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Open Space Changes: A Formal Analysis in Cache Valley, Utah

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OPEN SPACE CHANGES: A FORMAL ANALYSIS IN CACHE VALLEY, UTAH

by

Cameron Scott Bodine

Thesis submitted in partial fulfillment of the requirements for the degree
of

DEPARTMENTAL HONORS
in
Landscape Architecture
in the Department of Landscape Architecture and Environmental Planning

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Abstract

Open spaces are a valuable amenity that people often overlook. Open spaces allow for a system of water treatment, wildlife habitat, agricultural production, and recreation destinations. Too often, however, open space systems are systematically devoured by development with little regard of what that can mean for the future of a community. This thesis suggests that when open space systems are analyzed as having structure, shape, and a dynamic nature, interconnected with development, then an explanation of how it transforms and evolves can emerge. This thesis seeks to present a new method of describing open space change through understanding development trends through time in Cache Valley, Utah. Utilizing Geographic Information Systems (GIS) and parcel data, this thesis presents and analyzes various methods of describing open space change. Through developing a method of describing open space, then trends, development pressures, and potential areas for open space recovery can be identified and informed decisions can be made about development patterns in the future.
**Introduction**

In spite of the many uses and services open space systems provide, it is often seen as the vacant land surrounding development. When open space systems are analyzed as having structure, shape, and a dynamic nature, interconnected with development, then an explanation of how it transforms and evolves can emerge. Understanding change in open space systems will help to determine trends, development pressures, as well as potential areas for open space recovery or protection.

The author is interested in exploring the different ways open space systems contribute to and support a high quality of life and sustainable living. Good planning and design solutions need to incorporate a response to how communities value open space and the benefits these open space systems provide in conjunction with development. Through increasing knowledge on the contribution of open space to sustainable development, communities will then be able to make wiser development decisions. This research explores a new approach to describing open space change aimed to enhance understanding of the short and long term implication of development decisions. The case study selected for this exploration is Cache County, Utah with documented parcels data allowing time to be considered.

The purpose of this research project is to document and study the patterns of urban growth and the associated changes in open space occurring in Cache Valley UT, categorizing changes in different aspects:

1. Map the geographic distribution of open space through time.
2. Describe Cache Valley’s open space systems through a selection of relevant pattern and shape characteristics (patches and edges, connectivity and networks, etc.).

3. Track trends, patterns, and relationships between developed land and open space systems.

This project identifies, through historical data, the changes in the Cache Valley open space system. County data is classified and mapped in sequential series visualizing and measuring different features describing the system. Quantitative analysis explains associations between different variables describing open space in the valley. Through the use of Geographic Information Systems (GIS) and landscape ecology metrics, the author will test and track the change of connectivity, network systems, and edge development to formulate a method of quantifying and describing the relationship of open space and development based on pattern size, distribution, and connectivity.

This thesis represents an exploratory exercise describing open space formal properties as a result of a development process. The goal is to continue with this formal approach to identify relevant open space characteristics to expand and improve understanding of the transformation of the open space system and be able to identify thresholds and patterns to plan for its function and viability in the long term.

**Literature Review**

Leitão and Ahern (2002) discuss the application of landscape ecology principles and metrics to sustainable planning and management. Landscape ecology metrics are evaluated and a subset of metrics are determined to be best suited for sustainable landscape planning. In
addition, the authors have proposed an integrated framework through which these metrics can be applied to sustainable landscape planning. While the concept of applying landscape ecological theory and metrics to landscape planning is important and significant, the proposed metrics cannot be applied until a method of describing development change through time is proposed and utilized.

Esbah’s (2001) study on mountain preserves in Phoenix, Arizona applies three landscape ecology metrics to discuss the effects of environmentally less sensitive land use types on a land preserve:

- matrix utility analysis,
- isolation analysis; and
- connectivity analysis

Of particular interest to the efforts of this thesis is Esbah’s utilization of aerial black and white imagery of development in the Phoenix area. The focus of the paper is on how the development around three preserves in the Phoenix area has affected the preserves and the quality of ecology found within. Esbah quantifies intensity of land use on the mountain preserves by assigning intensity values to parcels of land based on land use type. This paper presents an important methodology of correlating land use intensity with ecology with a preserve. This study focuses on mountain preserves which by definition are not themselves subjected to formal change through time. They are protected tracts of land whose boundaries do not change. Only development around the mountain preserves can change. This allows for in-depth study of the effects of development on a specific parcel. The repeatability of this method for the purposes of this thesis are called into question. This study is focused less on the spatial
quality of development around the mountain preserves but instead on the type of development and the ecological effects that development has on the preserve.

As can be seen from these examples of applying landscape ecology principals to urban and open space planning, what is lacking is a clear and concise method of developing an image of development and open space change through time. Since the open space system in Cache Valley is variable and changeable (except for the Forest Service land found on the eastern edge), there is a need for a method of understanding the interaction between development and open space. This thesis seeks to understand the primary process of development through time, thereby creating a process through which a quantifiable method of measurement of open space and development systems can emerge. This will produce an image that can be analyzed and correlated to historical, cultural, and planning policy events.

Framework

This thesis sets forth to document, describe, and analyze the structure and interaction between development and open space systems through time in Cache Valley, Utah. The literature review presented two papers that describe methods of utilizing landscape ecology to describe both applications to landscape planning as well as effects of land use on open space systems. Leitão and Ahern (2002) demonstrate a framework for applying landscape ecology and certain metrics to landscape planning, but only in the theoretical sense. They lack an applied method of their theory. Esbah (2001) presents a highly applied method of utilizing landscape ecology to describe the effects of land use on a preserve, but this study looks at the effects of non-static development change on a spatially static open space system. The gap in research
results from the need for a repeatable approach to understanding, documenting, and analyzing the relationship of open space and development through time.

Figure 1 describes the framework used in this thesis. The purpose of this thesis is the understand the relationship between open space and development through time. The objective is to develop a simple, quantifiable image of open space and development change through time to allow analysis through landscape ecology metrics.

The data set utilized is parcel data made available by Cache County Development Services. Three attributes within this data set are utilized as variables:

- Parcel area
- Land type
- Year built

ArcGIS Desktop (2010) software is employed as an analysis tool. Different combinations of analysis tools and variables produce four different approaches (methods) that this thesis will discuss. In the flow chart pictured in Figure 1, the approaches resemble a stair step. That is because each approach led to a new finding which contributed to a development in framework. The new finding would then be applied to a new approach which uses a different combination of variable(s) and analysis tool(s). This stair step method was employed until the desirable outcome was achieved.
Framework Development

Figure 1: Depiction of the development of framework through the progression of the study
The Data Set

Cache County Development Services (2010) provided the primary data set for this project. This data set contains information related to every parcel in the county with the following attributes:

- Acreage (area of the individual parcel)
- Land Type
  - Agriculture, commercial, greenbelt, residential, secondary, vacant
- Building Type (applicable only to the first listed structure on the parcel)
  - Agriculture, commercial, residential, secondary
- Building Specific Type
  - Duplex, three-plex, four-plex, agricultural building, cabin, commercial, common area improvement, condo, low-rise multi-family, mixed-use, mobile home park, single family residence, secondary building, storage unit
- Building Square Footage (applicable to the total area of the primary structure)
- Year Built (applicable to the first primary structure on the parcel)

The Software

Extensive use of GIS software (ESRI, 2010) was required in order to map open space and development change in Cache Valley. GIS data is readily available from Cache County Development Services as it is the primary data and software utilized in day-to-day planning procedures. ArcGIS has a toolbox that can be used to analyze, interpolate, and manipulate spatial data in order to increase our understanding of how various data sets can be utilized to
solve a wide range of spatial issues. The following list shows the primary toolsets used during this process:

- **Buffer** (creates buffer polygons around input features to a specified distance)
- **IDW** (interpolates a raster surface from points using an inverse distance weighted technique)
- **Kriging** (interpolates a raster surface from points using kriging)
- **Spline** (interpolates a raster surface from points using a two-dimensional minimum curvature spline technique)
- **Create TIN** (creates an empty TIN surface)
- **Edit TIN** (adds feature classes to an existing TIN and creates surface features of a TIN based on an input feature class)
- **TIN Edge** (extracts triangle edges from an input TIN into an output feature class)

**Methods: A Contrast Solution Approach**

The focus of this thesis is on the methods employed in order to build an image of development and open space change through time. This process is desirable for a number of reasons. According to Leitão and Ahern (2002), landscape ecology metrics can be applied to a sustainable planning approach. That study describes the framework for applying those metrics to planning but does not describe the methods necessary to actually implement the metrics. This represents a gap between theory and application. This thesis signifies an attempt to fill that gap.

There is a need to modify the image of development and open space change. If an image is developed from the raw data that is the footprint of a developed parcel of land, then a patchy image with no understanding between the relationships in and among those parcels results.
Through developing an image that only focuses on those patches that are contributing to the primary development growth in the Valley, then trends, development pressure, and opportunities for open space recovery can be identified. This simplified image will allow for the measurement and tracking of change through time. It is only after this image of development and open space change is created that the methods described by Leitão and Ahern (2002) can become a reality for planning officials.

Four different approaches were developed to arrive at a final method of articulating development and open space change. These approaches can be thought of as a contrast solution. A contrast solution is a liquid dye that is injected into the veins that allow them to be seen by an x-ray. If we think of this study as an x-ray of development and open space relationships and changes, then the contrast solution is different combinations of the data attributes (variables) and GIS tools (analysis tools). Through using different contrast solutions, or approaches, different formal properties of development and open space emerge. We know that we have used the appropriate contrast solution once a clear, definable, and quantifiable image emerges.

Methods

The primary objective of this project was to develop a method of transforming open space and development patterns through time into an object that could be measured based on pattern size, distribution, and connectivity. Multiple avenues were explored in order to find the method that best describes the reality of open space change as well as presents the most simple image of open space and development change. This section will step through the multiple methods (identified as contrast solutions) that were utilized to develop a set of images that depict open space and development change through time.
First Approach: Development based on Density

Can building density be utilized to develop a simple image of development while indicating important processes in development? The first analysis approach in this project attempts to understand development in terms of density; that is through classifying development based on classes of density (rural, suburban, urban, and high). Through establishing this hierarchy of development class, then core areas associated with the primary structure of a municipality could be distinguished from areas of development that didn’t necessarily contribute to the larger development footprint. These areas include isolated instances of rural development within the open space system. While these patches of development are occurring within the open space system, they are not necessarily contributing to the development of the open space system since these can be farm houses located on large parcels of agricultural lands.

The process undertaken for this approach began by calculating the net density of every parcel in Cache County. Net density is defined as the number of building units located on an individual parcel divided by the acreage of that parcel (see figure below). The number of dwelling units a parcel contains was based on the building specific type attribute within the parcel data layer.

\[ Net\ Density = \frac{building\ units}{parcel\ acreage} \]

Some of the building specific type attributes do not directly indicate a number of building units that a parcel contains. For example, low-rise multi-family would be an attribute applied to an apartment complex but since we do not know how many dwelling units are contained within that apartment complex, we cannot accurately calculate the net density for these
parcels. For the sake of this study, low-rise multi-family parcels were defined as contributing to a compact development pattern and were therefore defined as “high” density. Commercial areas were also seen as contributing to a compact development pattern and were defined as “high” density. For mixed-use building type, it was assumed that at least one building type was present on the parcel and were calculated as described by the formula above.

<table>
<thead>
<tr>
<th>Density Category</th>
<th>Net Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Space</td>
<td>Less than 0.3 du/ac</td>
</tr>
<tr>
<td>Suburban</td>
<td>0.3-1.2 du/ac</td>
</tr>
<tr>
<td>Urban</td>
<td>1.2-4.8 du/ac</td>
</tr>
<tr>
<td>High</td>
<td>Greater than 4.8 du/ac</td>
</tr>
</tbody>
</table>

*Table 1: Density Values*

After net density was calculated, parcels were selected based on the year that they were built. Parcels were grouped in ten year clusters from 1900 to 2010 and were placed on separate data layers with GIS. In order to perform an interpolation of the development density of the valley, each parcel was treated as a single point with a single net density. The centroid of every parcel was calculated to create point data from the parcel polygon data. This was input into the IDW (Inverse Distance Weighted) tool within ArcGIS and was filled out according to Figure 2.

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1 Parcels larger than 3.333 acres (farms, isolated parcels, etc) to be considered “open space”. Suburban densities include parcels 0.833 acres to 3.333 acres (1 acre is traditional single family residential parcel size). Urban densities range from 0.21 acres to 0.833 acres. High densities are parcels smaller than 0.21 acres.
A fixed search radius of 660 feet was utilized. A traditional block in Logan, Utah is 660 feet by 660 feet. That means that only parcels located on the same block or a block directly adjacent to that point would have an impact on the interpolation of that point. An output cell size of 100 ft square (approximately 30 meters square) was utilized as this is an appropriate cell size for this level of analysis. The IDW was calculated for each ten year period and a sample of the results can be seen in Figure 3 (full results can be found in Appendix A).
This approach produced some very encouraging results. Higher densities can be found primarily around the city centers, where you would expect to find them. There is then a general progression in density from high to low from the center of the municipality outward. The images seem to illustrate a compelling message, but after further analysis, it is apparent that the visual is incomplete for the purpose of this study. The primary indicator for this is the small single circular areas of density that are occurring on the west side of the valley. These areas confuse the image of development in the valley. While it is true that these areas are representative of built parcels, they are really isolated instances of development within the larger context of the open space system. These are the farm houses located within the agricultural system of the valley and for the purpose of this study, are argued to not contribute to the overall development system of the valley.

Figure 3: Density Distribution

² Darker colors represent higher densities. The view extent includes Smithfield to the north, Wellsville to the southwest, and Logan in the center to the east. The red lines indicate the primary highway systems.
Figure 4: Acres built per decade for Cache Valley, UT

Figure 5: Percent Area Built
Figures 4, 5, and 6 represent the primary findings of this approach. As can be expected, the acres built per decade (Figure 4) consistently increased throughout the study period. The graph indicates an increase in the rate of development during the 1970’s. Urban development (net density 1.2-4.8 du/ac) consistently represents the highest built acreage throughout the time period.

In the percent area built graph (Figure 5), the trend towards an even spread of development type as time increases is a significant finding. Figure 6 depicts a comparison between built acres per capita and open space acres per capita. As can be expected, a steady decrease in open space acres per capita is experienced through time. Built acres per capita relate an interesting finding. 1900 to 1930 experienced a large increase in built acres per person. Then the trend evens out and begins to decrease. This could be attributed to an increase in the rate in population growth since 1940.
Despite the interesting findings of this approach, this method failed to produce an image of development as an object. The isolated parcels to the west hold too much visual weight within the image and are not contributing to the larger body of development within and around the centers of the municipalities. A method of removing these externalities is needed for the purpose of these studies. The next approach utilizes a network to achieve this need.

**Second Approach: Buffered Parcel**

If the shape of a parcel were standardized, and displayed proportional to the area of the parcel, can a simplified image result? A concurrent investigation during the period of investigation for the first approach was the method of a buffered parcel. This was a simple method of creating a circular buffer from the centroid of the parcel with a magnitude directly proportional to the area of the parcel (Figure 7 1900, 1950, and 2010. The red outline represents the municipal boundaries of Logan).

There are two primary issues with this method. The first is that despite the parcels being buffered, the grid network of the road system can still be seen in the images. For the purposes of this study, roadways that are near and within development are considered to be part of the development system. Since the buffering of the parcels does not cover the road system, it makes it appear as though the roadways are functioning as corridors within the open space systems, which for the purposes of this study, is not the case. Roadways promote development through allowing access to locations that would otherwise be left as open spaces.

The second issue arises as a direct result of buffering a parcel based on the size of the parcel. Through using this method, larger parcels are represented as larger circles which visually indicate a greater magnitude of development. This is not the case, however. Consider a large
parcel of land dedicated to agricultural purpose with a single dwelling on it. Even though this parcel could be ten acres plus with only one structure for that entire parcel, it visually carries more weight because it is larger in size and therefore gives a false impression of the built landscape.

*Figure 7: Buffered Parcel Distribution*
Third Approach: Buffered Parcel with Proximity Network

How can a proximity network identify the primary body of development? The focus shifted to clarify which buffered parcels were directly contributing to the development system and which built parcels, because of their size and isolation, could be considered part of the open space system. This is how the idea of utilizing a proximity network was first realized. Through identifying parcels that were near each other, a system of patches could be identified as part of the core development system.

The same point layers broken up by decade built were utilized as described in the first approach. Using an ArcGIS (2010) tool called Create TIN (Triangulated Irregular Network), a blank TIN layer was created into which new TIN information could be created. Edit TIN was then used to add the point feature class information into the existing TIN and creates surface features of a TIN based on an input feature class. In the height_field attribute, the net density attribute was used that was created in the first approach. What results is a TIN raster surface from which the edge that connects every point needs to be extracted. TIN Edge was used to perform this, which extracts triangle edges from an input TIN into an output feature class. The result is a line feature class whose lines are extracted edges of the input TIN.

From the TIN edge feature class, select by attributes was used to isolate only the edge lengths that can be considered part of the proximity network. For the purposes of this study, 660 feet was used because this is the average length of a city block in Logan. With this historic precedent of block size, it was determined that only those parcels within 660 feet of each other carry a relationship that promotes development. This results in a set of points that are connected to at least one other point, thus producing a proximity network. These points were selected and
placed on their own layer. They were then buffered by 660 feet and the result can be seen in
Figure 8 (a complete set of the images can be seen in Appendix B).

Similar to the results from the first approach, a defined core area around the center of
municipalities can be identified. What this process begins to show, however, is that a definable
structure in the development pattern can be found. The network helps to define this structure by
visibly connecting those parcels that are within the defined proximity network length. The
primary issue with this method is how to measure this seemingly complex system of shapes and
networks. This image is not simple enough to measure such things as edge of the network.
Also, the circular buffer continues to disproportionately convey the importance of a parcel in the
overall image. Parcels that are small and are connected by the network still do not cover the
roadway structure. A single image of the development pattern still has not emerged from this
approach. The value of a network in depicting the development pattern is noted and will be
utilized in the final approach.

Figure 8: Buffered Parcel with Network (1900, 1950, 2010)

3 The beige circles show the parcels that are not part of a proximity network and were made visible for comparison
reasons. The red circles are those that are part of a proximity network. The black lines on top show the network
itself.
Fourth Approach: Buffered Proximity Network

Can the proximity network alone be utilized to develop a simplified representation of development and open space change? The value of a proximity network became apparent in the third approach. This isolated and connected only the parcels that we close enough to begin to form an important patch of development. While there still remained patches on the west side of the valley that were close enough to form a proximity network, these patches ended up being small and carried relatively little visual weight to the image. Despite all of this, as noted above, the image produced was seemingly complex in visual nature and did not readily facilitate measurement.

At this point, a new thought emerged. That was, use the network essentially as a skeleton for development for the valley and utilize a buffer on the network that would help give the skeleton mass and a definable and measurable edge. Through buffering the network itself, large parcels of land would carry little weight in the image produced. It does not matter how large a parcel is, only if that parcel is close enough to another parcel to begin to form a relationship of proximity.

Utilizing the TIN network created in the previous approach and selecting only those network lengths that were 165 feet long or less, the network layer was simply buffered. Two different distances were utilized to see what the resulting image would look like and to understand which distance would produce the desired results. The distances were 330 feet (one-half the length of a standard Logan block) and 165 feet (one-quarter of a standard Logan block) and were fully dissolved. A sample of the results can be seen in Figure 10 (see Appendix C).
The buffer of 165 feet was chosen to begin to quantify statistics about the development change through time because it seemed to still illustrate a more defined edge and also more readily showed open spaces within a patch area indicating municipal parks, etc.

After creating a buffer around the network, the resulting layer contained only one object. The data was not broken up by each patch, so a method was needed to give each patch of development a unique ID so that statistics about the development pattern could be quantified. First, the polygon buffer was converted into a raster surface. A cell size of 100 feet was used (approximately 30 meters). This transformation takes detail out of the edge and produces an exaggerated edge calculation but is necessary in order to quantify statistics about each development patch. The raster surface was then converted back into a polygon without simplifying the edge. The result is a list of development patches with unique ID’s that allow for edge and area calculations for each development patch. Figure 9 shows a comparison of the buffered proximity network footprint from 1900, 1950, and 2010 (see Appendix D).

![Figure 9: Buffered Network Distribution Simulation](image-url)
Figure 10: Buffered Network Distribution
Analysis

Findings of this study indicate that the buffered proximity network described in the fourth approach is very close to depicting the reality of development change in Cache Valley. Figure 11 compares the area of the buffered proximity network with the actual developed area related to parcel size. Both distributions are closely related and the only difference appears in the number of developed acres, as can be expected.

Figure 12 depicts the relationship between the average development patch size with the average development patch edge length. The primary item to note about this graph is the large jump in average patch area compared to edge from 2000 to 2010. This would suggest that a large increase in development within existing development patches produced a less complex development edge within the buffered proximity network.
From this point, the frequency of patches occurring within half standard deviation steps were calculated, both for patch area and patch edge. This distribution did not follow a normal distribution, rather for every ten year period, the majority of patches could be found in the interval from a negative half standard deviation to the mean for both area and edge. This finding is significant because it shows that there is not a wide variation in the type of patches that are being developed through time.
A comparison was then made between the frequency of patches occurring within the interval noted above and compared to the average patch size. As is illustrated in Figure 13, the average patch area consistently increases throughout the time period, as can be expected. A significant item to note is the sharp increase in patch area from 2000 to 2010 when compared to the increase in patch area from 1900 to 2000. The frequency of parcels begins to tell a more interesting story. From 1930 to 1960, there is little to no increase in the number of new parcels within Cache County. This finding alone is not necessarily significant because this time period contains the Great Depression and World War II and a period of slowdown in growth could be expected. When this graph is compared to the average patch area graph, however, we see that this time period experienced the same amount patch area growth as the time periods before and after this time period. This means that the Valley experienced the same amount of growth, but that new patches of growth were not being created. Instead, new growth was contributing to already existing patches of development instead of as interruptions in the open space system. In
essence, it could be suggested that Cache Valley experienced a smarter growth pattern during this period which helped to preserve the existing open space system. The period from 2000 to 2010 could also be experiencing a smarter growth pattern because there is a large increase in average patch size with a small increase in the number of patches. Other possibilities include there not being enough available open space for development, large patches are too dominant and are absorbing new development, or patches are too close together for new development to produce new patches. These are avenues that should be researched further in the future.

Figure 14 shows a comparison between the number of new development patches and the amount of new developed area. This graph again depicts the slowdown in the number of new patches from 1910 to 1940 and a stagnation in the number of new patches from 1940 to 1960. From 1990 to 2000, Cache Valley experienced a period of increase in both parcel area and patch number. Particularly interesting is the decrease in new patches from 2000 to 2010 while new parcel area still increased. This would suggest that the past ten years have experienced a smarter
growth pattern in that new development was already occurring within existing development networks.

**Findings and Conclusion**

This method of understanding development and open space systems changes is important to our understanding of how these two systems interact and are formed by the other. This method presents a unique approach to quantifying this relationship. Developing a simplified image of the interaction between development and open space can allow planners to understand what past trends have looked like and what can be expected in the future. Through inserting this method into the sustainable planning framework (Leitão and Ahern 2002), then communities have the potential of developing in a smarter way into the future.

After comparing each method with the others, it becomes apparent that the Fourth Approach: Buffered Proximity Network presents the clearest image of development with quantifiable characteristics. The fourth approach is not too much of an abstraction of the reality of development in Cache Valley because there was a high correlation between its development trend compared with the actual development trend of the county.

The primary findings of this study indicate that two important time periods have occurred within the time period study. The first is from 1930 to 1960. This time period exhibited the same amount of new development, but that development occurred within existing development patches, pointing to a smarter form of development. The second time period is from 2000 to 2010 where we see a significant increase in the average patch size and a slowing in the number of new patches. These two time periods should be studied further and compared to significant events that occurred within the country and within the valley (planning policy change, new
employment sectors, etc). That way, a direct correlation can be found between significant events and development pattern.

Findings from the image of development can also translate to important findings about the open space systems. When a new patch of development erupts in an open space system, a door is opened and more development can be expected to follow. That’s why time periods in which new patches were being formed less frequently are so important to the preservation of open space systems. Careful study should be given to these time periods so that we can understand why the Valley developed in a different and potentially sustainable fashion. Was it an active decision as part of planning policy, or was it an unintended side-effect? Answering these questions will give planning officials insight into the way we develop within open space systems.

This body of work represents a jumping off point for future study of the interaction and relationship of open space and development. In regards to Cache Valley, for the time periods 1930-1960 and 2000-2010, more research is needed to understand how planning policy, census data, and important events may have effected these changes in development pattern. More work is needed to understand how open space systems are affected by the development images produced in this study. This could be done by utilizing more landscape ecology metrics, such as edge complexity to see what other patterns can be found. This method should also be applied to other counties within and outside of Utah to see if this can be a repeatable and useful tool for planning officials. Finally, this work could present an opportunity for creating growth models. Since this method tells us where we have been, perhaps it can help to inform where we will go in the future so that smarter methods of growth that include a preservation of open space systems can emerge.
Appendix A: Development based on Density
Appendix B: Buffered Parcel with Proximity Network
Appendix C: Buffered Parcel with Proximity Network
Appendix D: Buffered Parcel with Proximity Network Footprint
Appendix E: Map of Project Area
References


