THE VALUE OF FARMLAND: MAPPING ASSESSOR DATA
TO UNDERSTAND LAND USE CHANGE

by

Lyndi Perry

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in

Bioregional Planning

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ABSTRACT

The Value of Farmland: Mapping Assessor Data
to Understand Land Use Change

by

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Utah State University, 2018

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Findings show that representing land value as continuous surface maps is a useful approach. The maps reveal that Utah County has densified as its population increased while farmland loss still occurred in agriculturally-important areas. Vulnerable areas were identified by examining the value of changed lands. Change mapping shows that macro-level variables affect local land values and subsequent development patterns.

While limitations exist, the conclusion was drawn that this data is useful in connecting land value to location, examining change over time, and understanding how
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PUBLIC ABSTRACT

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INTRODUCTION

The regional planning profession is one that examines the interactions of humans with their landscape. Understanding how cities grow and impact their surroundings is integral to shaping livable places. To this end, planners use information from natural resource and social sciences to examine options, quantify impacts, and implement changes that will conserve the natural resources communities depend on—clean water, breathable air, open land. Many of these tools are used within a geographic context to extend our understanding of past and current conditions into hypothetical alternative futures. These alternative futures stem from a methodology that attempts to simulate and plan for the inevitable changes that come with population growth or decline. Improving the methodologies and tools that are used to build alternative futures improves planners’ ability to manage urban spaces.

In a separate discipline, economists have also developed methods for investigating city structures and growth in a specialized branch known as regional economics. This specific field looks at the geographical relationships between a city and its economic structure, using regression analyses to find stable, predictable relationships between land use, location, and price (Alterman, 1997; Bertaud, 2015; Evans, 2008; Vyn, 2012). These studies also show a stable pattern where land values decrease with an increased distance from an urban center at a stable rate. The price of a piece of land has also been shown to correlate with such variables as density, income, population growth, infrastructure, and land use (Conway, Li, Wolch, Kahle, & Jerrett, 2010; Ekeland, Heckman, & Nesheim, 2004; Plantinga, Lubowski, & Stavins, 2002; Rosen, 1974); all of
which are important considerations for planners working to manage change in local urban systems.

Because of this intersection of interests, it is possible that ideas developed by economists can be integrated into a planners’ methodological system of policy development. To test this idea, I explore the integration of the concept of an *economic landscape* within the planning field: using land values in geographic information system (GIS) models to examine a specific place (Utah County) facing a specific challenge (the loss of prime agricultural land to explosive population growth) to determine what growth and policy options may lead to citizens’ desired conservation outcomes. Several methods are tested toward the goal of identifying farm land that may be vulnerable to residential or commercial development, and both traditional economic models and GIS models are developed.

**Theory**

Regional economics describes the way a legible spatial pattern of land value develops from choices individuals make when purchasing and selling land. The following mathematical formula describes the relationship between the price of land and its distance from the center of the city:

\[ P(x) = P_o e^{-c x} \]

Where \( P(x) \) is the price of land at a distance from the center of a city; \( P_o \) is the price of land at the center, Euler’s number (indicating an exponential relationship), and \( c \) is the rate at which land prices decline as distance from center increases (Bertaud, 2015, p. 3). Known as the *bid-rent curve*, this mathematical description notes the tendency of land value to be highest as a city’s center and decrease at a predictable exponential rate
(internally consistent within a specific city’s individual landscape) as one moves farther away from the center point. This equation is later referred to as a gradient, describing the shape of the curve as it decreases from the center outward. Narvaez, Penn, and Griffiths point out that “centres can be considered as self-organizing systems sustained by social and economic processes” (2013, p. 89:2). This economic structure contains information of a probabilistic nature, as the easier a piece of land is to access and the more centrally it is located within the community, the more demand exists at that geographic point, and the higher the price it is likely to command on the market (Bertaud, 2015). The extent of the spatial systems (the radius of the city) develops from the aggregate attributes of its population and the choices of individuals who seek to balance their personal finances, the income they receive from a job at some location within that urban structure, against how much they can or are willing to spend on travel (Evans, 2008). Businesses and individuals alike seek the best real estate for their needs, trading off the accessibility of a central location for the decreased cost of occupying less desirable space and bounded by the willingness of the individual to spend money and time on transportation (Bertaud, 2015).

The mathematical gradient model above can be applied to any city to observe the effect that natural market forces have as they arise from and further shape the choices people in an area can make (Bertaud, 2015).

Planners may already notice that this price gradient follows a pattern that is similar to density. A school of planning thought, transect zoning, has even explored how this natural density development can be applied to the development of city zoning codes, both to enhance the natural appearance of the city and to separate agricultural uses from urban spaces (Duany, 2002). Economists have also used models to describe this pattern.
of density: by using the bid-rent curve equation above and simply substitution density for price, a density gradient can be statistically observed (Bertaud, 2015). The relationship between density and land value is noticeable but difficult to estimate, one cannot be perfectly explained by the other. This may be due, in part, to the factors that underlie human relationships within cities and lead to complex interactions (Bettencourt, 2013). As Bettencourt (2013) further explains, the bigger the population of a city becomes, the more interactions it can pack into its space. “A city may be denser because it is larger, everything else being equal, and/or because the relative cost of transportation is high” (Bettencourt, 2013, p. 7).

Density is generally seen as a desirable city attribute, and research suggests several benefits of denser cities, including better functionality (Okamoto, 2009), reduced greenhouse gas emissions (Jones & Kammen, 2014), and slower loss of farmland (Medvitz & Sokolow, 1995). Using an economic context, planners wishing to identify policies that will enhance density without creating overly restrictive zoning codes or unintended effects can examine the impact their policies have on the economic balance of an area. Policies may impact the ratio of the cost of living and transportation (expenditures) of a place to the potential income that can be made there. These opportunity-costs are managed individually as people choose between lower land prices at the urban periphery and lower transportation prices at the city core. Because concrete numbers exist for these ideas in government census data and through assessor offices, planners can begin to build models to show how plans affect the economics of an area. Policies that increase transportation costs, increase land prices at the urban periphery, or decrease people’s potential income will have the effect of increasing density.
Economic theories that show how price is related to land use may shed light on how these policies will interact with land use. There are two main lines of thinking about the mechanics of land use change. An idea suggested in early urban economic development theory (Alonso, 1960) is that the price curve (explained by the equation above) can be separated by use; the distance at which the economic viability of one use drops below another use can predict where that use will likely be seen in the real world. If that is the case, modeling the curve of agricultural land value separately from the residential land value may show where one value exceeds the other and could provide insight on where agricultural land is most likely to be viable. Evans (2008) best explains the second line of thinking, wherein all land prices are dependent on urban/developed use prices, especially when the supply of land is not a constraint. Evans posits that, because developers will only buy land if they can turn a profit, it is an increase in the price of housing that determines whether the land is developed (but the reverse is not true: the price of land does not influence housing prices). By contrast, the price of food has such a minimal impact on the price of land that it doesn’t appear to affect the bid-rent curve as food markets shift (Evans, 2008). Therefore, in this theory, the main driving factor underlying the bid-rent curve is likely to be the price of housing/development. In this case, influencing this structure to preserve agricultural land would include examining how policies interact with land values to create demand for housing and urban development.

To summarize the information from this section and emphasize the important points of the price and density gradients:
• Relationships between land value and distance/density are stable over time and offer insight into a community’s makeup;

• Land values incorporate information about the viability of its current use relative to other uses, and therefore could shed light on the conversion of agricultural land into residential use;

• Because data exists for these attributes, models can be used to examine place-specific economic attributes;

• These models may be insightful in considering how polices interact with land prices.

Application of Theory

“Property use conflicts are often emotional and exhausting. Fundamental values like property rights and home and family collide with the economics that drive our civilization. The stage is set for intense and open conflict in a society that is becoming more polarized and impersonal. In an arena where so much is at stake, it is not surprising that attempts by our local governments to forge a consensus and find middle ground are becoming more difficult” (2005, p.16).

—Craig M. Call, *A Utah Citizen’s Guide to Land Use Planning*

In interacting with planners and observing public meetings I have observed that, in practice, the success of a city’s general plan depends on marrying a large-scale, consensus-based general plan with site-specific implementation. Because of the difference in scale between the arena in which a plan is created (community, goal-oriented) and the arena in which the plan is implemented (case-by-case, individual decision making and property management), conflict can be high, and plans can fall apart one decision at a time (Call, 2005). It is in understanding and accommodating decision making at the individual property level that an economic landscape perspective (i.e.,
examining the spatial distribution of land values and how they change over time) could be most useful to planners. Understanding the effects of plans and policies on the economic landscape could lead to better policies and fewer unintended consequences.

Land value data has several defining characteristics that make it easy and helpful for planners to use. These attributes are: (1) It is place-specific and can be mapped; (2) It has a continuous landscape structure; (3) The data is readily available for current and historic time periods; (4) It can be used as a proxy for density; (5) It can quantify change; and (6) It contains a measure of potential. A deeper discussion of these points and references follows.

1. *It is place-specific and can be mapped.*

   Every property has an address and therefore its value information can be mapped within a GIS. In my case, the process was even simpler: the assessor data examined here contains parcel numbers and values, which made it possible to join the records with an existing GIS parcel map. While some studies have integrated the bid-rent curve aspect of economics into larger land use models for planning purposes (Clay & Valdez, 2017; Waddel, 2002; Naidoo et al., 2006; etc.), I suggest that creating a stand-alone map of land values (instead of using value data as a component in another model) allows the insight to be applied with greater flexibility.

2. *It has a continuous structure.*

   Data with a continuous structure does not have specific boundaries that define the units (e.g., a digital elevation model or DEM), as opposed to discrete structure, where the boundaries are necessarily part of the data (e.g., a map of the U.S.)
where every state is delineated). The gradient view of land value suggests that it is best viewed as a continuous surface. Work done by Brorsen, Doye, and Neal (2015) demonstrates three key ideas that reinforce this idea: First, land tends to be more fragmented (be composed of smaller parcel sizes) nearer to city centers; second, this fragmentation follows the same gradient pattern as the value of the land; third, as values increase over time the tendency to subdivide the land increases as well. Rather than using inflexible parcels to represent a very flexible attribute, I explore the potential to interpolate land value with basic geographic information system (GIS) functions.

3. *The data is readily available for long periods of time.*

Complete sets of property value data are maintained on an annual basis at county assessor offices; this data is part of the public record and can be accessed and used to create a land value map with a few simple steps. (My approach is detailed in the methodology sections on page 18.) Property value data have been recorded since the beginning of the administrative record, and more recently have been converted to digital formats (usually excel or some form of .csv file), which makes them easy to access and use.

4. *It can be used as a proxy for density.*

As previously discussed, land value has a role in forming density gradients (Bertaud, 2015), and it has the potential to be used to develop and meet density goals as well as examine policies for unintended effects on growth, like unintentionally incentivizing urbanization in agricultural areas.
5. *It can quantify change.*

Because land value data is readily available for nearly any time period, it is possible to measure the change in land value from one time period to the next. A simple mathematical differencing of map layers using GIS can track these changes over any interval (i.e., in a map where each unit contains a numerical measurement of value, that cell’s change in value can be calculated by subtracting one time period from the previous time period; when this process is repeated at each unit, a map of change can be observed). Such an analysis can indicate areas that planners might investigate to understand where development is occurring, thus allowing planners to improve, target, and measure the outcomes of the application of polices.

6. *It contains a measure of potential.*

People are willing to spend more on land based on its potential use, not just its current use (Capozza & Helsley, 1989; Plantinga et al., 2002). Economic literature explores many regression tools to quantify the impact of potential/future uses on the value of land. While not deeply examined in this thesis, there may be potential for planners to extend the datasets developed in this method into regression analysis. Quantifying potential value could serve as a probability for how likely a piece of land is to be developed.

These six attributes offer many pathways toward crafting management policies that are more effective at dealing with land use change in an individual-choice based system. Mapping land value data shows where change has occurred and could even help quantify the effect of underlying factors that planners already know drive change
(demographic shifts, population growth, increased road access, etc.). In the next section, I explore a study area in Utah County that is experiencing a rapid and undesired loss of agricultural land. This problem is addressed in the remainder of the thesis by examining Utah county’s specific land value data and potential avenues for quantifying and managing this problem.

**Background on Study Area**

Utah County rests at the heart of the state of Utah, and in addition to possessing some of the state’s best agricultural land, it also has the state’s fastest growing population and industry (Figure 1). Envision Utah, a state-supported planning agency, is working with local governments inside of Utah County to help balance these opposing forces in order to preserve as much agricultural land as possible, despite the huge pressures and incentives to convert these lands to residential area. Stakeholder meetings have been conducted to engage the public in the decision-making process and researchers are working on understanding the problem at hand (O'Donoghue, 2016).

According to the Census Bureau, Utah County’s population has increased from 516,564 in 2010 to 592,299 in 2016, a percent change of 14.6%. This is higher than the Utah average at 10.4% and well above the national average at 4.7%. Furthermore, income measures show stronger than average growth in Utah County compared to other areas. Median household income for 2011 to 2015 was $62,180 compared to $60,727 at the state and $53,889 at the national level (U.S. Census Bureau, 2017); this higher than
average earning potential is likely to attract a strong work force. Conversely, per capita income was actually lower in the study area—$21,335 in Utah County compared to $24,686 at the state and $28,930 at the national level (U.S. Census Bureau, 2017). At 3.63 persons per household compared to the national average of 2.58 (U.S. Census Bureau, 2017), the large family sizes drive the per capita income lower than the national statistic and suggest that housing trends would need to account for both the high household income (people can potentially afford large houses) and large family size (people likely need large houses). This rapid growth, increase in income, and need for
spacious family housing is occurring in the State of Utah’s highest ranked county for agricultural production (Utah Department of Agriculture and Food, 2016).

In response, agricultural preservation policies have been implemented statewide in Utah, including the Utah Farmland Assessment Act, which allows Utah farmland to be taxed at a rate proportional to the land’s productivity rather than full value (Israelson, Greenlaugh, & Heaton, 2009). In addition, the Utah Agricultural Protection Act, protects agricultural uses against complaints of nuisance, and places restrictions on eminent domain from governmental bodies (“Utah Agricultural Protection Act,” Utah Code, 17-41-4, 2017). Both of these policies, as well as several other area-specific protection policies, have been applied in Utah County. Additional protection policies include: parcels that have been set in easements (i.e., the development rights were purchased by holding organizations and can no longer be used for development), a strict agricultural “green belt” zone designated by the county, and a county policy that restricts subdivision outside of municipalities to five acres except in special circumstances. The goal of the policy is to shift denser development toward municipalities (R. May, personal communication, Jan. 25 to Mar. 22, 2017).

Citizens and policy makers see farmland loss as a point of cultural concern and Envision Utah has been involved in prioritizing and pursuing agricultural land preservation policies at a community level in Utah County. Envision Utah’s “Agricultural Toolbox” document states two main goals: “1. Work to make and keep agriculture economically and socially viable; 2. Encourage development patterns and implement measures that support agricultural land and water” (Envision Utah, 2016). Having an
economic context to support this work may help planners understand how their policy tools interact with the land market.

Utah County is not alone in facing the problem of agricultural land loss. It is against an international backdrop of exploding population growth that the application of ag-preservation policies has begun to attract economists’ attention. A popular policy tool is the green belt, a strict form of agricultural preservation and urban containment that seeks to lock-in the existing land use at some radius around a city as an attempt to prevent a sprawling spatial development pattern and create density at the city-level (Nelson, 1985). Examining the economic consequences and the effectiveness of these policies is perhaps the example of regional economics and land use planning can be integrated. Many economic studies have shown the counterintuitive effects that strict agricultural regulation has had on land uses (Boulder, Colorado, U.S. – Correll, Lillydahl & Singell, 1978; Ontario, Canada – Vyn, 2012; Seoul, South Korea – Bengston & Youn, 2006). Such regulations often exacerbate urban sprawl through a price function that essentially constriicts the land supply. These authors have shown how this constriction artificially changes the price gradient (in $P(x) = P_0 e^{-c x}$, $P_0$ is increased as the supply of land is decreased) and inflates land values both inside and outside the agricultural zone. The unintended consequence of this constriction is that development moves to the outside of the strict agricultural zones, and so the size of the city actually increases faster (and results in lower overall density), rather than achieving the intended preservation of agricultural land and efficient management of space.

The mathematical models developed in these studies could be returned to the planning sphere to derive maps of policy impacts on land value. This contextual use of
economic information could better target conservation policies and avoid unintended consequences.

**Research Objectives**

Based on my literature review and the information and assessor data available for Utah County, there are three main research questions that I will seek to answer in this thesis:

1. What insight can traditional economic models provide about agricultural land loss specific to Utah County? Can these insights be extended into spatial analysis?
   i. Can land value be accurately interpolated and visualized as a continuous surface?
   ii. Given that there are many ways to visualize, measure, and perform experiments with land value data once it is interpolated in GIS, what are the strengths and weaknesses of specific approaches? Criteria for measuring strengths and weaknesses include:

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<th>Gives temporal context</th>
<th>Information can be directly applied to decision making</th>
<th>Reflects a sense of place</th>
<th>Reflects a sense of change / suggests future conditions</th>
<th>Can be quantitatively extended to simulate future conditions</th>
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</table>

2. What is the economic landscape of Utah County? Does understanding this landscape help plan agricultural conservation policies?
   i. Do the land values of specific the uses of agricultural and development follow separate and distinct patterns? Are the patterns distinct enough to
identify where agricultural land becomes more economically efficient than residential land? If so, where?

ii. Is the economic density of Provo increasing over time?

3. What are the benefits and drawbacks of using regional economic theories in a planning context?

To seek an answer to these questions, assessor data is leveraged to build six data outputs. These different perspectives on the data can be difficult to distinguish, but the differences are important. I use the following terminology throughout, and a detailed description of how these outputs are created can be found in the methodology.

- Land Value Maps
- Land Value Gradients
- Comparative Land Value Gradients
- Land Value Change Maps
- Change Area Land Value Maps
- Agricultural Change Area Land Value Map
DATA ACQUISITION

Data Used for this Study

The foundational data used in this study was provided by the Utah County Assessor’s office. The assessor data is updated on an annual basis and kept in tabular form and serves as the basis of property taxation (Utah County Government). Utah County Assessor data is publicly available by request. Data for the year 2000, 2005, 2010, and 2015 were used in this study.

Parcel data from the Utah Automated Geographical Reference Center (AGRC) was used to represent the assessor data spatially. County and municipality boundary data from the AGRC were used to establish boundary layers. ESRI base layers were also applied to build context and to create “boundary” data, which will be referenced in the pre-processing section.

Special Consideration of Data Type

This study uses county assessor data from Utah County as the cornerstone for analysis. This may raise suspicion among economists as the market value, as recorded through primary sales records, is the gold standard for real estate valuation studies. It is easy to deduce from a behavioral dynamic why sales data is preferred to appraisal values. Neither city administrators, who can charge more taxes on expensive properties, nor individual residents, who get to see the value of their assets increase every year, want to argue that the property is worth less than an appraisal. On the other hand, sales data shows the outcome of negotiation between two parties with differing interests and the result is, ostensibly, a lower and more rational price. However, this deduction is hard to
substantiate in literature. Instead, what is apparent is a smoothing in data that reflects the appraisers’ algorithms and considerations. The literature indicates that appraisal data shows as much as a third of the volatility of the regular market (Geltner, 1989), though a gap in negotiation skills between different sets of buyers and sellers may be equally important in this volatility. Unfortunately, the difference in these values can pose serious threats to the validity of pricing models that academic economists and businesspeople use to understand markets (Ma & Swinton, 2012). Because the market behaves differently from appraised outcomes, market data is preferred for most economic studies.

However, there are also limitations to market data. Ma and Swinton concisely present these drawbacks, especially concerning agricultural land: “first, farmland changes hands infrequently so sale price data can be very sparse. [...] Second, the reported prices of some land transactions may be biased, further reducing the number of valid observations. [...] Third, recording errors may occur even for arm’s length transactions, such as recording the address of the seller rather than that of the property being sold” (2012, p. 2). Because appraisal data maintained by assessors requires high administrative involvement and annual updating, the quality of the data for spatial analysis is less suspect.

Finally, a difference in land use was considered. In a typical economic study on real property pricing, researchers are interested in how variables influence market outcomes at a very individual level. The method applied in such cases is typically a hedonic pricing model. Because every property has individual attributes, a hedonic model seeks to quantify the impact of desirable characteristics on the total value of a commodity (Xiao, 2017). Examples of variables used to explain price in hedonic real estate models
include location in relationship to desirable areas (e.g., forests, farms, parks, etc.) as well
as property-specific attributes like parcel size, number of rooms, neighborhood
desirability, views, and building age, just to name a few (Xiao, 2017). Research shows
that appraisal data is poorly suited to integrate the landscape-level differences that
influence price (Ma & Swinton, 2012). Instead of performing a hedonic pricing model,
however, this study seeks to use readily available data to develop a regional perspective
in which the spatial dynamic is more important than the individual property attributes.
So, while acknowledging the limitations of the outcomes of this research project, I feel
that using this highly accessible data is sufficient for the research questions being
examined.
METHODOLOGY

Because I begin with tabular assessor data, then transform the data in many different ways, I have included a diagram showing the methodology used in the thesis (see Figure 2). There are two main parts of this thesis: the left column represents the steps in a more traditional regional economic analysis using tabular data analysis where distance explains value in a non-geographic context; the right column shows the geographically information system data processing, using the ideas from regional economics to explore the spatial context of the land value.

Land Value Map Series

Overview 1. Tabular data is used to create land value maps for four time periods.

Because the data received from the assessor was in a tabular format, the first step in creating usable information was joining the assessor data to a spatial layer in ArcGIS. The parcel data and the assessor data both contained a standard parcel number, legally recorded to identify the property, which was used to join the data. At each step in this process, the number of records (rows in the data) decreases. The decreases happen for different but important reasons; the reason for and number of reductions will be reported at each step.
Figure 2. Assessor data from four time periods (T1-T4) is leveraged into several different perspectives; each letter corresponds to a step in the methodology section and represents a new data series that offers a distinct view of the study area’s land value.
1. *Keep only private parcels.* Because the parcel map included federally and state-owned land that is not recorded through the assessor, the private parcels were selected with ArcGIS’s “select by attribute feature” and exported to their own file. The number of records was reduced from 210,273 to 208,058.

*Keep only parcels with ID numbers.* 2,097 parcels in the spatial data had no ID number, meaning there was no key to match them with an assessor record. The reason for all of the mistakes in the dataset are unknown, but a cursory glimpse at different parcels shows at least two possible categories of mistakes. First, some appear to be remnants of the digitization process when empty space between actual parcels, like roads and open space, were automatically converted into shapes in the record (see Figure 3, below left; records with missing parcel numbers shown in red). The second possibility is an issue of data loss from a processing error: a parcel that should have a record appears to have been missed in the digitization process (below right; record with missing parcel number shown in red). After these items were removed, the number of parcels was reduced from 208,058 to 205,151.

*Figure 3.* Example of types of data errors that were found removed from consideration.
2. *Remove duplicate identification numbers.* Because some properties in the spatial parcel data set were fragmented by roads or geographic barriers but contained the same ID number, one legal parcel could appear in the record twice. To eliminate double counting, a dissolve operation was performed which merged the duplicates into one recorded row but did not eliminate any of the spatial extent. The number of records was reduced from 205,151 to 196,470. At this point, the spatial data was fully prepared; the following steps are for the pre-processing of the tabular (excel file) data.

3. *Change tabular excel files into .dbf tables.* To make the tabular Excel data easier to process within the GIS system, it was imported into the GIS through a “table to table” function that converted it to the supported .dbf file and created indices to support functionality. No records were lost during this step.

4. *Join tabular files to the spatial data.* In this step, the ArcGIS join function created a link between identical ID numbers. The output keeps all information from both datasets, so each unique ID number has a compilation of information from both records presented in one row. These linked tables were exported into new files and saved for each time period of interest. At this step, any items from the spatial record that did not have a joined parcel were eliminated from the record. This number of dropped records increased with each time step away from the year the spatial parcel record was made (2016). For a record of these decreases, see Table 1.
Table 1. Number and percentage of parcels lost from joining the tabular to the spatial dataset.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Parcels Successfully Joined (out of 196,470)</th>
<th>Percentage of successful joins</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>93,057</td>
<td>47%</td>
</tr>
<tr>
<td>2005</td>
<td>123,160</td>
<td>63%</td>
</tr>
<tr>
<td>2010</td>
<td>153,467</td>
<td>78%</td>
</tr>
<tr>
<td>2015</td>
<td>165,968</td>
<td>84%</td>
</tr>
</tbody>
</table>

*Important note:* parcel numbers change whenever the property is divided so despite having different periods for tabular data, the spatial file stayed fixed with 2016 data. Parcels that had undergone subdivision during previous time periods were not successfully joined and were eliminated from the dataset. The most obvious problem with this is that the changed parcels are the ones most central to this project, while also the most likely to be lost. Yet, because the spatial data are so reliable and the price gradient is continuous in nature, there is a reasonable solution to this problem: estimating the data that was lost through inverse distance weighting (see step 8). However, less data leads to lower resolution (decreased detail in the data), and since the lost data was different for each time period a brief analysis of the loss is conducted below.

5. *Calculate price per acre for assessor data.* In order to compare parcel values, a price per acre was established from the data. However, at this point each data set had two measurements for size of the parcel—one measurement recorded by the assessor’s office and one recorded by the calculation of geographic size according
to the spatial GIS data. To avoid potential oversimplification or projection
mismeasurements by the GIS data and to ensure internal data consistency, the
assessor’s measurement of acres to determine price per acre for each parcel (value
in dollars divided by acres of land) was used.

6. Remove outliers. A close inspection of the mapped data showed several outliers—
points of data that were significantly different from the proximate geographic
context—some with known causes (the city of Sundance, a resort town with
inflated land values, contained mostly million-dollar per acre parcels) and some
with unknown causes (a million dollar per acre parcel of farmland among
regularly priced farmland below Utah Lake; possibly a mistake in record
keeping). These outliers were removed from the data set to allow focus on the
more ordinary municipalities and economic landscapes.

7. Interpolate lost data. To fill in the missing portions of data and transform it into a
continuous, rather than discrete, map, an interpolation function was performed.
This also allowed for the estimation of missing parcels that would have been lost
during the join step above. The inverse distance weighting function was used for
this purpose and converted the discrete (non-continuous) parcel data,
geographically bounded by arbitrary property lines, and transformed it into
continuous data evenly divided into same-sized cells. Cells that contained a point
with a known property value retained that value, while the rest of the cells were
interpolated (estimated) by calculating the value of neighboring points and
accounting for the relative distance of those points. The interpolation process used
in this study, inverse distance weighting (IDW), uses the following equation to calculate missing information (de Smith, Goodchild, & Longley, 2015, 6.6.1).

\[ z_j = k_j \sum_{i=1}^{n} \frac{1}{d_{ij}^\alpha} z_i \]

Where \( z_i \) is the known value, \( d \) is the distance measurement to the distance being estimated, \( z_j \); \( k_j \) is an adjustment factor to ensure weights equal 1; and \( \alpha \) is the power of the distance relationship (1 is neutral, 2 is squared, etc.). In this interpolation, \( \alpha \) was assigned the value of 2.

8. Adjust to constant dollars. In order to make the datasets more comparable, all of the values were adjusted to 2000 dollars using the standard CPI index. See appendix A for a summary of this adjustment.

This process provided the initial data sets that could be queried for data that would become the basis for the tests performed in this study.

**Land Value Gradient Series**

*Overview 2: Use land value maps to extract average values at 1-km intervals for each time period; build graphs from this data.*

This step creates the price-distance curve that is often cited in regional economic literature (Bertaud, 2015). In addition to creating 1-km intervals around the main central
business district (Provo), I identified all municipal centers and measure their distance curve in aggregate. See comparison graphic in Figure 4 for a visual representation.

Figure 4. These maps provide an example of the two methods of measuring central distance: on the left, Provo is the single central point; on the right, measurements are taken to the center of the nearest municipality.

1. Using ArcGIS, a 1-kilometer interval shape file was generated using the buffer tool around the mean center of the Provo municipality as the initial point.

2. 1-kilometer interval buffer were generated around the mean center of all economically distinct municipalities within Utah County (using their recorded municipal boundary to calculate the median center).

3. Zonal statistics by table were used to extract the statistics for each year through the kilometer intervals.

4. Distance curves (value gradient) were generated for each time period and for both measurement methods, observing the equation for each line and r square adjusted.
Land Value Slope Comparisons

Overview 3: Compare slope of each gradient to assess density change over time.

1. ArcGIS was used to create a random point map inside of Utah county, which was used to sample the economic raster maps for each time period. This sampling process is described in greater detail in Appendix B. This data was extracted along with the distance measurement to Provo’s CBD. A tabular dataset was created.

2. The log of the distance and value was calculated, and the function was graphed in R.

3. The slopes of the line of each time period were compared as a measurement for density change in the area.

Comparative Land Use Value Gradient

Overview 4: Mark samples with land-use type and graph the types separately.
1. Using the original assessor data, agricultural land was marked to distinguish it from other developed uses. The points were extracted from a new ArcGIS-created random sample, with land use information marked. See Figure 5 below for example of separated random sample.

![Figure 5](image)

*Figure 5. Example of random sample of lands marked with land use (developed is blue, agricultural is green).*

2. The output was graphed in R, with two distinguishing lines (green for agricultural, blue for residential) to examine for evidence of a threshold where agricultural land becomes more economically viable than developed use.
Land Value Change Map Series

Overview 5: Using map algebra in ArcGIS, subtract maps from one time period from the subsequent time period to examine change in land value over time.

1. The difference was taken from one time period to the next in each series of data (T2-T1, T3-T2, and T4-T3). These were labeled Land Value Change data sets, 1-3.

2. The results were displayed as divergent maps (near zero values are represented in yellow, positive values in green, and negative values in red).

Change-Area Value Map Series

Overview 6: Extract land value data for areas where change in land use has occurred. Output map shows the land value in changed areas.

1. All development values were extracted from the 2006–2011 National Land Cover Database change dataset. This showed areas that have had any change, with two main possible categories: land use changing from some other undeveloped use to developed use, or a developed land use increasing or decreasing in density level.
(The NLCD uses the following categories of development: developed open space, low intensity development, medium intensity development, and high intensity development; the recategorization process is described in greater detail in Appendix C.) This data layer was referred to as the Land Use Change Area map.

2. The Land Use Change Area data were used to extract the land values from the Land Value Map for 2010.

3. The Land Use Change Area data were used to extract the value from the change in land value data for the 2005–2010 period.

4. The descriptive statistics were extracted from these two datasets and compared.

5. The 95% confidence interval for the 2010 land value map was mapped by categorizing the land values that fell within 1 and 2 standard deviations, as calculated from the descriptive statistics in the prior step.

6. Using the same statistical information from 2010, the 95% confidence interval for the 2015 land values were mapped.

**Agricultural Change-Area Value Map Series**

Overview 7: Performs the same experiment tailored to agricultural land use changes only.

1. To tailor the results to the problem of interest, the NLCD 2006–2011 change data was pared down to only the areas where agricultural land had been replaced by
some other use. These areas were overlaid with the Land Value map series from the first step of the methodology. The resulting data included the land value of areas that were changed from agricultural to developed use.

2. The descriptive statistics were again measured, and the confidence interval mapped for the 2010 time period and extended to the 2015 time period.
RESULTS

Land Value Map Series Results

The results of the land value map series are as expected: the highest land values (price per acre) occur at municipal centers and along U.S. Interstate 15, decreasing in value toward the municipal boundaries and nearly leveling off in rural areas. The pattern holds true for every time period. Figures 6a-6d are presented on the subsequent pages.
Figure 6a. Land value map built from year 2000 assessor data; blue areas are low values and purple areas are the highest values. The geographic distribution follows the expected pattern, with rural areas having low, nearly flat values and the Provo area having the peak values.
Figure 6b. Land value map built from 2005 assessor data; this second time period follows the same expected pattern as the first.
Figure 6c. Land value map built from 2010 assessor data; the expected pattern is seen, with increasing land value becoming apparent (purple) in the agricultural land area below Utah Lake.
When compared with the map of city centers in the background section on page 24, the visualization of this data indeed shows the expected structural nature of the economic landscape concept. The highest land values are located in the municipals centers and the values decrease to the edges of the urban system. Perhaps the most

Figure 6d. Land value map built from 2015 assessor data; the pattern holds, with continuing value increases seen in the Utah Lake agricultural areas.
important attribute of this data is its potential: it can be mined for geographic relationships and used to visualize the effect of land value of community development. This data set is further explored in the next steps.

**Land Use Value Gradient Results**

Integrating these ideas into planning documents needs to be done at the correct scale to ensure the information remains relevant. Because there are many municipalities within the Utah county area, secondary to the main Provo CBD, it is important to know if there are major differences between measuring the distance to a single center versus measuring the distance to the nearest center. The results of the two approaches to extracting distance data, from Provo vs. localized municipalities, are shown in Figure 7. The left shows Provo as the central measurement, and the right shows the measurement to nearest municipality from the random sample locations. Each time period was considered.
<table>
<thead>
<tr>
<th>Provo-centric Average for 1-Km Intervals</th>
<th>Multi-centric Average for 1-Km Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 2000</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
</tr>
<tr>
<td>$y = 469127e^{-0.124x}$</td>
<td>$y = 306931e^{0.288x}$</td>
</tr>
<tr>
<td>$R^2 = 0.8897$</td>
<td>$R^2 = 0.9563$</td>
</tr>
<tr>
<td><strong>Year 2005</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>$y = 444936e^{-0.113x}$</td>
<td>$y = 219849e^{0.266x}$</td>
</tr>
<tr>
<td>$R^2 = 0.8119$</td>
<td>$R^2 = 0.9741$</td>
</tr>
<tr>
<td><strong>Year 2010</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td>$y = 543613e^{-0.123x}$</td>
<td>$y = 342852e^{0.279x}$</td>
</tr>
<tr>
<td>$R^2 = 0.8272$</td>
<td>$R^2 = 0.973$</td>
</tr>
<tr>
<td><strong>Year 2015</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
</tr>
<tr>
<td>$y = 543613e^{-0.123x}$</td>
<td>$y = 342852e^{0.279x}$</td>
</tr>
<tr>
<td>$R^2 = 0.8272$</td>
<td>$R^2 = 0.973$</td>
</tr>
</tbody>
</table>
Figure 7. As expected, Utah County follows the typical land value gradients: peak value at the center decreases at a stable exponential rate. Here, two different distance measurements are compared. On the left, Provo’s CBD is the main measurement and shows the highest central value and most dramatic drop off. On the right, the distance is measured from the sample to the nearest municipal center, and the curve achieves a much higher R square adjusted but loses definition and the high center value.

The first noticeable difference is that the right-hand column (the multi-centric approach) smooths much of the variability and therefore reaches a much higher r square adjusted. Every jump in the data on the left correlates with the distance from another municipal center in the proximate area. Another potential reason for the dramatic peaks and valleys of the Provo-centric curve could be the physical geography. Measuring the distance to near towns irons out barriers such as mountain ranges, water bodies, and roadway limitations. However, this smoothing comes at the expense of aggregating Provo’s very high CBD value with the significantly smaller values of the neighboring town’s CBDs. The highest point of value in this system, represented at the Provo city center (about $424,600 per acre in 2015), is cut nearly by half when averaged against 13 smaller towns (falling to $227,500 per acre in aggregate).

In summary, the benefit of a multi-centric view is comparing apples to apples: city centers are compared to like centers and rural areas are compared with other rural areas. The benefit of examining a single center is that there is no loss in the definition of
central value; the center point retains its full meaning and impact and the definition in the data can explain much of the geographic variation in an area. Despite the trade-offs, both perspectives follow the expected pattern discussed in the introduction.

The traditional means of running the test include aggregating the data at 1-kilometer intervals to the end of the urban extent. In economic projects that rely on recording sales data over time intervals, there can be geographic holes and it makes sense to average the data in kilometer intervals to account for these absences. However, since the assessor data is geographically complete, I surmised that using random samples and dropping the 1-kilometer aggregation could better represent the dataset’s complexity. In Figure 8, the time periods show the Provo-centric view filtered through a log-log transform (this flattens the curve of the original relationship and gives a more direct perspective of the relationships in the data). The slope of the line represents the change in dollar per acre value from the center of Provo outward, and can be thought of as economic density.

![Figure 8](image)

*Figure 8.* Graphic comparisons of the land value gradient of Utah County at each time period.
At each timestep, the slope becomes slightly more negative (decreases), suggesting that denser economic development is occurring over time; i.e., the center values are increasing faster than the values at the edge (Table 2).

Table 2. Comparison of the slope measurement from the graphic representations for each time period.

<table>
<thead>
<tr>
<th>Slope for each time period</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>–0.00009122</td>
<td>–0.00009539</td>
<td>–0.00009841</td>
<td>–0.0001008</td>
</tr>
</tbody>
</table>

**Comparative Land Use Gradient Results**

The bid-rent curve results from the previous section show expected results, but the results lack application value to planners. Separating the land uses into agricultural and developed samples, then running these comparisons again has potential to shed light on the problem of interest. Two outcomes could be expected (for more detail, refer to the introduction of this thesis on page 1). The Alonso (1960) theory of land use would suggest that the agricultural value will at some point exceed the residential use value; the Evans (2008) theory would suggest that housing prices will be the main driver of agricultural land prices.

The results (see Figure 9) of graphing the separated land uses with a multi-centric distance measurement showed no crossover between the two different land type values, only a slightly different slope between the two below shows the log-log transform of value against distance):
Figure 9. In this version, a log-log transformation flattens the curve, but shows the same relationship of value decreasing with distance. The result was not as expected: a crossover of the lines would suggest that agricultural land (green) at that distance and beyond was more economically viable than residential use (blue). No crossover is seen.

In order to examine Alonso’s theory, the same analysis was undertaken with the Provo-centric measurements, and the results showed a similar pattern (Figure 10, below).

Figure 10. Land value curve from centralized measurement data where green represents agricultural land and blue represents developed land, represented with a log-log value transformation applied. The expected crossover in value is still not observed.
To give Alonso’s theory a rigorous defense, I decided to narrow the scale and reexamine the problem in one of the critical areas for agricultural land identified by Envision Utah. The bounding box in Figure 11 below shows the narrowed range of values I examined:

![Figure 11](image)

*Figure 11.*
Geographic boundary of random sample to test, narrowed to area of interest.

Yet again, as seen in Figure 12, the results show no sign of crossing. The decrease in density at greater distances from the city center is apparent, but the residential land value is not seen declining faster than the value of farmland.
Figure 12. Results of gradient for narrowed area of interest where green represents agricultural land values and blue represents developed land values. The expected crossover in value is still not seen.

Evans theory seems to best hold, as the value of farmland almost perfectly tracks the value of residential land in every iteration of the model.

Land Value Change Map Series Results

This series of analyses uses the mathematical difference in land value over five-year time periods to contextualize land value change over time (the map is made up of a series of cells, and each cell is differenced to calculate the change). The scales on each map show the increase (green), decrease (red), or limited change (yellow). Interestingly, three distinct economic regions begin to appear.

These are labeled in Figure 13 and referred to further on as: (1) Salt Lake City Growth Area; (2) Provo Growth Area, and (3) Western Rural Growth Area.
Figure 13. Distinct regional growth areas include (1) Salt Lake City Growth Area; (2) Provo Growth Area, and (3) Western Rural Growth Area.

The growth in the northernmost portion of the county shows a distinct region that grows and contracts in tandem with the influence of Salt Lake City (area 1 in the map key above). The remainder of the county seems to follow a pattern that is distinctly different, which I refer to as the Provo growth area (area 2 in the map key above). At times, the western portion of the county follows a distinct pattern of growth (area 3 in the key map above). This pattern appears in each interval but is especially distinct in the 2005 to 2010 map. See Figures 14-16 below. In the time period between 2000 and 2005 (Figure 14), a notable increase in value in the west side of the county is also observed.
Figure 14. Absolute change in land value (in ln of dollars) between 2000 and 2005; the graduated color scheme uses red to show where values decreased, yellow to show no significant change, and green to show value increase. Three regional patterns can be observed.

Growth from 2000 to 2005 occurs at the urban periphery, especially along areas near access to I15 (the main road connection between Provo and the rest of the state). Figure 14 shows the incredible growth that occurred during this time, which is likely related to the beginning of the housing bubble. The burst, consequently, features prominently in the subsequent map.

Between 2005 and 2010 (map featured in Figure 15, below) the two main economic regions show stark differences in their response to the 2008 housing crisis and
the following recession. Areas ideal for commercial growth, like freeway offramps and land with potential for retail development, saw increases across the county. Agricultural lands seem to experience speculation, with areas of increased value showing up in unexpected areas of the rural, southern portion of the county.

While the land values sank for the map overall, the rapid decline in home values seemed to most drastically affect the Salt Lake City growth area, while the Provo growth area saw limited declines, included many areas of no change at all, and even saw pockets of expansive growth (Figure 15 below).

*Figure 15. Absolute change in land value between 2005 and 2010; red shows a significant land value decrease, yellow is neutral, and green is a significant value increase. Provo’s moderate declines are offset by growth in its suburban regions; the northern border of the county shows significant land value declines likely associated with decline in the Salt Lake City housing market.*
Finally, the 2010 to 2015 time period shows mild decline in some of the formerly explosive commercial growth areas, suggesting a market correction on speculation after the sub-prime mortgage crisis. Housing values have stabilized and growth at urban peripheries begins to correct. The Salt Lake City growth area shows volatility—a small geographic area contains a broad scale of growth and decline. Explaining the intense growth to the west of Utah Lake is somewhat trickier—but could potentially have to do with transportation improvements that increased access from I-15 and improved roads throughout the area between 2010 and 2015 (UDOT) (Figure 16).

Figure 16. Absolute change in land value between 2010 and 2015; red shows a significant value decrease, yellow is neutral, and green is a significant value increase.
In general, these changes are illuminating in that they contextualize the macro-level economic effects of national trends on a regional economy. With some work, a model could be created that could use national projections to extend these patterns into the future.

The statistical properties of the maps are also interesting. The following information in Table 3 reports the observed statistics for each time period.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.122932891105877</td>
<td>0.232706423003174</td>
<td>0.142652240685690</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>-5.8905110359191</td>
<td>-6.49922657012930</td>
<td>-5.07869434356690</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>5.81899833679199</td>
<td>5.15367794036865</td>
<td>5.13780212402344</td>
</tr>
</tbody>
</table>

Interestingly, despite the housing market declines in 2005–2010, the average increase in land value is highest for this time period. This is likely due to increases seen in large swaths of agricultural land, as well as the value added by speculation on commercial properties. This time period also has the most negative change of any time period by a wide margin, hinting at the volatility of the market during this period.

**Change Area Value Map Series**

To see what land values appeared in areas where change occurred, I used the National Land Cover Database’s land use change layers to clip the land value maps and the land value change maps shown in the previous two sections. The mapped output (Figures 17a and 17b) shows that land use change is mostly clustered around urban areas,
as one would expect. The map represents the land value on a continuous scale (blue is low, red is high) in areas that had experienced land use change.

- Figure 17a. Extracted area from 2010 Land Value Maps. Using the 2006 National Landcover Database, I extracted the land value map (above) and the change in land value map (below), tailoring the larger datasets down to areas where any form of development had occurred.
Figure 18b. Close-up view of Provo/Orem area, showing the scale of land value in areas that have experienced change.

Figures 18a and 18b show change in land value for areas where any change in land use had occurred between 2005 and 2010.
Figure 19a. Change in land value limited to areas where land use change has occurred.
Figure 18b. Close-up of change in values for areas where land use change has occurred.

There is no obvious spatial pattern in the previous two maps, except to note that the change occurs near already-developed areas. However, looking at the statistics associated with these maps showed some interesting shifts in the data. The following figure (Figure 19) shows the distribution of data before and after it was extracted to change areas, with the overall distribution for the full data set presented on the left, and the distribution of the extracted dataset presented on the right. Note the shift from a random or exponential distribution to a nearly normal one. Figure 20 shows the same shift for the change data.
Figure 19. The frequency distribution, or number of observations (X) of each land value (Y), for all land (left) versus frequency distributions of values limited to change in land use or intensity between 2006 and 2011 (right). The extracted data shows a shift from noise to a more normal pattern of distribution.

Figure 20. Frequency distribution, or number of observations (X) of each land value (Y), of all land value changes (left) versus frequency distribution of land value change limited to areas of change in land use or intensity between 2006 and 2011.
The contrast is stark: from a lack of meaningful spatial pattern in the datasets of land value for the entire study area, the extracted area shows that the land value in change areas follows a normally distributed pattern. A potential explanation is that when land use changes from undeveloped to developed or from developed to more dense development, it is because the land value will be within a range that would make it profitable to make such changes. The average value shows the most common price at which land changes use, but some land that is more expensive will also change (people will buy even when the price is high) and some land that is less expensive will also change (people will sell even though the price is low).

The geographical potential for change can be observed by mapping the 95% confidence interval, highlighting on the map all values that fall within two standard deviations of the mean. By mapping the values that fall within this range, we can show the areas where change is most likely to occur. The values at the break points for one standard deviation were 11.43 to 13.10 (log of the dollar value of land), and two standard deviations ranged from 10.59 to 13.93 (log of dollar value of land). All cells from the full 2010 dataset that contained a value within that range can be seen in Figure 21. The pink areas are where actual change occurred. The most important observation is that the sheer amount of land covered by the confidence interval map means the output simply isn’t focused enough to show where land use is likely to change.
*Figure 21.* Map of the price range in which change occurred using standard deviations to cover the 95% confidence interval; the red is actual change, while the black and grey show the areas where land values fall within the same range.

The NLCD data does not yet extend to the 2016 time period, but using the data from 2006-2011 has given a hint about the range of land values within which change is likely to occur. There is a high potential that this value is steady over time. If the pattern holds true, the following map overlaying the current land value distribution over the next time period data could potentially predict the changes that will be observed in the forthcoming NLCD dataset (as a 95% confidence interval) (Figure 22).
Figure 22. Map of the value range at which change occurred in 2010 superimposed onto the 2015 data. This is essentially a predictive model: if current purchasing patterns hold true, the next NLCD change data layers will be 95% contained within the mapped areas.

While interesting, the limitation is clear: this is a huge spread of data, and it occurs in the places that one would already expect development to occur. The predictive application of this map is extremely limited. However, the next section provides an approach to further narrowing change by land use type, which could reveal the drivers behind the conversion of agricultural land, an application that has value toward achieving Envision Utah’s goals of agricultural land conservation in Utah County.
Agricultural Change-Area Land Value Maps

To achieve this, the NLCD change map was further narrowed to show only the areas that had been agricultural in the previous time period but were now listed as development of any intensity. Again, as observed in Figure 23, the data shows a normally distributed pattern when extracted in this way.

Figure 23. Frequency distribution of price data for 2010 limited to areas where land use changed from agricultural to developed show the same normal pattern.

Figure 24 shows the resulting 95% confidence interval map for the 2010 land value data when limited to agricultural land (no other land use type considered).
Figure 24. Map of the price range in which change occurs on lands converted from agriculture to residential using standard deviations, limited to agricultural use. Actual change is represented in red, while other land that falls within the same price range is represented in black and grey. The limited use reveals a much more insightful pattern of growth.
Finally, the 2015 data, when limited to agriculture land, predicts the following change areas (Figure 25). Again, this map cannot be validated with the change data available now but could potentially be validated when the 2016 national landcover data is released or proofed by on-the-ground observations or county record comparisons.

*Figure 25. Map of the price range in which change occurred on lands converted from agriculture to developed in 2010, applied to 2015.*

With this narrowed range of values, this map could serve as a basis for investigating land use change management policies. If this layer does indeed reveal the most economically vulnerable agricultural land, planners could use this data to target specific areas and potentially manage the random spread of communities into inefficient, disconnected, and randomly placed suburbs and help to target conservation policies.
Further context is gleaned when this map is overlaid with all agricultural land and then zoomed to the specific agricultural areas being targeted by Envision Utah policies. Figure 26 shows an area of concern near Payson, Utah.

*Figure 26. Close-up of agricultural area with values from 2015 highlighted to show where growth is likely to happen.*

The first and second standard deviations predicting farmland conversion occur mainly where near the borders of existing towns. Land within the primarily agricultural areas, away from the towns, contain few of the values associated with change but some pockets of elevated values exist. These elevated values could become nodes for future,
undesirable development. The potential of this map to target policies that manage growth on agricultural land is high.
DISCUSSION

This discussion is divided into three main sections that answer the research questions: (A) What insight can traditional economic models provide about agricultural land loss specific to Utah County? Can these insights be extended into spatial analysis? (B) What is the economic landscape of Utah County? Does understanding this landscape help plan agricultural conservation policies? (C) What policy and planning recommendations can be made from this assessment?

Understanding the Use of Each Perspective

What insight can traditional economic models provide about agricultural land loss specific to Utah County? Can these insights be extended into spatial analysis?

Land Value Maps. Figures 4a–4d provide a spatial context highlighting the structural economic background of an area. Because they are spatially explicit, they show where prices are high or low relative to the average and can show where policy changes may guide individuals’ decision making toward a long-term planning goal. Since it is in a raster format, it can be used in models to project future values based on economic and growth projections. When the land value maps are compared with each other or overlaid on land use and policy data, an understanding of temporal context can be gleaned, though not quantified; for example, by examining Utah County’s data for 2000, 2005, 2010, and 2015 and recalling the ups and downs in the housing market at this time, observations about the impact of the decline can be seen even though there’s not a good way of quantifying these changes in this data format. All of these attributes suggest that interpolating value data into a continuous surface is a suitable management technique for
this type of information. The main limitation of this dataset is that it does not provide a
direct measurement of change.

**Land Value Gradients.** Perhaps the most foundational form of data for
economists, the economic land value gradients are very limited in application to land-use
planning. Some macro-level insights can be gleaned: major economic centers are
reflected, an overall pattern of development is seen, and a theoretical pattern of the city’s
economic ratios (the ability of people to pay to live in and move through the space)
become apparent. It is somewhat predictive in that a property at a given distance can be
estimated within a certain range. Its main limitations are that it is not geographically
explicit and therefore doesn’t provide a spatial decision-making context and that it does
not provide information about change. This data representation is more useful as a
conceptualization tool than an applied, land use management tool.

To extend the economic gradient perspective, the data for various intervals can be
compared over time. The main limitation of this representation is that the change can’t be
directly measured, only compared for its potential meaning (in other words, the change in
slope of the gradient does not have a statistical measure and instead has to be interpreted
based on context). Yet, this informal measure can show the nature of change and answer
the following questions: is a place becoming more or less economically compact? Is
overall price increasing or decreasing? How do core values affect overall development?
These questions can then be paired with contextual information to examine the impact of
change.

**Comparative Land Value Gradient.** Separating the land value data into land use
type and then measuring and comparing the economic gradients is also a useful technique
for understanding a place. While the outcome for this experiment didn’t show the expected cross over between the graphed agricultural and residential values, an interesting aspect that emerged did help understand how land values function. The average values of each land use stayed stable (parallel to each other) over the measured distance in this experiment, rather than crossing where agricultural use becomes more profitable. While the Alonso theory (the idea that the value for one use that of another at a certain distance) is more applicable to land use planning, the results show that the Evans theory (the idea that the main driver of land value is demand for housing) is far more likely. However, it is also possible that the factors that traditionally limit the extent of a city, the ratio of income to transportation expense, could simply not apply the same way when population growth and individual income are high and transportation expenses are low. Further confounding geographic factors could include the bottleneck shape of Utah County, limited by a lake on one side and a mountain range on the other and with freeway access providing rapid transportation access up and down the length of the county; and the lack of a farmland buffer on the north side of the county as Salt Lake City’s suburbs merge almost seamlessly with Provo’s, which could elevate the aggregate value.

Despite the unexpected results, separating the data into categories still provides some useful insight: predicting the price of land at a given distance can be done with more accuracy if the land is categorized and calibrated to the lands’ specific use.

**Land Value Change Maps.** The land value layers can be differenced to create land value change maps that show where land values have increased or decreased. Because the data provide a geographic context, a deep understanding of collective
decisions, the impact of proximate features (roads, infrastructure, etc.), and the influence of policy areas can be examined.

**Change Area Land Value Maps Results.** There are clearly many lenses through which to view economic change, but the Change Area Land Value maps seem to give the most definitive picture of the price brackets within which change happens. The results show that a normally distributed pattern emerges as people buy and sell land for developed uses. Ostensibly, this pattern shows the interactions of individuals at a large scale, the map showing where property in this community is economically viable for conversion to urban or densified land use. The range of land values emerges as a measure of interactions between community and global factors that inform peoples’ willingness to buy and sell property for development within this community. Unfortunately, the amount of land that falls into the “change” range has a large geographical distribution. While it does have a predictive quality, the sheer magnitude of the land that falls within the predictive range is unwieldy.

**Agricultural Change Area Value Maps.** Tailoring the considered land to agriculturally-specific land use change holds promise in narrowing the focus and combatting the unwieldiness of the previous model, leading to better predictability. The same appearance of a normal distribution becomes apparent within the changed land, but with far less geographical extent to try to manage. Vulnerable agricultural lands really pop out on these maps, offering a range of possibilities for narrowed policy applications that could preserve the agricultural use in these areas. For example, this data could show where to limit infrastructure development like road access, target stricter zoning policies
for highly vulnerable areas, and loosen zoning in areas that can take development pressure off vulnerable areas.

Matrix Comparing Data Usability. Each item here provided some context, but certain outcomes were better than others and offered deeper insight. The following matrix (Table 4) compares the data perspectives based on the criteria noted in the objectives section of the thesis.

What is the Economic Landscape of Utah County?

Utah County Study Area Follows Standard Models. From this discussion of data strengths and weaknesses of the data, we can build a holistic picture of Utah County’s economic landscape. The first observation is that Utah County does follow the expected pattern: The land in and around the main “economic engine,” Provo, has the highest economic value which decreases at a somewhat stable rate away from this central point; this means that standard economic models can be applied in a meaningful way.

Macro-level Influences Appear in Change Maps. Second, the land value change maps show how macro-level variables like national economic conditions affected Utah County in various time intervals. Change between 2005 and 2010 show the influence of the 2008 great recession, and a clear decrease in most housing areas is seen. Residential land values then recover in the next time interval.

Two Distinct Economic Regions Can Be Seen. Next, the influence of Utah’s primary economic engine, Salt Lake City, also shows a strong influence. The northernmost properties in the county grow and contract differently than those at the southernmost area and the areas immediately surrounding Provo. Housing prices in the
Table 4. Matrix of Data Outputs and Usability Criteria.

<table>
<thead>
<tr>
<th>Data Item</th>
<th>Gives spatial context</th>
<th>Gives temporal context</th>
<th>Information can be directly applied to decision making</th>
<th>Reflects a sense of place</th>
<th>Reflects a sense of change / suggests future conditions</th>
<th>Can be quantitatively extended to future conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Value Maps</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Land Value Change Maps</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Land Value Gradients</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative Land Value Gradients</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change Area Land Value Maps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Change Area Land Value Map</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

south are lower but remain more stable than those in the north. This context separates the county into two main economic regions that function significantly differently. Policy decisions should keep this distinction in perspective.

**Land Value Changes Differently by Region and Time Period.** Fourth, the *land value change maps* also show that land purchases shifted during the economic downturn,
moving from a housing development focus to a speculative commercial development focus. The distinct economic regions—those influenced by Salt Lake City and those influenced more by Provo—showed different changes with the Provo housing areas declining less dramatically than the Salt Lake housing areas. The downturn also brought an increase in value for agricultural land and areas that have a high potential for commercial development (especially at freeway offramps and other major intersections). A regression analysis on this subject could quantify this change.

**Land Value Density Is Increasing over Time.** Fourth, while the economic gradient snapshots don’t provide a meaningful perspective on their own, their extension into a comparative analysis shows that the land value density of growth is increasing at each time interval. This suggests that overall density is likely increasing as well. Yet, it does not suggest that agricultural land is being spared; this perspective simply does not provide enough information to know whether or not agricultural land is under pressure from development. The relationship to agricultural land remains unclear.

**Narrow Range of Values Identifies At-Risk Agricultural Areas.** The land use change maps are helpful in understanding the relationship between land value density and agricultural land. They identify where change has occurred, and in these interim zones, a range of economic values can be identified. Whether or not these values are significant and predictive requires further testing. Yet, as land use change monitors develop a longer range of data (right now only a decade’s worth of information is available), the methods tested here can be validated and examined for potential integration into planning models.
Determining Policies that May Alleviate Development Pressure in At-Risk Areas. While future research on validation of these land use change extractions will help justify incorporation of these ideas into planning models, the data can still produce useful insight into policy development as it is. If planners want to prioritize the conservation of produce useful insight into policy development as it is. If planners want to prioritize the conservation of certain agricultural areas over others, the map could be used as a certain vulnerability assessment to identify where protection policies could best be applied.

Further, and to return to the literature basis, agricultural land converts to urban use when the value of its agricultural products drops below the market value for residential/urban development. If policy makers wanted to devise a tax structure incentivizing urban-core growth and incentivizing agricultural peripheral uses, the numbers extracted from these models can provide the basis for understanding how big those incentives would need to be to work. Other large-scale measures could include applying stricter agricultural zoning. However, to avoid the unintended consequences that can accompany a strict “greenbelt” policy, these zones could be applied with attention to context and the land value changes that would occur. The economic gradient can also allow policies to be viewed as fluid rather than fixed: since the outward boundaries of a city will inevitably push more outward, the gradients can be measured over time and used to adjust tax policy in an iterative manner.
Summary of the Use of Regional Economic Information in a Planning Context

What are the benefits and drawbacks of using regional economic theories in a planning context?

Regional Economics Ideas Have Planning Applications. There are some limitations when using estimated values rather than sale data, I feel that the information available from assessor data is sufficient to equip land managers and planners with tools to gain an understanding of their cities, as economic places, and grant them the ability to integrate these ideas into land use planning. At the very least, this data is capable of building beautiful maps, highlight a novel perspective of community space.

Further, the economic patterns that underlie urban development are geographically explicit, specific to a region, and show the aggregate outcomes of the individual interactions that happen in communities. The data can be used to answer research questions that connect land value to property location, to examine change over time, and to understand how individuals’ choices (as viewed through property values) may conflict with (and potentially solve) collective goals.

Finally, while it is difficult to say exactly how much peoples’ personal moral values are worth to them, looking at a map of land values offers a glimpse into the way individuals behave. Economic maps contain some measure of peoples’ willingness to pay for the landscapes they most prize, or the relationships they most desire to maintain. This enhances an intangible understanding of the elusive sense of place, which planners are often searching to include and represent in plans.
Regional Economic Ideas Have Planning Limitations. There are both practical and philosophical limitations apparent in this project. First of these practical limitations is that using these theoretical ideas in a very applied way is relatively new and hasn’t been fully vetted by planners or academics. Second, economics changes as peoples’ choices change, and this constant shift is hard to account for within static planning documents. Finally, while some of these models are simple, understanding what they mean isn’t always easy and it may lead to confusion within stakeholder meetings.

As for the philosophical limitations, the on-the-ground planners I have talked to about this project have been skeptical about the ability of economics to inform the planning field. I understand this hesitancy: all fields come with bias and economists tend to define free markets as the ideal tool for defining the worth of all mankind’s endeavors. The view of perfect markets is off-putting to those who have seen how community goals can crumble under developers’ profit-based designs. A growing economic philosophy identifies weaknesses in rational market theories, showing they are not necessarily the best measure of collective ideals and that price doesn’t always reflect worth. In this view, economics is simply an outcome of the short scale at which humans tend to consider the world from a rational point of view.

It is by taking this behavioral view that planners can strive toward collective goals and integrate the useful attributes of economic theories. The study of human choice and how that choice changes under different conditions can lead planners to the best conditions for their goals. The ideas I’ve shown here show the potential of economics to grant plenty of insight, but that insight doesn’t immediately translate into achieving collective goals. So far, scientific literature that ties end goals to incentive structures has

...
been limited to natural resource scientists interested in ecosystem services, but the idea is sound, showing the potential for economic concepts to illuminate how things are now in order to move toward a more desirable future. There is a bridge yet to be built between what is available in academic circles and how that can be applied toward some meaningful goal in the real world, but a planner’s role of building a better future makes this intersection of interests a path worth exploring.

**Potential for Future Research.** The dataset and concepts developed for this project contain yet more possibilities for research. First and most applied, the farmland vulnerability map could be the centerpiece of a study examining the effect of Envision Utah’s policy toolbox in those specific areas, or otherwise examined for its potential in farmland conservation efforts.

Further and more theoretical projects could focus on the GIS models’ potential to output datasets that can serve as the basis for regression analyses that quantify the influence of the various change agents that have only been examined informally here. Variables like population growth and other demographic data, proximities to geographic features of importance, macro-level economic changes external to the system, and the cost of travel and social maintenance with the system could be tested in regression analysis. It would also be simple to take this data, identify policy areas that target specific goals over the past decade, and then run regression analysis to test the hypothesis that these policies alter the underlying economics of a region. For example, the land values in and around the greenbelt agricultural zone areas could be measured before and after the application, then regression analysis could be applied to show if there was an effect on
value, and whether that effect was positive or negative. The regression models could be extended to model potential policies and measure their impact on end-goals.

Finally, because these economic data suggest an underlying structural landscape, modeling the interactions on the land in an agent-based interface calibrated to demographics and other pertinent variables of the area could give a better perspective of change. While lacking in spatial explicitness, the predictive potential about the effects of growth on land use and city space could be far higher than with traditional, non-behaviorally oriented economic models.
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UDOT. Projects Map. Retrieved from:


APPENDICES
APPENDIX A
SUMMARY OF CONVERSION TO CONSTANT DOLLARS

X \textsubscript{t,2,3,4} adjusted to T\textsubscript{1}$ = X\textsubscript{t,2,3,4} * \text{CPI}_t/\text{CPI}_{t,2,3,4}

Change in Mean Value by Time Period

<table>
<thead>
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<th>Year</th>
<th>Unadjusted</th>
<th>Adjusted</th>
<th>CPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 = 2000</td>
<td>31080.418863867</td>
<td>-</td>
<td>172.2</td>
</tr>
<tr>
<td>T2 = 2005</td>
<td>41380.659643412</td>
<td>36486.17274716382</td>
<td>195.3</td>
</tr>
<tr>
<td>T3 = 2010</td>
<td>55866.055482093</td>
<td>44117.7254511154</td>
<td>218.056</td>
</tr>
<tr>
<td>T4 = 2015</td>
<td>67603.972881971</td>
<td>49116.32755536631</td>
<td>237.017</td>
</tr>
</tbody>
</table>

APPENDIX B

SUMMARY OF RANDOM SAMPLE SELECTION

Population (number of private/nonexcluded parcels in Utah County: 165,968

Margin of error: 5% (lowest possible means least possible spatial autocorrelation)

Confidence level: 99%

Sample: 661
APPENDIX C

NLCD CATEGORIZATION TABLE

Left and center columns show original values from the National Landcover Database; right column shows if the dataset was recategorized to development, agriculture, or null (dropped from the dataset) for the purposes of this thesis.

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Recategorized to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Open Water - All areas of open water, generally with less than 25% cover or vegetation or soil</td>
<td>Null</td>
</tr>
<tr>
<td>12</td>
<td>Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.</td>
<td>Null</td>
</tr>
<tr>
<td>21</td>
<td>Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.</td>
<td>Development</td>
</tr>
<tr>
<td>22</td>
<td>Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.</td>
<td>Development</td>
</tr>
<tr>
<td>23</td>
<td>Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.</td>
<td>Development</td>
</tr>
<tr>
<td>24</td>
<td>Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.</td>
<td>Development</td>
</tr>
<tr>
<td>31</td>
<td>Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.</td>
<td>Null</td>
</tr>
<tr>
<td>Code</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>41</td>
<td>Deciduous Forest</td>
<td>Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.</td>
</tr>
<tr>
<td>42</td>
<td>Evergreen Forest</td>
<td>Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.</td>
</tr>
<tr>
<td>43</td>
<td>Mixed Forest</td>
<td>Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.</td>
</tr>
<tr>
<td>51</td>
<td>Dwarf Scrub</td>
<td>Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.</td>
</tr>
<tr>
<td>52</td>
<td>Shrub/Scrub</td>
<td>Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.</td>
</tr>
<tr>
<td>71</td>
<td>Grassland/Herbaceous</td>
<td>Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.</td>
</tr>
<tr>
<td>72</td>
<td>Sedge/Herbaceous</td>
<td>Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.</td>
</tr>
<tr>
<td>73</td>
<td>Lichens</td>
<td>Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.</td>
</tr>
<tr>
<td>74</td>
<td>Moss</td>
<td>Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.</td>
</tr>
<tr>
<td>81</td>
<td>Pasture/Hay</td>
<td>Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Class</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>82</td>
<td>Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.</td>
<td>Agriculture</td>
</tr>
<tr>
<td>90</td>
<td>Woody Wetlands - Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.</td>
<td>Null</td>
</tr>
<tr>
<td>95</td>
<td>Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.</td>
<td>Null</td>
</tr>
</tbody>
</table>