Figure 1 Digital aerial orthophotos taken for analysis in the Salt Lake City metropolitan area, overlaid on a map.
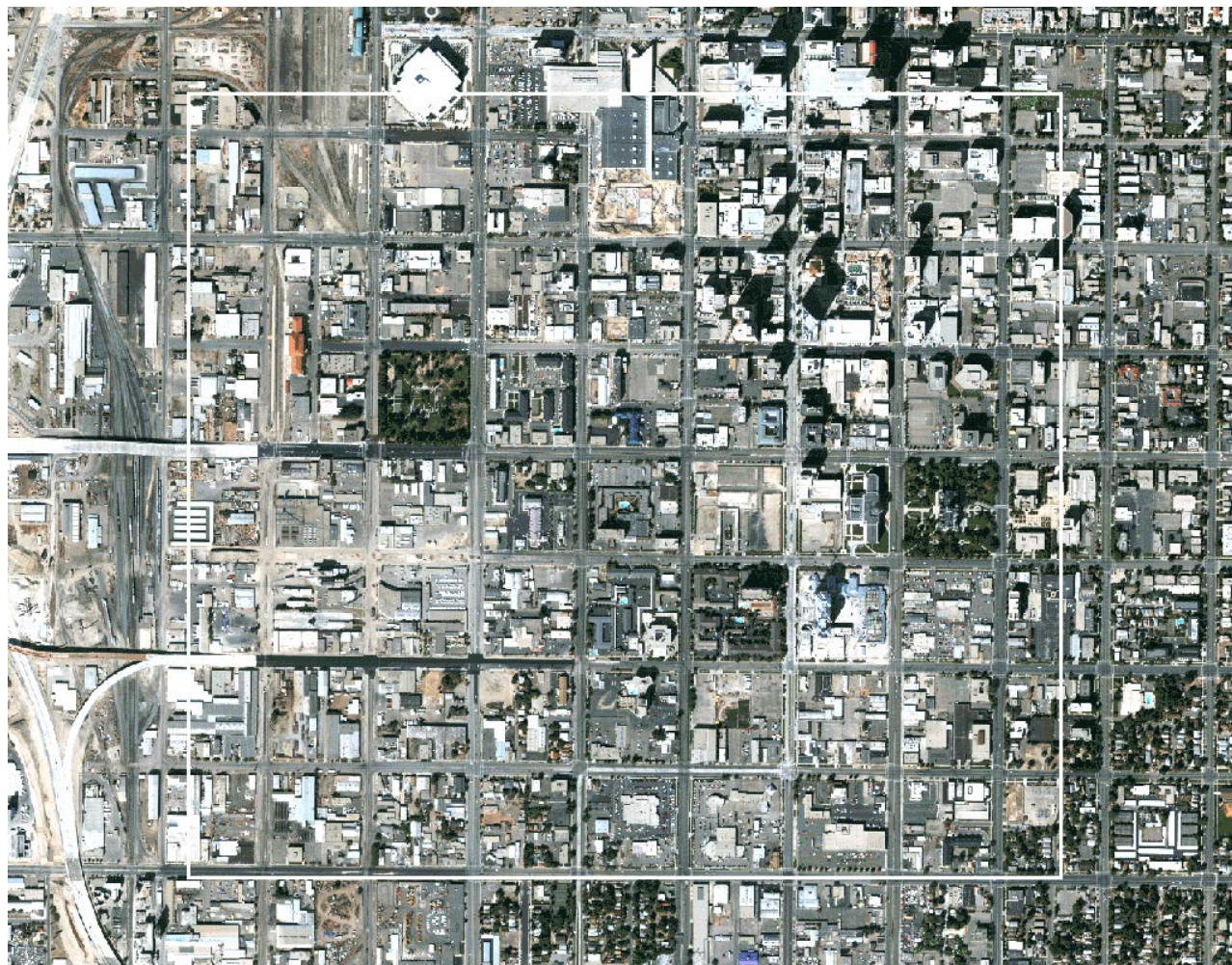
Figure 2 Aerial orthophoto of Downtown Commercial area in Salt Lake City.

Figure 3 Aerial orthophoto of Downtown Mixed-Use area in Salt Lake City.

Figure 4 Aerial orthophoto of an Industrial area in Salt Lake City.

Figure 5 Aerial orthophoto of New Commercial area in Salt Lake City.

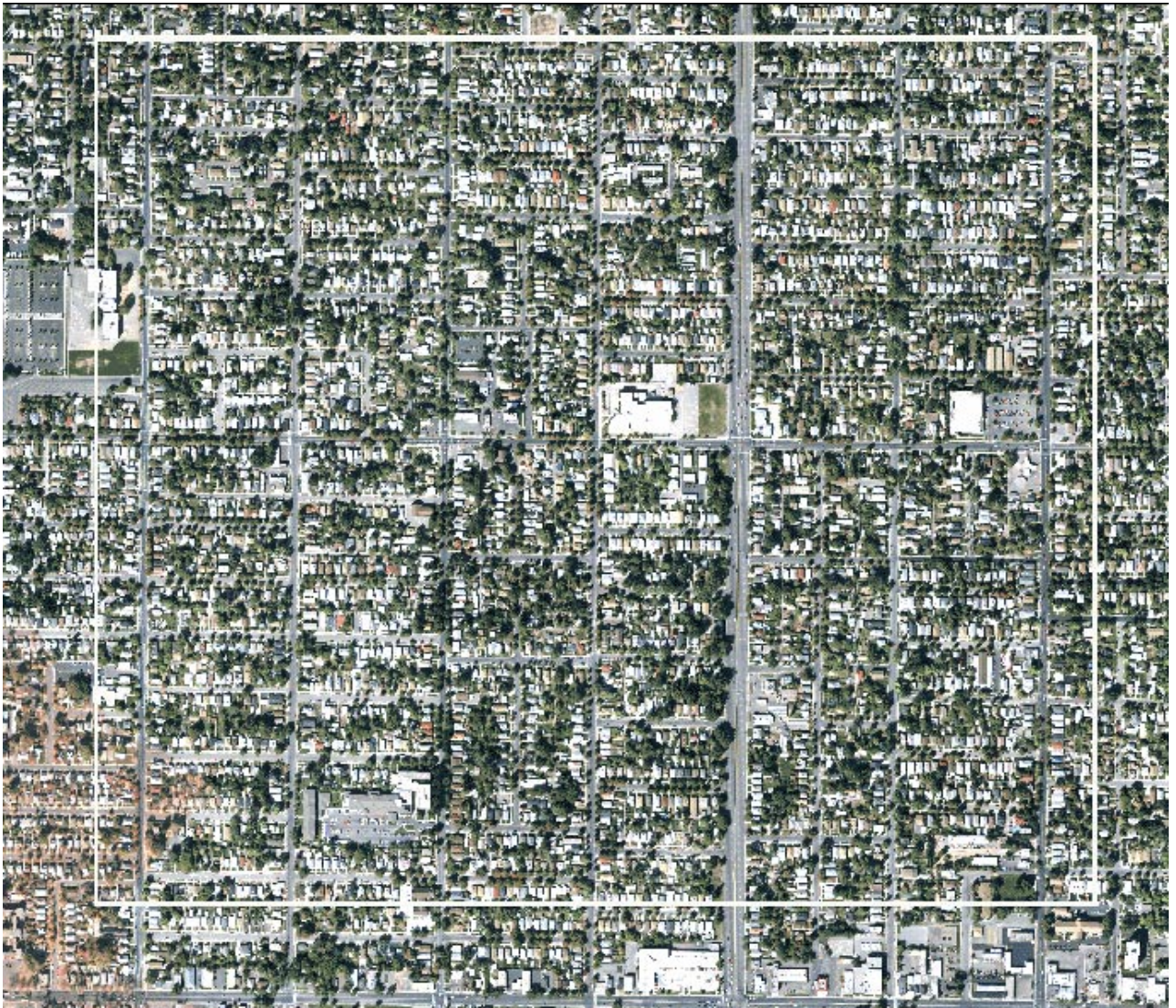**Figure 6** Aerial orthophoto of University area in Salt Lake City.

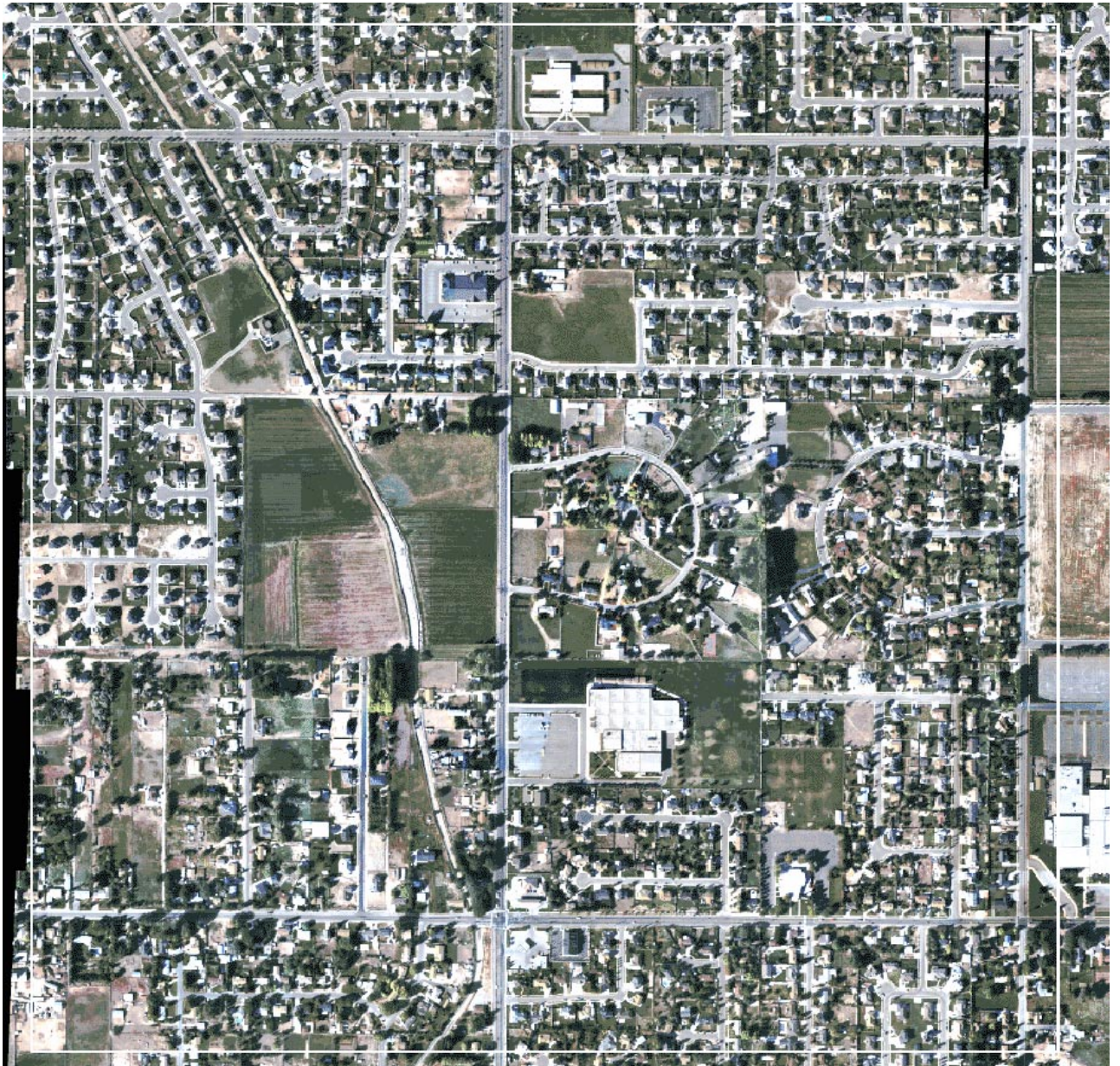**Figure 7** Aerial orthophoto of an Old Residential area in Salt Lake City.

Figure 8 Aerial orthophoto of a Low-Density Residential area in Salt Lake City.
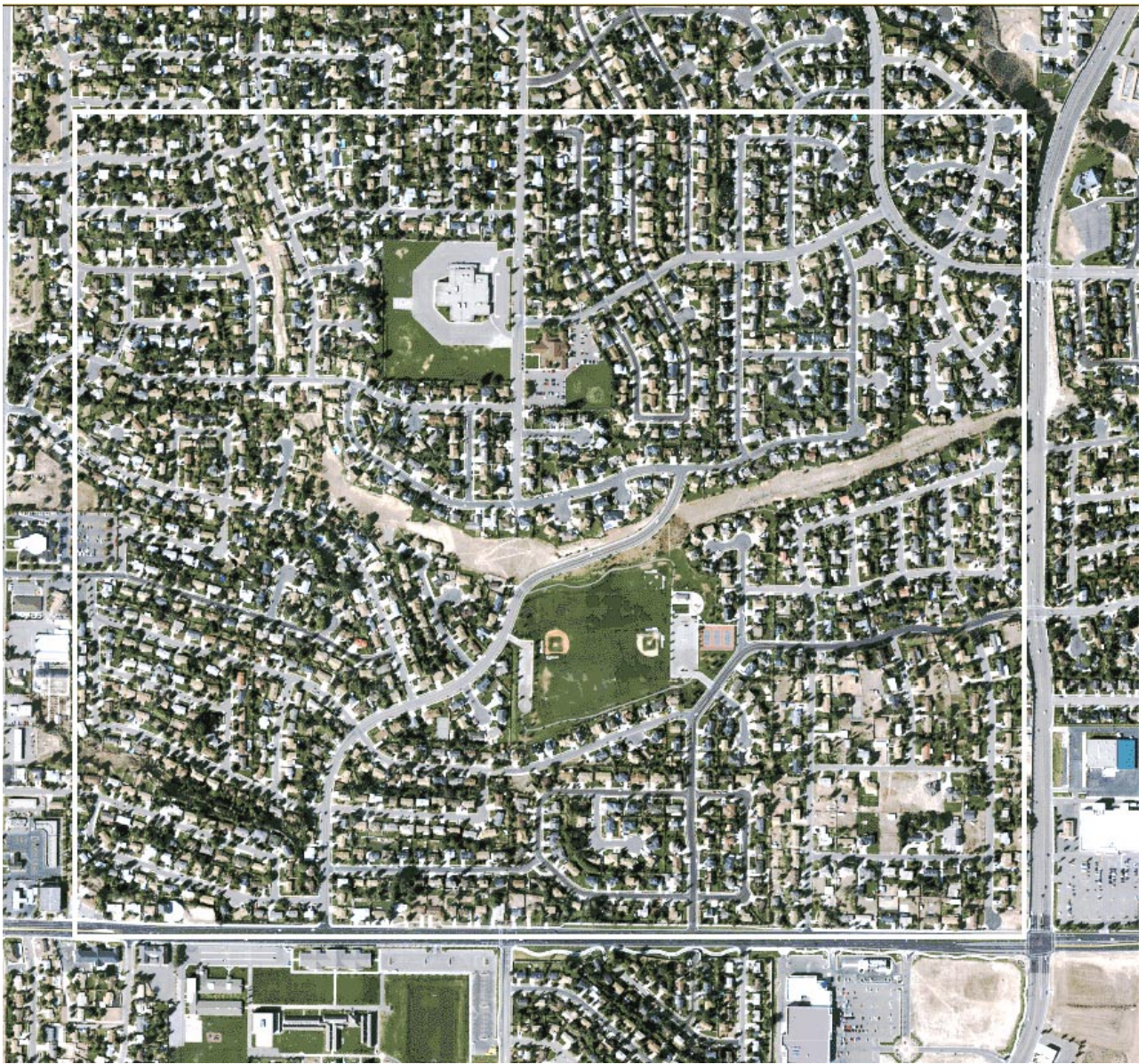
Figure 9 Aerial orthophoto of a Medium-Density Residential area in Salt Lake City.

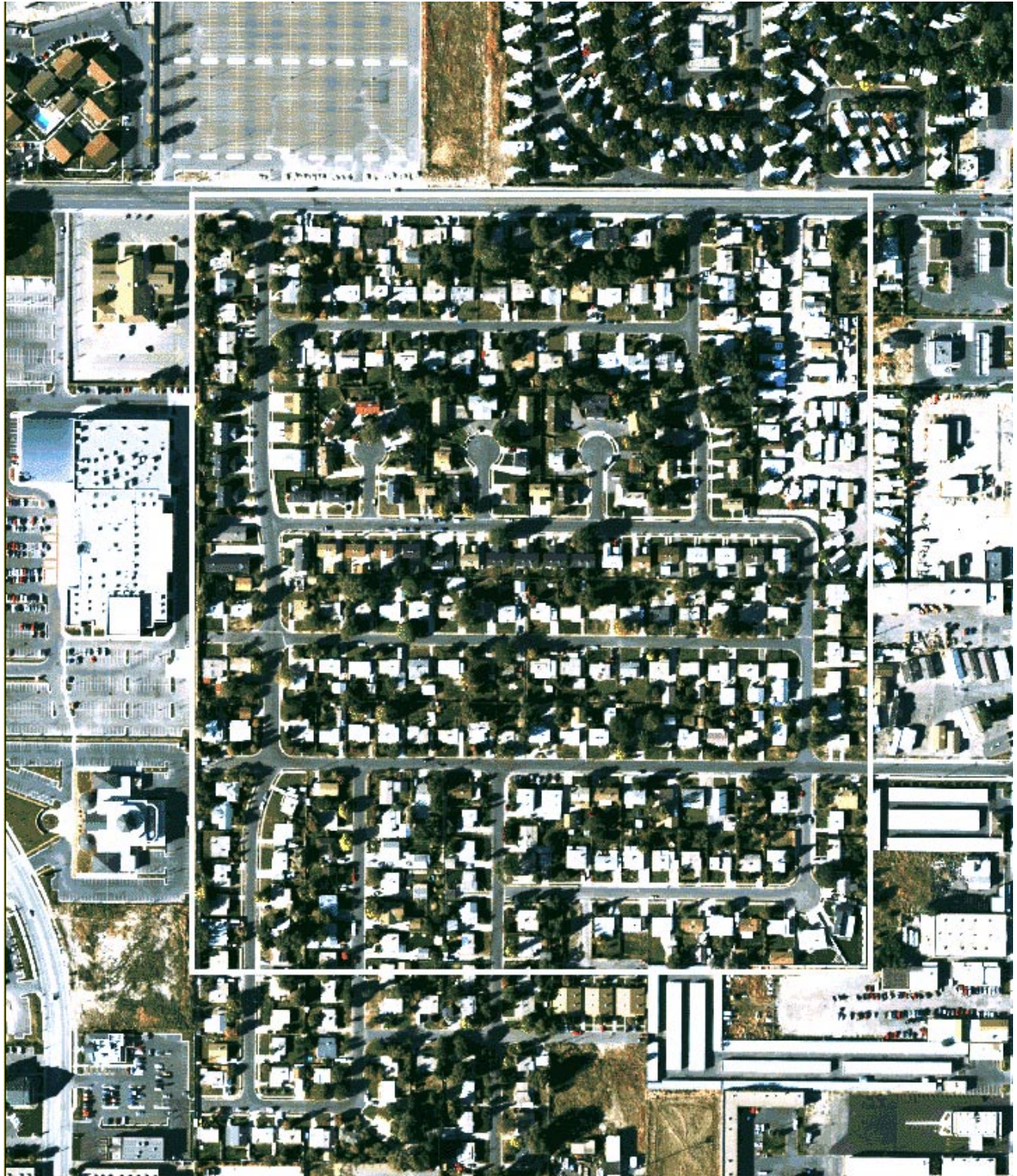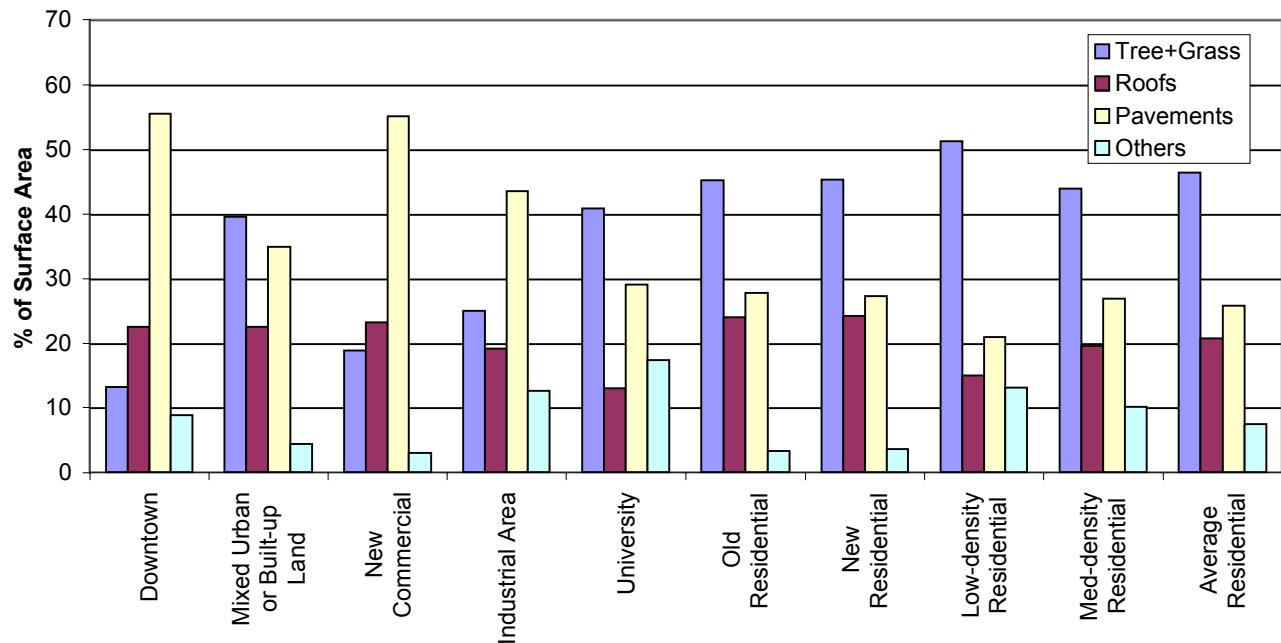**Figure 10** Aerial orthophoto of a Newer Residential area in Salt Lake City.

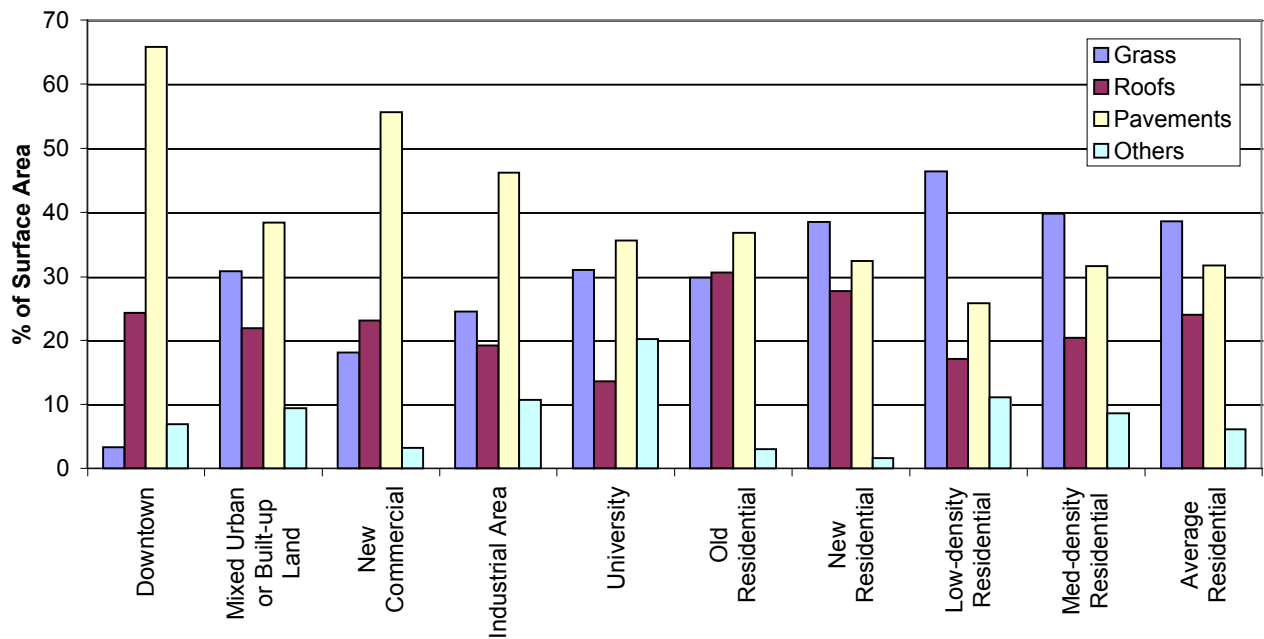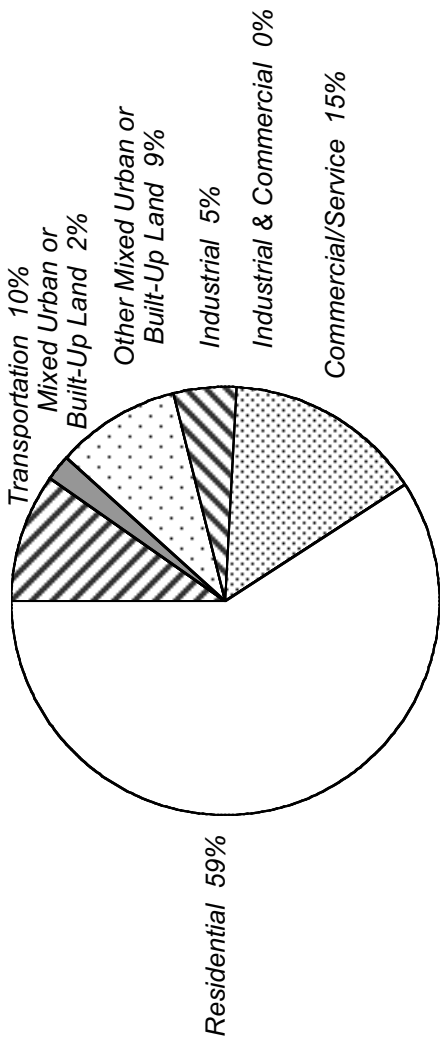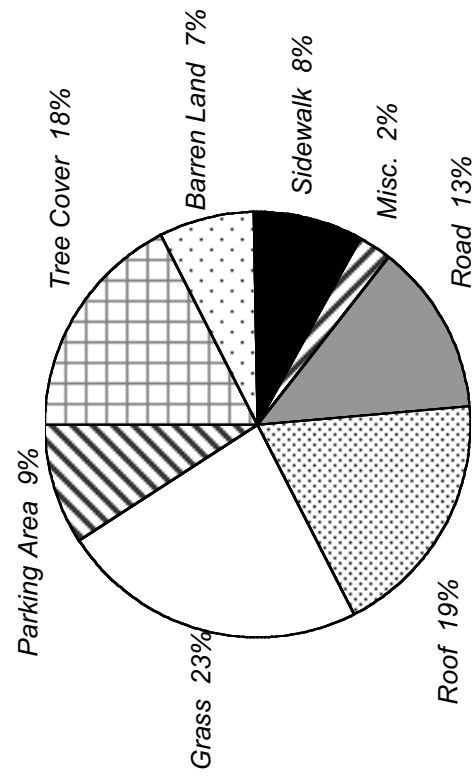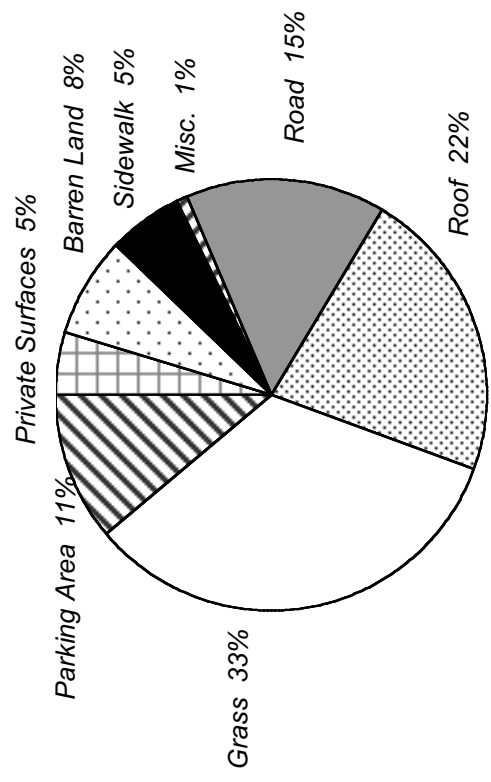**Figure 11** Above-the-canopy fabric of Salt Lake City, Utah.

Figure 12 Under-the-canopy view of Salt Lake City, Utah.

a) Area by USGS LULC Categories

b) Area by Land-Cover Category Above the Canopy

c) Area by Land-Cover Category Under the Canopy

Figure 13 Land-use/land-cover of the entire developed area of Salt Lake City, Utah.

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Appendix A
An Analysis of Potential Sources of Error in Extrapolating the Fabric Data
to an Entire Metropolitan Area

Using imagery acquired from one of the areas in the Salt Lake City overflight, a study was performed of methods of extrapolation from small-scale, city-fabric data to larger areas to quantify sources of error in extrapolating the fabric data from the analysis of aerial orthophotos to the entire metropolitan area. In this analysis, a large set of random points (1000) was generated over an entire flight area, regardless of the specific land-uses it contained. The fraction of different land-uses were obtained using a Monte Carlo statistical analysis. The selected area contained several distinct land-uses (**Figure A.1**). The land-uses in the area were identified as single-family residential, multi-family residential, and commercial (**Figure A.2**). Then three independent sets of random samples were generated to characterize each area independently. Finally, the results for each of the land-uses were weighted according to their geographic coverage to generate results for the entire area. **Table A.1** compares the fabric results from the extrapolation method and the direct analysis of the entire area.

The results obtained agree fairly well for most surface types. The largest percentage of error occurs with the Barren Land and Vegetative (grass and tree) categories. The data suggest that significant errors occur in the identification of natural features as a result of the complexity of natural features both in their actual shapes and in their health. Errors occur in the tree-cover category because of the irregular shapes and complex structure of trees and their shades. A pixel is difficult to identify, for example, when it is situated on the fringe of a forested area or at the edge of a tree. In determining whether vegetation is dry, barren, or healthy, the near-infrared band is used in addition to the three visible bands. Even with the near-infrared band a determination is still more subjective than identifying a man-made feature. The average NDVI[1] (Normalized Difference Vegetation Index) of the area can be determined by taking advantage of the near-infrared and red bands of the data. This well-established calculation gives insight into the characteristics of vegetation in an area.

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[1] The Normalized Difference Vegetation Index (NDVI) is a vegetation index that uses the light reflected in the near-infrared and visible bands of light to measure vegetative quantity. It is calculated as (Near Infrared Band -Visible Band) / (Near Infrared Band +Visible Band).

Figure A.1 Multi-land-use area selected for analysis of extrapolation errors.

Key
Green = Single-Family Residential
White = Multi-Family Residential
Brown = Commercial

Figure A.2 Land-use map created for the analysis of extrapolation errors.

Table A.1 Comparison of calculated area percentages obtained by extrapolation and by direct analysis of the entire data set.

Land-use	Tree Cover	Roof	Road	Sidewalk	Parking Area	Barren Land	Grass	Misc.
Under the Canopy								
Multi-Family Residential	21.6	3.4	7.5	20.8	33.2	7.0	6.2	0.3
Single-Family Residential	11.3	0.5	13.9	2.1	53.2	10.8	4.4	3.9
Commercial	20.6	3.2	13.5	34.1	17.5	7.9	2.4	0.8
Weighted Average	16.5	2.0	12.3	15.9	37.9	9.1	4.2	2.1
Entire Area	16.4	1.9	12.8	15.6	35.8	13.5	1.5	2.7
Difference	–0.1	–0.1	0.5	–0.3	–2.2	4.4	–2.8	0.5
Above the Canopy								
Multi-Family Residential	15.3	21.0	7.3	3.1	19.5	7.0	25.2	1.6
Single-Family Residential	23.9	11.1	12.6	3.6	2.1	10.0	35.2	1.5
Commercial	6.1	20.6	13.5	3.2	31.7	7.9	14.3	2.6
Weighted Average	16.6	16.2	11.6	3.4	14.9	8.7	26.7	1.9
Entire Area	13.1	16.1	12.6	4.5	14.7	12.2	25.6	1.2
Difference	–3.5	–0.1	1.0	1.1	–0.3	3.5	–1.0	–0.7

Appendix B
An Analysis of Characteristics of Residential Neighborhoods Using Census Data

By examining land-cover data in combination with census housing data it is possible to determine characteristics of individual lots in a neighborhood. Also, other information, such as the age of the houses can be used to estimate when roof repair or replacement might be needed, thus making implementation of albedo increases more effective. Using the imagery of the neighborhoods it is possible to count the actual number of buildings in a given area. By comparing the number of buildings with the number of Housing Units, some of the characteristics of residences in the area can be determined. As census data only includes housing units, whenever a storage building or garage is separate from a home on the same lot, only one building is counted.

1   Old Residential (A2)

There are six census block groups that cover the selected area (Table B.1). While these six block groups cover an area slightly larger than the area analyzed (2.4 km^2), they provide general information relevant to the study area because of homogeneity that exists over the entire area (Bureau of the Census 1990). Based on the census data, over half of the housing units in this area were built prior to 1941. The term "Housing Units" does not refer to separate buildings, but only separate living quarters. Therefore, these numbers alone do not give much information about the characteristics of the neighborhood.

Table B.1 Census data for the selected Old Residential area.

Block Group	Housing Units (HU)	HU Built Before 1940	Median Year HU Built	Area (km^2)
490351031-1	583	354	1939	0.41
490351031-2	703	393	1939	0.41
490351032-1	603	279	1941	0.36
490351032-2	711	398	1939	0.39
490351033-3	571	279	1941	0.44
490351034-3	606	326	1939	0.39
Totals	3,777	2,029	N/A	2.4

From aerial orthophotos, we estimated 1,157 residential buildings per km^2 in this Old Residential area. Census data indicate that there are approximately 1,695 Housing Units per km^2. Thus, assuming a mixture of single- and double-story housing units in this area, we estimate that at least 54% of the buildings in this area are single-family homes.

2   *Low-Density Residential (A4)*

According to 1990 census data, the homes in this area were built primarily during the 1980s. The density of these homes is estimated to be 93 units per km^2 (240 units per mi^2). Thus, since these units are single-family residences, the average lot size should be approximately 10,753 m^2. Based on these data, the average roof area per home in this area should be 1,075 m^2, or about 11,568 ft^2. Since the homes in this area are obviously not that large, it is recognized that the 1990 data are insufficient for a current analysis of this area because of new development over the past ten years.

3   *Medium-Density Residential (A6)*

Based on census data alone, only about 0.3 percent of the homes in this area were built before 1940; most were developed primarily in the 1970s and 1980s (see Table B.2). The housing density is estimated at 668 units per km^2 (1,731 units per mi^2). These data approximate an average lot to be about 1,498 m^2, making the average roof area 304 m^2 (3,270 ft^2).

Table B.2 Census data for the selected Medium-Density Residential area.

	Housing Units (HU)	HU Built Before 1940	Median Year HU Built	Area (km^2)
49035112608-1	357	0	1980	0.41
49035112608-2	405	0	1981	0.80
49035112608-3	444	0	1973	0.62
49035112608-4	421	5	1976	0.60
Totals	**1,627**	**5**	**N/A**	**2.43**

4   *Newer Residential (A8)*

The selected area includes only single-family residences. According to census data, 1967 is the median year these houses were built. Since the boundaries of the aerial photo for this area did not correspond well to the borders of any census block group, we did not estimate an average lot size from the census data.