. Expressed as a percentage of total farm acres in 1997, some places like Broward and Collier Counties in Florida lost 60-70% of their farmland. Farmland loss showed significant spatial auto-correlation, centering on Florida and California. This finding is most likely due to how agricultural census data is collected and the change from conservation lands to farmland classification. Due to this aberration, changes in USDA Census farmland acreage data are discounted as a proxy for measuring farmland loss.

Annual agricultural commodity sales per acre were as low as $30.00 in Meade County, South Dakota to as high as $5,900.00 in Suffolk County, New York. The income from commodities compared to the expense of operations ran from -$45,000 in Marion County, Florida to $800,000 in Kern County, California. Total 1997 sales ranged from $50M to $2.8B in Fresno County, California while 1997 farm acres ranged from 19,000 in Pickens County, Georgia to over 2M in Kern, California, showing the vast spread of revenue and size of county farming operations. The top seven counties with the highest commodity sale returns for expenses were in the state of California. Fifteen of the twenty-eight counties that made less in commodity sales than their expenses were in Texas. This pattern is partially due to value-added sales from high-grossing farm products like wine in California, while low farm commodity sales in Texas could be supported by auxiliary farm incomes through on-farm oil drilling. The regional variations in farmland products, sales, auxiliary farm operations and farmland loss make it difficult to distill national truisms about farm productivity.

Direct farm sales through CSAs and agritourism data give an idea of where farms are more spatially engaged with urban areas. Reported agritourism revenues were highest in the following counties: Lehigh County, Pennsylvania ($2.14M); Burlington, New Jersey ($1.9M); Napa County, California ($1.8M); Hartford, Connecticut ($1.5M); Macomb, Michigan ($1.4M); Tom Green County, Texas ($1.2M); and Utah County, Utah ($1.1M). Agritourism revenues showed significant spatial auto-correlation in the northeast and California (Moran's I: 0.002). CSA prevalence showed much the same clustering in the northeast and western seaboard and was similarly spatially auto-correlated.

Rugosity in Relation to National Agricultural Production

Statistics on urban morphologies, on the other hand, showed minor regional spatial auto-correlation. Due to lack of spatial auto-correlation and no co-variate correlation, the measurement of rugosity as urban concentricity was determined to be the most useful. The county with the most concentric UA was Ogelthorpe, Georgia and the least Robertson, Tennessee (Figure 8). The raw measurement of urban perimeter was associated with larger populations and spatially auto-correlated around high population concentrations in the northeast and California. Due to these correlations, UA perimeter can also be used but only if controlling for farm acreage and population. Farm rugosity was heavily influenced by counties with large urban areas and small farm acreages, thereby discounting the measurement as a useful variable for the regression analysis.

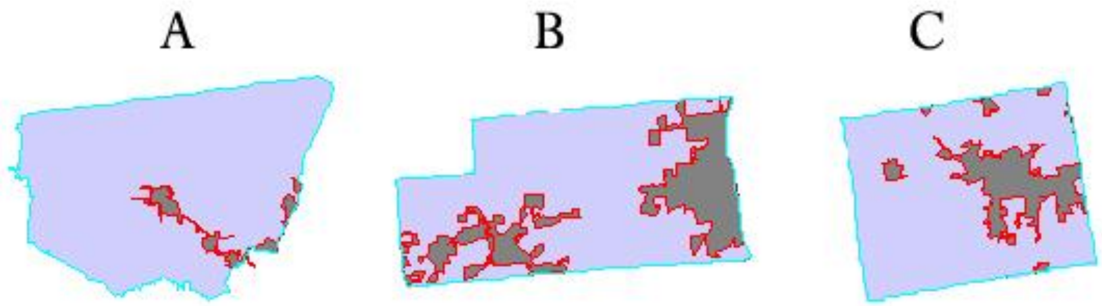


Figure 8. Counties with the least concentric UA in order of images left to right: A.) Robertson, TN; B.) Kenosha, WI; and C.) Washtenaw County, MI. Dark gray: urban area, Red: urban area perimeter, Blue: county line.

Counties showed no significant spatial auto-clustering in amount of urban area, and ranged from having nearly zero urban area to Tarrant County, Texas which houses Fort Worth, contains a large ring-road, and is considered to be 75% urban. Population change significantly auto-clustered, with one-ninth of the counties losing population, largely located in northeast middle America. Erie County, New York lost 30,000 people from 2000-2010, while Maricopa, Arizona gained 750,000. Farmland loss did not correlate with population gain spatially and many counties that gained population also gained farmland, rendering a farmland-conversion-to-development variable meaningless. This anomaly may be related to the sampling methods employed in the agricultural census or to the re-classification of idle farmland to conservation land. Future studies would do well to rely on remote sensing land cover data with changes in land cover calculated from satellite imagery.

Statistical Correlations

The three rugosity calculations were spatially joined by county with USDA amenity scores, U.S.D.A. Agricultural Census data (1997, 2002, 2007), U.S. Census data (2000, 2010), and 2004 County Typology codes.[4] The 2004 County Typology codes classify all U.S. counties according to six non-overlapping categories of economic dependence and seven overlapping categories of policy-relevant themes. The economic types include farming, mining, manufacturing, services, Federal/State government, and unspecialized counties. The policy types include housing stress, low education, low employment, persistent poverty, population loss, non-metro recreation, and retirement destination. State-fixed effected are controlled for by relating county variables to their state.

Pearson correlation statistics were used to compare all variables to each other. Pearson products measure the extent to which two variables "vary together," indicating correlation, not causation. The researcher wants to limit use of co-linear dependent variables in regression models, created in the subsequent sections. Correlations are explained for rugosity variables, agricultural economics, farmland loss, agricultural land values, and regional and state controls.

[4] An area's economic and social characteristics have significant effects on its development and need for various types of public programs. To provide policy-relevant information about diverse county conditions to policymakers, public officials, and researchers, ERS has developed a set of county-level typology codes that captures differences in economic and social characteristics. The 2004 County Typology codes classify all U.S. counties according to six non-overlapping categories of economic dependence and seven overlapping categories of policy-relevant themes. The economic types include farming, mining, manufacturing, services, Federal/State government, and unspecialized counties. The policy types include housing stress, low education, low employment, persistent poverty, population loss, nonmetro recreation, and retirement destination. In addition, a code identifying counties with persistent child poverty is available

Longer urban interfaces correlated with larger populations and county population increases from 2000-2010 (Figure 8 and 9). Partly, this finding is due to the draw of large urban areas to add more people, but may also be a function of the desirability of fringe living. Nonetheless, the correlation showed that every 100 kilometers of urban interface generated an average of 5,000 people added each year. Similarly, longer UA perimeter correlated with high values of agricultural land and buildings, indicating that greater exposure to the urban interface will drive up farm values. There was no correlation with county population or commuting population and the value of agricultural land and buildings, indicating that urban interface may be a better predictor of land markets than population. Farm-rugosity correlated with sale/acre (0.72), showing that the more urban interface per farm acre, the greater sales per acre. The degree of urban concentricity did not correlate with any other spatial, agricultural, or census variables.

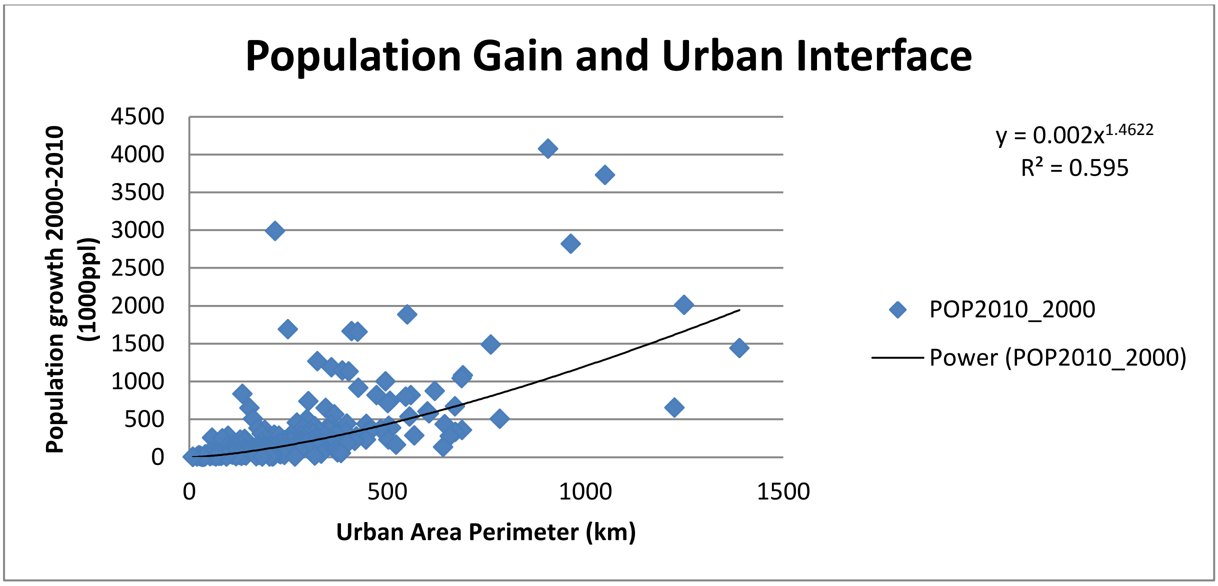


Figure 9. Relationship between population growth and UA perimeter length. 2002 Urban area perimeter charted against county population growth from 2000-2010, excluding those counties that lost population. Almost two-thirds of the nation's 3,143 counties gained population between 2000 and 2010. Study counties showed a similar breakdown. Some of the outliers the fastest growing counties, including Los Angeles County, CA; Harris County, TX; and Maricopa County, AZ which gained over 300,000 people this decade. Outliers for urban perimeter length include San Bernardino and Riverside Counties in California, Worcester County, MA and Maricopa County, AZ with over 1000 km of Urban Area perimeter.

Total farm sales per county strongly correlated with farm expenses in chemicals, fertilizers, farm labor, value of land and buildings, fuel and taxes (Figure 10). This indicates that farms with more expenses will have higher sales. Greater farm inputs, require greater farm outputs. Total county agricultural sales also strongly correlated with fruit, vegetable and dairy sales, but less so for other agricultural products like poultry and hogs, which may be more divorced from similar agricultural support industries or high-value agricultural-producing counties because they are not as contingent upon soil quality for productivity.

Sales per acre correlated with the UA perimeter length per farm acre (0.58) but not the length of urban interface or total farm acres, hinting at a potential relationship between farm profitability in relation to farm acres and urban interface. Sales per acre also correlated with the value of land and buildings per acre (0.7), total expenses (0.99), and expenses per acre (0.94), showing that greater investment in farm input will give or is demanded by higher per-acre yields. The value of sales per acre correlated negatively with the total percent of farmland per county, showing that the scarcer the farmland, the more productive it becomes per acre. Value of land and buildings also correlated with the sales per acre (0.7).

Focusing on total county agricultural sales from crops, fruit and vegetables, correlation stats showed that total sales from these categories correlated with total farm acres (0.5) due to the larger amount of land needed to produce these crops as compared to livestock. Crops and fruit sales also correlated with the acres of farmland lost from 1997-2007 (0.5) but not the farmland lost as a percentage of total 1997 acres, again showing that crops (0.56), fruit (0.53) and vegetable sales trend with areas with more farmland.

Similarly, counties with more farmland experience greater farmland loss, indicating that farmland loss may not be correlated solely with fruit and vegetable production though these production types are more likely to occur in the path of development as urban areas expand. Farm acres lost as a percentage of total 1997 county farm acres did not correlate with any variables and appear to fluctuate with development patterns unrelated to population growth or loss.

The value of land and buildings correlated with total sales (0.89), crops (0.85), fruit (0.84), vegetables (0.56), livestock (0.58), and dairy (0.6) but not poultry or hogs. This indicates that correlated categories occur on more expensive lands, a finding that is supported by the correlation of total expenses with sales (0.98), crop (0.89), fruit (0.86), vegetable (0.64), livestock (0.76), and dairy (0.64). The percent of the county in farmland anti-correlated with the value of land/buildings (-0.48), showing that the scarcer the farmland, the greater the value of land and buildings on farms, where most of that value is presumably due to increases in land value not necessarily building values. To that end, total expenses correlated with the value of land and buildings

(0.89) and with total sales for all agricultural products expect hogs and poultry. This indicates that more valuable farmland, which is presumably scare due to urban proximity, has greater expenses, and is more likely to have greater outputs with sales in produce and dairy.

Commodity sales (total, livestock, cattle, dairy, eggs, poultry, swine, crops, vegetables, and fruit) from 1997, 2002, and 2007 highly correlated across years as expected. This correlation indicates partly that counties exhibit stability in production type and expected sales. Total production in dollars correlated most with crop sales (0.92), fruit (0.86), vegetables (0.72), livestock (.71), and dairy (0.63) but not with hogs (0.06) or poultry (0.37) indicating that crops, particularly fruit and vegetable, correlate with high grossing counties more than livestock. Livestock sales correlated with dairy (0.8) and poultry (0.6) but not hogs, indicating the hog sales may be highly concentrated geographically or not dependent on relationships with other types of farming operations. While crop and vegetable sales did not correlate with any of the livestock sub-categories, fruit sales correlated with dairy (0.5) possibly indicating co-location of these industries as supported by Von Thünen 's agricultural land-uses paradigm.

Organic agriculture and on-farm energy generation correlated with total sales (0.7) and total farm acres (0.5), showing that organic agriculture and energy production may be more rural practices. On the other hand, the number of CSAs correlated with total sales (.54) but not farm acres, indicating that CSAs may function in counties where farming is a marginalized land-use.

State and regional control variables indicate that California farm data is significantly correlated with multiple variables and should be controlled for so that California data will not skew a national dataset. California was the only state that correlated with test variables. California positively correlated with total sales across all years, crop sales, fruit sales, value of land and buildings on farms, farm expenses, money spent on chemicals, contract labor, hired labor, fuel used, taxes paid on land and buildings, and housing stress. The Pacific region also trended in this way, and is a control variable in future multi-variate regression models.

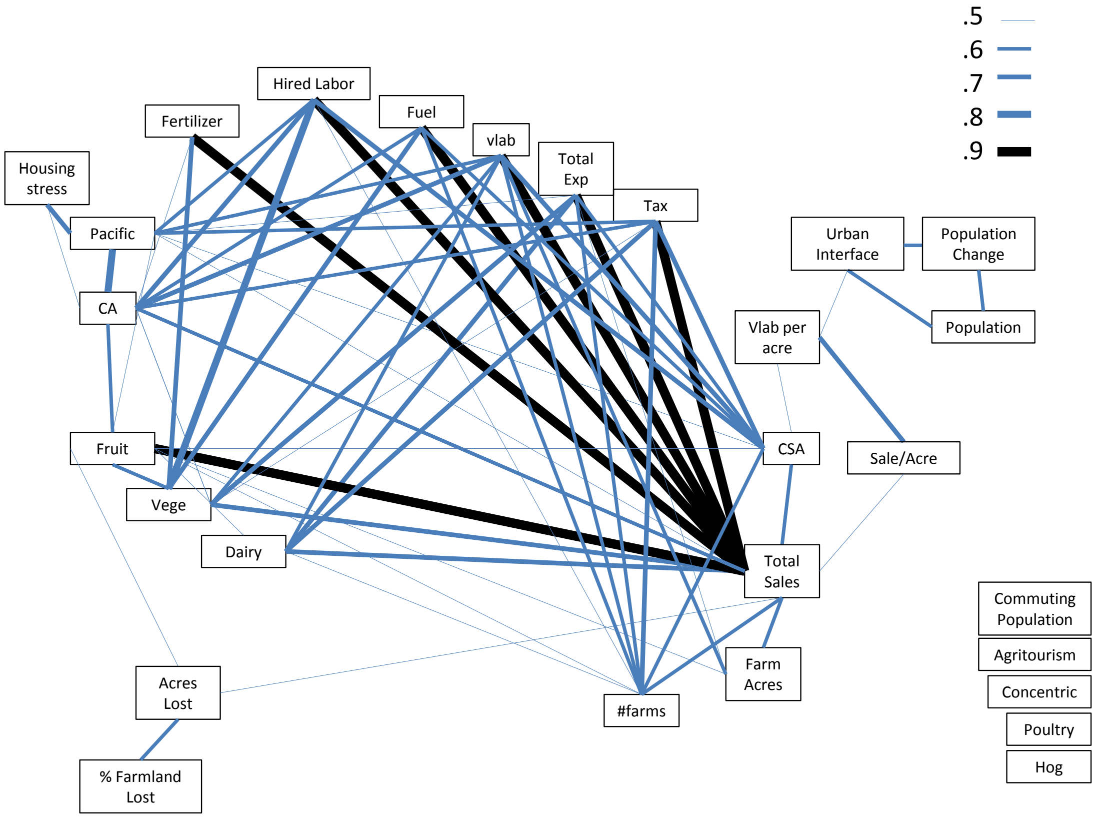


Figure 10. Correlation web for select variables. Vlab: 1997 value of land and buildings, Vege: 1997 total vegetable sales, CA: California, Total Exp: total farm expenses 1997, CSA: number of county farms with community supported agriculture.

T-Test: Using 118 county pairs with statistically different urban concentricites and UA perimeters but statistically similar county populations, farm acres and percentage of the county in urban land, shows similar total acres of farmland lost from 1997-2007 and similar percentages of farmland loss. This indicates that counties with greater rugosity will not experience greater farmland loss as a result. The t-test also revealed no significant differences in the expense-to-income ratio of farming operations, indicating that rugosity may not drive up farm operating expenses. The t-test showed a significant difference in total agricultural sales across all three agricultural census data years (1997, 2002, 2007) with more non-concentric counties outperforming more concentric counties by 40% (average: \$111K, +/-7.37E+09, p two-tailed: 0.04). This finding could be due to greater access to markets for farmland as predicted in the rugosity model. Similarly, counties with more non-concentric urban areas had on average 25% greater value of agricultural land and buildings (average: \$1.2M, +/-1.49E+12, p two-tailed: 0.03) and 30% greater expenses (average: \$174K, +/-6.22E+10, p two-tailed: 0.04).

This component revealed that metropolitan areas with greater rugosity did not statistically lose more farmland and had greater farm commodity sales indicating that non-concentric urban growth boundaries that would maximize the rural-urban interface may be desirable for functional farmland retention and profitability. On the other hand, farms with greater UA interface exposure experienced high land and building value and greater farm expense burdens. Because the expense-to-income ratio was statistically similar for counties with concentric and non-concentric UA, this speaks to farmland adaptation where farms near more non-concentric urban areas will have higher expenses, but will modify operations to produce higher farm outputs. The added pressure to recoup high expense costs through high value production is a significant concern for peri-urban farms, particularly those with greater exposure to the urban interface. Planners must consider economic development and agricultural economic support structures in addition to farmland protection programs to prevent high-cost, high-value farms from being sold for highly desirable development. Property tax relief and farmland preservation will be key land-use components if farmland is to remain in agricultural use in a county with high rugosity.

Multivariate Regression

In the past two decades, developments in the field of spatial econometrics (Anselin 1988, 2001a) have influenced the social science disciplines by allowing researchers to explicitly acknowledge spatial effects in explanatory statistical models. Such studies can be found in economics (Case, Rosen, & Hines, 1993; Holtz-Eakin, 1994), agricultural economics (Nelson, 2002), land use and land cover change (Bell & Irwin, 2002; Mertens, Poccard-Chapuis, Piketty, Lacques, & Venturieri, 2002; Muller & Zeller, 2002; Munroe, Southworth, & Tucker, 2002; Nelson & Geoghegan, 2002; Vance & Geoghegan, 2002), and environmental and resource economics (Anselin, 2001b; Bockstael, 1996; Walker, Moran, & Anselin, 2000). Spatial analyses are important because regression models that exclude explicit specification of spatial effects, when they exist, can lead to inaccurate inferences about predictor variables. For planning, and particularly the study of urban morphology, place-based effects matter in crafting policy and explaining farming patterns.

All spatial analyses were conducted using GeoDa 0.9.5-i (Anselin, 2003b). To achieve the most normal distribution, a distance weights matrix was utilized based on the inverse distance between counties. The threshold distance obtained (using Euclidean Distance) was 405km, representing the minimum distance required so that each observation had at least one neighbor (Anselin, 2003a). Neighbor lists were built using GeoDaTM (Anselin et al. 2006). Following Anselin's (2003) method, I tested the residuals from ordinary least squares (OLS) regression for spatial autocorrelation using a Moran's I test with 999 permutations. In each regression reported in the findings, a test of the residuals using Moran's I indicated that no further spatial error dependence occurred.

In combination with OLS regression, I tested spatial error and spatial lag models using the same distance weights matrix. Compared to the OLS regression models, spatial regression models incorporate spatial dependence in the form of lag or error dependence (Ward and Gleditsch, 2008). In other words, spatial autocorrelation is allowed and accounted for explicitly by noting dependence among errors and/or dependent variables. In spatial error models, the error terms across different spatial units are correlated. Goodness of fit for spatial error models suggests the presence of omitted explanatory variables that unite neighbor counties. The spatial lag model is a linear regression model with a spatial variable incorporated to reflect spatial autocorrelation. In spatial lag models, the dependent variable is affected by the independent variables in adjacent places. Goodness of fit for spatial lag models indicates the possibility of a diffusion process (i.e. an event or policy in one county increasing the likelihood of the same event occurring in neighboring counties). Both models thus remove any biased trends in spatially dependent data. As R^2 values measured in the usual way are meaningless for spatial models (Anselin 1988), I assessed goodness-of-fit with pseudo-R^2 values, which are the squared correlations between predicted and observed values. Final model selection was based on R^2 or pseudo-R^2 values, and graphical analysis of the residuals.

Lagrange multiplier (LM) diagnostics and their robust forms (Robust *LM*) were preferred to identify the form of spatial dependence (spatial error or spatial lag) and because Moran's *I* is inappropriate in the presence of heteroskedastic or non-normally distributed errors (Anselin and Rey, 1991; Anselin and Florax, 1995; Anselin et al., 1996; Anselin, 2005). The Jarque-Bera statistic was used to test the assumption of normality. Using the Lagrange multiplier tests, I chose between the two possible spatial regression models: 1) the spatial lag model, which incorporates a spatially lagged dependent variable, and 2) the spatial error model, which incorporates spatial autocorrelation in the error term using a spatial autoregressive process (Anselin 2002). If the *p* value was significant and the rho (the spatial autocorrelation coefficient) was either positive or negative in value, then spatial autocorrelation was evident and needed to be controlled.

Spatial statistic models could not be fit to explain farm acres lost, concentricity, or agritourism; but a model was found to explain total agricultural sales in terms of UA perimeter. Counties were spatially weighted based on a threshold distance of 405km to their nearest counties such that every county had a neighbor. A step-up ordinary least squares regression revealed significant Moran's I and LaGrange Multiplier effects, indicating the appropriateness of a spatial error model. There was no significant spatial auto-correlation for the residuals of this model, and the Jarque-Bera test for multicollinearity was 4.177342 but statistically significant. A score under 10 is considered passable in the literature. The Breusch-Pagan test for heteroskedascitity was significant, and the Likelihood Ratio Test for spatial error dependence was similarly statistically significant, which in combination with an insignificant Moran's I test on the residuals, indicates that the model has omitted other underlying explanatory variables which are not spatially correlated. Due to the appropriateness of the spatial error model, one can assume that high agricultural sales is not a social condition arising from imitation of one's neighbors, a ''feedback'' process yielding spatially autocorrelated residuals. Rather, high agricultural sales seems to result from a complex mix of social, economic, and cultural factors, only a small number of which can be brought into a statistical model of the process. Much of it remains unaccounted for and summarized in the model's spatial error term ($148M).

Several variables dropped out of the agricultural sales per county model: natural amenity score, average temperature, hours of sun, regional fixed controls and agritourism dollars. Natural amenity scores, regions and weather-related variables were expected to play into agricultural output in terms of the types of production possible in many counties and warmer weather or longer growing season would allow different types of crops. That these factors do not feed into total agricultural sales speaks to the variety of agriculture possible, and perhaps particularly to animal agriculture as a high value product that does not hinge on weather or soil quality. Agritourism and community supported agriculture variables were intended to capture counties with greater farm-to-city networks and markets, but their sales figures may be considerably under-estimated due the sampling techniques of the USDA, under-reporting in cash-based businesses, and potential misrepresentation where a bed and breakfast near a farm benefits from agritourism dollars not captured or reported in the farming operation. Other variables, such as percent farmland lost or housing stress, showed a significant nonlinear relationship with total sales (Figure 10), but were omitted by the stepwise regression model because inserting the variable into the regression model did not significantly improve the model prediction. This is partly due to the fact that these variables are highly correlated to total farm acres lost and California state-fixed effects respectively (see Figure 10 for the linear correlation web).

The resulting stepwise spatial error regression model predicts up to 69% of total agricultural sales in all counties with similar results across all agricultural years surveyed (1997, 2002, 2007). Controlling for total 2002 farm acres, state effects of California and the commuting zone population, a spatial error model was created with the following significant variables: farmland loss, low employment, and UA perimeter length. The table below is a 4-step hierarchical regression, which involves the interaction between four continuous scores and two non-continuous control variable (California and low employment). In this example, control variables for farmland area, commuting zone population, and California state-fixed effects are entered at Step 1 (Model 1), change in farm acreage from 1997-2008 is added at Step 2 (Model 2), employment as an indicator of purchasing power is added at Step 3 (Model 3), and the UA perimeter in meters is added at Step 4 (Model 4). The OSL model had a mean for county agricultural sales across the 458 counties of \$160M; Standard deviation of total agricultural sales in 2002 (Model 4): +/-\$281M, with a standard error of \$148M, and constant of constant of \$ -38M. The constant shows the baseline for agricultural sales, where counties must have positive variables to overcome the negative baseline.

Table 1. Summary of Hierarchical Regression Analysis for Variables Total Agricultural Sales Per County (N = 458) *p < .05. **p < .01. The mean for county agricultural sales across the 458 counties was \$160M; Standard deviation of total agricultural sales in 2002 (Model 4): +/-\$281M, with a standard error of \$148M, constant of \$ -37.875M. B= \$1.00 units.

Variable	Model 1 (B, SE B)	Model 2 (B, SE B)	Model 3 (B, SE B)	Model 4 (B, SE B)

California	**316,358,700, 42,579,890	**332,695,900 87,842,420	**286,898,000 89,135,990	**263,473,500 83,848,820
Commuting zone population	-.007, 5.59	-2.30, 5.57	-0. 602, 5.29	-5.54, 5.30
Farm acres	**581, 33	**521, 34	**467, 34	**473, 33
Farm acre change 1997-2007		**680, 168	**650, 160	**510, 160
Low employment			**324,180,000 46,275,720	**338,883,100 45,473,060
UA perimeter length (m)				**212, 48
R^2	0.632168	0.639516	0.675221	0.687939

If a county is in California, it can automatically add \$316M +/- \$42M to its annual agricultural sales. Because California is such a high agricultural-producing state, the effects needed to be controlled for in the model. Similarly, every acre of farmland yields an average of \$500.00 +/- \$30.00 more in agricultural product, a much smaller predictor of agricultural sales though still significant. This figure matches the significant variable of farmland lost over the ten year span, showing that for every acre of farmland lost, the model predicts \$680 more in annual agricultural sales +/- \$168, potentially as remaining farms turn to more diversified marketing strategies to overcome the pressures to operate on high value lands sought for development. If a county has low employment, that can add \$324M in agricultural sales, presumably as the county benefits from a more rural nature. The ERS bi-nomial low-employment indicator surveys counties, with the national finding that 460 counties (396 of which are nonmetro) had less than 65 percent of residents 21-64 years old employed in 2000. This variable may act more as an indicator of rural character than labor-force or earning power. Lastly, every kilometer of urban interface, adds \$212,000.00 in agricultural sales. To verify the coefficient of the sum of the urban interface, the coefficient and significance were tested as variables were dropped from the equation, revealing similar outcomes that indicate that all variables equal, for every kilometer added to the urban interface, the annual agricultural sales per county increase by ~$230,000.00 when the below coefficients are averaged.

Table 2. Verification of UA perimeter constant by systematically removing variables.

Variables Removed	UA perimeter (m) coefficient and significance * (<0.01 pval)
Total equation (none removed)	212 *
farm acres lost	294 *
low employment	215 *
Commuting Zone	210 *

A spatial error multi-variate regression with the UA perimeter as the dependent variable revealed several state fixed effects. Counties were spatially weighted based on a threshold distance of 405km to their nearest counties. Agritourism and the value of farmland and buildings were not significant variables in determining the length of the urban interface, nor did they improve fitness of the curve. Coefficient signs and probabilities were compared across ordinary least squares regression, spatial lag and spatial error models as a robustness test with the finding of similar signs and no change in significant variables (in red). The residuals showed no significant spatial autocorrelation (Moran's I, 0.2). The Jarque-Bera test, used to examine the normality of the distribution of the errors, is a test of the combined effects of both skewness and Kurtosis. The low probability of the test score indicates non-normal distribution of the error term, possibly due to variables not captured in the below equation.

Table 3. Regression on length of UA perimeter. Number of Observations: 458, Mean dependent variable: 202 km , Standard deviation of dependent variable: +/-200 km , Lag coeff. (Lambda) : -0.981981 , R-squared : 0.754651, *probability <.05, ** probability 0.01

Variable	Coefficient (m)	Std.Error
CONSTANT	13614.79	31634.46
**Population	0.03777895	0.007471347
Farm acres	-0.005634071	0.02928988
**Percent farmland lost 1997-2007	2925.991	477.7759
**2000-2010 Population change	1.392061	0.1010802
*Economic dependency on farming	-76512.8	32286.87
**Housing stress	71029.63	17198.83
**CSA	4032.735	829.903
Washington	10477.09	38075.11
Virginia	-11151.48	57801.18
Vermont	-61988.68	106566.4
Utah	3233.598	70080.68
Texas	14100.52	33683.74
Tennessee	55637.13	53242.14
South Dakota	43227.89	59388.55
**South Carolina	109291.3	43285.13
**Pennsylvania	215666.8	37802.4
Oregon	-49328.51	43784.46
Oklahoma	11840.73	55294.31
*Ohio	71593.55	37145.72
North Dakota	-6139.251	75909.62
North Carolina	-593.6287	37185.04
**New York	245700.6	37014.68
New Mexico	30136.13	139280.7
**New Jersey	142524.1	47155.62
Nebraska	-11394.33	45911.69
Montana	101163.3	71174.02
Missouri	-665.3413	40150.49
Mississippi	76969.15	61854.35
Minnesota	39799.37	37138.85
**Michigan	107391.6	35632.67
**Massachusetts	461924.2	60590.26
Kentucky	-8864.634	42536.08
*Maryland	71827.15	42842
Maine	50118.28	106965
Louisiana	55120.38	75236.57
Kansas	25248.23	45744.9
Iowa	-12731.07	36477.58
Indiana	37978.86	36574.77
**Illinois	93675.54	36088.54
Idaho	-36772.19	42774.35

Georgia	67812.29	44949.31
**Florida	116321.1	35301.75
Delaware	109423.1	104958.1
**Connecticut	384175.3	59073.16
Wisconsin	56776.65	35751.44
Colorado	-133608.9	133463.3
Wyoming	66792.86	126327.4
California	-53585.67	40598.35
Alabama	63507.34	40233.86
**Arizona	-235123.9	91952.51
**LAMBDA	-0.9819809	0.1926488

This regression indicates that the urban interface is likely to be greater in areas with greater population, population growth, greater percentage of farmland loss, lower economic dependency on farming, more housing stress, and counties with more CSA sales. Certain states were associated with longer urban interfaces: South Carolina, Pennsylvania, Ohio, New York, New Jersey, Michigan, Massachusetts, Illinois, Florida and Connecticut. Arizona was the only state with a significantly negative coefficient.

The results can be explained broadly by farmland diversity and land governance structures which unintentionally create rugosity. Positively significant states tend to have a long history of urban growth and agricultural production as many were part of the first American colonies and subsequent westward expansion. Unlike their counterparts in Maine and Vermont, these states focus more on farmland than forestry. Unlike agriculture in the American Midwest, many of these states have highly diversified farming types with production in produce, crop and animal categories.

Land use regulations reflect these early agricultural settlement patterns. In the Northeast, the township and city/village structure creates a fragmented pattern of local government and development, and thus often high rugosity (See Ohio, New York, Connecticut, Massachusetts, Michigan, and New Jersey in the results table). The city-county form of local government is also fairly fragmented because of the incorporation of suburbs into cities and annexations by cities in somewhat awkward (and high rugosity) patterns. In some city-county places, there is one city in the county, but these places tend to have low rugosity and tend to be quite rural—for example, Iowa and Kansas. Rugosity patterns at the state level have presumably been the result of long-term incremental land use decisions in farm-rich states with a decentralized local government structure.

When cross-referenced with the Wharton Residential Land Use Regulatory Index (Gyourko, 2005), and the General State Planning Legislation compendium provided by the Institute for Business and Home Safety, no patterns could be established for state planning control measures in significant states. States ranged from highly regulated top-down state-mandated planning in Maryland to Michigan with no state-mandated local plans, requirements that plans be consistent with zoning codes or horizontal consistency between local plans. To this end, UA perimeter length is not necessarily a function of any particular state or county-level planning efforts, but is probably related to governance structures and surrounding land typologies.

That every percent of farmland loss is associated with three kilometers of UA perimeter is a finding that contradicts the t-test and correlation results. The significance of this variable in the model needs to be evaluated in future step-wise regression models to further ascertain the association between farmland loss and rugosity. Future studies would do well to tease out cause and effect for these variables as well. It could well be that farmland loss leads to high rugosity, but the reverse may not necessarily be true.

Top 30 Counties with the Most Non-concentric Urban Areas

To identify if rugosity is a byproduct of specific state legislation, landscapes or planning regimes, the top 30 counties with the most non-concentric urban areas were analyzed for land-uses bounding the UA, state and county-level growth management policies and their effectiveness (Table 4). Using remote sensing agricultural land data and satellite imagery on googlemap and Cropscape, land-uses that bound urban areas were identified to see if particular land-use typologies create rugosity. Growth management models were identified in county comprehensive plans, zoning ordinances, state law, the Wharton Residential Land Use Regulatory Index (Gyourko, 2005), and the General State Planning Legislation compendium provided by the Institute for Business and Home Safety (http://www.disastersafety.org/content/data/file/statutes2009.pdf, 2009). Growth management policy effectiveness was noted where discussed in county comprehensive plans or ancillary studies. Similarly, private and state farmland preservation data was captured where reported as a measure of grassroots, non-traditional planning and community engagement. Permanently preserved farms act as hard boundaries to urban area expansion even if they are not formally part of the land-use planning process at the state or local level.

Though the majority of study counties were bounded by farmland (partly a factor of the county selection process stipulating annual agricultural sales over $50M), many counties were dominated by large state or national parks, lakes and water ways which acted as boundaries to the urban morphology and increased rugosity. For example, Pasco County, Florida can attribute much of its rugosity to environmental protection zones, which have been upheld by planning authorities since a 2000 Settlement Agreement with the county requiring modifications to the Comprehensive Plan to preserve wildlife corridors. Presumably, permanently protected national lands, such as state parks or lakes, would provide hard boundaries for urban morphologies, whereas farmland is more malleable unless lands are preserved. Few of the least concentric UA counties had ring roads, like those surrounding Boston and Houston in Hartford and Harris County respectively. Ring roads would presumably constrict urban growth and produce more concentric urban morphologies depending on urban development outside the ring road. This finding suggests that farmland may influence UA growth patterns, potentially generating greater rugosity.

In addition to significant farmland surroundings, several counties supported large urban populations as well. Nearly a third of the high rugosity counties added over 200,000 new residents from 2000-2010, making them members of the top twenty fastest growing counties in the United States. All but five counties added over 30,000 people from 2000-2010, with Harris, Riverside, San Bernardino and Los Angeles counties in the top five population growth counties. From this stance, one can ascertain that the high rugosity counties are also under extreme growth pressure.

Table 4. Counties with the most non-concentric urban area perimeter, where the variable 'concentric' is a measure of how many times greater the circumference of a circle the UA is. A concentric reading of 1 is an exact circular circumference. A concentric reading of 1 is an exact circular circumference. A concentric reading of 2 is twice the circumference of a circle for the same given area.

County	State	Core-Based Statistical Area	Concentricity	Population 2010	Total Agricultural Sales (year 2007, $1000)	Farm Acres (2007)
Robertson	TN	Nashville-Davidson	2661	66283	82028	227298
Washtenaw	MI	Ann Arbor	570	344791	73197	166881
Orange	NY	Poughkeepsie-Newburg	510	372813	73748	80990
Harris	TX	Houston-Sugar Land	468	4092459	62533	259039
Stanislaus	CA	Modesto	380	514453	1820564	788954
Pasco	FL	Tampa-St. Petersburg	345	464697	111275	149963
Hartford	CT	Hartford-West Hartford	326	894014	133582	53504
Tulare	CA	Visalia-Porterville	300	442179	3335014	1168684
San Diego	CA	San Diego-Carlsbad	208	3095313	1054182	303889
Hidalgo	TX	McAllen-Edinburg	190	774769	314256	722582
Hillsborough	FL	Tampa-St. Petersburg	187	1229226	488220	219800
Polk	IA	Des Moines	144	430640	122713	249427
Jasper	MO	Joplin	139	117404	92665	258815
Los Angeles	CA	Los Angeles-Long Beach	133	9818605	325880	108463
Solano	CA	Vallejo-Fairfield	120	413344	244295	358225
Jackson	MI	Jackson	112	160248	56878	182345
Riverside	CA	Riverside-San Bernardino	110	2189641	1012041	354753
Middlesex	MA	Boston-Cambridge	108	1503085	81708	33893

Dane	WI	Madison	106	488073	470593	535756
Marion	OR	Salem	95	315335	586743	307647
Will	IL	Chicago-Joliet	88	677560	127597	220851
Pierce	WA	Seattle-Tacoma-Belle	82	795225	83402	47677
Woodford	KY	Lexington-Fayette	74	24939	341058	119087
Mercer	PA	Youngstown-Warren	71	116638	60655	171860
Stark	OH	Canton-Massillon	69	375586	135671	138061
Canyon	ID	Boise City-Nampa	67	188923	420928	260247
Bell	TX	Killeen-Temple-Fort	66	310235	61748	431945
San Bernardino	CA	Riverside-San Bernardino	66	2035210	743661	514234
Santa Cruz	CA	Santa Cruz-Watsonville	65	262382	447417	47489

Much of planning in the United States is subject to local control only, with few states coordinating or mandating land-use form. Historic reasons for lack of state land-use control stem from the first municipal charters granted to European medieval cities and indoctrinated with the first villages constructed in the United States (Platt 1996, 69-75, 121-152). Even as land-use planning was institutionalized in the 19th century with planning professionalization, nuisance laws, density control through health acts and later zoning codes, municipal adoption and enforcement remains fragmented and uncoordinated. For example, many cities plan without reference to their urban growth and annexation of unincorporated nearby county farmlands. Counties may also plan, but may or may not be guided by state-wide goals, and may not reflect a knowledge of neighboring county plans.

Even if counties or cities wanted to plan, many U.S. states lack enabling legislation to allow counties or cities to plan, retaining that power at the state level or granting the power only to municipalities; and even where zoning enabling legislation exists, not all cities or counties have adopted plans or zoning, much less the more technical and modern elements of planning such as land-banking, farmland preservation, farmland reserves, transfer-of-development-rights, or purchase-of-development rights. These planning elements are also at the mercy of local economic policy and financial climate. For example, land can be zoned for agriculture, but if the county lacks supporting agricultural policy or ancillary support industries, farming will not occur on that parcel. To gain a better sense of the power of county-level planning and its coordination, county comprehensive plans and ordinances were cross-checked with state land-use regulations, right-to-farm legislation, agricultural extension programming, the Wharton Residential Land Use Regulatory Index, and General State Planning Legislation provided by the Institute for Business and Home Safety (Foster and Summers, 2005; Gyourko et al, 2008).

Local land-use planning in the United States is highly fragmented partly because a majority of states do not engage directly in land-use planning or mandate coordination. According to the Institute for Business and Home Safety index of 'Strength of State Planning Role,' study counties are represented in four of the eight states that possess a substantial state planning role (10/30 counties). That only eight of the fifty states have substantial state land-use planning policies speaks to lack of planning coordination or regional vision in American planning. Nearly half (14/30) of study counties are in states with a very weak state role in planning. By this measure, rugosity may be a byproduct of low levels of state planning involvement, and potentially a result of more local planning efforts or lack of planning altogether.

Similarly, twenty-eight states in the U.S. do not have a state development plan. Of the states that do have a development plan, only 18 have a land-use component to this plan; five of these 18 states are represented in the top 30 study counties, totaling 6/30 study counties with a land-use component to their state development plan. By this measure, high rugosity counties appear lower than the national average in having a state land-use plan in effect. Further, twenty-five states mandate local plans though only 18 of those stipulate that zoning be consistent with comprehensive plans, a national average represented in the 15 study counties with state-mandated local plans where 13 of those mandate consistency. Study counties match the national average in that the majority lack state planning oversight and mandated consistency with zoning.

The 2006 Wharton Residential Land Use Regulatory Index offers another measure of state land-use control and ranges from Hawaii with a score of 2.56, representing the state with the most land-use regulation, to Kansas with a score of -1.17, indicating it is the state with the least land-use regulations. The top 30 most non-concentric counties spanned the range of the Wharton Residential Land Use Regulatory Index with Massachusetts (1.56), the second most regulated state in the continental United States to several low-regulated states such as Kansas (-1.17) and Texas (-1.01).

Surprisingly, many states that planners consider to have tight land-use regulations, such as Oregon (0.08) and California (0.59) rank behind more well-regulated states such as Rhode Island (1.58), New Hampshire (1.36), New Jersey (0.88), and Maryland (.79), perhaps indicating a mismatch in planning literature, best practice recommendations and actual best practices in this highly fragmented landscape of planning potentials.

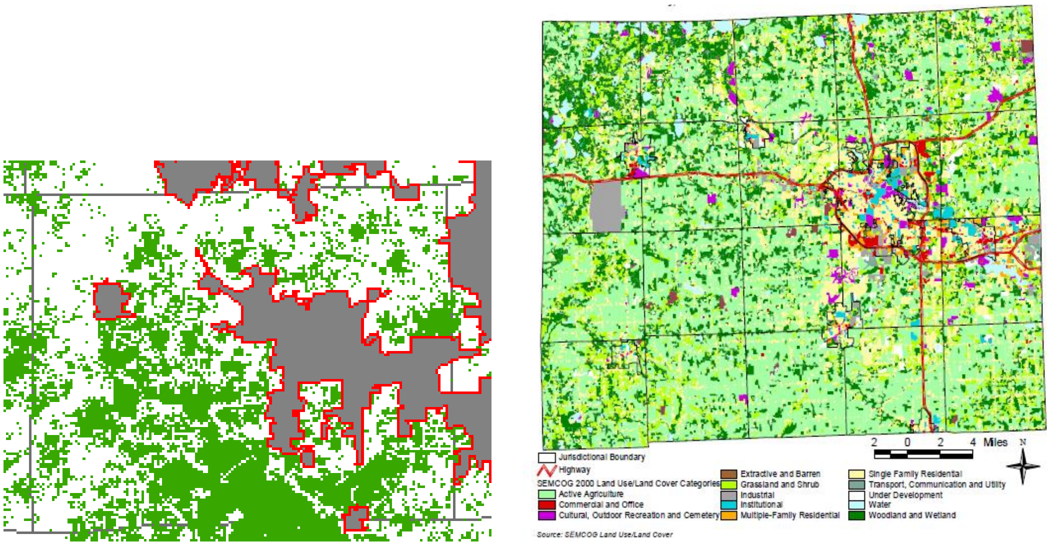


Figure 11. Washtenaw County, Michigan Remote-sensing farmland data (left: farmland: green, UA: gray, UA boundary: red) supports the finding that agricultural zoning does not always prescribe agricultural use but that actively farmed agricultural land largely bounds the UA perimeter. Composite zoning map (right, *Washtenaw County Department of Planning & Environment*, *SEMCOG*, *Local Unit of Government Master Plans*) illustrates in comparison with the Urban Areas, how agriculturally-zoned land bounds the irregularly shaped urban core. Compare with Figure 8.**(8**C).

In addition to evaluating land-use planning measures through state land-use indexes, I investigated county-level planning and zoning documents and ancillary county information about land protection from private endeavors, such as land trust activity in the study counties. The need to protect and plan for agricultural economies is identified in several of the comprehensive plans. Yet the majority of planning documents that do mention farmland protection, only go so far as to suggest or encourage farmland protection without creating any policies that would firmly direct a process in considering whether county farmland should be developed for alternative uses.

This study does not cover planning for agricultural economies or the presence of agricultural economic business councils in relation to farmland retention in the study counties. It should, be noticed, however, that agricultural zoning or farmland protection planning cannot prescribe agricultural use where agribusiness cannot remain solvent (See Figure 11). Agricultural zoning can only allow these uses, whereas economic policy councils can encourage these uses. The Orange County, New York Comprehensive Plan gives five recommendations for creating quality communities, the last being, "direct efforts to help reduce the costs and provide incentives to help overcome market forces that encourage the conversion of farms to residential and commercial development" (2003). Similarly, many plans speak to value-added products and the need to support non-traditional farmland economic development through planning support for ornamental horticulture, orchard products, aquaponics, equine industries, "U-Pick"operations, hay rides, agritourism, and seasonal events along with farm stores (Orange County Comprehensive Plan, 2003;Washentaw Comprehensive Plan, 2004). These suggestions when made in comprehensive plans are rarely followed by a policy or process to encourage farm profitability. For this reason, only process-oriented policy in planning documentation is reported in the table of county land-use regulations (Appendix).

Many county growth management tactics are in flux or have been introduced only in the past five to ten years (Appendix). Roughly half of the counties have had some form of county land-use planning since the 1970s, others started planning in the last five to ten years, and still others like Robertson County, Tennessee; Jasper County, Missouri; and the Texan counties lack comprehensive plans that address farmland.

Less obvious to the effectiveness of land-use regulations are the consequences of changes to the funding sources and policies that enforce many well-meaning comprehensive plan documents or zoning ordinances. For example, since the 1970s California has offered agricultural land protection through the Williamson Act, which, similar to many other states, offers property tax breaks for large blocks of voluntarily submitted farming parcels and releases the farmers from special assessments. In California, counties provide the property tax breaks, which can range from 20 percent to 75 percent, depending on the age and location of each ranch or farm. Statewide, 16 million acres of farmland are protected under Williamson Act contracts (The California Land Conservation (Williamson) Act Status Report, 2010). The state historically made up the difference in tax income to the counties, granting them back some of the money -- about $35 million a year statewide. When the state's calamitous budget struggles began in 2008, after the housing bust and rising unemployment sharply lowered tax receipts, Governor Arnold Schwarzenegger cut the state’s share of the Williamson Act to $1,000 in 2009, but compromised in 2010 and boosted it to $10 million. Fluctuation in funding supply has some scholars worried that counties will not pursue Williamson Act contracts in the future as state budgets prove more wobbly. Thus, strong land-use regulations are not always indicative of effective, well-funded, long-term farmland protection policies.

State and local land-use policies varied widely from Texan counties without any comprehensive plans, zoning or farmland preservation to Connecticut with no county government but semi-coordinated state farmland protection to Californian counties with significant state mandated farmland protection, voluntary farmland preservation, and extensive county land-use planning of both effective and non-effective varieties. Texas had the least planning oversight with regards to farmland. Even the subdivision regulations for Harris County, Texas do not make mention of agricultural uses of land. Other counties had mixtures of grassroots county-level preservation and top-down state mandated farmland protection with no clear bias to one form or the other.

Many of the top 30 counties have been the subject of growth management studies and grassroots efforts to raise awareness about farmland loss, though not all of these efforts have, succeed in promoting or implementing state or local policy to preserve or maintain farmland. Woodford County has the distinction of tracing the grassroots farmland preservation efforts to a singular event, an 800 acre leap-frog subdivision development. Woodford County had seen a change in the type of agriculture practiced with a 150% increase in the number of horse farms from 1978 to 2002, and ranks second in Kentucky in the total value of all agricultural products sold where the sale of horses represents 88 cents of every dollar of agricultural value generated in the county. The change in agriculture type did not create as much of a community stir as the development pressures. In 1972, the Charter Oaks subdivision was proposed with

125 homes on 5 acre lots about halfway between the cities of Versailles and Frankfort with no sewers or natural gas, a rural water and fire district, and on a two lane road. The subdivision approval sparked a documentary, a land grant group, and a call to action for legislators to enforce or create new land-use regulations. This leapfrog development was approved despite the strong state and local oversight of land-use. Kentucky granted power to counties for comprehensive planning in 1966. Woodford drafted their first County Comprehensive Plan in 1989 after the Charter Oaks subdivision was built. The County also established urban service boundaries which were expanded in 2005 and 2011, and has 30 acre agricultural zoning. This is to show that state enabling legislation is only useful once it has been exercised in making a plan and changing zoning. Woodford County was too late to act.

Though many of the counties have been featured in farmland preservation studies, few had effective farmland preservation strategies. For example, Robertson County, with the most non-concentric urban area of all study counties, began to focus on farmland conservation only after a 2005 study by the American Farmland Trust, entitled the 'Cost of Community Services Study: Robertson County Tennessee'. The study revealed that Robertson County made more from taxes on farmland than it provided in services to farmland, a common argument in advocating for farmland retention and balanced growth approaches. Following the COCS Study, Cumberland Region Tomorrow (CRT), a private, non-profit, citizen-based advocacy group released the CRT Quality Growth Toolbox in 2006 and partnered with the American Institute of Architects to fund and implement the region's first Quality Growth pilot project in Robertson County. Citizens from these grassroots groups formed a Quality

Growth Advisory Committee to work with Nashville Area MPO in 2008 on the Tri-County Transportation and Land Use Study which is awaiting adoption in 2013. Robertson County, like the other study counties, possesses rich agricultural land under high development pressure and is governed with a general lack of effective land-use planning, though the latter is the norm for counties in the United States. The ten year trajectory in operationalizing study findings and farmland protection in Robertson County speaks to the slow nature of urban policy in the face of rapid development.

Robertson County's history of grassroots-led farmland preservation efforts are in direct contrast to Kenosha County which has developed state-led land preservation for over 30 years and is continuing to strengthen these efforts with further state involvement. The initial Farmland Preservation Plan recommended 74,980 acres of farmland for preservation in Kenosha County, an acreage that covers 42.1 percent of the total area of the County. In 2011, Kenosha County still retains 61,372 acres of farmland in agricultural preservation zoning districts or about 82 percent of the farmland in the county. This protection is local zoning and is not preservation under a permanent easement, but this top-down land-use planning still offers some measure of protection. The success of Kenosha County is largely due to supportive state land-use regulation. Wisconsin's 1977 farmland preservation law (Chapter 91) was updated in 2009 with Wisconsin Act 28 (2009-2011 Budget Bill) to create the "Working Lands Initiative" requiring every county in the state to update their existing farmland preservation plans.

The success of Kenosha County's extensive farmland protection programming offers yet another contrast to Tulare County, California, a county with ample state land-use planning support and county-level efforts which has nonetheless resulted in farmland loss. Tulare County limits development in unincorporated areas, diverting it instead to cities. As well as serving to protect farmland and other open space, city referral policies aim to reduce public infrastructure and service delivery costs, limiting the role of county government as an urban service provider, and promoting "compact and contiguous" development. Such policies are often backed up by formal county-city agreements that may require county-to-city referral of development proposals in certain areas and may include revenue sharing arrangements.

An American Farmland Trust report, Farming on the Edge (1993) declared Tulare County the most productive farmland under most intense development pressure. A follow-up 2006 American Farmland Trust Report, "The future is now: central valley farmland at the tipping point," noted a decade later that Tulare was the only Californian county to develop less efficiently despite adopting smarter growth policies and stricter planning. Tulare has had 31% of growth outside the UGB (1990-2000) and a farmland conversion rate per new resident that is 1.4 times higher than surrounding counties. Interestingly, one of Tulare County cities mentions a desire for concentric growth in this non-concentric pattern of urban development. Visalia General Plan calls the county to "manage planning area growth to be contiguous and concentric from the City's core area: (Goal 6, Visalia General Plan (VGP), Land Use Element, 1-25). Despite this goal, Tulare County has some of the more non-concentric urban areas in the United States.

The only commonality among the top 30 counties is both extreme development pressure and farmland productivity. The combination of these two factors may create rugosity under a variety of different planning land-use policies where development is necessary and even desirable near farmland, and where farmland remains economically profitable despite or even because of urban outgrowth. The Polk County comprehensive plan acknowledges not only the pressures of balancing urban growth with highly productive farmland, but the distinct and desirable partnerships between the two land-uses:

> "Agriculture in Polk County is supported by the proximity of high-quality agricultural areas to the urban core. This proximity provides more opportunities for synergy between agricultural production and agricultural processing. It also provides broader marketing opportunities than more remote agricultural areas. In addition to access to large corporate markets, there are opportunities for direct marketing to consumers and the food service industry. Direct marketing to consumers could occur through farmer's markets, community supported agriculture, sale of products at point of production, and farm tourism such as wineries, corn mazes, and seasonal sales. Access to the food service industry could include marketing of locally-grown foods in local stores and sales to local restaurants" (Chapter 6, page 3).

Perhaps the urban proximity to farmland has contributed to both highly desirable development and highly productive agriculture as each use competes *and* compliments the other. Similarly, the 2003 Orange County, New York Comprehensive Plan calls for development of "residential/agricultural corridors," with "a mix of land uses lead by single family, detached housing and agriculture," intentionally pairing development with farmland. This is in contrast to the majority of comprehensive plans that call for buffers or separators between agricultural lands and urban lands (Tulare County, San Diego County).

In summary, the counties with the highest rugosity do not share similar state, county, or local planning structures though they are all located in areas with intense development and many in areas with highly productive farmland. Counties also had various levels of success in farmland retention, which neither supports rugosity as a growth model nor disputes it. Because so many of the counties without growth plans and with un-enforced growth plans have lost farmland, this suggests that a high rugosity growth model would need effective farmland protection and economic support planning, though this is also true for concentric growth models! To that end, the question in planning should not be whether to pursue top-down or bottom-up farmland preservation techniques, but to use both with continual oversight in the permitting process. It should also be noted that none of the counties intentionally planned for high rugosity. In instances where density or urban form were mentioned, all plans called for compact or Duany-esque tapering land-use densities (Figure 12, top), which are in direct opposition to rugosity theories of urban form and high fringe density.

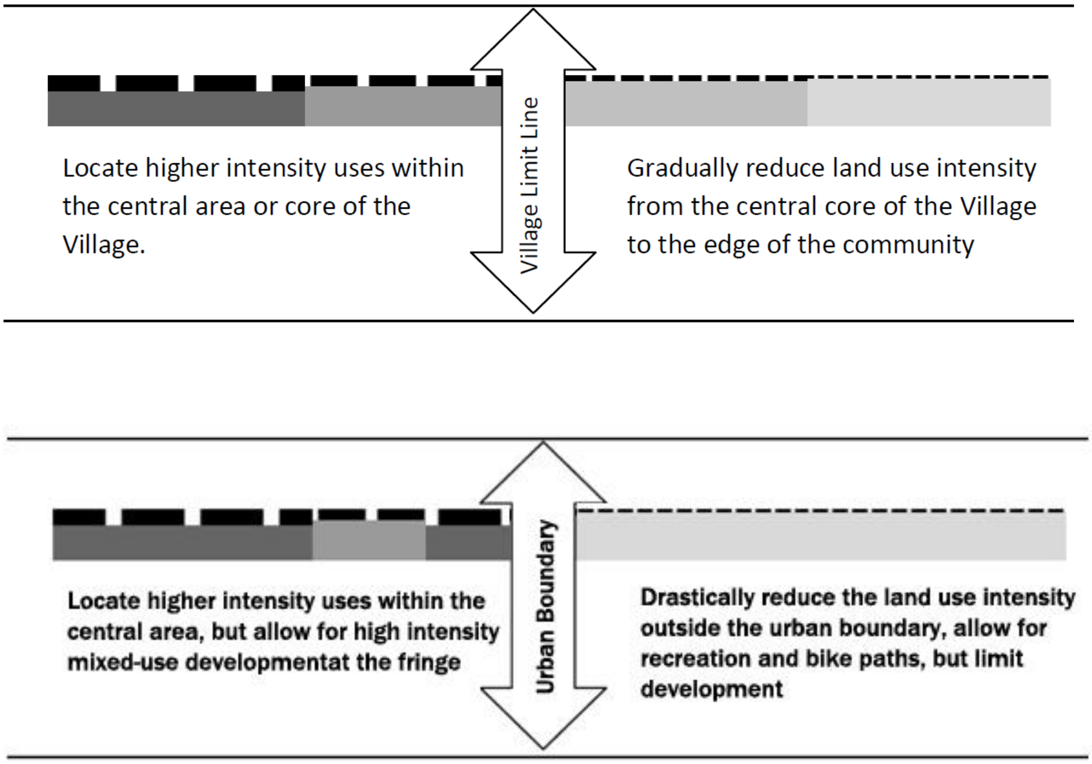


Figure 12. Urban development density gradation drop-off. Above: Gradation of development land-use presented from the San Diego County General Plan (2011). Below: The author suggests steeper drop-off of density, allowing more residents and business to benefit from the type of agricultural amenities presented by peri-urban farmers. To allow for this, the author recommends an uptick in development density at the fringe, and strict control to minimize development outside the urban growth boundary.

CHAPTER 6. Rugosity, Planning and Farmland Loss: Four Case Studies

To get a better impression of how rugosity is influenced by or influences farmland loss, four cases were selected with different levels of rugosity and farmland loss. These cases also explore if rugosity is an intentional result of different planning motives and arrangements in the county. Most importantly, the cases give an understanding of how rugosity influences farm function by mapping farm-to-market networks. The geographical boundaries of these networks help explain farm-market functions in relation to different urban morphologies and land-uses. The cases will compare framework of state and local planning regulations, county farm product, landscape, and the policy network of each county.

Case Selection

Cases were selected from the national scan based on varying county farmland loss and rugosity measurements, but similar farm acreages, commuting area populations and urban markets. Case match was imperfect due to extreme regional, state-level and county-level variation in population, farming practices, and county size. Future studies would do well to expand the number and diversity of cases for a broader comparison.

Case data explores state planning and farmland preservation legislation as it relates to county-level planning and zoning ordinances. Planning measures are contrasted in comparison to agricultural profiles and supporting agencies. The timing of various planning measures and the success of their enforcement is considered in relation to the timeline for farmland loss as many successful programs may be implemented too late to have stemmed the bulk of farmland loss.

Case studies review five elements:

1. Land-use profiles to ascertain agriculture type and buffering land-uses for UA.
2. State-level plans, mandates, and enabling legislation
3. County-level plans and ordinances
4. Farmland preservation and grassroots farmland protection in the county
5. Scholarly literature evaluating policy success in each county

In addition to these five elements, the case study component also includes a farm network analysis to ascertain the types of networks in the county. Program director interviews allow the researcher to verify the network findings, make sense of why certain networks flourish in certain counties, and how state and county-level policies influence these farm-city networks in relation to urban morphology.

Table 5. Case selection based on differential rugosity and farm acres lost, similar total farm acres and populations, and proximity to similar urban markets.

	Farm Acres Stabilized	Farm Acres Lost

High Rugosity (expect greater farm networks)	Baltimore, MD	Chester, PA
Low Rugosity (expect fewer farm networks)	Salem, NJ	Kent, DE

Land-Use Profile Comparison

None of the study counties is considered farm-dependent, to have housing stress, or alternate ratings of poverty, education, recreation or retired populations. The counties with greater farmland loss had greater total agricultural expenses and value of land and buildings, presumably prompting the sale of farmland due to the development opportunities and expense of staying in farming. Counties with greater farmland loss also had a greater number of farms, total sales, and sales in dairy, hog, and fruit, but not vegetables. Case study counties largely mirror findings in the national scan t-test, in that rugosity did not preclude greater farmland loss, but counties with greater sales, expenses, and value of land and buildings experienced greater farmland loss as demonstrated in the correlation web (Figure 10).

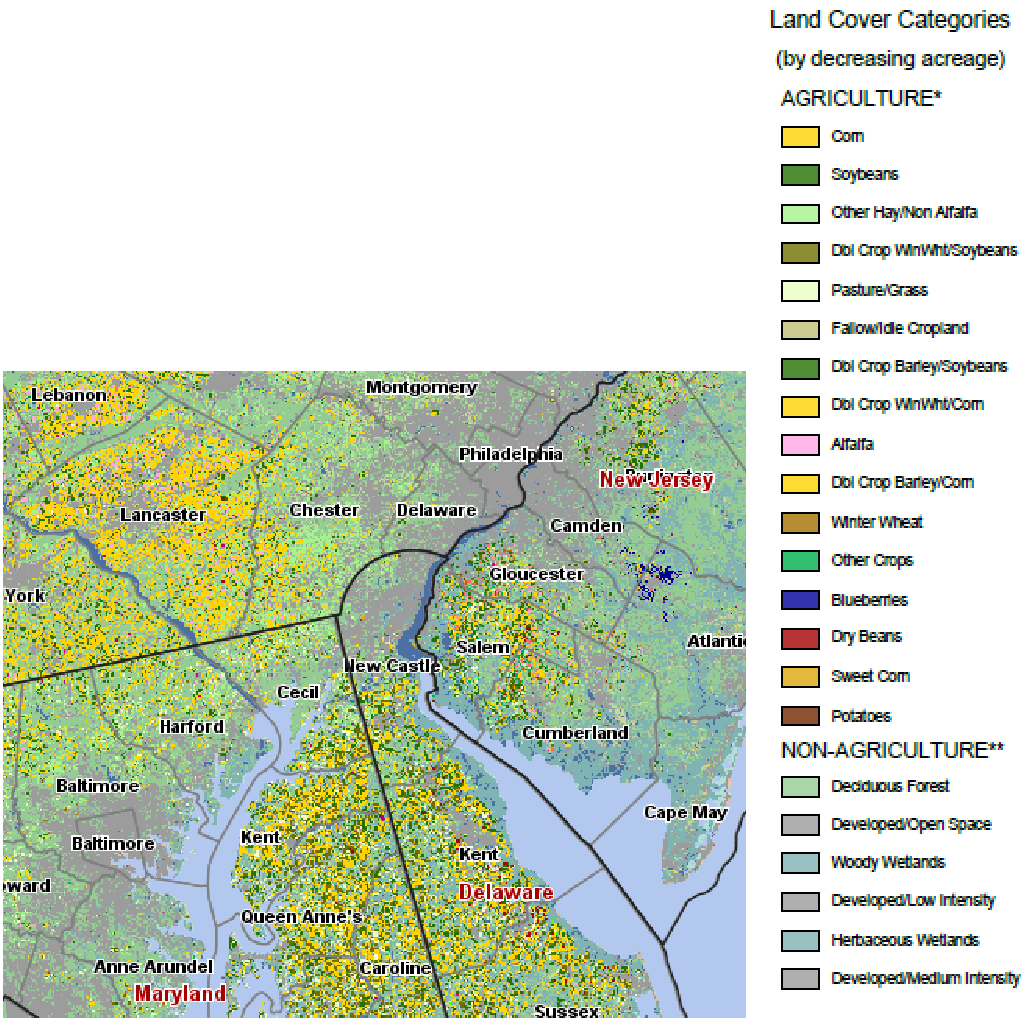


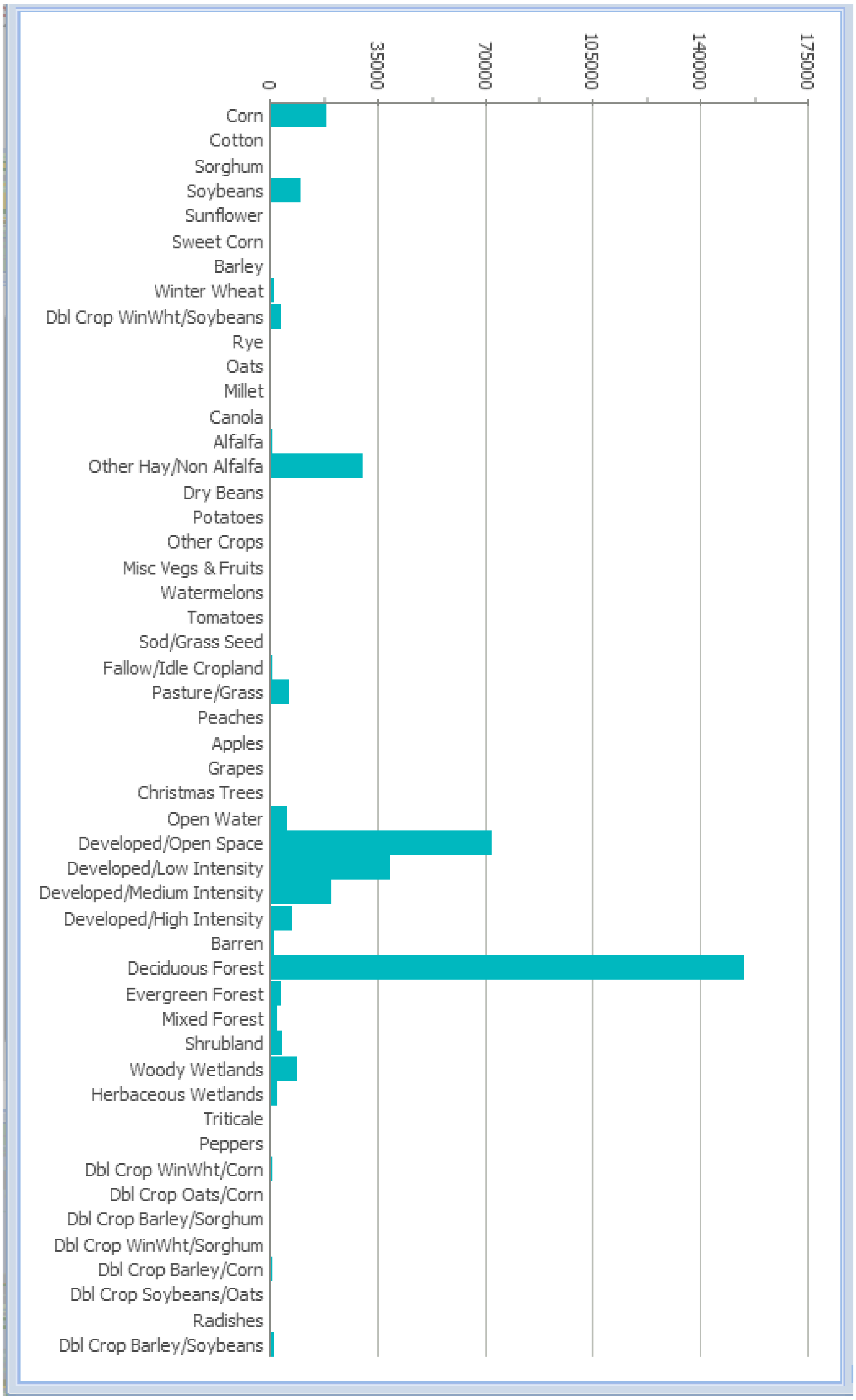
Figure 13. Remotely sensed land-uses in case study counties (Baltimore, MD; Chester, PA; Kent, DE; and Salem, NJ) and surrounding environs. Source: http://nassgeodata.gmu.edu/CropScape/

The remote sensing land-use data represents just over 50% of the farmland reported by the 2007 USDA agricultural census data at the regional scale, showing that the four states (NJ, PA, MD, DE) encompass 6,066,252 acres (2,459,250 sq km) of farmland, as compared to the 2007 agricultural census total of 11,104,703 acres (MD: 2,051,756 acres, NJ: 733,450, PA: 7,809,244, DE: 510,253). Six percent of remote sensing farmland data overlapped with defined UA areas at the four state regional level, leaving 94% of the remote sensing farmland in non UA. Thus, remote sensing data is most likely an underestimate of land-use typology, but this under-estimate does not grossly conflate urban and farm uses.

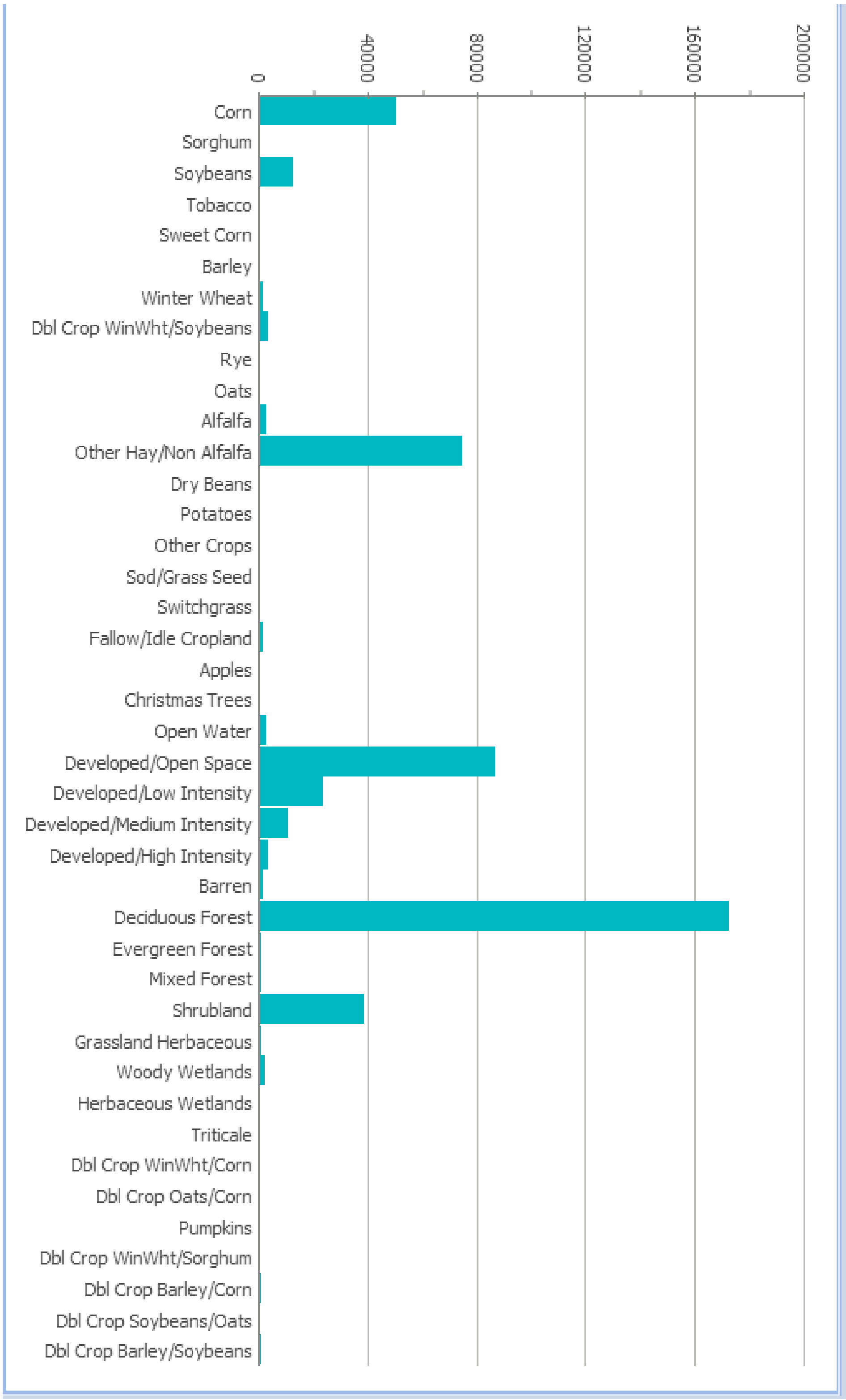
Table 6. Agricultural profiles in study counties. Counties with red text have high rugosity and shaded counties experienced greater farmland loss.

CBSA	**Baltimore-Towson, MD**	**Philadelphia-Camden-**	**Dover, DE**	**Philadelphia-Camden**
STATE	**Maryland**	**Pennsylvania**	**Delaware**	**New Jersey**
County	**Baltimore County**	**Chester County**	**Kent County**	**Salem County**
UA perimeter length (m)	344947	645242	230988	119876
Concentricity (X times greater than circle)	28	27	5	6
2010 population	805029	498886	162310	66083
2010 Commuting Zone Population	2512431	4200408	439269	1752600
2007 farm acres	78282	166891	173808	96530
percent farmland	3.16	6.20	8.65	7.72
2007 number of farms	751	1733	825	759
percent of farmland lost	1.51	14.38	11.94	-3.92
acres lost	1197	28036	23564	-3640
2007 total agricultural sales ($1000)	68423	553290	188390	79962
2007 sales per acre ($/acre)	874.06	3315.28	1083.90	828.36
2002 fruit sales ($1000)	242	1621	1313	1196
2002 vegetables sales ($1000)	6398	2724	24562	31735
2002 hog sales ($1000)	197	2408	417	148
2002 dairy sales ($1000)	4636	47367	11387	6550
2002 poultry sales ($1000)	240	12213	-1	-1
value of land and buildings ($1000)	720862	1792359	1725299	1011192
2007 total agricultural expenses ($1000)	64585	508292	153200	69337

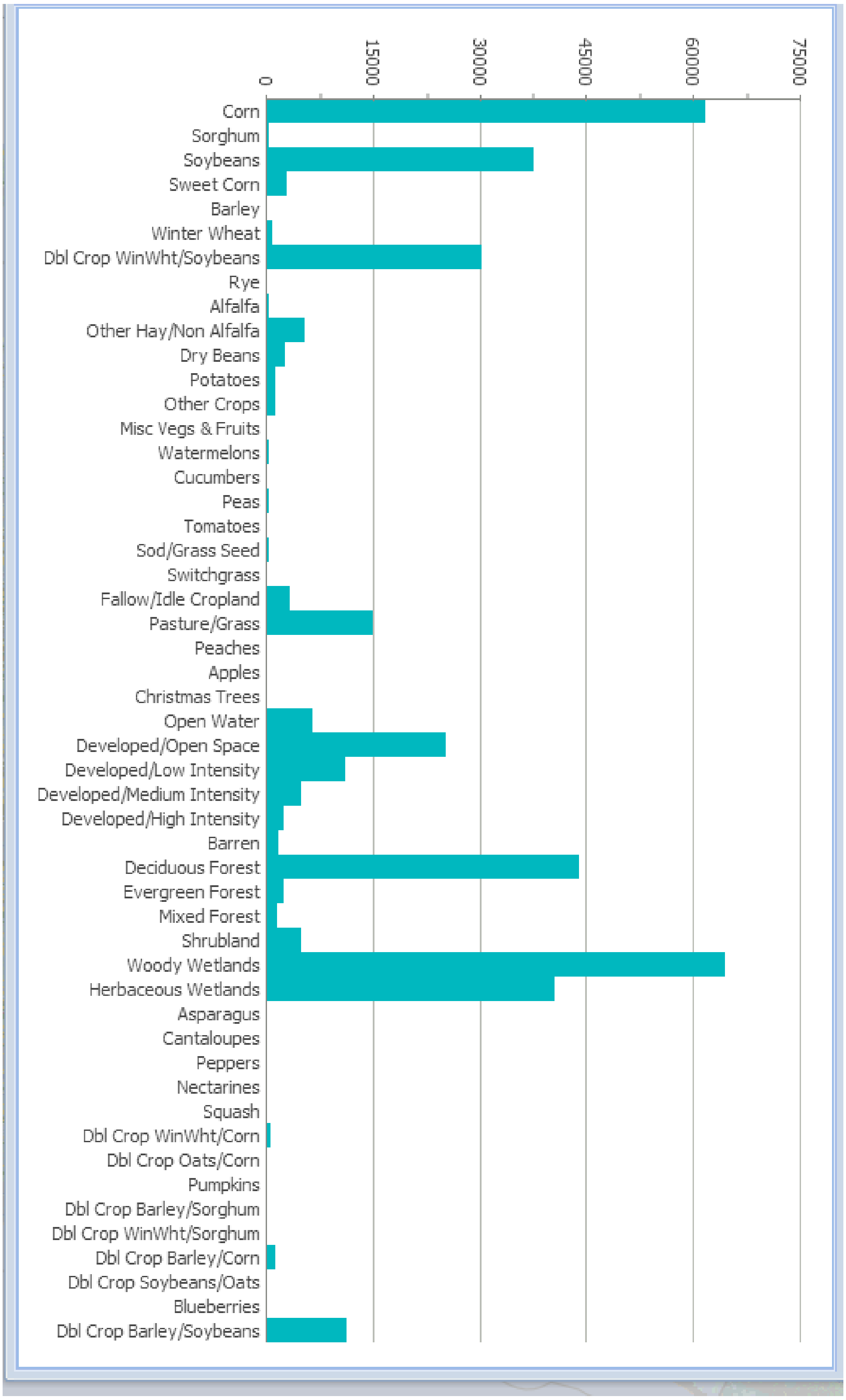
All counties have more low intensity development than high or medium intensity development (Figure 14). Baltimore and Chester County land-uses are dominated by urban area and forest, where forest lands tend to bound Urban Areas (UA). Conversely, Kent and Salem have more farmland and wetlands. In Kent, farmland bounds UAs; while in Salem, wetlands largely bound the urban areas. These land-uses may provide different barriers to UA expansion. For example, Salem County may have more concentric urban areas and less farmland loss simply because wetlands prove more difficult than farmland to develop and are in the immediate path of development.



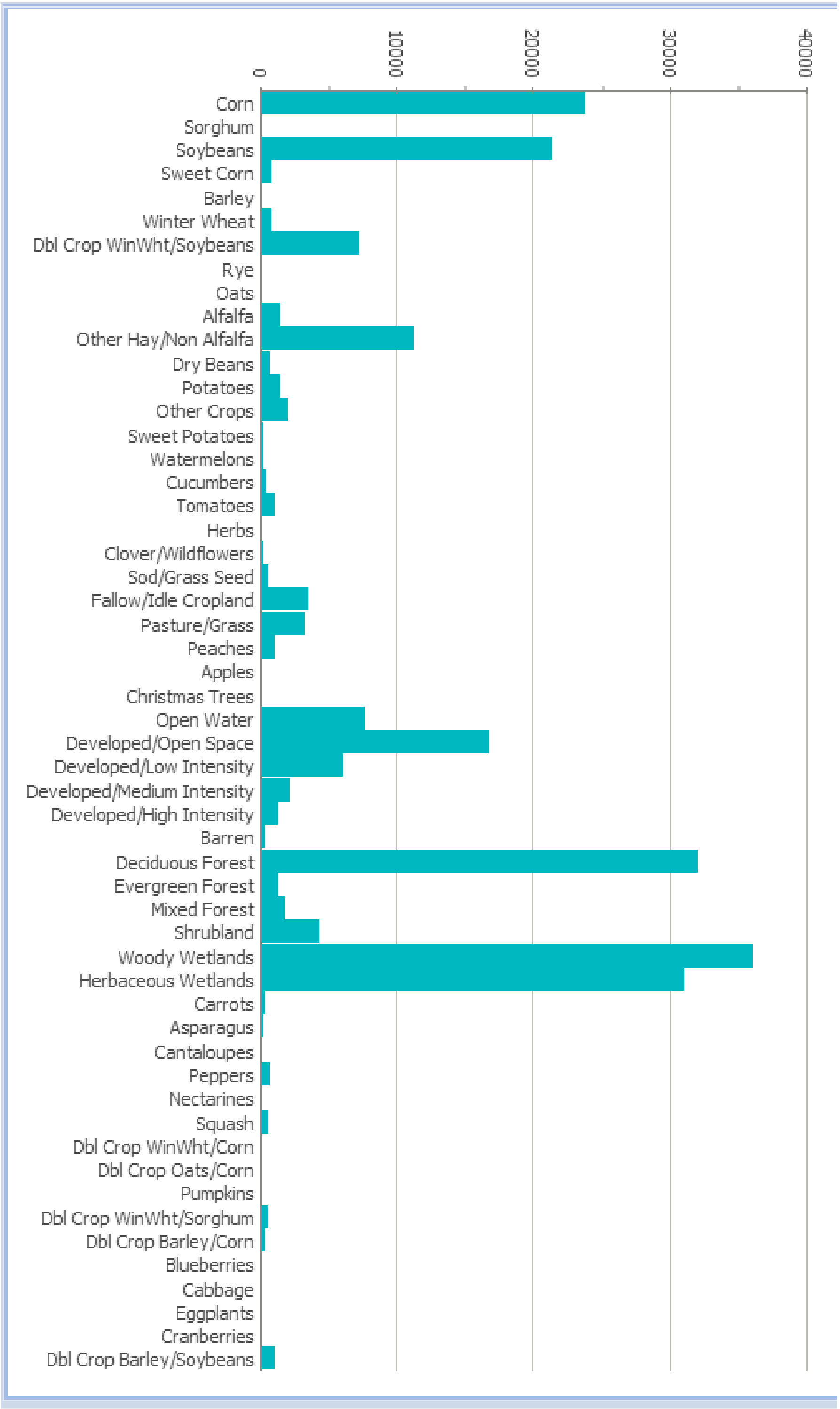
Baltimore land-use profile



Chester County land-use profile



Kent County land-use profile



Salem County land-use profile

Figure 14. Land-use profiles in study counties. Top to bottom: Baltimore, Chester, Kent and Salem County.

Unlike Baltimore County, the other counties are more economically reliant on agriculture and are agricultural economic powerhouses in their respective states. While none of the counties is the absolute top agricultural producer in their state, with the exception of Baltimore County, they rank second in agricultural production (Lancaster County in PA; Sussex County, DE; and Burlington County, NJ are the highest grossing agricultural counties in their respective states). According to the Delaware Department of Agriculture, the agricultural industry in Delaware provides jobs and impacts in the State's economy more than any other sector. According to the 2002 Census of Agriculture, 49.1% of the total land area in Kent County contains 721 farms. Similarly, more than 10% of the New Jersey's farmland is located in Salem County. Salem County's largest single land use continues to be agriculture. Aerial surveys show 43% of the County's land as agricultural (*N.J. DEP Land Use/Land Cover, 2002 Census of Agriculture*).

State and Local Farmland Preservation Efforts

Despite having vigorous state Purchase of Agricultural Conservation Easement (PACE) programs in place for over 20 years in all four states, only Baltimore and Chester County have local PACE programs. Delaware has a robust land preservation program started in 1991 which covers 105,558 acres of the total 510,253 farm acres or over 20% of the total farmland; yet, there is no local PACE program in Kent County. Nonetheless, Delaware ranks first in the United States in farmland preserved as a percent of total land area of the State at 6.5% (State of Delaware Agricultural Statistics), and most of that preservation has occurred in Kent County as opposed to the two other Delaware Counties, Sussex and New Castle Counties.

The New Jersey Farmland preservation program began in 1983 and has protected 195,470 out of 733,450 farm acres. There is no local PACE program in Salem County, though there are in six of the 23 other New Jersey Counties. Like Delaware State for Kent County, New Jersey's state farmland preservation programs are focused on Salem County, which ranks second behind Burlington County in total number of acres of farmland preserved. Unlike the other study counties, there is a comprehensive and up-to-date map of Salem County's preserved farmland, which is not necessarily contiguous or near the urbanized areas in the county (See Figure 15).

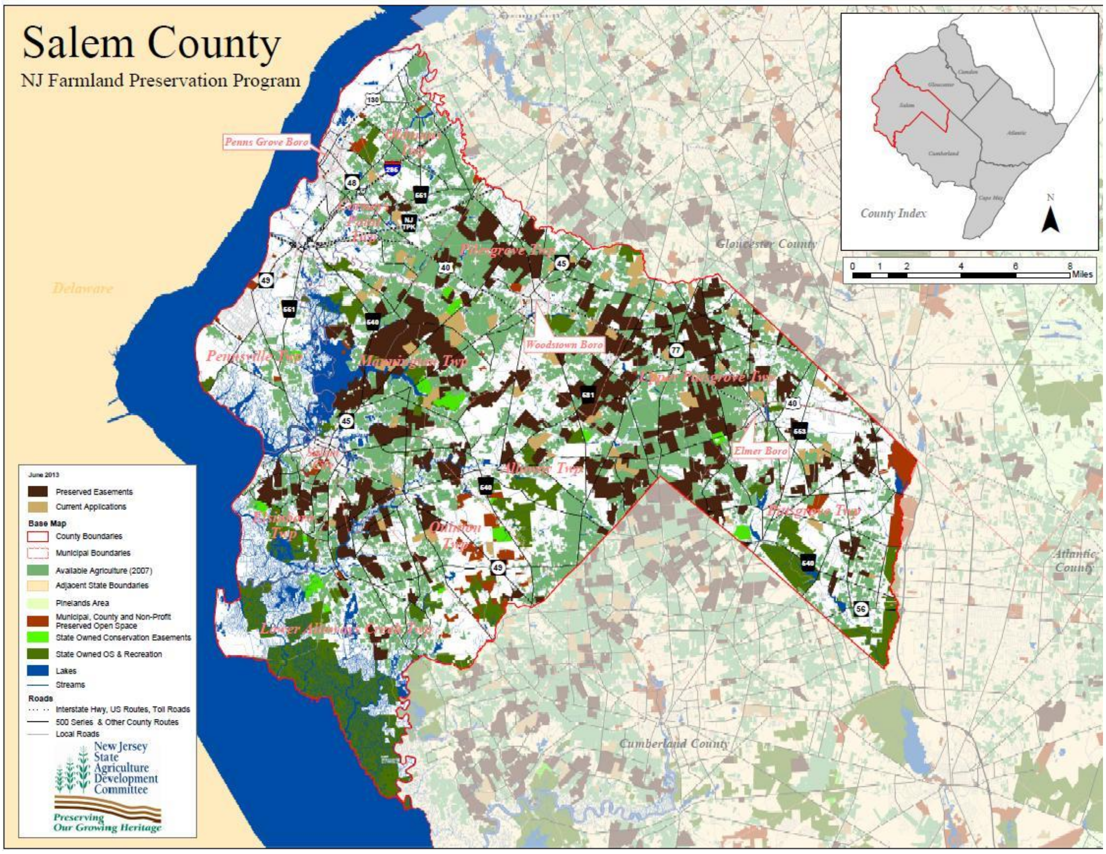


Figure 15. Salem County farmland preservation (dark brown). Notice that the preserved farmland (dark brown) is not necessarily contiguous, nor near the urban areas.

In Baltimore County, there are several land conservation programs, statewide and countywide, that work in conjunction with many nonprofit conservation organizations, the federal government, and local government agencies to fund agricultural and open space preservation. Two of the most important public programs are the Maryland Agricultural Land Preservation Foundation and Rural Legacy. Maryland has a long history of farmland preservation. The Maryland Agricultural Land Preservation Foundation (MALPF) started in 1977. This statewide program seeks to preserve enough agricultural land to maintain the local base of food and fiber production for citizens in Maryland. Since its inception, MALPF has preserved more than 280,000 acres, of which 21,675 acres are in Baltimore County. Realizing that MALPF was not doing enough to stem the loss of farmland, the Maryland General Assembly adopted the Rural Legacy Program in 1997 to permanently preserve land through easement programs, and limit new residential growth in these areas. The Rural Legacy Program enables local jurisdictions and private organizations, such as Land Trusts, to apply for designation of "Rural Legacy Areas." The County and its Land Trusts have received designation and funding for five Rural Legacy Areas: Coastal, Piney Run, Gunpowder, Long Green, and Manor. Over 70,000 acres, 3,000 of which are in Baltimore County, have been preserved statewide through this program. Despite this long history, Maryland has protected fewer acres percentage-wise than other study county states, with only 353,921 acres protected out of 2,051,756 total farm acres. State enabling legislation and funding has, however, enabled local programs to flourish in Baltimore County, picking up where state programs drop off.

The local farmland preservation program in Baltimore County began in 1979, and has protected 53,969 acres out of the current 78,000 farm acres with just over $17M in funding ($322.00/acre). From 1980 through 2009, 4,351 acres have been preserved under the Baltimore County program, 22,250 acres under the Maryland Environmental Trust and private land trusts, and 3,929 acres in R.C.4 cluster conservancy areas. This cumulative 55,000 acre preservation achievement represents about 24% of the total land area outside the URDL, and 70% of Baltimore County's remaining farmland. Based on a 2006 study by The Conservation Fund, an additional 50,300 undeveloped, unprotected acres meet agricultural program criteria, and the County has plans to preserve another 30,000 acres of farmland by 2020.

Nationally, Pennsylvania leads all other states in farmland acres preserved, with over 470,000 acres preserved. The Pennsylvania Agricultural Conservation Easement Purchase Program began in 1988 and has protected 457,537 acres out of 7,809,244 total farm acres in the state. A local program started in Chester County shortly thereafter in 1989, and has protected 28,800 acres out of 195,000 farmland acres at a per acre cost nearly three-times that in Baltimore ($1150.00/acre). The Brandywine Conservancy, a private organization, has preserved nearly 30,000 acres in Chester County. While these programs are well-funded and have the capacity to expand, their spread is partly limited by the reluctance of Old Order Amish farmers to protect their land through publicly funded initiatives.

While the amount spent and acres preserved in each county gives a general idea of the rigor and extent of farmland protection and grassroots planning efforts, parcel location is crucial in determining the effects of farmland preservation on growth management and county-level rugosity. Because there is not yet a comprehensive state, local, and private library of preserved farm parcels and their location, mapping preserved plots in relation to other land uses remains difficult. Few counties nationwide have up-to-date GIS maps available of their preserved farmland parcels, for example, Lancaster County, Pennsylvania or Carroll County, Maryland. These maps were not available in the four study counties. To that extent, evaluating the impact of county-level farmland preservation efforts on farmland retention can only be done in broad strokes.

State Land-Use Planning Requirements

All of the four states except New Jersey require local planning. All four counties require Internal Consistency wherein the state imposes a requirement that zoning be based upon and consistent with the legally adopted comprehensive plan. All four counties also receive planning assistance from the state but do not have requirements for vertical or horizontal consistency in planning; that is, the state does not impose a requirement that local comprehensive plans not conflict with plans from higher levels of government within the state; nor do the states require intergovernmental coordination among neighboring jurisdictions. This is not to say that some measure of vertical and horizontal consistency does not occur through other programming, such as Maryland's Priority Funding Areas for targeted development on a combination of city and county lands.

The county comprehensive plans in Pennsylvania and New Jersey are only advisory. Further, Pennsylvania and New Jersey do not have county-level zoning. A county planning commission has no approval powers over any amendment, repeal or adoption of a municipality's zoning ordinance or master plan. There are instances, however, in which a county planning board has the option to comment on municipal land-use actions. The opportunity to comment should not be confused with "review power" because county planning boards are not required to review and make decisions. This county-level lack of planning structure or mandate is typical of many states in America.

Baltimore County Land-Use Planning

Baltimore County is located in the northern part of Maryland, just north of the city of Baltimore and surrounding it on three sides. The county has a total area of 682 square miles—599 square miles (87.8%) of land and 83 square miles (12.2%) of water. Farm land in Baltimore County is characterized by large contiguous areas with little fragmentation from urban development. In 2007, there were 751 farms comprising 78,282 acres in Baltimore County. The average farm size was 91 acres. Of those 751 farms, 83.7% were operated by a family or individual and 54.1% of the land was held as harvested crop land (American Community Survey, 2000, U.S. Census, 2000, Census of Agriculture for Maryland and Its Jurisdictions, 2007). Despite the current economic downturn, Maryland's population is projected to increase by 0.9 million from 2010 to 2030 and the number of households is expected to increase by 20% (Maryland Department of Planning, 2009).

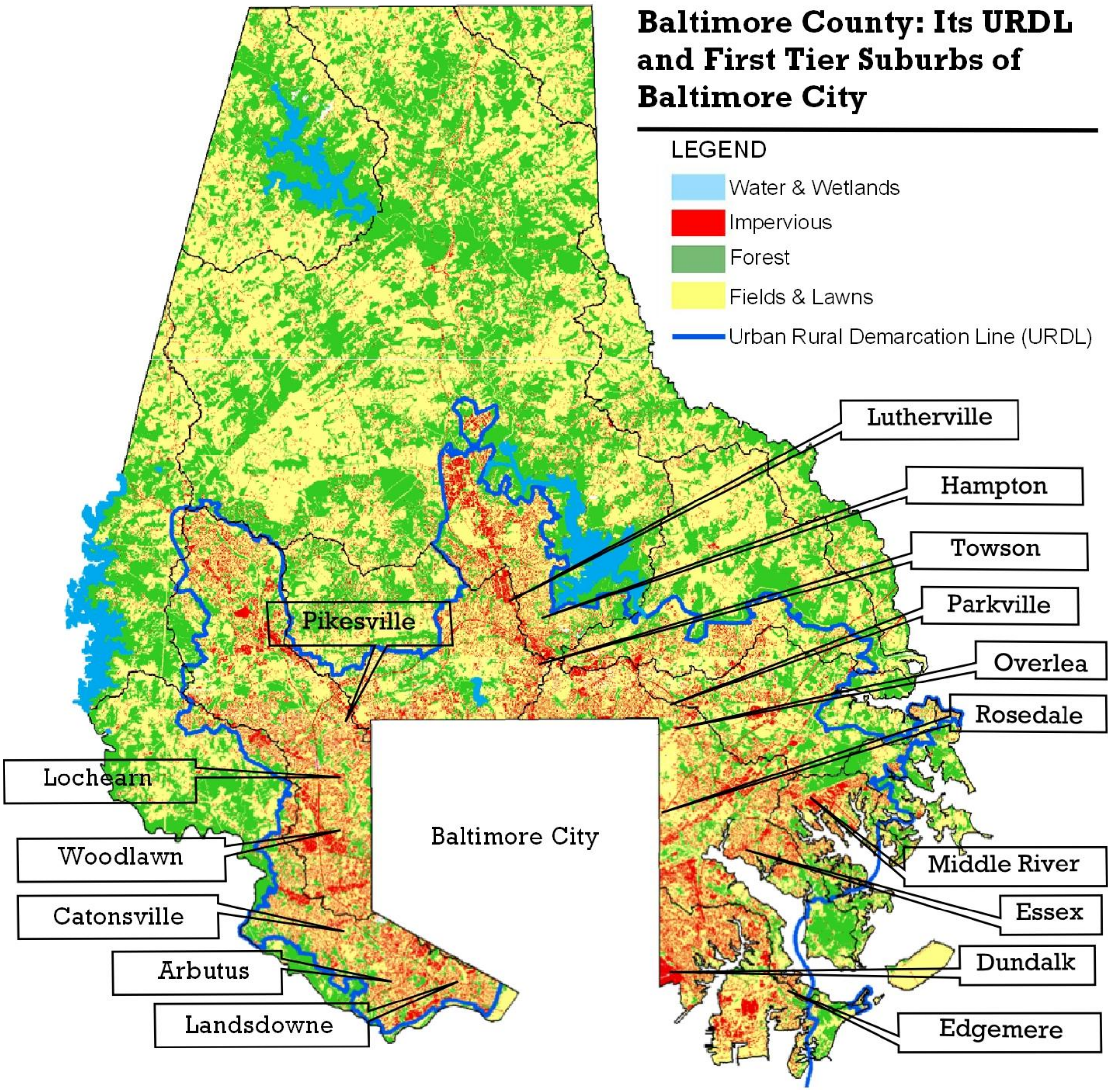


Figure 16. Baltimore County Urban-Rural Demarcation Line boundary.

Baltimore County employs a variety of tools for farmland protection, from public ownership and land conservation easements to low density zoning. A 1967 Urban Rural Demarcation Line (URDL) around Baltimore has been successful in containing 90% of the county's population on one-third of the land with most urban growth occurring within the URDL. The most used tool for farmland protection in Baltimore County is farmland preservation through purchase or donation of conservation easements; 70% of all farmland is preserved this way. Overlaid on farmland preservation is agricultural zoning, such that in combination a total of 94% of the farmland is protected.

Baltimore County has one of the oldest and strictest agricultural zoning ordinances in the country, allowing for agricultural use in all 9 of the rural zones which cover nearly 70% of the county. With Resource Conservation Zones since 1975, the 1989 Master Plan further designated "Agricultural Preservation Area" boundaries (now called Agricultural Priority Preservation Areas, or APPA's). These areas have been re-confirmed in subsequent plans. The strictest of these zones is for agricultural protection (RC2) with a density allowance (new houses per acre) of one residential unit per 50 acres. This zoning covers 32% of the county or 140,000 acres. Similarly, RC 50, covers only 4,100 acres, or 1% of the county, and allows one residential unit per 50 acres. RC20 is zoned at 20 acres and covers 7,100 or 2% of the county.

In addition to land-use planning, Baltimore County's comprehensive plan seeks to address a variety of agricultural economic concerns, including sustainable farming with an emphasis on agritourism, the equine industry, state fair promotion, and large-scale farming supports. These planning supports are in reaction to the 2009 "Rural Baltimore County Agricultural Profitability Study and Action Plan," which identified county agricultural regulatory impediments to on-farm processing and sales, inconsistent application of state level transportation regulations, varied wildlife management standards, water quality standards, and difficulty in maintaining local worker housing. In addition to these current issues, many farmers are limited from moving towards more intensive types of agriculture, which are restricted under current agricultural zoning drafted with nearly 40-year old production practices.

The County plan identifies numerous ancillary economic agricultural planning agencies that can offer farming supports. The Baltimore County Center for Maryland Agriculture promotes a sustainable agricultural industry by providing educational and recreational opportunities to the public while encouraging agro-tourism. The Center also serves as an incubator for new ideas to help sustain agriculture in many aspects, including protective measures such as best management practices. Best Management Practices (BMPs) prevent soil erosion and protect water quality provide long-term benefits for maintaining the productive quality of farmland. Farmers are assisted in their efforts to apply BMPs by the Baltimore County Soil Conservation District, University of Maryland Extension (UME), the Maryland Department of Agriculture, the U.S. Department of Agriculture's Natural Resources Conservation Service, and the U.S. Farm Services Agency. The county planning department also works closely with the Maryland Department of Agriculture (MDA), the University of Maryland Extension (UME), and the County Department of Economic Development to assist farm businesses in marketing to new local, national, and international consumers. The comprehensive plan makes renewed commitments to support Farm Bureau educational activities such as the "Agriculture in the Classroom" program at Hereford Middle and High Schools, and a new mobile agricultural classroom, and branding and marketing of Baltimore County agricultural products. Where a program does not exist, the comprehensive plan calls for the creation; for example, the county plan calls to “establish a program to assist young farmers in accessing capital to purchase farmland.” Baltimore’s farmland support services are characterized by coordination of a broad array of public, private, academic, and non-governmental agencies.

Many of these ancillary programs are leveraged for farmers through the county’s farmland preservation programs. For instance, landowners on preserved farmland are required to implement soil and water conservation plans. These requirements come with a network of supporting services from allied agencies such that cost-share programming can be implemented in conjunction to offset the expenses incurred by landowners. Similarly, planning authorities work with local land trusts to monitor comprehensive resource protection in Rural Legacy Areas, such as forest buffers, endangered species habitat, and planning measures that reduce sprawl.

In addition to protecting farms, the Baltimore County comprehensive plan focuses on compact and sustainable urban development. Community Conservation Areas (CCA) established in the Baltimore County Master Plan 1989-2000, with a legacy of the preceding 1972, 1975, and 1979 Plans, direct development in growth areas, with the goal of improving the quality of development. In combination with the Priority Funding Areas established in 1997, Maryland’s 2009 ‘Smart, Green and Growing’ Act requires county plans and zoning to include twelve elements of smart growth for walkable neighborhood design and urban redevelopment. In response, the county has created Community Enhancement Areas (CEA) in the Master Plan 2020. CEAs call for compact, mixed-use, walkable, transit-oriented development with a sustainable design and construction of residential and non-residential structures within the URDL.

Farmland planning also operates in conjunction with broader green infrastructure goals in the support of the County greenway system, adopted in the 2010 Baltimore County Master Plan. Baltimore County does not encourage high density development on these greenways. Reasons for not encouraging high density fringe development include the maintenance of quality drinking water, disturbance of agricultural enterprises, and inadequate infrastructure, such as insufficient public sewer capacity or over-crowded schools.

Maryland is consciously monitoring other development concerns that could negatively impact farming viability. According to the 2012 Maryland State Senate Bill 236 limiting on-site septic use, Maryland has approximately 426,000 on–site sewage disposal systems which release nitrogen and other pollutants into drinking water aquifers and other ground water systems. Federal EPA Watershed Implementation Plans (WIP) allocate pollution loads among different sources including agricultural and residential run-off. If current trends continue, 120,000 new on–site sewage disposal systems will be added over the next 25 years, resulting in a 31% increase in the State's total nitrogen load from on–site sewage disposal systems. To balance the increase in waterway pollutants, Phase II WIP will force other sources, such as farms to reduce their pollution loads even further, constraining economic growth and placing additional burdens on the agricultural community. By limiting on-site septic use, the state will allow farming to continue with fewer constraints- particularly for animal agriculture farms. These principles of limiting on-site septic systems are recommended in Plan Maryland (2012), the statewide comprehensive plan.

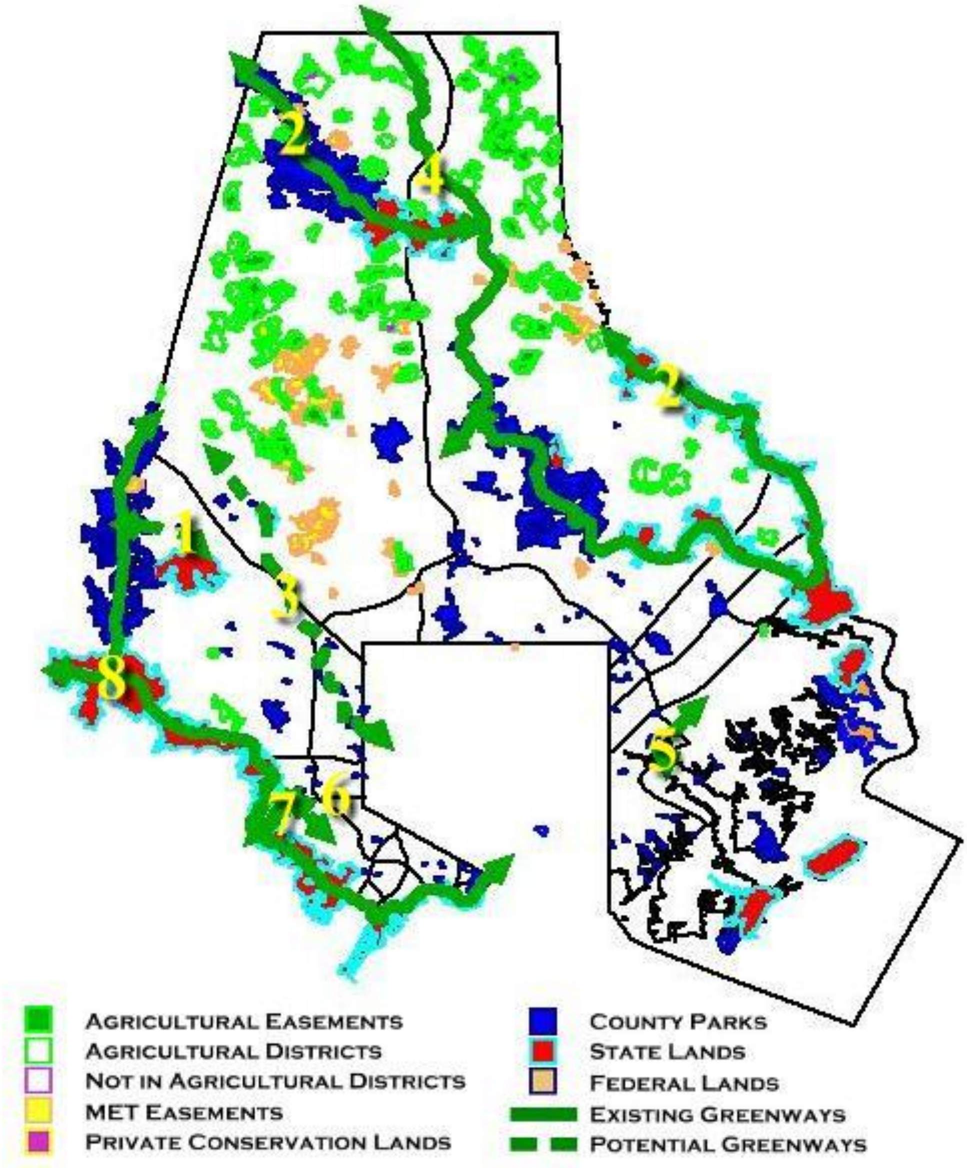


Figure 17. Baltimore County's eight existing greenway and planned greenways (numbered) in relation to permanently conserved lands.

Chester County Land-Use Planning

While Baltimore County celebrates years of effective growth management, the Chester County comprehensive plan bemoans decades of sprawl and seeks to correct for it. Like Baltimore County, Chester County is under heavy development pressure. Chester County had the highest population growth rate of any county in Pennsylvania, having added 70,000 people from 2000 to 2010. Additionally, Chester County ranks second in Pennsylvania, only after adjacent Lancaster County, for farm production. Because of heavy development pressure, agriculture continues to be threatened. For instance, the 2007 Census of Agriculture reported a 10 percent decline in the number of farms and 14 percent decline in farm acres from the previous census in 2002.

The 1996 county comprehensive plan, Landscapes, helped promote a change in Chester County's sprawling growth pattern- with a large effort to preserve farmland and coordinate municipal growth plans to achieve consistent planning programs for managing growth through the creation of the Vision Partnership Grant program and the Urban Centers Revitalization program.

Because planning and zoning are fragmented by 73 local units of government and municipalities are not required to adopt county land-use plans, Chester County has struggled with coordinating multiple municipal agencies exerting various levels of jurisdiction over claimed and unclaimed non-incorporated land. Moreover, municipalities are not under compulsion to plan in conjunction with the county master plan. To work around this impediment to county comprehensive planning, Chester County has created a planning incentive program in which municipal planning costs are defrayed for complying with the county master plan. Grants to municipal planning authorities and county-agency planning help defray the cost as long as municipal plans are in compliance with the county-wide vision. The County also provides grants to establish effective agricultural zoning in municipal ordinances. The municipal planning fragmentation and non-coordinated plan roll-out has undoubtedly allowed farmland loss as individual municipalities compete against each other for growth.

Unlike Baltimore's URDL, Chester County's master plan does not rely on a strict growth boundary, but proposes a patchwork of critical mass landscape visions that blur into one another instead of proposed linked, distinct communities and greenways. The 2009 Landscapes2 Chester County Comprehensive Plan is divided into urban, suburban, and rural landscape visions (Figure 18). Some agricultural activities are included within the suburban landscape vision. Community Supported Agriculture (CSAs), small specialized farms and nurseries, community gardens, and farmers markets in suburban areas are meant to "provide residents with fresh locally-grown food." Preserved open space will be dominated by parks, recreation areas and homeowners' association common areas. The suburban open space network is designed to conserve natural resources and to provide opportunities for a future interconnecting trail and greenways system.

The Chester County rural landscape vision is made up of three visions: the rural landscape, agricultural landscape and rural center (Figure 18). The rural landscape is made up of scenic vistas, and not as characterized by active farms as the agricultural landscape. The rural centers are characterized by small villages. The agricultural landscape is largely located in western Chester County, where the character is more similar to the large agricultural area in Lancaster and Berks Counties rather than to the nearby Philadelphia metropolitan urban area. Agricultural production is diverse, including dairy production, horses and other livestock, poultry, mushrooms, nurseries, orchards, and field crops, making Chester County second among all Pennsylvania counties in the value of agricultural products sold. This landscape is not planned to accommodate future projected growth, and is dominated by a concentration of active farms, Agricultural Security Areas, large clusters of land permanently protected by agricultural easements, and areas with municipal commitment to adopt effective agricultural zoning. In eastern Chester County, the rural zoning is typically one house per two acres, with only a few municipalities requiring one house per 10 acres.

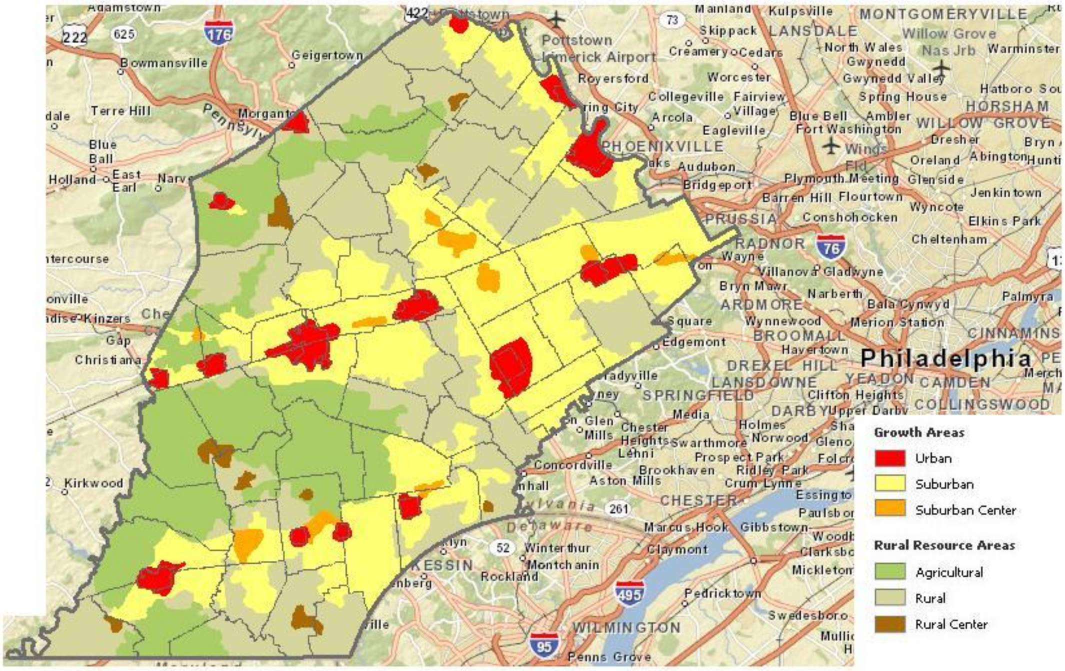


Figure 18. Map of Chester County, Pennsylvania and its planned and existing landscapes, from Landscapes2.

Like the Baltimore County plan, high density development is discouraged on the fringe, and the Chester County Master Plan promotes cluster development options to allow buffering of agricultural uses from suburban or urban uses. The County plan aims to "direct housing development within rural landscapes to existing rural centers and villages and encourage compact, dense development to preserve farmland and retain rural character." Clustering acts as a softer form of sprawl as small, dense developments proliferate along county roads. Utilizing Duany-esque calls for mixed-use, dense development and redevelopment, Chester County plans also aim to taper densities off such that the lowest densities are at the interface between rural and urban areas. The problem with this mindset is that most new developments will occur, not in the town center, but on the edge of town, where the Duany transect recommends more low-density development rather than mixed-use, dense development.

The county-level plan contains several contradictions on the use and multi-functionality of farmland. The 2009 Landscapes2 plan calls to "restrict public access to farmland that is protected by a publicly-funded agricultural conservation easement" (OSG-5c), while also including the goal to "encourage appropriate public access, such as a trail on a wooded or natural portion of a tract that is proposed for an agricultural easement or over appropriate lands that are already encumbered with an agricultural (or other) easement" (A 1.4). On the one hand, these recommendations seek to maximize the recreation potential of county farmland while also restricting multi-functional use and access to publically preserved lands and farmland. These contradictions, in combination with uneven municipal plan adoption, lends ambiguity to what is and is not allowed in peri-urban farmlands. Potentially discouraged multifunctional farm operators would have an easier time selling their farmland for development than complying with county or municipal-level plans and stipulations for how or how not to monetize added-value farm services such as agritourism.

Like Baltimore County, Chester County's master plan seeks to acknowledge and support agricultural economic planning through a variety of measures that focus economic development efforts on farm-related businesses, promote agritourism, transition younger farmers into employment, and allow construction of farm labor housing. Unlike Baltimore County, Chester County lacks an inventory of current agricultural support services and partners, but seeks to create a list. In the absence of a comprehensive list of partners, the county has committed its own staff for agricultural economic development and local food marketing within the county, while offering county facilities as hosts for farmers markets. The county plan also recognizes the synergy between agricultural land uses and alternate energy or emerging biofuel markets- but does not go so far as to encourage model siting legislation for these industries on agricultural land.

Going further than agricultural economic planning, Chester County ties its agricultural planning to food security planning. In the effort to keep farms viable, the county makes a commitment to work with the Delaware Valley Regional Planning Commission (DVRPC) to keep the regional food-shed/food system viable. The County plans recognize that nearly 25% of the county is food insecure and encourages local farms and citizens to participate in a gleaning program to harvest local food to help feed the food insecure in Chester County (A-3g). This effort to encourage gleaning and food bank donations speaks to the success of the local food bank in garnering local produce, but also strengthens that effort, tying farmland planning and protection with county-level food security.

Kent County Land-Use Planning

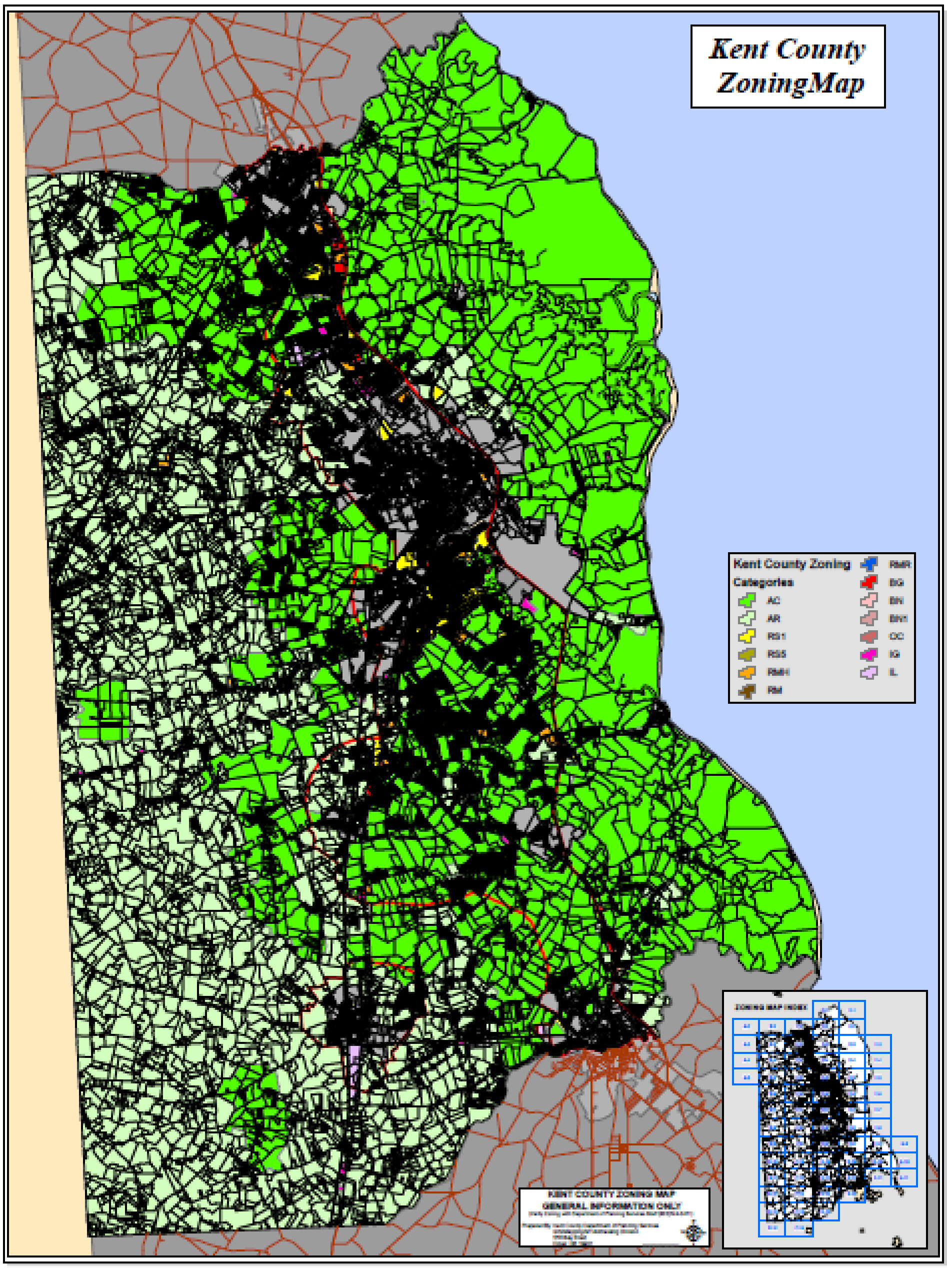


Figure 19. Kent County zoning map. Notice that AC (Agricultural Conservation) areas largely bound urban areas as opposed to AR (Agricultural Residential) areas. These two zones make up most of the county's planned zoning.

The decrease in Kent County's farmland is primarily due to conversion to low density residential uses from a history of allowing one acre minimum lot size zoning in its countryside. The county grew by 35,000 people from 2000-2010. These trends are also now affecting the Amish community in Kent County. While exact numbers are hard to come by, The Dover Post, in an article dated July 13, 2005, indicated that some Amish are choosing to sell their farms to developers and relocate to more rural parts of the country. Reasons cited in the article for the Amish leaving Kent County include the high price of land, traffic and development. In the same article, Michael Scuse, Secretary of the Delaware Department of Agriculture stated that the Amish are "….part of our agricultural heritage that's sort of preserved….agriculture in its purest form." In response to this development climate and acknowledgement that the county is losing its living cultural heritage, the State and Kent County continue to promote agricultural preservation. Supports include enactment of the Delaware Agricultural Lands Preservation Act and a number of policies launched by Kent County since the adoption of the 2002 Comprehensive Plan.

Like Baltimore County, Kent County enjoys county-wide zoning and comprehensive planning authority. The Kent County Comprehensive plan, adopted in 2008, shows that urban areas are largely bounded by Agricultural Conservation (AC) zones and not Agricultural Residential (AR) zones (Figure 19). Though both zones have the same density requirements of one residential dwelling unit for to every ten acres, residential development in the AC zone is contingent upon an approved septic system use permit from the Delaware Department of Natural Resources and Environmental Control. In this sense, septic permitting could act as one more growth control if levied before construction begins.

The primary growth control used in Kent County is the Growth Zone Overlay established in 1996 and adopted in 2002. The Growth Zone Overlay guides county and state public infrastructure investments to encourage more intense development in and around existing developed areas including municipalities. The predominant land use outside the Growth Zone Overlay is agriculture, the most significant industry in Kent County.

In conjunction with the Growth Overlay Zone, Kent County has a Transfer of Development Rights (TDR) program which identifies sending areas outside of the Growth Zone Overlay and receiving areas within the Growth Zone Overlay resulting in the ability of landowners outside the Growth Zone Overlay to sell their right to develop to land owners within the Growth Zone Overlay. The monetary value of a development right is determined by the free market just as the monetary value of land is determined by the free market. The TDR program is voluntary and the base development density is still relatively high as compared to the transfer density. As an example, Primary Sending Areas in the existing program may transfer at a rate of 1.5 acres to one (1.5 sending credits per acre) but alternatively may develop for residential purposes at a rate of 1 unit per acre. Likewise, a Secondary Receiving Area may develop at up to 5 units per acre depending upon the number of development rights purchased but alternatively may still develop at a rate of 3 units per acre without use of TDRs. The permitted density bonus cannot exceed seven units per acre in the Primary Receiving Area. It is essential to note that both the

Receiving Areas and Sending Areas Maps are currently overlays to the County's Official Zoning Map and are contemplated to remain as such. In addition, the county subtracts wetlands and floodplains from available transfer credits on Sending Area parcels. In combination, this recent TDR program gives only a small bonus to developers and farmers.

Like the other county plans, Kent County acknowledges agricultural economic planning and associated partners in the Department of Agriculture and Farm Bureau for promoting farm markets and other agri-business opportunities. The agricultural support networks are not as broad as those found in Baltimore County, nor are there goals to formalize outreach to the extent that Chester County has with planning department support for agricultural economic development. Promotion of planning programs is, instead, tied to partnerships where the three agencies (Planning board, Farm Bureau, and Department of Agriculture) share information regarding available transfer credits and can approve transfer credit certificates.

The growth management controls in Kent County are poised to be effective at reducing farmland loss, yet Kent County's pro-active farmland preservation planning measures were enacted and enforced a little too late to stem the loss of farmland for which case selection was predicated. For this reason, the case study exploration of growth controls provides a retroactive look at what has contributed to farmland loss (1 acre zoning) and suggests how this trend is likely to change with septic permit limits, newly differentiated agricultural zones, and a transfer of development rights program.

In some ways these controls add to rugosity and in others they do not support rugosity. For example, the TDR program can allow for greater density development where there is both developer and market demand. This program could increase fringe development density, or at least maintain it at seven dwelling units per acre; a tactic that does not go along with the Duany decreasing density transect model. However, the Growth Overlay Zones are largely concentric and do not allow for high rugosity. Nonetheless, Kent County could readily deploy a high rugosity growth management plan that simultaneously preserves contiguous farmland and continues contiguous urban development by approving high density fringe development and adding rugosity to the rural-urban fringe.

Salem County Land-Use Planning

Like Chester County, the planning and zoning power in Salem County planning power lies at the municipal level. The Salem County Smart Growth Plan was completed in 2004 and was the first comprehensive planning effort in the County since 1970, the year of the last Salem County Comprehensive Plan. This Plan provides an update to the County profile, reviews issues and assets, and identifies goals, objectives and next steps for Salem County to promote growth along the Delaware River and I-295/N.J. Turnpike Corridor. The preservation of agriculture and natural resources are some of the identified goals of the 2004 Smart Growth Plan; yet, this goal exists against the backdrop of haphazard local development permitting.

Salem County is under the least development pressure among the study counties. Having added only 1,700 people from 2000-2010, Salem county ranks in the bottom third of all metropolitan Area counties for population growth. The Salem County Growth Management Plan attempts to hold the eastern most limit of Fringe Planning Area to the boundary line agreed upon by the County and State Planning Commission. Approximately 300 square miles, or 88 percent of the County, falls in the environs outside the regional planning area and designated urban centers, leaving 10% of the county available for growth. With low projected levels of growth, this should not be of consequence, yet the generous permitting system in the County has allowed numerous developments in non-designated areas.

Arguably, Salem County has not accommodated even its minimal growth in an effective development pattern. State pressure to reduce farmland loss abuts county-level permitting to allow low-density growth in non-designated areas. Salem County has been congratulated on improving its growth management; the largest percentage increase in building permits issued from 2000 to 2005 occurred in areas the County has designated for growth (that is, within the 2004 Smart Growth Corridor west of Route 295 or in designated centers east of the Turnpike). In contrast, the largest total number of building permits were issued throughout areas that are not designated for growth, indicating the inefficiency of landuse planning in Salem County.

The 2006 Salem County Open Space and Farmland Preservation Plan covers the remaining parts of the county and plays to municipal plans while remaining consistent with the State Development and Redevelopment Plans for Rural Planning Areas, Rural Environmentally Sensitive Planning Areas and Environmentally Sensitive Planning Areas. The goals of the State Plan for these areas support the preservation of the land to maintain and improve the viability of the agricultural industry. Salem County has chosen to pursue these goals through state farmland conservation easement purchase while rejecting proposals to downzone.

The County Open Space and Farmland Preservation Plan discourages municipal down-zoning, arguing that it would cause a reduction in the "value of the landowner's investment and incentive for entering into a farmland preservation program," the preferred farmland protection method. Currently, more than 88% of municipal land is zoned for minimum residential lot sizes between one and five acres with only one large-lot zoning option found in a Conservation District with a minimum of 25 acre lots (Figure 20). Development as of right under existing zoning provisions would result in a highly sprawled and fragmented landscape across the county.

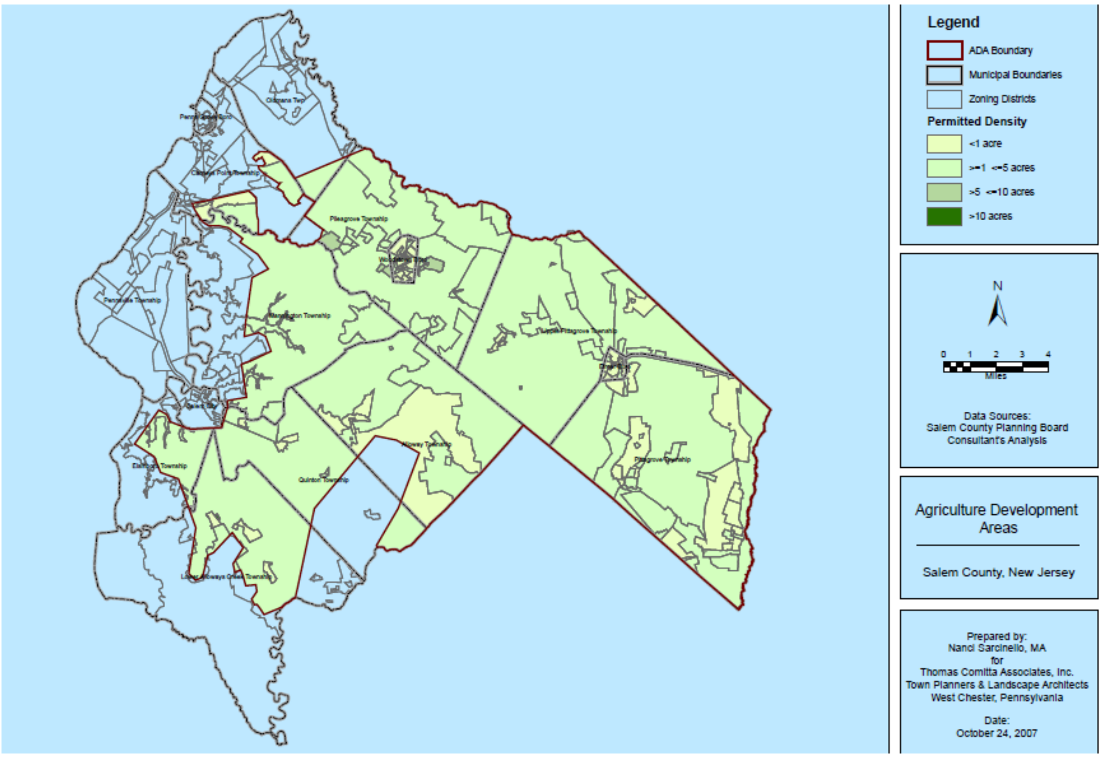


Figure 20. Salem County zoning map. Most of the county is zoned for 1-5 acres developments.

Unlike Kent County, but similar to Baltimore and Chester County, Salem County promotes agricultural buffers, strips of natural vegetation between agricultural lands and adjacent non-agricultural uses, such as residences, industrial complexes and roads. These buffers are intended to protect farming operations by minimizing encroachments, such as trespassing, while also minimizing conflicts between neighbors. Within Salem County, six municipalities have Agricultural Buffer provisions in their Land Development Ordinances ranging from 50-200 feet, hardly enough to really prevent nuisance complaints or agricultural run-off.

While the County farmland preservation documents do not make mention of specific agricultural economic planning support agencies or county goals in these regards, the state and county do have ties to economic development agencies. In addition to the nearby Rutgers Food Innovation network and extension services, the county draws from Jersey Fresh, a state advertising, promotional and quality grading program originally developed in 1983 to help farmers inform consumers about the availability and variety of fruits and vegetables grown in New Jersey. Initially begun as a radio advertising campaign, the Jersey Fresh program has also used billboards, television and print ads, and colorful point-of-purchase materials to remind consumers about the availability of locally grown products. These programs do not, however, designate farmers markets or other in-county agricultural economic ventures but supply umbrella program supports to all New Jersey farming operations.

Conclusion

Though achieving rugosity is not an explicit goal in any of the county plans, Baltimore County's effective and longstanding URDL in combination with established greenways, induces non-concentric, yet contiguous, development and directly contributes to that county's high rugosity. Baltimore County's URDL has not moved since 1967 with the exception of one sewer line extension, causing some critics to suggest that the URDL has not been constrictive or limiting enough. Yet, because the URDL acts as an urban services boundary and operates in conjunction with strict farmland preservation tactics, Baltimore County has conserved much of its farmland while accommodating high growth and maximizing the rural-urban interface. The URDL in combination with Baltimore County's other growth management tools offer one example of achieving high rugosity while discouraging sprawl and agricultural landuse fragmentation. The greenways throughout the county also offer another element of rugosity in planning.

Baltimore County's rugosity differs greatly from that in Chester County, where greater rugosity results from the many scattered villages encouraged in the patchwork of landscapes. Highly fragmented local government may be at the root of Chester County's fragmented urban development as municipalities compete for jobs, growth, and tax bases. In these instances, non-contiguous rugosity could result in disproportional and inefficient levels of farmland consumption. The case comparison suggests a need to adjust or qualify rugosity readings to the extent that urban areas are fragmented or contiguous, adding another component to future studies on the impacts of rugosity on urban and farmland function. In Chester County, planning to control sprawl has also happened relatively late and ineffectively, contributing to disproportionate farmland loss. The comparison between Baltimore and Chester Counties suggests that high rugosity should be pursued if urban areas are contiguous and comprehensive, strict, county-wide farmland protection measures can be levied in tandem. To this end, high rugosity may not be an ideal urban morphology to pursue in states with municipal planning authority as it requires a more conscientious farmland protection effort and planning coordination across municipalities and non-incorporated areas. In the case of municipal government, fringe developments, particularly high density fringe developments offer an invitation to extend sewer and water lines into adjacent farmland that is not prohibitively zoned or planned. As municipalities compete for growth on a smaller scale, they may be less likely to coordinate efforts to preserve farmland from urban growth.

In comparison, Kent and Salem County have more concentric development patterns due to both a lack of long-standing growth planning and no networks of dispersed villages. Salem County has not lost much farmland even with little planning oversight, little farmland protection, and non-effective permitting systems. One potential reason that Salem County, with less recent planning measures, inefficient permitting systems, and more concentric urban areas has seen so little farmland loss could be because the urban areas are bounded by wetlands. Wetlands would be the type of land use lost as urban areas expand. Similarly, Salem County has seen less development pressure than other study counties and any measure of farmland loss may be offset by wetland conversion to agricultural land in census readings. Future studies on rugosity should employ measures of farmland conversion ratios based on remote sensing land-use data to ascertain development efficiency in relation to urban morphology. Conversely, Kent County, with its urban areas surrounded by farmland, could see more farmland loss with development pressure in the absence of growth management and strict farmland protection.

Due to the small sample size in a comparative case study, it is not fair to extrapolate beyond these individual cases to argue that Salem County's lack of state-level or local planning results in minimal farmland loss. Similarly, due to the time-lapse component of planning, legislative adoption, and enforcement, Kent County could very well prevent future farmland loss with their many newly implemented and coordinated growth management tools. If these cases were to be revisited in ten years, the researcher would wager that Salem County would see greater farmland loss unless the state imposes growth management legislation.

Both low-rugosity counties have the potential to adopt a high rugosity growth strategy, though this might not be advantageous given their varying planning systems and levels of farmland protection. After the advent of its farmland protection system, Kent County could more readily practice high rugosity development by harnessing its TDR program to strategically protect farmland and contiguously grow urban areas with higher density developments. Using the TDR program would allow Kent County to develop in a manner non-prescribed in both the high rugosity counties by encouraging high density fringe development that maximizes farmland amenity access. On the other hand, Salem County, with its fragmented development permitting system, lack of county-level development control, and resistance of downzoning on agricultural land, could encounter more farmland loss regardless of whether the county chooses to pursue high rugosity or concentric growth.

These cases show that while rugosity may be economically profitable and beneficial, it has the potential to invite sprawl and development to convert farmland when growth management tools are not utilized and urban development does not occur contiguously. While it is difficult to extrapolate from only four case studies, the author proposes that Baltimore County's longstanding, high-rugosity controlled growth is a more sustainable form for farmland preservation than Chester County's dispersed village model due to the dissimilar rates of farmland loss experiences across these cases. At the same time, none of the counties encourage high density development near agriculture or natural resources, another component of rugosity theory. Kent County with the density incentives of the TDR program is best poised to adopt the theory of rugosity in its planning practices to maximize the desirability of the fringe.

Ranking the case counties by the strictness of their land-use regulations would show Baltimore County with the oldest and strictest development regulations with the URDL, highly restrictive agricultural zoning, and high levels of farmland preservation, followed by Kent County with the TDR program and Growth Overlay Zones, Chester County with semi-coordinated municipal plans, more than 60,000 acres of preserved farmland, and several townships with effective agricultural zoning in the western part of the county, and Salem County with more recent and less comprehensive planning initiatives. If current county plans are effective, one would expect that Baltimore County would lose the least amount of farmland for future development, while Salem County would lose the most. Similarly, development in Baltimore County may cost more as re-development in existing urban areas is more strongly encouraged while Salem County exerts only loose oversight in municipal development permitting in low-zoned agricultural areas.

CHAPTER 7. Rugosity and Farm Function: Farm-to-Market Network Analysis

In order to understand the types, variety, and reach of farm services in relation to the different urban morphologies in each county, a farm network map was created. This map of geocoded farm and market locations helps to qualify the predominant relationships with farm operators in each county while also indicating geographical boundaries for these relationships in relation to different urban morphologies and farmland loss.

Limitations of farm network mapping

The generated network map is an under-estimate of a county's direct farm networks for a variety of reasons. Many farms allow online purchases through their own website or a crowd-sourcing website. Farms also sell directly from their farmgate. These sales and connections are not documented in this study. Larger direct-distribution networks were not captured in this study mainly because large suppliers did not respond to the query nor do they list their outlets online, while smaller suppliers readily listed their outlets on their websites and confirmed them in the research query as points of pride and to market their products to interested buyers. Additionally the online query method limited the response to farms whose networks could be verified by email correspondence. Farms that only listed phone numbers were not contacted. Numerous Amish farms were not included in this study due to inability to reach the farmers via email. Conversely, the study county farmers' markets list Amish farmers as prominent suppliers.

- Many stores sell to chains in DE, MD, PA (eg milk suppliers). These larger distribution networks were not captured in this study.
- Some farm products such as wine and cheese, may use raw products produced on surrounding farms but did not report these relationships.
- This study does not include non-food producing farms, thereby omitting many fiber alpaca farms, greenhouse nurseries, and horse farms that play a vital role in supporting food-producing farms through the sale of ancillary products (mushroom substrate).
- Many farms allow online purchases through their own website or a crowd-sourcing website. These sales and connections are not documented in this study.
- The email query method limited the response to farms whose networks could be verified by email correspondence. Farms that only listed phone numbers were not contacted. Numerous Amish farms were not included in this study due to inability to reach the farmers via email. Many farmers' markets, however, list Amish farmers as prominent suppliers.
- Coding the type of network is difficult. Some farms sell through supermarkets that they run from their farmgate. In this study, farmgate sales were given precedence as a code over wholesale because they bring the customer to the farm, qualifying a more personal relationship between consumers and the farm. Further, many retail/wholesale establishments may have a café (reported as WS/rest where noticed). These wholesalers may sell to restaurants which then report the local products as "direct sales."

A priori coding was based on the type of first-point-of-sale relationship to the farm. For example, wholesale networks represent larger-volume supply chains which may sell further or can sell directly to the customer. Institutions are large-scale buyers which, like restaurants, directly feed consumers and can act as marketing agents for location-specific farm products. Farmers markets are seasonal and represent a direct connection for consumers with the farmer where the farmer usually travels to an urban or suburban location. Restaurants prepare food for end-users and represent a steady relationship between the purveyor and farmer. Restaurants also operate as a marketing tool for location-specific farm products by advertising them to restaurant customers. CSA networks, like educational visits, represent mainly on-farm visits that tend to bring the farmer and end consumer in contact. Similarly, farmgate sales would bring consumers to the farm, but this study could only capture farm-to-farm farmgate sales as a measure of collaboration in product movement.

A priori coding of network type yielded 8 main networks:

1) WS: farm sale to wholesalers such as supermarkets, auctions, or distributers,
2) Inst: farm sales or donation to institutions,
3) FM: farm sales to farmers' markets,
4) Rest: farm sales to restaurants,
5) FG: farm sales to other farms for on-farm (farm gate) sales, denotes farmer cooperation

6) CSA: Community Supported Agriculture (CSA) or Buying Clubs (BC) purchases through direct farm pick-up or off-farm drop-off locations, CSA and BC member zipcodes were used for mapping
7) Schooltrip: school or educational group visits to farms
8) BYPRODUCT: farm byproduct sale or donation in the form of compost, spent mushroom substrate, spent grain, hog feed, poultry litter, or on-farm energy production.

Table 7. Apriori-derived Codes used for network analysis.

WS	wholesale or retail- permanent bricks and mortar store
Inst	Institution, large-scale buyer
FM	farmer's market, pop-up retail, not there every day of the week
FG	farm gate- sold at the farm
CSA	Zipcode for CSA member or drop-off location
Rest	restaurant
schooltrip	Educational visit to a farm
Byproduct	Waste removal, energy production, compost

When the code was questionable due to the transaction falling into multiple categories, precedence was given to certain types of farm transactions based on the end-customer experience and relationship to the farm. Some farms sell through supermarkets that they run from their farmgate. In this study, farmgate sales were given precedence as a code over wholesale because they bring the customer to the farm and represent nested farm-to-farm relationships that offer alternate agricultural knowledge sharing when compared to farm-t-wholesale relationships. Many retail/wholesale establishments may have a café (reported as WS/rest where noticed). Further, these wholesalers may sell to restaurants which then report the local products as “direct sales” instead of second-point-of-sale. One Chester County institution sourced products from over 100 local gardens, which were given their own code for analysis so as to not upset the coding in other counties (Figure 23). This source also operated a gleaning program, which because of the unique farm-relationship was similarly given a separate code, ‘glean,’ and not included in the final report on farm networks but will be used in separate studies.

Reach and Direction of Farm Networks

Networks across study counties exhibit similar patterns of reach and direction in relation to major urban centers (Table 8, Figures 22 and 23). CSA and BC member zipcodes and pick-up locations reveal that most CSA/BC members live in suburbia and farm pick-up sites are located in suburbia instead of inner cities. Located further away from farms are suburban/urban restaurant and farm market networks which operate in suburbia as often as they operate in cities. The networks with the most penetration into urban areas are wholesale markets. Similarly far-reaching are the farm gate markets where farms located further from cities partner with peri-urban farms for farm-gate sales. Farm byproducts, such as compost, spent grain and generated energy generally move away from cities. Byproduct and school-trip networks had the shortest average distances, showing that these social networks rely more on proximity of resources than wholesale networks.

Table 8. Farm network reach and direction for study counties.

County	Total farm network reach and direction (km)	Nodes/ Edges	Dominant Network Type As percentage of total network With reach and direction
Baltimore	58.04 stdev 66.11km 161S19E	351/703	FM: 28%, 45km +/-27km, 259(S79W) Rest: 22% k46km +/-56km, 181(S) Rest-WS: 16%, 99km +/-102km, 359(N) WS: 13%, 48km +/- 42km, 227 (S47W) Inst: 10%, 94km +/-96km, 10(N10E) FG: 4%, 28km +/-24km, 355(N5W) CSA: 4%, 36km +/-28km, 202(S22W) BYPRODUCT: 37km +/-30km, 356 (N4W)
Chester	44.14 stdev 52.89 89E	754/1087	WS: 34%, 51km +/-51km, 213(S33W) CSA: 13%, 36km +/-46km, 146(S34E) FM: 13%, 59km +/-68km, 222(S42W) Rest: 11%, 49km +/-63km, 309(N51)W Garden: 10%, 20km +/-14km, 339(N21W) FG: 9%, 56km +/-59km, 360(N) Schooltrips: 5%, 22km +/- 27km, 0(N) Inst: 2%, 40km +/- 63km, 194 (S14W) BYPRODUCT: 2%, 14km +/- 16km,180 (S) Glean: 1%, 16km +/- 6km, 180 S
Kent	49.95 stdev 46.38km 359N	82/89	CSA:41%, 38km +/-24km, 178 (S2E) WS:28%, 57km +/- 25km, 180 (S) FM:18%, 52km +/- 25km, 181 (S1W) FG: 6%, 117km +/- 145, 179 (S1E)
Salem	42.81 stdev 34.81 N30E	73/79	WS: 37%, 62km +/- 40km, 344(N16W) FG: 30%, 27km +/- 32km, 186 (S6W) FM: 19%, 47km +/- 20km, 180 (S) Schooltrips: 8%, 25km +/-14km, 1(N1E)

As expected, counties with more non-concentric Urban Areas and longer Urban Area perimeters had more farm networks. Moreover, their farms and markets (nodes) had nearly twice as many networks (edges) as their counterparts in counties with more concentric and less intertwined rural and urban areas (Table 8). This indicates that counties with more rugosity may have greater marketing opportunities for their farms as farm abut non-agricultural markets.

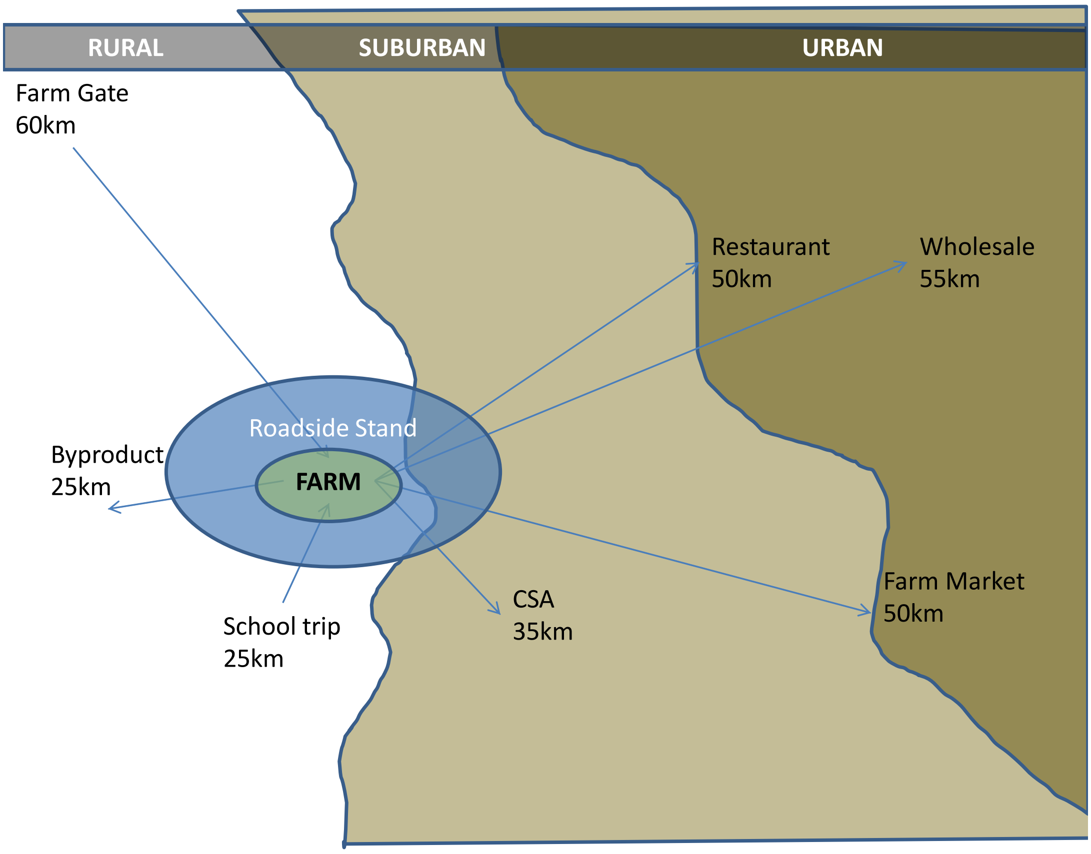
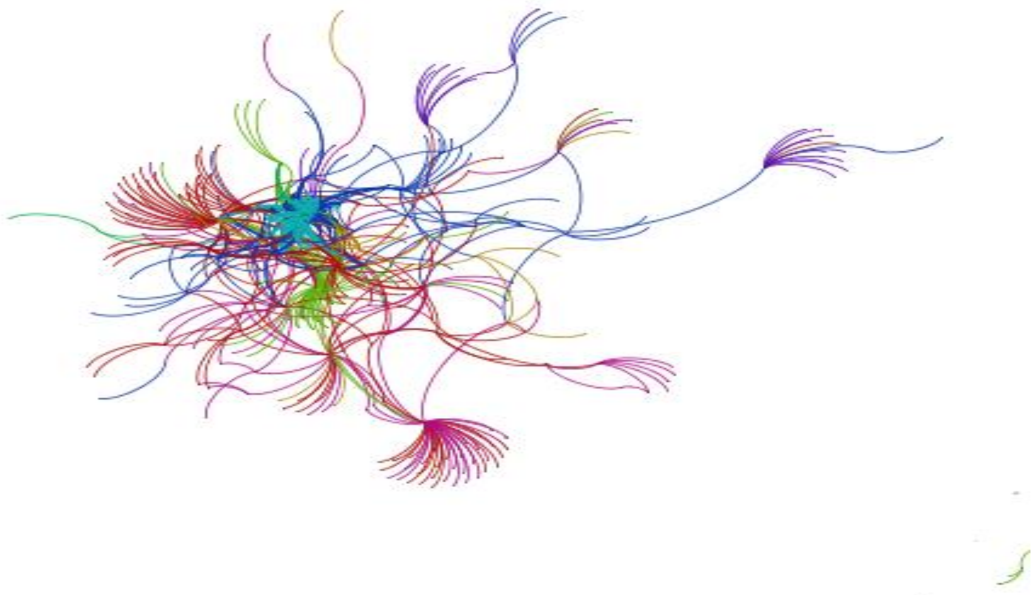


Figure 21. Reach and direction of averaged farm network sub-sets in relation to urban, suburban and rural land-use patterns.

Mapping of farm networks over remote-sensing farmland shows that farms that are land-locked are more likely to engage in more direct-farm networks (CSAs, retail, farmers markets, donations to food cupboards) and the majority of direct-farm sales penetrate suburbia but not major cities. This finding was corroborated with interview material, indicating that urban proximity influences the type and reach of farm sales, particularly direct-to-consumer sales.

Farms tended to specialize in one type of network (Figure 22). For example, a farm may attend multiple farmers' markets but not sell to supermarkets or visa versa. These business preferences potentially shape the cultural attitudes and resulting policies between agricultural areas and their consumer bases. The extent to which this 'know-your-farmer" culture influences land-use patterns and funding for farmland preservation is unknown, but interview material hints that the more direct networks garner support for agricultural outreach programs while also serving as agritourism marketing opportunities to urban customers that would not otherwise meet a farmer or have occasion to visit a nearby farm.



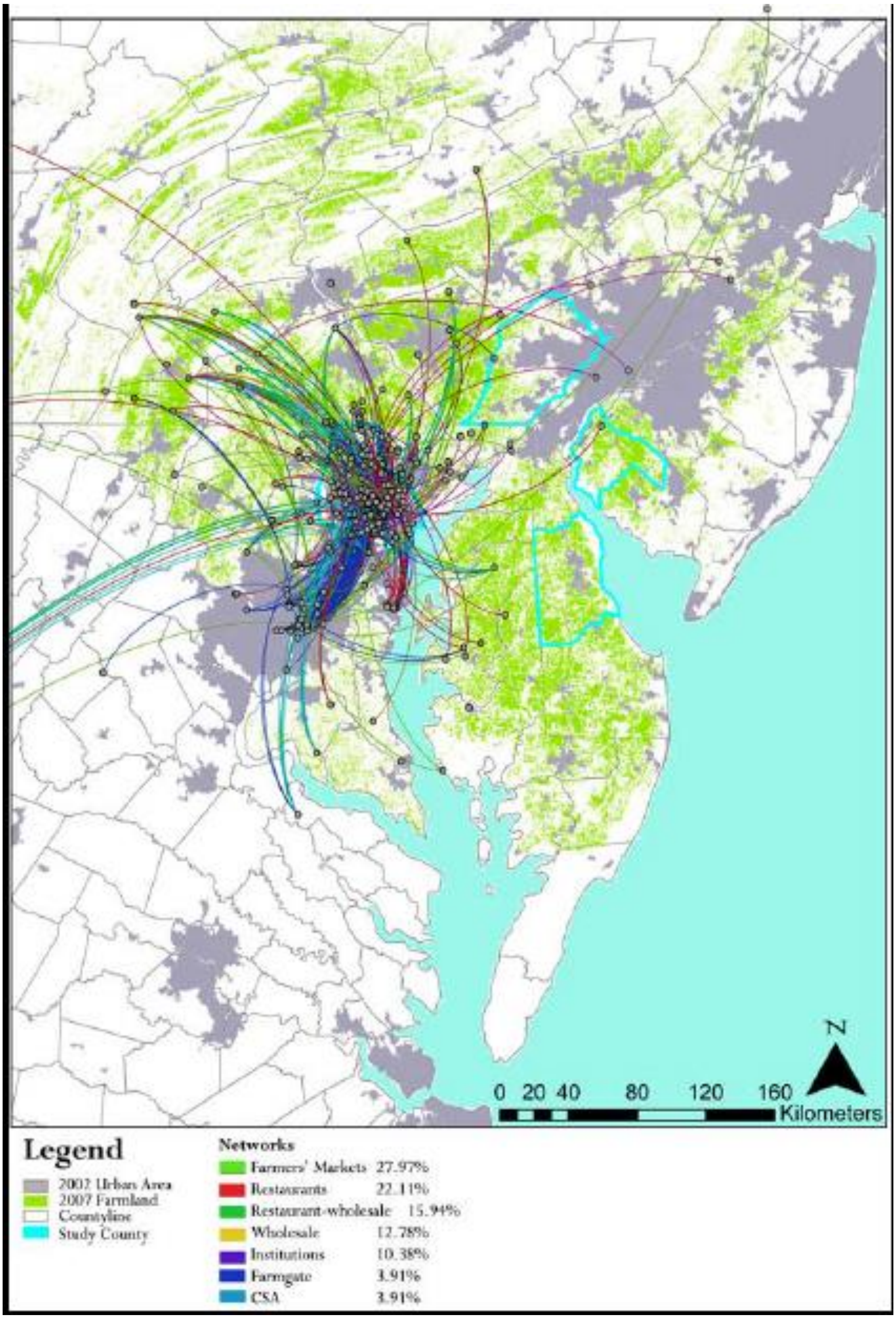


Figure 22. Baltimore network represented geographically (bottom) and socially (top). The geographical network shows that Baltimore County draws from nearby farms and sells to nearby major cities. Notice from the social network, that farms tend to specialize on type of marketing effort.

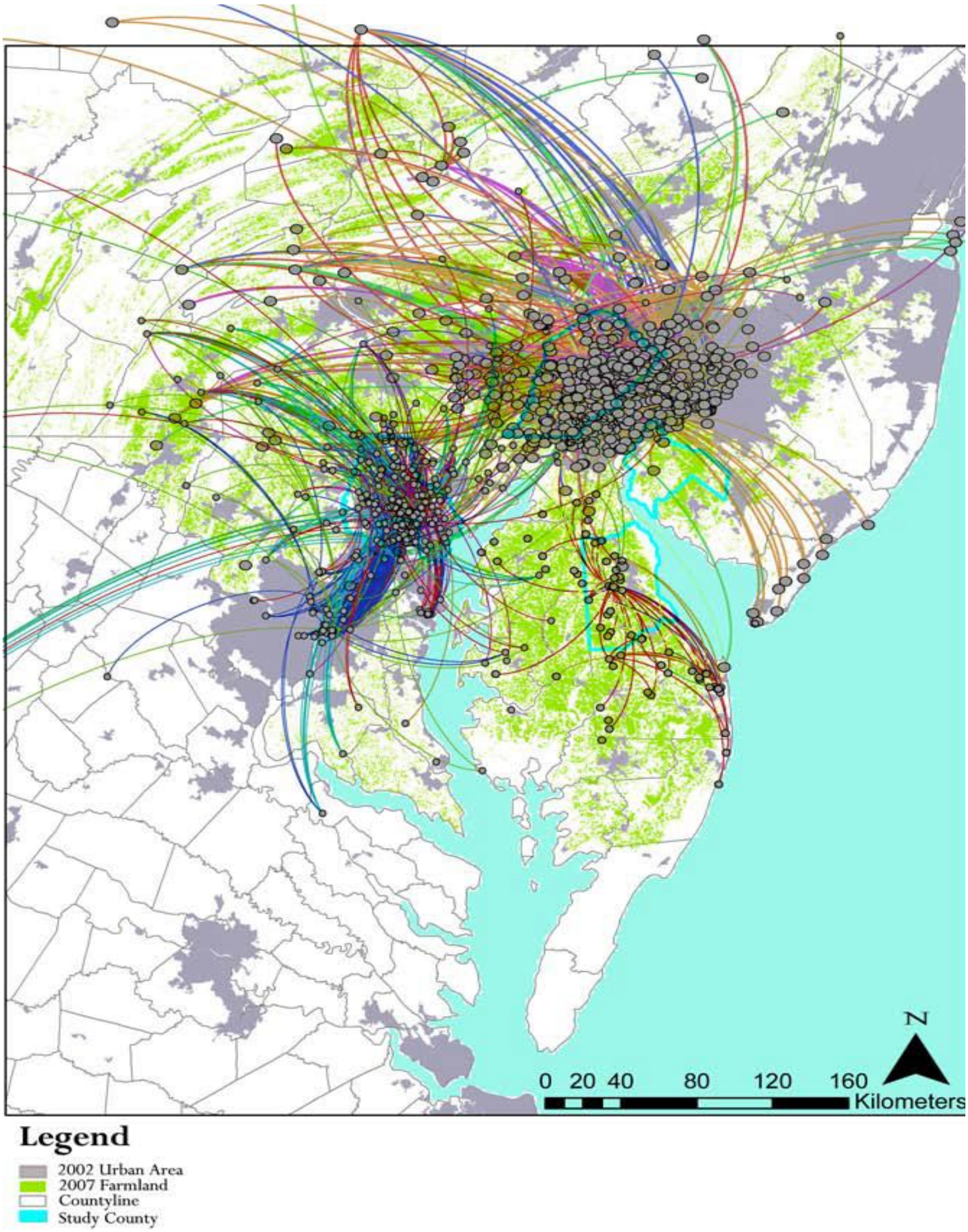


Figure 23. Farm-market networks for all study counties. Baltimore and Chester Counties represent network hotspots in comparison to Salem and Kent counties where there are fewer networks.

CHAPTER 8. Interviews about County Form and Function

Though interviews were solicited from planning departments, buy fresh buy local chapters and agricultural extension offices in all four counties, few departments felt prepared to comment on agricultural land-use patterns or local food marketing. The hour-long 15 interviews, consisting of formatted and open-ended questions represent two national organizations, Food Routes which coordinates the national Buy Fresh, Buy Local campaign; and Real Time Farms. Both organizations host online data connecting farms to markets and consumers.

Chester County was the only county to have all interviews represented: interviews from the agricultural extension office, economic development planning, and Buy Fresh Buy Local chapter, with additional interviews from the farm-to-city NGO and local food bank purveyor. Baltimore County was the next most represented county with interviews from the agricultural extension office, fish and wildlife service, and an NGO for farm-to-table procurement. Kent County is represented by an interview from the Delaware department of agriculture. Salem County did not have a buy fresh, buy local chapter, and is presented with interviews from a local farmer who runs the downtown farmers' market, the Rutgers Food Innovation Center, and the statewide farmers' market coordinator.

Baltimore County, MD

The large farm-market network reach and extent in Baltimore County (Figure 22 and 23) was attributed to urban proximity. As the agricultural extension agent noted comparatively, Baltimore County is closer to the markets, where as nearby Carroll County is not- with the result that "Baltimore County has one of the fastest growing (agricultural) incomes per acre- and that is because Baltimore has gone to direct marketing and Carroll county plows corn." Embedded in this statement is acknowledgement that the local farm networks induce tighter feedback loops, changing what is demanded in restaurants and what is grown by farmers. This theme was echoed in other interviewee answers in other counties where direct networks ultimately changed what farmers planted based on demand for niche or ethnic products. One particular farm started as a CSA and moved into farm-to-restaurant sales. Now, "they are selling directly to restaurants and growing products that they want directly," notes Jeffery Smith, a former chef and director of the Maryland Farm-to-Table purveyor business.

Similarly, Jeffery Smith notes that restaurants that are further from farms *or* urban areas will have a harder time getting local food. "With my restaurant, I had a lot of problems getting farmers to come because I didn't have a lot of refrigeration. I couldn't hold a lot of product. It was hard to get farmers to come out for small orders. And I wasn't around a lot of restaurants. So they would have had to go out of their way for small orders." Jeffery's comment speaks to the practicality of dense urban, contiguous developments near contiguous farmland to decrease the distance and direction of food supply. Existing in ambiguous, low-density, non-farm territory, Jeffery's rural-suburban-based restaurant was neither near urban restaurants nor supplying farms. His comment also verifies farm network findings that farm-to-restaurant services are geographically bounded not only by distance, but by surrounding land-use type and network magnitude.

Interviewees indicated that there may be a scalar progression in farm networks, where farms start selling from their farmgate or a CSA, branch out to farmers' markets to make connections with restaurants, institutions, and distributors. Similarly, large farms may diversify their sales in the opposite order, testing the waters of more proximal relationships with customers. Ginger Myers, the agricultural extension officer for Baltimore County, also suggests that there may be a progression of farm products, starting with first marketing produce before branching out to milk, eggs, cheese and meat. Where the more immediate farm networks fail to be financially sustainable, the more distance and complex local food markets will likely not be attempted. Similarly, where produce fails to sell to nearby markets, more regulatory complex marketing items like animal products may have a harder time penetrating the market. This 'natural progression' of farm products and types of farm network growth could partly influence farm profitability and land use patterns, and will, in turn be influenced by land-use patterns and regulations.

To that extent, Myers notes that the limits to local farm procurement are not market-based but regulatory, "The hard part has never been getting the customer to the market- the more difficult part has been regulatory- food safety. … whole house regulations, the transport of the product, regulatory requirements, and permitting in different counties. …Many counties have their own layer of permitting on top of the state. For instance, if you wanted to sell eggs in five farmers' markets in five different counties, you had to get five different egg sales permits, which could be anywhere from $50-$150 per county. No one could afford to do that and sell the eggs. We've since been able to do away with that- and have one permit to sell in any county. The same with the permits to move frozen food throughout the county. We now have a state one-time license called a mobile farmers market permit which says you can move frozen products to any farmers' market in the state." Myers also notes that the food safety and transport regulations are stricter for animal products, perhaps a reason for why they are the late comers to local markets. "It's only been in the last five years that we've been able to sell retail cuts. You could sell the whole animal, but you could not sell processed cuts."

Myers hazards that regulatory land-use permits may have allowed Baltimore County to get the edge on evolutionary multifunctional agricultural practices, but since then, planners have been hesitant to grant new on-farm permits. When Baltimore County re-did the comprehensive plan, local farmers saw the opportunity to pursue on-farm retail and increase revenue from their property through agritourism ventures. At the same time, some landmark court cases in the county have disputed the right of farmers to develop agritourism and value-added processing facilities on-farm (Miller, 2009; Long Green Valley Association v. Prigel Family Creamery, No. 0350, 2011). The push back is most strongly characterized in the case of Prigel Creamery, an organic dairy on preserved land with neighborhood letters of support, and planning permits for construction of an on-farm bottled milk and ice cream processing plant, which the conservation easement did not permit though the zoning did. A community group was upset over the change in viewscape, and after tens of thousands of dollars spent on legal fees, the creamery was eventually built. The repercussions from this court case have made Baltimore County increasingly shy of permitting on-farm value-added facilities. Farms that were early to adopt multi-functional on-farm value-added ventures are continuing to expand, but new farms that would like to join have significant barriers to entry. As Myers notes, “the existing facilities are expanding and growing, but the new facilities are having a much harder time getting the permits. The review process is more stringent that it used to be.” In this sense, the further development of agritourism and its ancillary farm networks may stagnate in Baltimore County.

Chester County, PA

With a wide and well-developed market reach, Chester County has had a long history of direct-to-consumer sales. According to John Berry, the agricultural extension officer in Chester County, “in colonial times, we had a thriving direct-to-consumer farm sector. It’s kind of had its ups and downs through the years, but we have a long history of using the excellent soil and growing conditions that we have to meet the needs of the public consumers right across the street from us. That could continue to be our future, a bright future. It will evolve and change but, we are ideally situated for a thriving direct-to-consumer farm business.” Berry goes on to say that the urban proximity continues to be a marketing strength for Chester County. “I think we’re fortunate here in this part of the east coast because we have ready consumers almost at the end of the farmers’ driveway. The big cities have a bigger concentration of consumers and there’s always commercial activity moving to the big cities, but there’s not necessarily a need to travel. Many farmers have a road side stand and go to the local farmers market and as they develop more and more productive capacity they maybe go to some markets in the big cities and add that to the mix.” This was similarly stated by Marilyn Anthony, the director of the Pennsylvania Alliance of Sustainable Agriculture, a state-wide farmer support group that supplies grants and technical assistance for marketing, “if you are suburban or rural, the likelihood of farm pick-up is much greater. We get into the dilution of the basic principal of the CSA. They really were started to bring people onto the farm. To foster that direct involvement, commitment and participation with the producers. … The CSA is more about restoring the role of that land (peri-urban) as an integrated part of the community.” These statements indicate that the distance-decay function of farm networks but also a natural evolution of farm networks, where the profitability at the roadside stand encourages CSAs outreach, followed by farmers' markets and direct sales to restaurants, institutions and wholesalers.

Chester County interviewees agreed that the proximity of suburbs, particularly wealthy suburbs, aided in the establishment of farm-to-market networks throughout the region. At the same time, many of these same farm networks are leveraged in support of the low-income residents. Over 25% of Chester County residents are on food assistance programs. The pioneering county Food Bank has become a national leader in purveying local, fresh food by harnessing a large volunteer base and generous farming community. A study by the University of Pennsylvania ranked the Chester County Food Bank sixth nationwide in the percentage of fresh food it disperses, with over twenty-two percent of the 2,000,000 pounds of food distributed being fresh (Vitiello et al, 2013). This amount does not include the many pounds of fresh food grown in raised beds at food cupboard sites and distributed directly to the community without ever being transferred through the food bank.

The Food Bank supplies fresh, local food through a variety of programs: gleaning, urban gardening, and school-based high-tunnel greenhouses. The Food Bank, which has been in operation for over 80 years, started its gleaning program in 1996 with the help of state Senator Andy Dinniman and the newly hired Larry Welsch, the Food Bank's current director. The concept of gleaning is based on the Biblical description of scavenging for food left in harvested fields. Some farmers' crops are earmarked for the Food Bank while others make their leftovers available to be picked by volunteers.

The Food Bank currently has a fleet of over 3,000 volunteers. The size and willingness of this volunteer base speaks to Chester County's wealth but also the draw of agritourism as volunteers flock to farm-based activities after school or on the weekends. While farms have a hard time finding farm laborers or year-round farm operators, the volunteer community in Chester County offers the paradox of a ready and willing, no-cost work force. Through the volunteer participation in the gleaning program, the farms generate goodwill and ensure that none of their surplus food goes to waste by donating the excess to the food bank. Gleaning program participation also allows these farms to showcase the good work they do to volunteers and further build their market potential for agritourism activities beyond volunteer days. Gleaning program farms may be more adept at operating on-farm agritourism events, CSAs, and farmers' market stands to further their market base and generate more profit per pound of product sold.

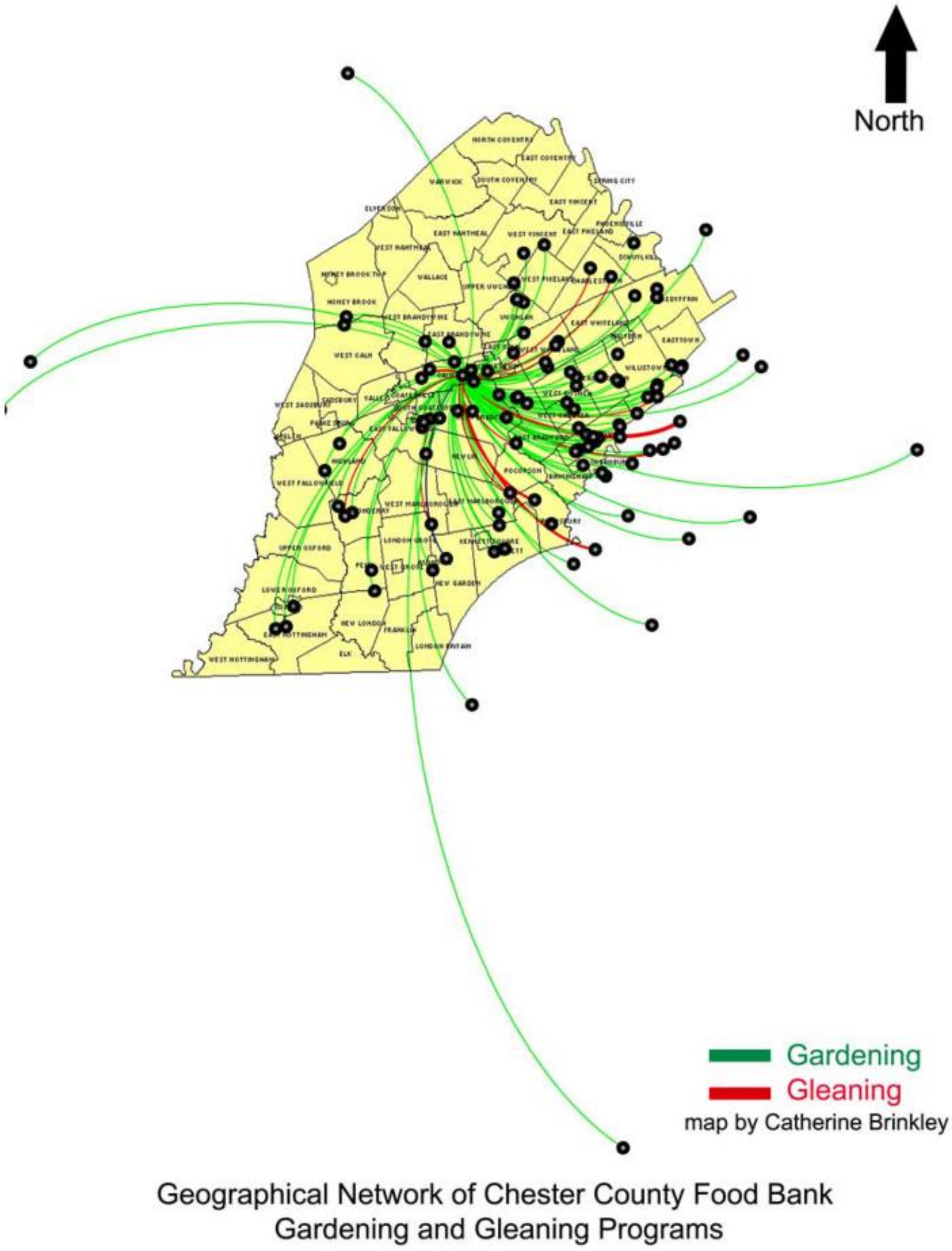


Figure 24. Geographical Network of Chester County Food Bank Gardening and Gleaning Programs.

All of the forty odd farms that participate in the gleaning program are landlocked, incapable of agricultural expansion and surrounded urban land-uses. Moreover, the participating farms are located in southwest Chester County, the headquarters of the Food Bank before it moved to its more eastern location in 2010 (Figure 24). Though the northwestern portion of Chester County has large, contiguous blocks of farmland, few of these farms participate in Food Bank programs for gleaning or donations- a potential consequence of the distance-decay functionality of farm networks? The proximity of the gleaning program farms to the food bank speaks to the importance of distance in social networks. These social networks have remained strong after the Food Bank's relocation to its more central Chester County location.

In combination with the gleaning program, the Chester County Food Bank runs a variety of outreach programs whose education and social networking aims dovetail with gleaning program farms. Larry Welsch, the director of the Chester County Food Bank, attributes the success of gleaning program with spawning the more recent "raised-bed" program, in which local churches, businesses, schools or residents grow produce for the Food Bank. The Food Bank now has 546 gardens at 129 sites, including 49 schools, up from a total of 25 in 2009. From this overwhelming and rapid success, the Food Bank launched a greenhouse initiative, providing schools with high tunnels so that students can grow food year-round for their cafeterias. The school presence spurred the development of curriculums for healthy eating, farming and nutrition in elementary and middle schools with high tunnels. Staff have pioneered cooking classes and lunch-time tastings of fresh food, such as frozen squash popsicles, in order to introduce children to vegetables that they grow and try to persuade school catering companies to source locally and provide more fresh food. All of these programs make use of the same knowledge networks, facilitating farm visits, agricultural education, and healthy eating between low-income Chester County residents and the more affluent volunteer base.

Like the Baltimore County interviewees, Chester County interviewees agreed that the limits to farm networks were not farmer will or consumer demand, but regulation. As Marilyn Anthony stated, “The barriers to entry- it’s policy, regulation. Many of those things are controlled by small groups- whether that’s county commissioners or land conservation groups. They can change the language in their easements, but that doesn’t happen easily.” Moreover, zoning regulations “can be counter-intuitive, irrational, arbitrary. A lot of it is really outdated. It’s based on false assumptions of agriculture.” These sentiments are supported in recent studies, such as the Green Space Alliance Commission’s report on “Transforming Open Space,” which highlights zoning language as an obstacle for the transformation of vacant land. Zoning restrictions apply not only to the farm parcel, but to traffic regulation. As Marilyn Anthony explains, “you may be farming in an area that is zoned agricultural, but it may not be able to have any retail or commerce on that site, so you would have ag(ricultural) zoning but not commercial. And you may not be able to conduct retail or have a farm store. There may be ordinance restrictions on traffic, so you may not be able to have parking for 20 cars- or it’s a two-lane road and they don’t want that level of traffic on it.”

Bryan Snyder, one of the original founders of Buy Fresh Buy Local, a national local food marketing campaign that started out of Pennsylvania, goes further in asserting that more local networks could be had if there were receiving points in urban areas.

The farm-to-city network requires infrastructure; ironically, an infrastructure that most cities had until shortly after the 1950s when many central covered farmers markets were removed for public health reasons (Donofrio, 2013). As recently as 1918, a majority of cities (56%) in the United States with populations over 30,000 had a municipal food market where local and fresh produce was hocked to urbanites (Rogers, 1919). “That kind of infrastructure used to be common. If you were in a coastal city, you could go to the market and get fresh seafood plus fresh produce from farmers. Sometimes the farmers get blamed for not going into the city. But at the same time they are often not treated very well in the city. There’s often not a friendly place to go with a cover over their heads and a bathroom. Sometimes farmers have to go a mile away from the farmer’s market to go to the bathroom. That kind of stuff could all be dealt with.”

In summary, the Chester County networks grew out of proximal relationships between farms and urban areas. County experts agree that there is more capacity to grow these networks, particularly if already existing networks are leveraged to create more synergies. Gleaning farms already participate in a variety of CSAs, farmers markets, school education outreach and host school field trips. To allow these farm networks to flourish, zoning codes should accommodate agritourism with parking, signage, and non-traditional farm uses model citation. Zoning reform to allow or promote urban gardening, raised beds, or high-tunnels may also help stimulate agricultural education programs, fresh food production, and nutritional meal plans for the county’s under-served.

Salem County, NJ

Different from Baltimore and Chester counties with their vast farm networks, Salem County exhibits a relative paucity in farm networks, a finding that was verified in the interviews. The reason behind the lack of farm networks was expressed as lack of immediate and intermediary markets from which Salem County farmers could branch out to the larger nearby cities like Philadelphia.

Beth Feehan, the coordinator for the fledgling New Jersey State Farmers' Market group, asserts that "unfortunately the foodies in the state are centered more around Philadelphia and New York, so the grassroots activity really comes from those areas. Salem is so rural, I think that the agriculture community in New Jersey is really kind of stuck in the old model of agriculture and is not really looking at who the end-user is and who the buyer is- and the new movement in CSAs and local. It's an awareness thing. Salem is so rural and it doesn't have that exposure." She goes on to say that, "it's the urban areas that have created the demand for local food. And the Salem counties of the world don't have access to that buyer. It's not as if they are getting in their trucks and – there's no distribution system that exists for them- for them to grow product and go to the cities- only the most innovative farmers are doing that. It doesn't fit everybody's method of doing business. You would think that would, but it's not a natural transition. It's taken years to engender that city country divide and they don't understand that their buyers are in the city."

That's not to say that farmers would not garner a greater profit if they sold in Philadelphia. All interviewees agreed that local, direct sales would give greater profitability, but that Salem County lacked the build-up to branch out to major markets. Diane Holtaway of the New Jersey Food Innovation Center notes that, "throughout the state, you will see that there are many farms participating in numerous farmers' markets doing very well creating a new revenue stream in direct sales to consumers. … The New Jersey Department of Agriculture came to say 'look at the revenue opportunities that could be yours.' And the growers up north understand it. They've seen the returns. Yeah, it's a lot of hard work and a lot of hours that has to go into it. And there are some growers that are out there pounding the pavement, doing direct sales to restaurants and supermarkets." In short, Salem County's lack of networks is not an artifact of New Jersey policy or general difference in farming typology, it is an artifact of Salem County's rural character.

The lack of farm networks is considered logical. Beth Feehan says, "you don't really need farmers' markets in places where there are farmstands because there's already access to produce. And you don't have the density of population to justify gathering a bunch of farms because you need a buying public with money. And Salem is the poorest county in New Jersey, the least densely populated." Diane Holtaway concurs, "Salem County and Cumberland County are such rural communities that there's a lot of farms and a lot of farm stands. People have access. ... There's a farmstand on every corner. When you're up in a more urban area in north jersey- you see a community farmers' market, the farmers coming out to people that live many miles away. People are like 'wow! I can go and get fresh vegetables from a farm right in my neighborhood.' There's a lot more interest there. If you look at economics, the demand is not there for community farmers' markets. The (Salem County) city of x,y,z is trying to have a farmers' market, but it's been very, very difficult to get people out to them- because they can get this product in so many places."

Beth Feehan emphasizes that farm networks have feedback loops that require farmers to change the way they do business. "It's just a different way of doing business. It might be growing a different product for the ethnicity of the people buying it. It might be creating relationships that don't exist now, which a lot of farmers don't even want to deal with. They just want to dump their product. They don't want to deal with the end-user." The interviewees agreed that many farmers have contract obligations and would not want the excess hassle of changing the way they plant, harvest, or bring to market their produce.

There was consensus between the farmer, food innovation team, farm bureau and farmers' market outreach coordinator that the lack of Salem county networks was not a result of policy but of lack of farmer will which was directly attributed to lack of "exposure" to urban end-users and "connections" to buyers. "Salem is so rural and it doesn't have that exposure," noted Gilda Doganiero, a local farmer, café owner, and the Salem city farmers' market manager. Gilda has managed the Salem City farmers market for nearly ten years, often driving out to the farms herself to get produce to bring to market or to sell to restaurants. Though Salem City has a working base that will frequent the downtown farmers' market for lunch, many restaurants and business people are hesitant to change the food culture and purchase more locally-produced products. The County relies on farmstands and farmgate sales more than other social networks, and Gilda notes that even farmstands with the "Jersey Fresh" logo may sell cantaloupe and bananas, produce that clearly is not produced in New Jersey. The ethos of local farm networks is simply less developed.

Kent County, DE

Kent County is much like Salem County in its rural nature and lack of farm networks. Perhaps the lack of land-locked farming communities has allowed the Salem and Kent County farmers to make use of simpler, higher volume marketing opportunities as they are not forced to valorize multifunctional farming ventures in order to remain solvent. To that end, Kent County farms, like Salem County farms, are less exposed to the development pressures to further valorize their operations. The lack of agricultural and urban land integration may also cause a gap in the evolution of farm network typologies where farmgate sales to consumers are more prevalent in the counties with less rugosity. These farmgate direct-to-consumer sales would not be captured in this study, and are therefore undervalued.

This is not to say that rural farms do not engage in broad outreach. In Kent County, the farm that is most engaged in direct sales with a CSA and farmers markets throughout the region is a third generation orchard, rurally located. “It’s a destination place. People aren’t just going to stumble on it,” asserts David Smith of the Delaware Farm Bureau. They “have a large staff and a couple people just dedicated to going to these farmers markets. They’ve got to load the truck up, drive to such and such a town, set up a tent, set up a table, get everything very aesthetically presented. They do these things with the baskets on their side with the produce spilling out of it. There’s a lot of work that goes into that.” David’s comments echo what other interviewees noted about the level of input required in establishing successful markets and how the marketing experience can change how farmers do business, from what they grow to how they display the produce. David goes on to explain why other farms shy away from farmers' market, CSA and direct sale opportunities, "You talk to some of these farmers- they just want to grow it, pull it out, and sell it. They don't want to get all pretty with it and put it in little baskets and stuff." This particular farm is what David Smith refers to as a "microcosm of all that is right with Kent County farming." The farm hosts festivals, school visits, a U-pick operation and participates in farmers markets throughout the three-state area while also maintaining a vigorous conventional retail distribution network to grocery stores and restaurants.

With the dominance of roadside sales and an absence in other farm network types, the Department of Agriculture sees a new method of advertising local farms and playing off of the Kent county strengths in farmgate sales. Based on a Kent County study of direct produce marketing in 1999, researchers showed that the most common method of hearing about U-pick, farmers markets, or roadside stands is word of mouth or by passing a sign on the road (Kuches et al. 1999). This happenstance method of marketing could be a limiting factor in growing Kent County networks, and the restrictions on farm signage are easily controlled in county zoning documents. At the same time, the majority of respondents indicated that produce purchased directly from the farmer was less expensive than what they bought in the grocery store, indicating that the farm networks in Kent County could make local, healthy food available at a lower cost. The Department of Agriculture has recognized the need to further market local produce and the desire for consumers to purchase locally. In response, the Delaware Department of Agriculture (DDA) and the state's Government Information Center (GIC) launched the Delaware Fresh app for smartphones so that over 80 seasonal farm stands and farmers' markets can be located with an interactive map.

This technological fix to road signage offers an easy work-around for marketing local produce and encouraging farmgate sales while potentially expanding farm networks and buoying farmer confidence in the economic opportunities found in direct-to-consumer or direct-to-wholesale ventures.

Conclusions

Interviewees acknowledged that the farm networks change the pattern of doing business and the function of the farmland. As Beth Feehan, the director of New Jersey's farmers' market association noted, "It's just a different way of doing business- it might be growing a different product for the ethnicity of the people buying it." In Baltimore County, Jeffery Smith of Maryland Farm-to-Restaurant also noted that "they (farmers) are selling directly to restaurants and growing products that they want directly." The networks change the end-user and consequently what the farmers grows on the land, creating feedback loops with land-use implications.

The demand for farm-city connections is as much as urbanite-driven as farmer-driven. The Philadelphia farm-to-city farmers' market agency has a waiting list of 40 farms for farmers' markets, while they also have over 20 applications to open new farmers' markets throughout the city. There is supply and there is demand, but forming the connection for each farm network is difficult.

Farm networks struggle not only with physically traversing the rural-urban divide, but also with variation in state and county-level land-use regulations. On the policy side, the Farm-to-City NGO that runs over 17 farmers markets in Philadelphia does not work with New Jersey farms or farmers' markets giving the excuse of "the geographical mental boundary. But then there is also dealing with a whole bunch of different state regulations," noted Matthew Wiess, the Farmers' Market program manager for Farm-to-City. These regulations can be limiting for farms and their markets.

On the farming end, “you may be farming in an area that is zoned agricultural, but it may not be able to have any retail or commerce on that site- so you would have agricultural zoning but not commercial, and you may not be able to conduct retail or have a farm store. There may be ordinance restrictions on traffic, so you may not be able to have parking or 20 cars- or it’s a two-lane road and they don’t want that level of traffic on it,” asserted Marilyn Anthony of PASA.

As the food is moved, it is subject to regulations. As the Maryland extension agent notes, many counties have their own layer of permitting on top of the state regulations for food safety. “For instance, if you wanted to sell eggs in five farmers markets in five different counties, you had to get five different egg sales permits. Which could be anywhere from $50-$150 per county. No one could afford to do that and sell the eggs.” Similar food safety regulations limit the sale of fresh or frozen food and prohibit the sale retail cuts of meat but allow the sale of the whole animal.

Land-use and food safety regulations also apply to the market locations. Managers struggle with the cost of street closure permits for farmers markets and various approval processes for new farmers market citation. Philadelphia has an ordinance for farmers’ markets, but to put a new site on the ordinance, the city council member in the proposed district has to introduce and pass new legislation. Beyond the governance of creating new farm markets is the decay of old market infrastructure. While there used to be covered farm markets in every city, most of the buildings have been torn down or repurposed for alternate uses.

Even where farming communities are geographically proximal to urban areas, cultural support for farm networks exists, and marketing opportunities receive regulatory support, the feedback loops are fragile. As with the case of Baltimore County, where the initial wave of value-added on-farm development proved financially successful if legally disputed.

From these limited cases, it may be fair to say that the rugosity seen in Baltimore County's mostly contiguous urban areas differs from that in Chester County's fragmented village model, yet both forms of mixing urban and agricultural land-uses result in more multifunctional farming and farm networks. The emergence and proliferation of farming networks appears to be a function of proximity between urban and agricultural land-uses rather than a specific urban morphological design. This finding is upheld in Kent and Salem Counties, where urban and agricultural lands do not readily abut and there are few farm networks.

While interviewees agreed that farm networks strengthen community support for preserving farmland and economic support for multifunctional farming, it was unknown if these networks are an artifact of farmland loss or can be engendered before farmland is loss. To this extent, planning to protect farmland appears to occur most retroactively, with Baltimore reacting in the 1970s, and Chester and Kent Counties taking more recent concerted measures. Salem County is reluctant to welcome urbanization, farm networks and farmland preservation. In this sense, the reluctance to engage in farm networks reflects a similar reluctance to change the current growth paradigm or adopt multiple growth management strategies. The other counties exhibited more progressive approaches to both fostering local farm marketing opportunities and farmland protection, while Salem County appears to culturally prefer the traditional marketing ventures and traditional land-use governance.

CHAPTER 9. Conclusions and Recommendations

By fusing planning theory with rural development theory, this work challenges planners to account for the over-looked residential and agricultural desirability of the rural-urban fringe and brings to light a new theory in shaping urban morphology found in the ecological construct of rugosity. This combined rural-urban theory not only helps to explain the current phenomena of decentralization, disinvestment in center cities, and amenity valuation of open lands. Rugosity theory opens predictions for future land-use models that would allow for high density urban expansion, farmland adaptation, and increased networks and services over the rural-urban boundary to maximize complimentary economic markets and land-uses.

Establishing the Theory of Rugosity

Rugosity is a measurement commonly used in ecology to capture a surface-to-area ratio where the surface is a functional barrier between two mediums with competing but complimentary needs. This study focuses on the functional area of the city as it relates to peri-urban farmland. If an urban area is considered as an organism, the urban perimeter would be the functional surface through which a city absorbs a host of vital nutrients such as food, recreational services, and ecological benefits (Brinkley, 2012). Conversely, farmland can be viewed as the organism which operates through the functional surface of the urban perimeter to gain access to markets, labor, and culture. Just as Ian McHarg (1967) considered the layers of urban growth and Andres Duany (2010) championed the concept of urban transects, rugosity offers another method of viewing the form and function of urban growth. This new theory of city development hypothesizes that maximizing the rural-urban fringe will maximize the interaction between urban and rural/natural environments for the synergies that exist between these two regions.

Contiguous and controlled urban growth with added rugosity may enable urban areas to capture value from fringe developments without detracting from core economical agglomeration economies and needlessly over-consuming farmland. While the attraction of rural natural amenities is found to increase urban decentralization (Deller et al., 2001; McGranahan, 1999; Shumway and Otterstron, 2001), researchers have found that natural amenities also reduce urban fragmentation due to the concentration of development around these amenity features (Irwin and Bockstael, 2007). Thus, preserving key amenities, farms, open space, and scenic rural viewsheds, will create a market for dense, contiguous fringe development that maximizes the economic potential of the land while preserving the natural heritage of working farms. As opposed to accommodating growth as low density concentric suburban expansion or leapfrog development, planners that recognize this theory can encourage in-fill development on underutilized urban land and as a second option planners can advocate for contiguous, dense fringe development while preserving the rural and agricultural amenities through strict zoning, urban growth boundaries, and strategic farmland preservation.

Applying the rugosity concept to urban areas helps identify previously overlooked drivers and limits to the process of ex-urban development in relation to its effect on peri-urban agriculture and center cities. From this analysis, a new growth management paradigm is derived to maximize the rural-urban interface**.** With this understanding, planners could seek to maximize urban rugosity through non-concentric urban growth boundaries, green wedges and greenbelts to allow rural ecosystem services to penetrate the city and maximize the desired functions along the peri-urban fringe.

In this study, rugosity expressed as non-concentricity appears to be a naturally occurring phenomenon in counties with a high farmland-to-urban-area ratio despite different geographical locations or planning modalities. Michael Batty's work on fractal cities confirms the widespread phenomenon of high rugosity urban areas across multiple different landscape typologies and planning systems, asserting that this is the natural form of urban growth (Batty and Longley, 1997). Future studies could further develop the concept of a functional land-use interface by testing rugosity at a variety of different land-use interfaces to describe form and function as each land-use relates to the other (eg. urban and forest land, farm and forest land).

That rugosity is theoretically desirable, a prevalent land-use model, and has the potential to optimize land-use in urban and agricultural land-uses, has either been overlooked or downplayed due to the perceived risk of engendering sprawl. This is particularly true when planners face the realities of the profession. As the scan of the top 30 high rugosity counties in comparison to national state-level planning has shown, few counties in the U.S. are mandated to plan, have ample planning funding, can plan comprehensively with their municipalities and non-incorporated areas, and produce plans and enforcement in under a decade. Case studies reveal that farmland preservation is a key component, manifesting local will to retain farmland which further encourages county and state level agricultural protection programs. With or without high rugosity planning, planners and communities seeking to retain farmland should consult experts on establishing, financing and building agricultural land banks for TDR and PDR programs.

Testing the Theory of Rugosity

Geographically-weighted spatial regression on United States metro-level counties reveals that non-concentric urban areas do not have more farmland loss despite the finding that there is greater population growth (2000-2010) in areas with more urban interface. This finding has significant implications for managing urban growth and lends credence to the call for developing star-shaped cities that integrate integration of rural and urban lands. Counties with high rugosity urban areas can be revisited with every population and agricultural census to develop trendlines that further establish a rugosity index with planning programs and results on farmland loss.

Farms near more non-concentric urban areas also showed higher sales per acre, indicating that non-concentric urban areas help generate more value for nearby farms. Some of this value per acre comes from a change from grain and livestock to more intense value-added produce production with agritourism capabilities. This finding of urban proximity's influence on farmland was upheld in network mapping. Farm network mapping and interviews suggest that the more integrated farmland and urban areas are, the farm-direct sale networks will increase in this order: farmgate sales, CSAs, farmers markets, restaurant sales, and wholesaling. According to interviews, this progression also follows the profitability for the farmer, with on-farm sales garnering the highest returns for outlay of effort. This study did not measure or map the many other farmland ecosystem and social services, nor their distance decay functions; this is an area for future work.

This dissertation based rugosity measurements off the urban area perimeter, but future studies could test various measurements of rugosity based on alternate urban densities in relation to particular farmland types to determine what the density form and function of the urban perimeter does for both housing markets and farm production alike. As the case study section highlights, there is a need to test rugosity with contiguous patches of farmland and contiguous urban areas versus more fragmented landscapes. There is more work to be done in further quantifying rugosity and testing its economic and land-use outcomes against other more established notions, such as retaining critical mass. Future studies will also want to employ remote sensing land data for land-use coverage in order to decrease the amount of error involved in estimating farming parcels based on agricultural census data. Satellite land-use mapping will enable more detailed, fine-grained and reliable land-use profiles for agricultural and urban densities alike. The same methods can be applied to low density, medium density, and high density urban developments to compare how their spatial orientation to each other and farmland influences development patterns and farm networks.

As the spatial regression and case studies have shown, high rugosity is not a preclusion to farmland retention, nor it does it preclude farmland loss. In part, farmland conversion is fueled by rising real estate values and property taxes as well as conflicts between farmers and their non-farming neighbors. High rugosity would maximize farmland values, and potential taxes and urban-rural conflicts if not managed appropriately. On the other hand, farmland conversion is also spurred by declining agricultural profitability; the rugosity model shows that farms are more profitable the more integrated they are with urban areas. Further research will need to tease out the balance between these many variables in maintaining farmland parcels and active agricultural economies.

Adjusting Planning Practice

Concentric growth, the common theoretical growth vision, minimizes the rugosity of the rural-urban edge. This theory often plays out practically in planning, with concentric greenbelts or concentric urban growth boundaries that have often been criticized for choking urban growth and limiting the desirable fringe to a wealthy few (Anas and Rhee, 2006 and 2007, Kotkin, 2009). In light of the discovery that people want to live on the fringe, near farmland and natural amenities, it becomes desirable for urban regions to maximize their connections to fringe areas. Conversely, creating 'green wedges' throughout urban areas can maximize the rugosity of the urban form, putting it in contact with the highly desired rural lands.

To secure working farmland near urban areas, agricultural land-use will need to be recognized as a highest and best use of land and protected from the nuisances of urban development, such as special assessment fees levied for new sewer lines into rural areas. This can be encouraged through formal planning measures such as non-concentric urban growth boundaries and agricultural zoning with only one residential development per every 20 acres; as well as informal, supportive planning measures such as farmland special assessment protection, economic farming support and outreach, tax breaks for agricultural land uses, and right-to-farm laws (Table 9). Planners can coordinate efforts with well-established federal programs and private interests to guide competitive farmland economics through subsidies for produce production near cities or permanent farmland conservation easements to protect farmland through the purchase of development rights. Though planners already control parcel uses through zoning allowances, as the case studies have shown, many counties grant abundant zoning variations as part of a more reactive than proactive planning process. To make the planning process more proactive, legislators may also wish to create a formal process through which farmland must be offered for sale first to other farmers and then to developers if the zoning is approved to allow development. Such a system requires the local government to hold a right of first refusal on property, a common tactic in Europe that has not been deployed widely in the U.S. which seeks to achieve the same aim by restricting land-use through zoning. Similarly, numerous scholars have suggested adjusting property taxes to reflect higher taxes on land and lower taxes on buildings, thereby discouraging speculative land holding and encouraging land conservation (Gihring, 1999). These proposals may also tip the scales to favor urban infill where vacant lots are more heavily taxes for their land value than their non-existent building structures. Urban vacant lots can be idled for decades before investors deem them profitable to develop.

Planners and state legislators must make a concerted effort to preserve both agricultural land and economies through a variety of land-use planning tools and less conventional policies, such as limits on septic systems (See Table 9). To that end, blended land-use could be a highly cost-effective proposal, particularly for maintaining a healthy tax base. Farmland generates more in local tax revenues than it costs in services while taxes on residential uses consistently fail to cover cost. Farmland requires few public services, while residential subdivisions require many services including: new and improved roads, schools, public safety, and related community services. These services are expensive and are typically funded by increasing property taxes.

To maximize the rural-urban interface, planners will also want to increase urban density around natural areas and farmland. By maximizing fringe density, the area of land consumed by urban expansion will be minimized in comparison to low-density expansion models. This can be accomplished through the zoning code by citing high-occupancy development in condos on the contiguous fringe, as opposed to the tapering off transect envisioned by Andres Duany where fringe development consists of isolated New Urbanist settlements of detached single-family homes. In designing high density neighborhoods on the fringe, planners will want to pay attention to providing other key neighborhood amenities, such as food access and high quality neighborhood schools and mass transit. To maximize access and visibility of natural amenities and farmland, planners can designate bike lanes and recreational paths through farmland and scenic areas. By zoning the fringe, a desirable place for the wealthy, as high occupancy with a variety of housing types not precluding multi-level condominiums, planners can mix high and low income contributions to the local tax base as well as neighborhood public school children from different income levels to create more equitable school systems and mixed neighborhoods. As condominiums require less building material, as well as heating and cooling energy per person due to shared wall, ceiling and floor space, this construction may also contribute to more sustainable urban development. Planners can also combine these goals of increasing density on the fringe around farmland and open space amenities through the use of transferable development rights where permanently preserving key farming parcels can give developers higher density permits in specifically designated areas.

Table 9. Examples of programs that strengthen local farms.

Policy Goal	Strategies
Farmland Preservation	Land use controls: agricultural zoning <1 dwelling unit every 20 or more acres. Urban growth limits and boundaries with sewer and water line restrictions Tax incentives, eg. Williamson Act- tax breaks for retaining farmland in agricultural uses for specified time period Purchase of development rights (PDR) Transfer of development rights (TDR) Conservations easements Right of first refusal regulations Higher property taxes with lower development taxes
Agricultural Infrastructure	Develop grain belts, food processing stations, added value processing, and manure removal/composting. Allow ancillary operations and multifunctional agriculture: agritourism, green energy production via methane digesters, wind or solar Education and training through farm bureau and agricultural extension agencies Farm Link assistance for beginning farmers
Local Purchases	Food Policy Council "Buy Local" program Examine regulation barriers to establishing and maintaining farmers markets and farm gate sales Supportive county health and food trade policy Public outreach and education
Farm Financial Viability	Farm ombudsman Technical assistance: business plans, agricultural marketing specialists Financial assistance Permit assistance
Image & Identity	Inclusion of agriculture in the comprehensive plan County agriculture policy Regulatory streamlining

Regardless of whether planners adopt a high rugosity or concentric growth model, they must apply strict growth controls to minimize farm loss and support multifunctional agriculture. When planners can adopt strict growth control measures, there is already a widely tested and verified portfolio of successful farmland protection measures (Daniels, 1998). Planners must also consider if their community desires this land-use vision. As in the case with Salem County, some communities may wish to remain rural and keep their urban areas buffered from agricultural uses. Some states may also prefer to keep urban areas concentric instead of encouraging rugosity. Indeed, many states have no enabled municipal or county-level zoning or farmland protection programs for various reasons. To this end, states that have not already done so and wish to, should adopt enabling legislation for these land-use policies- and mandate local planning requiring consistency with the zoning documents and vertical and horizontal coordination with surrounding counties.

One of the most popular mechanisms for farm land preservation in the United States is to purchase agricultural conservation easements (PACE) from landowners. This method was found in all four case studies with varying degrees of deployment and success. PACE programs can be leveraged at any government level and even by private or non-profit organizations. The purchase permanently restricts the type and amount of development that can occur on that farm land in the future regardless of changes in ownership of the property. Government farmland conservation programs that apply this mechanism can use it in conjunction with Transfer of Development Right (TDR) programs. By targeting desirable ACEs to maximize rugosity, conservation programs can adjust development patterns, form large contiguous areas of protected farmland to provide social and ecological benefits, potentially boost farm-to-market networks and farm viability, and reinforce other planning measures to shape urban growth, such as urban growth boundaries. Planners and farmland preservationists operationalizing rugosity theory need make only small adjustments to the deployment of PACE programs, which would still aim to protect culturally or ecologically sensitive land, but would encourage a greater rural-urban fringe.

Examples of High Rugosity Planning

Though land preservation as a growth management tool is not new (Daniels, 1997), the notion of drawing a growth boundary with high rugosity instead of a circular buffer is a new concept. Indeed, planners may be naturally adopting the concept of high rugosity without explicitly embracing it. Examples of high rugosity planning already exist, but are not recognized as such. Some highly successful farmland preservation counties, such as Lancaster County, Pennsylvania and Portland, Oregon, have deployed successful, high rugosity urban growth boundaries (See Table 4 and the Appendix for counties with high rugosity urban areas and urban growth boundaries). Yet, the more common paradigm in planning documentation proposes concentric urban growth with tapering densities to limit the urban-rural interface and exposure (See 30 county case study section for examples).

More explicitly, the concept of rugosity is developed in Copenhagen's *Finger Plan*. Though this plan was developed as a transportation solution in 1947 rather than a rural-urban solution it also spurred a long tradition of planning for ecological networks in urban areas (Brant, 1995). In this plan the urban wedges, or "fingers," are separated by rural wedges. According to the original objectives of the Finger Plan, the city's most important functions were administrative and cultural, while the clusters of smaller communities (towns) that developed along the radials fulfilled a residential function. These towns included institutions such as schools, banks, recreational centers and shopping malls (Egnsplankontoret, 1947). Nearly 70 years later, the success of the Finger Plan is maintained as Copenhagen is a unique European capital without major traffic congestion (Greater Copenhagen Authority, 2004) and with ready access to the many benefits of rural amenities (Caspersen et al, 2006). This highly productive urban morphology was wrought from long-term planning policies at the regional and local level.

Rural-urban spatial interdependencies are not new (Sorokin and Zimmerman, 1929; Jacobs, 1984), but the call to strengthen them by allowing more contact is new. Similarly, economists have suggested developing land in "fingers" to ensure that value stays in both the rural and urban areas (Brueckner, 2001). Though planners have adopted the notion that urban areas grow as fractals (Batty and Longley, 1994), they have not acknowledged that this growth into rural areas can be healthy for both rural and urban systems, and can help retain value in both land-uses.

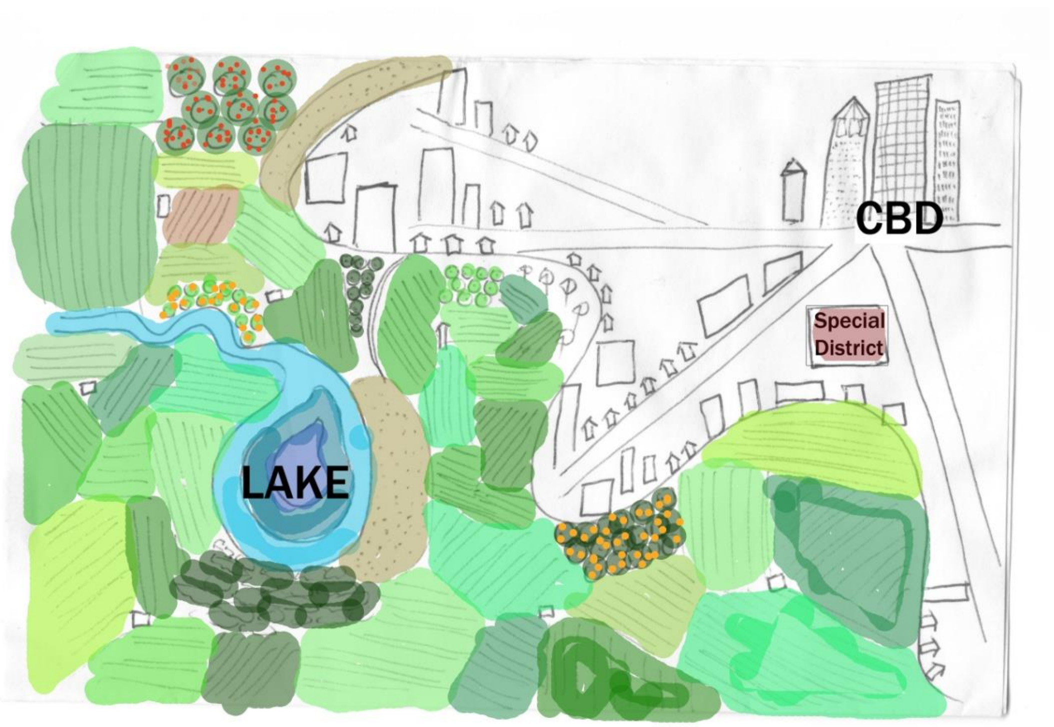


Figure 25. Vision for Rugosity and Urban Land Uses.

APPENDIX

Appendix A: Planning regulations in the top 30 counties with the most non-concentric Urban Areas

County, State	Main City	Prominent land features	Concentric	Land-use Regulations	References
Robertson County, TN	Springfield, Nashville	farmland (77% of county)	2661.35	Currently crafting county-wide comprehensive plan, no land trust preservation in the county.	2008 Tri-County Transportation and Land Use Study, 2013 The Robertson County Comprehensive Growth and Development Plan (in progress) http://www.robertsonchamber.org/growth
Kenosha County, WI	Kenosha	Small lakes, farmland	831.88	Agricultural Preservation Plan since 1981, Countywide Zoning Ordinances in 1983, State Farmland Preservation tax credit program	Kenosha County Agricultural Preservation Plan, "Working Lands Initiative" Wisconsin Act 28 (2009-2011 Budget Bill)

Washtenaw County, MI	Ann Arbor	farmland	569.76	Chapter of county comprehensive plan devoted to agricultural planning, 19 out of 20 townships in Washtenaw County have an agriculture component or element in their local master plans, urban service boundaries, Ann Arbor Greenbelt, 2.5 acre agricultural zoning. State Farmland Development Rights Agreements: temporary, voluntary agricultural-use restriction on the land for a minimum of 10 years in exchange for tax benefits and preclusion from special assessments. There are 636 properties totaling 34,630 acres in Washtenaw County with PA 116 agreements that extend over 20 years. State PDR program provides 75 percent matching grant fund to townships, counties, and other local governments who have local PDR programs. There are six PDR properties in Washtenaw County totaling approximately 1,100 acres. There are three land trusts in the county which have preserved over 5000 acres of farmland, the most preserved in the state	2004 Comprehensive Plan for Washtenaw County, Michigan Farmland and Open Space Preservation Program (PA 116), Legacy Land Conservancy (http://legacylandconservancy.org/)
Orange County, NY	Goshen	farmland (16% of county), mountains	509.88	The County Planning Department provides staff assistance to the County Agricultural and Farmland Protection Board (AFPB), which meets monthly to address issues impacting agriculture and to promote agriculture. Open Space Fund Program offers up to 50% matching funds for the acquisition of open land, including farmland. The County Planning Department has also helped create and circulate plans and documents written to improve agriculture and address farming issues, such as the Orange County Agricultural and Farmland Protection Plan (1996) and the Orange County Agricultural Economic Development Strategy. Local right-to-farm law (2006). PDR programs (2003). >4000 acres preserved.	Orange County Comprehensive Plan (1987, 2003 and 2010); Orange County Agricultural and Farmland Protection Plan (1998), Orange County, NY Agricultural Economic Development Strategy (2004), Local Law No. 5 of 2006 – Establishing a Right-to-Farm Policy in Orange County, New York

Harris County, TX	Houston	Farmland, ring roads, lake	468.27	no agricultural zoning (no zoning in Texas), no farmland preservation programs, no state farmland support or preservation programs in operation in county	Harris County Master Plan (2003), Texas Farm and Ranch Lands Conservation Program (created 2005), Regulations of Harris County (2011)
Stanislaus County, CA	Riverdale Park	State parks and farmland (41%)	380.37	County-wide General Plan with Agricultural Element since 1994. In 2010, the Stanislaus County Local Agency Formation Commission (LAFCO) required cities to prepare farmland conservation plans before they annex land. The countywide Farmland Mitigation Program (FMP) requires developers to preserve an acre of farmland for every acre developed. 20 acre minimum agricultural zoning (reduced from 40). California Land Conservation Act of 1965 (Williamson Act) participant since 1970 allows farmers of >10 acres to pay agricultural land tax instead of market value land tax upon agreement to keep land in agriculture for 10 years. Over 690,000 acres are enrolled under the Williamson Act. Stanislaus achieved the lowest per capita land consumption of all Valley counties in the 1990s.	Stanislaus County General Plan (1994, 2006), The California Land Conservation (Williamson) Act Status Report 2010. http://www.conservation.ca.gov/dlrp/lca/stats_reports/Documents/2010%20Williamson%20Act%20Status%20Report.pdf
St. Joseph County,	South Bend	farmland (70%)	371.18	1973 Comprehensive Plan designated urban uses, no agricultural land-use considered (only residential and industry), 20 acre agricultural zoning.	1973 Transportation and Land-Use Plan (never adopted), Comprehensive Plan for South Bend and St. Joseph County (2002)

Pasco County, FL	Dade City	wildlife preserves, farmland, swamp and ocean	344.84	County settled litigation in 2000 calling for more focus on land protection in the 2025 comprehensive plan, which was re-focused on wildlife corridors with appointment of an Environmental Lands Acquisition Selection Committee (ELASC) since 2003 to direct density transfer credits, Penny for Pasco sales tax passed by citizen referendum in 2004 provides the Environmental Lands Program 25% of the County’s share of the proceeds, agricultural zoning 10 acres in county comprehensive plan.	Pasco County Comprehensive Plan (2006)
Hartford County, CT	Hartford	farmland	326.44	In Connecticut there is no county-level executive or legislative government nor county comprehensive land-use plan. State Farmland preservation enabling legislation passed in 1963 (Public Act 490) which preserves agriculture land, forest land and open space land by assessing these lands at their use value not their market value. The 1978 farmland preservation legislation established the Department of Agriculture's Farmland Preservation Program. Hartford has preserved 7000 acres, and leads other counties with the largest acreages preserved by private land trusts.	Altobello, M (2013) "Evaluation of Land Use Policies and Practices for Enhancing Agricultural Sustainability in Connecticut." http://www.are.uconn.edu/landuse.php Connecticut Department of Agriculture annual report, 2010.
Tulare County, CA	Tulare	Sequoia National Park, farmland	300.08	County Comprehensive Plan since 1976 adopted Urban Growth Boundaries and Agricultural Element in 2013. Rural Valley Lands Plan (1976) directs growth within Urban Development Boundaries where farm parcels are considered for development on a points system with Land Evaluation and Site Assessment (LESA). Over 1,000,000 acres are enrolled in the Williamson Act.	Tulare County General Plan (2013), Rural Valley Lands Plan (1976), "Public Act 490" - C.G.S. Sections 12-107a through 12-107f , The California Land Conservation (Williamson) Act Status Report 2010. http://www.conservation.ca.gov/dlrp/lca/stats_reports/Documents/2010%20Williamson%20Act%20Status%20Report.pdf

San Diego County, CA	San Diego	Anza Borego Desert State Park, Cleveland National Forest	208.27	Unincorporated parts of county are zoned for agriculture since 1970s (minimum 5-8 acre zoning) and designated as Agricultural Preserves eligible for the 1965 California Land Conservation Act (Williamson Act) 10-year property tax abatement which covers 61,000 acres. All development on agricultural lands subject to CEQA (California Environmental Quality Act) review as defined by the California Department of Conservation's Farmland Mapping and Monitoring Program. State and County Right to Farm Acts. Nearly 10,400 acres have been committed to future non-agricultural use due to the approval of subdivision maps, the sale of bonds for infrastructure, or other permanent commitments. Between 1980 and 2005, only two property owners have requested Williamson Act contracts on their land within San Diego County.	San Diego County General Plan (1978, 2011), Zoning Ordinance of Sand Diego County (1978), The California Land Conservation (Williamson) Act Status Report 2010. http://www.conservation.ca.gov/dlrp/lca/stats_reports/Documents/2010%20Williamson%20Act%20Status%20Report.pdf
Hidalgo County,	McAllen	farmland (91%	189.77	No zoning enabling legislation in Texas, no farmland preservation programs though county comprehensive plan does encourage agriculture, farmers markets, and the placement of easements on farmland.	Hildago County Comprehensive Plan (2004, 2011 updates)

Hillsborough County, FL	Tampa	Old Tampa bay, state parks, farmland, rivers	186.54	TDR program since 1980s, but no transfers made to program. Comprehensive planning for entire county. 20 acre agricultural zoning. Agricultural Exemption from Natural Resources Permitting for agricultural land-use changes. 'Greenbelt' assessment taxes farmland value in use not market value. Amendment 10 provision does not allow the assessed value of the property to increase greater than 3% in any given year unless improvements are made to the property. Hillsborough County Agriculture Industry Development Program (2009) is a component of the Hillsborough County Economic Development Department. The program works under the guidance of the Agriculture Economic Development Council.	Comprehensive Plan for Unincorporated Hillsborough County Florida (2008), Daniels T (2008) "Farmland Preservation in Growth Management: Lessons for Florida," 2008 FSU DeVoe Moore Center Critical Issues Symposium
Polk County, IA	Des Moines	Lake, farmland, rivers	144.04	County comprehensive Plan (1990, revised 2006) includes an agricultural element, 35 acre agricultural zoning, the dominant zoning ordinance for the county. Iowa Code Section 352.6 (1982) establishes a county land preservation and use commission to oversee Right to Farm nuisance mitigation and prohibit assessments for sewer and water in voluntarily created agricultural districts of 300 acres under Iowa Code Section 352.6 . Comprehensive plan calls for creation of PDR or TDR program. Over 127,000 acres are designated as Agriculture, and over 16,000 acres as Agricultural Transition on the Land Use Plan map, totaling over 60 percent of the unincorporated area.	The Polk County Comprehensive Plan (1990, 2006), Polk County Zoning Ordinance (2007)
Jasper	Carthag	Farmlan	138.55	No county planning commission established. 5 acre agricultural zoning.	Jasper County Zoning Ordinance (2009)

Los Angeles County, CA	Los Angeles	National forest, ocean front	132.5	County-wide comprehensive plan (1980, 1993, 2035 plan under review currently). Agricultural zoning 1-40 acres and encouragement of farmers market citation. All development on agricultural lands subject to CEQA (California Environmental Quality Act) review. Agricultural Preserves and Potential Preserves created under the Williamson Act encompasses over 40,000 acres. Use and management of agricultural lands located within Local Coastal Program (LCP) areas of Los Angeles County are subject to those Coastal Act policies that protect agricultural resources. Los Angeles County was the leading agricultural producer in the United States in 1960, dramatic urban expansion over its citrus groves have curbed farming practices.	County of Los Angeles General Plan (1908, 1993, 2013 draft), The California Land Conservation (Williamson) Act Status Report 2010.

Solano County, CA	Vacaville	Grizzly Bay, farmland (62%), Utah Creek wildlife area, air force base	120.04	County-wide comprehensive plan (1984, 1994, 2008) allows 20-160 acre minimum agricultural zoning. Citizens' Advisory Committee (CAC) Agricultural Subcommittee conducts farmer workshops to inform comprehensive zoning measures. Agricultural Reserve Overlay designates Community Separators and promotes a toolkit for Farmland Mitigation where developers must permanently protect 1.5 acres of farmland for each acre of farmland converted, farm buildings are exempt from county design review, develop mobile seasonal farmworker housing, promote local agricultural product sales. County Right to Farm Ordinance. Solano Land Trust has permanently protected 22,161 acres of natural areas and agricultural lands. Agricultural Preserves and Potential Preserves created under the Williamson Act cover 270,000 acres. Williamson Act contracts on lands classified by the California Department of Conservation as Important Farmland can be extended to 20-year Farmland Security Zone contracts (called super Williamson Act contracts), which offer landowners greater property tax savings. In Solano County, roughly 215,000 acres are held in Williamson Act contracts, representing 62 percent of the county's agricultural lands.	Solona County General Plan (2008), The California Land Conservation (Williamson) Act Status Report 2010.

Jackson County, MI	Jackson	farmland	111.83	Comprehensive County Plan (1971, 2005) updates call for regional zoning committee under the 2001 Township Planning Act and the Municipal Planning Act amendments requiring that zoning change notification be provided to adjacent communities, the county planning commission, and the regional planning agency; as well as to each public utility and railroad company. Agricultural zoning is typically 2 acres in townships. County Purchase of Development Rights program created in 2006 and approved by state in 2010. Jackson County Farmland Preservation Program to occur in designated Agricultural Preservation Areas directed by the County Agricultural Preservation Board protects farmland by acquiring development rights voluntarily offered by landowners, authorizes the cash purchase and/or installment purchases of such development rights, places an agricultural conservation easement on the property which restricts future development, and provides the procedures and guidelines governing the purchase of development rights and the placement of an agricultural conservation easement.	Jackson County Agriculture & Open Space Preservation Ordinance (2006), Jackson Community Comprehensive Plan (2005)

Riverside County, CA	Palm Springs	Joshua Tree National Park, farmland (7%), mountains	109.88	County Comprehensive Plan (2003, 1987 plan did not zone unincorporated areas) provides agricultural zoning of 1-10 acres and limits general plan amendments to once every 10 years. Right-to-Farm Ordinance. Between 2000 and 2005 only 435 acres enrolled in the Williamson Act Easement Exchange Program, which covers 52,654 acres of prime farmland and 6,653 acres of non-prime farmland.	Riverside County General Plan (2008), Chen X, Li BL, Allen MF (2010) Characterizing urbanization, and agricultural and conservation land-use change in Riverside County, California, USA. Ann N Y Acad Sci. 1195(1):E164-76., Wassmer, R. (2008) California's Farmland Preservation Programs, Taxes, and Furthering the Appropriate Safeguarding of Agriculture at the Urban Fringe to Reduce Greenhouse Gas Emissions. California Department of Conservation, Division of Land Resource Protection (2006), The California Land Conservation (Williamson) Act Status Report (2010). Ordinance No. 625.1: Riverside County Right-To-Farm Ordinance
Middlesex	Boston	Irregular	107.63	State Right to Farm laws. Chapter 61 Program provides a tax break for farmland. State Farmland Preservation' Agricultural Preservation Restriction Program (1977).	Middlesex County Comprehensive Farmland Preservation Plan (2008)

Dane County, WI	Madison	Lakes, farmland, no ring	105.84	County Comprehensive Plan (2007) stipulates 2, 5, and 35 acre agricultural zoning. Wisconsin Working Lands Initiative (2009) established Agricultural Enterprise Areas (AEA) with a Farmland Preservation Program (FPP) to focus the Purchase Agriculture Conservation Easements (PACE) and farmland tax relief credit.	Dane County Comprehensive Plan (2007)
Marion County, OR	Salem	Farmland (47%), Santiam State Forest	95.48	Willamette River Greenway (1967) plan to acquire lands was supported by state ORS 390.310 and 390.368, establishing the Willamette River Greenway requiring the State Department of Transportation (DOT) to prepare a plan for the development and management of the Greenway. Senate Bills 100 and 101 established Oregon Land Conservation and Development Commission (1973) requiring county comprehensive plans in compliance with state-wide agricultural preservation goals administered under the Land Conservation and Development Commission (LCDC). LCDC required urban growth boundaries and planning and zoning for unincorporated communities in 1994. Minimum agricultural zoning of 5-40 acres in Special Agriculture areas and 80 acres in Exclusive Farm Use agriculture areas. Farmland taxed at agricultural use value	Marion County Comprehensive Plan (1981, 2010), Marion County Rural Zone Code (2012)
Will County, IL	Joliet	Farmland, no ring road	88.24	Comprehensive County zoning Ordinance (2012) establishes 2.5 acre agricultural zoning allowing one-time farmstead split. Illinois Agricultural Areas Conservation and Protection Act (1980) allows 350 acres of contiguous farmland to be voluntarily placed in a protected district for 10 years such that no benefit assessments for community improvements can be imposed on farmland. Will County experienced the greatest loss of any Illinois County with 52,114 acres of farmland loss from 1950-1998.	Will County Zoning Ordinance (2012); Agricultural Areas Conservation and Protection Act, Illinois Compiled Statutes, (1980). Ag Areas: An Introduction (1998). Illinois Farm Bureau.

Pierce County, WA	Takoma	Mt. Ranier	82.3	Washington mandates county-wide planning (1991) for Agricultural Resource Land (ARL) zones. Pierce County creates Pierce County Development Regulations (1995) with 10, 20, 40 acre agricultural zoning and designated Urban Growth Areas (1997). County Right to Farm.	Pierce County Comprehensive Plan (1994), Pierce County Development Regulations (1995); Title 19C PCC. Ord. 97-84 § 8; WAC 365-190-050
Woodford County, KY	Versailles	Farmland, near Lexington	73.9	Kentucky (1966) grants power to counties for comprehensive planning. County Comprehensive Plan (1989) established urban service boundaries which were expanded in 2005 and (2011) 30 acre agricultural zoning. State Agricultural District program (1982) allows farmers to form 250 acre agriculture areas where protected from annexation and deferment for community service assessments. The Kentucky General Assembly established a PACE program (1994). State Right to Farm.	Woodford County 2011 Comprehensive Plan; The Woodford County Zoning Ordinance (2012), Kentucky Revised Statutes, Chapter 100, Section 100.201

Mercer County, PA	Hermitage	farmland, forest (37%)	71.24	County comprehensive plan (1995, 2006) 30/48 municipalities have local Zoning Ordinances and 12 have local Subdivision/Land Development Ordinances. 25% of county enrolled in Agricultural Security Area program (Act No. 43) which allows a landowner or landowners, who collectively own 250 or more acres of farmland, to protect their land from nonagricultural uses and obtain special considerations under local ordinances and state regulations for 7 year periods with renewal options. According to the Pennsylvania Farmland Preservation Board, Mercer County has purchased conservation easements for 32 farms totaling 5,684 acres as of 2005. Even though the County's population has been decreasing over the past 30 years (-5.4 percent between 1970 and 2000), there was a 46 percent increase in residential land uses between 1973 and 1993.	Mercer County Comprehensive Plan (2006)
Stark County, OH	Canton	Farmland	69.03	20 acre ag zoning in unincorporated areas with provisions to allow subdivision at a rate of 15% of the total land area provided that each lot has a minimum area of one acre and a minimum of two hundred (200) feet frontage on an existing public road. Stark county has no agricultural easements held by *the Department of Agriculture or in Agricultural Security Areas as of 2013. From 2000 to 2007, the County lost over 7,000 acres of farmland to development attributed to lack of growth management.*	Sustainable Planning and Zoning Handbook (2012)

Canyon County, ID	Boise	Farmland	67.36	agricultral zoning of 40 acres. The bulk of Idaho's farmland loss has occurred in Canyon County. Extension study showed that for every 100 acres of Canyon County irrigated farmland taken out of agricultural production results in annual reductions in total sales and total income in the county of about $853,400 and $137,200, respectively. About 70 jobs and $204,000 in annual property, sales, and excise tax receipts would also be lost.	2011 Zoning Regulations Canyon County Code of Ordinances 11-007, Nelson, JR, Neufeld JD, Peterson SS (2003) 41 (5). Journal of extension, Using Regional Economic Analysis Tools to Address Land Use Planning Issues
Bell County,	Kileen	farmland (41- 50% prime	66.42	Main recommendation is a new highway through farmland. No farmland preservation or zoning.	Bell County Thoroughfare Plan 2025 (2001), 1984 Master Thoroughfare Plan
San Bernardino County, CA	San Bernadino	Mojave Desert, National Preserve	66.04	Agricultural Preserve (AP) Overlay District with 10 acre agricultural zoning of prime farmland and 40 for non-prime farmland. 4,500 acres enrolled in the Williamson Act. As of June 2003, 9 acres in San Bernardino County were protected under the Farmland Protection Program as conservation easements. Southern California Agricultural Land Foundation has preserved 350 acres	San Bernardino County General Plan (2007). San Bernardino County Code - Title 8, Development Code. November 6, 1997. Division 5, Overlay Districts, Article 1. USDA Natural Resources Conservation Service; California Farms and Ranch Lands Protection Program(2003); The California Land Conservation (Williamson) Act Status Report (2010).

Appendix B: Interview and Farm Network Solicitation Materials

IRB-approved Interview Recruitment Letter

[First, Last Name]

[Position]

[Organization]

[Address]

[Date]

I am a PhD candidate in the Department of Regional Planning at the University of Pennsylvania. My research focuses on the non-market and market benefits of metropolitan farmland. I am currently working on my dissertation, "Fringe Benefits: farmland adaptation," exploring how urban morphology and land-use tools impact farms and the services they provide. This study tests the hypothesis that specific types of urban morphology at the rural-urban fringe allow farms to create value for their regions in amenity destinations, decreased sprawl, social networking around local food, and organic infrastructure services that connect cities to their hinterlands. Once the dissertation is complete, I will publish it as a book of a series of policy-oriented articles to help inform regional development and planning activities.

[Name of County case study] is one of my featured cases (along with Chester County, PA; Salem County, NJ; Kent County, DE; and Baltimore County, MD) because of its unique land-use and agricultural programs that reinforce local agribusinesses and ties to nearby cities. Specifically, I am interested in learning more about the ways that land-use has impacted farm-city collaboration projects around local food, clean energy, waste management or agritourism.

As the [Position and Organization], I am interested in speaking with you about city-farm collaboration projects in the region. I plan to do one site visit to gather program information, and I will conduct a follow-up expert interview to assess program extent, longevity, context, and farmland products in the four counties. Supportive planning policies that enable or hinder farm-city collaborations will be identified. Data will be triangulated with web-based and printed material from each program and county, and mapped. I would be grateful for an opportunity to interview you, as your input would provide invaluable information for my research. I will not directly attribute any content without your permission and we can discuss any other issues of confidentiality prior to or at the start of the interview.

In case you would like more information about my research and background, I have attached my Curriculum Vitae and a project statement. I look forward to hearing from you, and hope that my research can be constructive for [Organization's] regional goals. If you have any questions, please feel free to contact me anytime via email (catb@vet.upenn.edu) or phone (267-252-2165).

Kind Regards,

Catherine Brinkley

Doctoral Candidate

City and Regional Planning, School of Design

Short form to be sent as a follow-up if no response is received from the long-form:

Hello,

I am a PhD candidate at the University of Pennsylvania in the department of Regional Planning. My dissertation project focuses on mapping farm-city collaboration projects (eg. agritourism, CSAs, on-farm green energy production). I wondered if anyone in your office could spare 30 minutes for an interview?

My CV, dissertation proposal and a copy of my interview questions are attached.

Sincerely,

Catherine Brinkley

Sources used to find county farms

- maps.google.com, search query "farm"
- Agricultural Business promotion networks
    - http://www.jerseypeaches.com/shippers_nj_peach_promotion_council.asp
    - http://www.drnupe.com/PA_Organic.htm
    - http://eatlocalphilly.com/category/vendor/
    - http://pa-chestercounty.civicplus.com/DocumentCenter/View/1350
    - http://www.mda.state.md.us/md_products/agritourism_sites-farms
    - http://agmap.psu.edu

    - http://www.salemcountyagritourism.com/agritourism/RoadsideFarmMarkets.asp
    - http://www.state.nj.us/jerseyfresh/, http://www.eatsouthjersey.com/salem_farm_stands.html,
    - Maryland Ag Extension, http://www.marylandagriculture.info/showall.cfm?categoryid=1
    - Maryland growers' directory: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRD3433168
    - Delaware find farms: http://www.naturallygrown.org/farms/list/227/DE
    - www.njfb.org New Jersey Farm Bureau
    - Kent County: http://www.kentcounty.com/harvest/KentCo.htm
    - Salem county: http://www.salemcountyagritourism.com/agritourism/RoadsideFarmMarkets.asp
    - Maryland Niche Meats & Poultry Producers 2012 Directory, http://mysare.sare.org/mySARE/assocfiles/965817EB-402_MDNicheMeatsPoultryProducers2012Directory.pdf
- http://www.farmplate.com/
- farmer's markets listings
    - http://www.growingtraditions.org/market_on-farm.asp
    - http://www.farmersmarketonline.com/fm/Pennsylvania.htm
    - http://www.bop.org/bop/uploads/File/BALTIMORE_FARMERS_MARKET_PARTICIPANTS_BY_COUNTY_-_2012.pdf
- http://foodroutes.org , buy fresh buy local affiliates
    - Buy Fresh Buy Local Jersey City – Jersey City Division of City Planning (Local Chapter Affiliate Coordinator)
    - Buy Fresh Buy Local Chesapeake – Chesapeake Bay Foundation (Local Chapter Affiliate Coordinator)

- http://www.buylocalpa.org/map?lat=39.971000671387&lng=-75.826499938965&zoomlevel=11&checkedcats=1
- http://www.realtimefarms.com/farms?profileid=5102071

- http://www.localharvest.org

Farm Network Recruitment Email Query

Hello,

I am a researcher at the University of Pennsylvania in the department of regional planning. I am mapping local food networks, and wondered if you have a list of restaurants, farmer's markets, wholesale, auctions and institutions that you sell to? If you have a list of CSA member zipcodes and schools/institutions that have visited your farm in the past year, this will also help me situate you better in the mapped network of local food movements.

Please feel free to contact me if you would like more information about this study. 267-252-2165

Sincerely,

Catherine Brinkley

Additionally, if you have accepted or donated/sold compost or other food byproducts (spent grains, or used programs like beneficial residual management), or if you use bees from nearby farms for pollination services- these programs can be added to your "food network" profile."

Retail locations that were reported to do business with identified farms and markets, were verified through response to the following email query:

Hello,

I am a researcher at the University of Pennsylvania in the department of regional planning. I am mapping local food networks, and wondered if you have a list of producers/farms that sell regularly?

Farm X has reported that they sell Y product to/through your business, can you confirm that?

Please feel free to contact me if you would like more information about this study.

267-252-2165

Sincerely,

Catherine Brinkley

Template for Interview Questions, Approved by IRB

In each case, the following research question is asked, "how and to what extent do cities and their surrounding farms collaborate?" Under this broad research question, are the following sub-questions:

1. What types of farm-city collaborations does your organization facilitate?/ What is the product or service produced from farm-city collaborations?

    a. Suggested subtypes include: local food production, farm visits, waste management

2. Tell me the story for creating each farm-city collaboration project? Examples?
3. Are collaboration projects rural or urban based/initiated?
4. How might these projects influence land-use patterns?
5. What planning tools have been supportive or detrimental to forming farm-city networks?

List of Interviewees

Chester County

- Hillary Krummrich, Director of Chester County, PA Agricultural Development Council
  housed in the county Planning Office
- Larry Welsch, Director of the Chester county Food Bank
- John Berry, Agricultural Marketing Director, Penn State Extension

Baltimore County

- Stephen Vilnit, *Fisheries Marketing Director*, Maryland Department of Natural Resources Fisheries Service
- Jeffery Smith, director of Maryland Farm to Table (www.mdfarmtotable.com), chef
- Ginger Ryan, University of Maryland Extension Marketing Specialist and Director of Maryland Rural Enterprise Development Center

Kent County

- David Smith, Agricultural Marketing Specialist, Delaware Department of Agriculture

Salem County

- Gilda Ann Doganiero, farmer, chef, manager of Salem City Farmers' Market

- Beth Feehan, Director of New Jersey Farm to School Network and founder of New Jersey Farmer's Market Association
- Diane Holtaway, Associate Director of Rutgers Food Innovation Center

Regional:

- Matthew Weiss, Program Manager at Farm to City
- Marilyn Anthony, Eastern Region Director of the Pennsylvania Association for Sustainable Agriculture (PASA), CEO of the White Dog Cafe in Philadelphia and the Summerhouse Grill, a seasonal restaurant in Montrose, PA (Susquehanna County) showcasing local products. Marilyn is currently leading efforts with the Farm Lease Connection program.
- Brian Snyder, director of Food Routes and founder of national Buy fresh, Buy Local campaign
- Karl Rosaen, Co-Founder of Real Time Farm

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INDEX