

Assessing the Impacts of Xeriscaping on Water Usage in Beverly Hills, California



DECEMBER 2022

Remote Sensing and Imagery Analysis
University of California, Los Angeles
Authored by: Shane Clement



Executive Summary

California has a long history of severe water droughts that negatively impact the water supply for cities across the state. Water conservation programs have been implemented to reduce water usage since the 2000s. These programs include water-wise irrigation, plumbing, appliances, and turf replacement. The City of Beverly Hills began adopting these programs in 2009 and has since reduced water usage by over 20%. Research proves that xeriscaping can reduce water usage by 20-50% per single-family household. Therefore, the city has attempted to incentivize its high-income residents to convert their lush green lawns into xeriscaping. This analysis indicates that there has been a 27% reduction in irrigated grass in Beverly Hills over 11 years. However, errors in the data make it unclear whether this percentage is accurate. The city's successful water conservation efforts are likely due to participation in other programs. Without sufficient evidence, it is challenging to convince high-income residents in the City of Los Angeles to participate in the turf replacement program.

Problem Statement

This study aims to analyze the impacts of xeriscaping on water usage in the City of Beverly Hills from 2009 to 2020. In addition, to provide these results to the City of Los Angeles.

Introduction

California has a recorded history of severe water droughts dating back to the 1920s. These events gradually increase health, safety, environmental, and economic risks such as wildfires, drinking water shortages, and unemployment (Drought n.d.). In 2007, California experienced one of the worst wildfire seasons during the 12th driest periods in the state's measured hydrological record. The water years from 2007-2009 prompted the first statewide proclamation of drought emergency through the provisions of California's Emergency Services Act (Cowin, 2010). In February 2009, Governor Arnold Schwarzenegger urged cities to implement 10-year plans to reduce water consumption by 20% and warned that severe drought could potentially cost \$3 billion in economic losses (Henderson, 2009). The Metropolitan Water District of Southern California (MWDSC) was one of the many water agencies to answer the Governor's call to implement water conservation programs.

The Metropolitan Water District of Southern California (MWDSC) imports its water from the Colorado River and Northern California. MWDSC is a state-chartered cooperative with 26 members that serve approximately 18 million customers, including the City of Beverly Hills. Since 2009, MWDSC has implemented residential, commercial, and industrial water-saving programs. These programs include SoCal WaterSmart and the Turf Replacement program (Schaadt, 2017). The SoCal WaterSmart program provides residential and commercial rebates for adopting water-saving habits, sustainable landscapes, and water-efficient appliances and plumbing. In attempts to encourage residents to replace their existing grass for xeriscaping, MWDSC offers \$2.00 per square foot to 5,000 square feet of a converted yard per year. According to the City of Beverly Hills Urban Water Management Plan, MWDSC processed over 30,000 WaterSmart rebate applications in 2020, totaling over \$18 million.

The City of Beverly Hills obtains approximately 92% of its water from MWDSC via the Colorado River. The secondary source is local groundwater from the Hollywood Basin. The demand for this water depends on an area's climate, population, demographics, land use, and economics. Beverly

Hills has a Mediterranean climate and a population of approximately 32,000 residents, with a median owner-occupied home value of about \$2 million (U.S. Census Bureau 2021). The water service area includes a portion of West Hollywood, covering approximately 6.35 square miles and 43,000 residents. Residential connections consist of 83% of the water service area. With such an affluent demographic, Beverly Hills consumed approximately 9,273 acre-feet per year (APY) of water in 2020 (City of Beverly Hills Water Management Plan 2020). An estimated 35% of water usage is due to outdoor irrigation (Beam, 2022). This indicates that out of 9273 APY, about 3245 AFY was used for outdoor irrigation. The city projects water consumption will increase to approximately 12,000 AFY by 2025, respectively increasing the water usage for outdoor irrigation. Despite these projected increases, the city announced that water conservation programs have contributed to an over 20% water reduction from 2010-2020. The savings are attributed to outreach and incentive programs, including turf replacement, weather-based irrigation controllers, and rotating sprinkler heads. Lastly, the city is committed to participating in the California Green Building program that reduces high-irrigation lawns and plants, emphasizing drought-tolerant plants and weather-based controllers.

Background

Several previous studies have been conducted to determine the impacts of turf replacement and water conservation programs in the Western United States. These studies applied various analytical methods and data types to support their results. For example, a study conducted in Utah utilized NAIP imagery, parcel data, and water meter data to determine the different types of public irrigation areas and water consumption rates (Seliger, 2018). The GIS process included digitizing parcels and applying color composites to identify land cover types, irrigated (culinary and residential water), and non-irrigated areas. Furthermore, Seliger employed the xeriscape conversion calculation presented in previous studies by Sovocool and Morgan (2005) and Gleick et al. (2003) to provide landscaping and water usage recommendations for Daybreak, Utah.

In the study "Estimation of residential outdoor water use in Los Angeles, California" by Mini et al., Quickbird imagery and high spatial resolution aerial imagery were used to identify land cover types: tree, shrub, grass, dry grass, and impervious surfaces. Landsat normalized difference vegetation index (NDVI) identified healthy plants and impervious, non-vegetation surfaces in single-family residential areas. The Landsat data was also used to select the endmembers for irrigated, non-irrigated, and impervious areas. The analysis quantified outdoor and landscape irrigation use during drought periods with water conservation programs and concluded that 54% of single-family water usage is due to outdoor irrigation.

In 2006, Sovocool et al. published "An in-depth investigation of xeriscape as a water conservation measure" that utilized statistical analysis to estimate water consumption rates over a 5-year period in Las Vegas, Nevada, with three different groups: Xeriscape, turf, and a comparison group. This study applied a widely published conversion factor of 55.8 gallons/square feet/year to calculate the impacts of replacing grass with xeriscaping. The results concluded that converting to xeriscaping reduced water consumption for a single-family home by 20-53% (Sovocool et al., 2006).

This analysis was conducted using similar data, methods, and calculations from previously published studies on turf replacement and water conservation programs in Utah, Nevada, and Southern California.

Data and Methods

The data for this study was collected from the National Agriculture Imagery Program (NAIP) via Earth Explorer. NAIP imagery has a 1-meter spatial resolution that assists in reducing classification errors in comparison to lower-resolution Landsat imagery (15-meters or 30-meters). Seasonality was initially considered in an effort to analyze images with relatively bright vegetation and minimal cloud cover. March and April typically follow the rainiest season in the Los Angeles area and have fewer cloudier days. NAIP imagery was unavailable for those months of 2009 and 2020. Therefore, the available

imagery covering the extent of Beverly Hills was collected for June 26, 2009, and May 15, 2020. A city boundary shapefile was downloaded from the City of Beverly Hills datasets website.

After downloading eight NAIP images from Earth Explorer, it was determined that two images from 2009 and 2020 covered the entire extent of the City of Beverly Hills. For the workflow process, the images were uploaded to ArcGIS Pro, mosaicked, and exported to raster using the city boundary line as the clipping extent. An infrared color composite and histogram equalized stretch was applied to emphasize green vegetation and visually differentiate between turf and tree features.

Next, a supervised, pixel-based image classification method was applied first to the high-quality 2020 image. The supervised, pixel-based classification was selected because the nearest neighbors are not considered when assigning pixels to a class and could return more accurate classifications than other categorical classification methods. After the classification method, the National Land Cover Data (NLCD) default was chosen for the basis of the classification schema but was refined to five classifications: turf, trees, non-irrigated, impervious, and water, based on previously published studies. For this study, irrigated grass is defined as turf. Non-irrigated is defined as areas that have natural vegetation, i.e., not human-cultivated. Impervious is defined as concrete and non-vegetation surfaces such as houses, buildings, sidewalks, streets, tennis courts, and hard clay/soils. Finally, pools, ponds, and water fountains are defined as water. Tables 1 and 2 show the classification schema, class values, the number of training data areas, and the sum of the surface area per classification for the 2020 and 2009 NAIP images.

Table 1: Image Classification for 2020

Classification	Class Value	Total Selected Shape Area (Sq Meters)	Number of Training Data Areas
Turf	1	179,391.73	116
Trees	2	78,026.79	111
Non-irrigated	3	46,526.47	49
Impervious	4	741,051.49	156
Water	5	8,044.85	37
Grand Total		1,053,041.33	469

Table 2: Image Classification for 2009

Classification	Class Value	Total Selected Shape Area (Sq Meters)	Number of Training Data Areas
Turf	1	243,037.53	104
Trees	2	87,139.44	88
Non-irrigated	3	140,917.96	21
Impervious	4	1,113,232.49	123
Water	5	16,588.66	47
Grand Total		1,600,916.08	383

Following the classification process, a hundred (100) points were chosen in the “Create Accuracy Assessment” tool to test the accuracy of the classes measured by the training data. The tool outputted 108 +/- random stratified points total to “ground-truth”. After self-assigning the ground-truth points, the Confusion Matrix provided a Kappa of 37% for 2009 and 47% for 2020. It is important to note that turf (C1) resulted in ten (10) misclassifications for 2020 and nineteen (19) misclassifications in 2009. The trees (C2) resulted in fifteen (15) misclassifications in 2020 and sixteen (16) misclassifications in 2009. Furthermore, all ten (10) water (C5) points were misclassified in 2020. Tables 3 and 4 show the results from the Confusion Matrices.

Table 3: 2020 Confusion Matrix

Class Value	C_1	C_2	C_3	C_4	C_5	Total	U_Accuracy	Kappa
C_1	8	1	0	0	0	10	0.8	0
C_2	7	16	1	2	0	26	0.62	0
C_3	2	2	0	9	0	13	0.00	0
C_4	0	2	1	45	1	49	0.92	0
C_5	0	0	0	10	0	10	0.00	0
Total	17	21	2	66	1	108	0.00	0
P_Accuracy	0.47	0.76	0.00	0.68	0	0	0.64	0
Kappa	0	0	0	0	0	0	0	0.45

Table 4: 2009 Confusion Matrix

Class Value	C 1	C 2	C 3	C 4	C 5	Total	U Accuracy	Kappa
C 1	4	2	0	3	0	10	0.4	0
C 2	4	13	2	4	0	23	0.57	0
C 3	8	3	1	13	0	25	0.04	0
C 4	1	1	0	38	0	40	0.95	0
C 5	1	0	0	6	3	10	0.3	0
Total	18	19	3	64	3	108	0	0
P Accuracy	0.22	0.68	0.33	0.59	1	0	0.55	0
Kappa	0	0	0	0	0	0	0	0.37

Finally, the “Raster to Polygon” tool was used to the classified images to find the shape area for the surface features and exported by class value to filter the polygon for the turf feature. Within the attribute table for the turf polygon, the surface area was initially outputted in square meters. Additional fields were added to the attribute table to calculate square feet, acre feet, and gallons per foot.

Starting with the higher-quality image was a strategy to become familiar with the surface features, but the images for each year were processed separately using the same methodology. The final calculations in the turf polygon attribute tables established the changes in turf area and inferred the changes in water consumption rates over the 11 years. Table 5 summarizes the workflow.

Table 5: Workflow	Software
Determine the Years/Months for Data Collection	Various Imagery Services
Download the data	NAIP Imagery
Mosaic images	ArcGIS Pro
Export to raster with city boundary line extent	ArcGIS Pro
Choose a color composite type	ArcGIS Pro
Visualize data via band combinations and contrast stretching	ArcGIS Pro
Define classification method for determining class types and refine NLCD schema	ArcGIS Pro
Create Accuracy Assessment	ArcGIS Pro
Validate with Confusion Matrix	ArcGIS Pro
Run raster to polygon tool to create polygons for classifications	ArcGIS Pro
Export polygon to isolate turf area	ArcGIS Pro
Calculate estimated water usage per Acre-Feet	ArcGIS Pro
Determine the change difference from 2009 to 2020	ArcGIS Pro

Results

The findings from the workflow indicate that the 2009 turf area covered 1,439,145 square meters or 355-acre-feet, and in 2020, the turf area covered 1,049,127 square meters or 259-acre-feet. This 96-acre-foot (4,198,109 square feet) difference implies a 27% reduction in irrigated grass (turf) areas in the City of Beverly Hills over 11 years. The 2009 and 2020 maps show the surface features by classification.

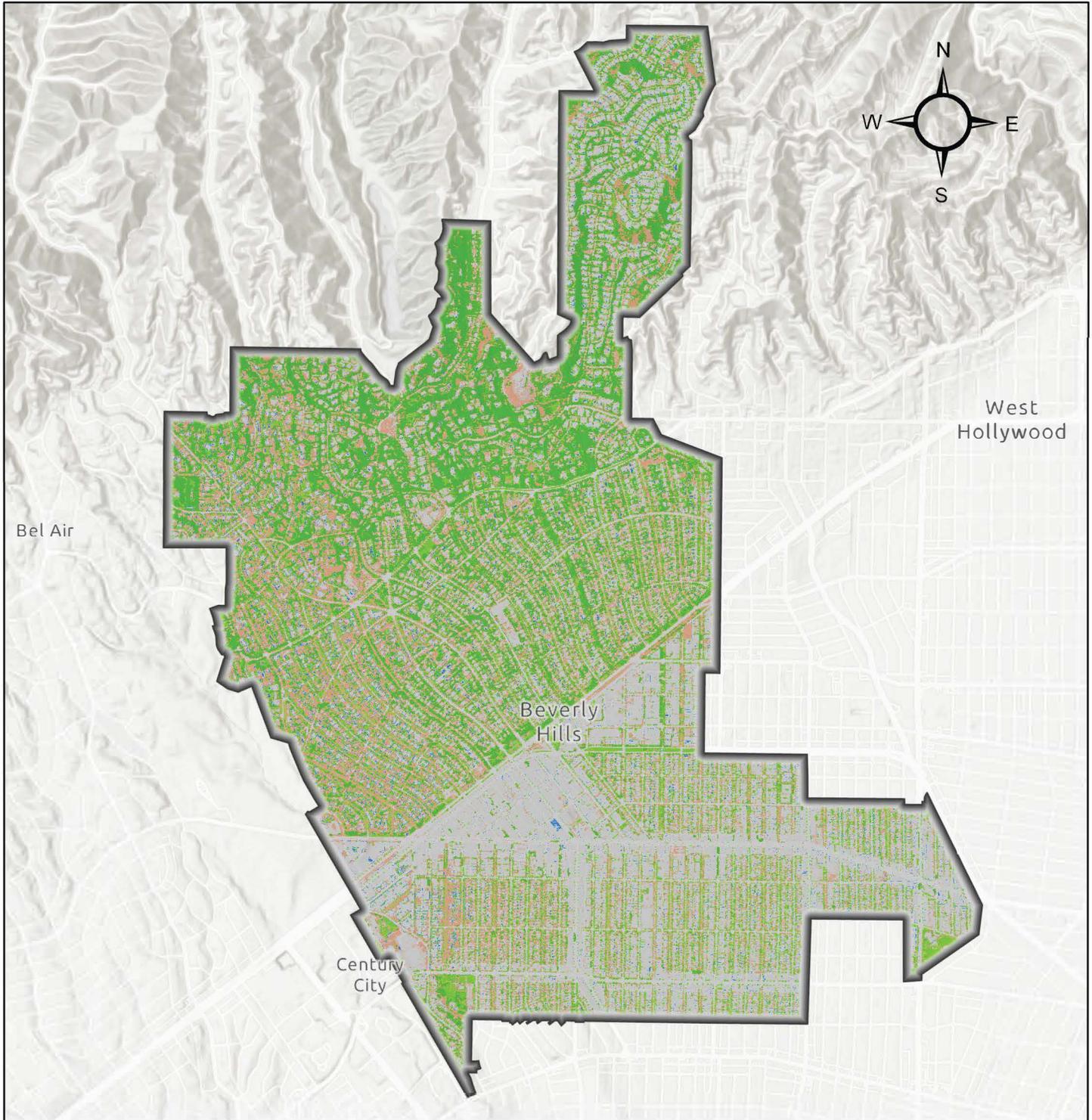
The xeriscaping conversion factor presented by Sovocool et al. was applied to the 96-acre-foot turf reduction. Based on this calculation, it was determined that Beverly Hills saved an estimated 234,255,000 gallons per square foot or 718-acre-feet (of water) over 11 years or 65-acre-feet per year.

The dollar savings from 2009-2020 were estimated by using a weighted average hundred cubic feet formula (HCF). The City of Beverly Hills uses a tier system for single-family households, multifamily households, and commercial properties. Beverly Hills comprises 36.54% single-family homes and 63% multifamily homes (Houseable, 2022). This analysis applies these percentages, the Tier 2 single-family household rate of \$7.23 and the Tier 1 multifamily household rate of \$4.98, to calculate an estimated weighted average water consumption rate of \$5.78/ HCF. Applying the 718 acre-feet (312,760 HCF) indicates that Beverly Hills residents would save an estimated \$1,807,000 from 2009-2020.

2009 Surface Features

City of Beverly Hills, California

Supervised, Pixel-Based Classification



0 0.25 0.5 1 Miles

Cartography by: Shane Clement

Sources: NAIP Imagery - Earth Explorer, City of Beverly Hills

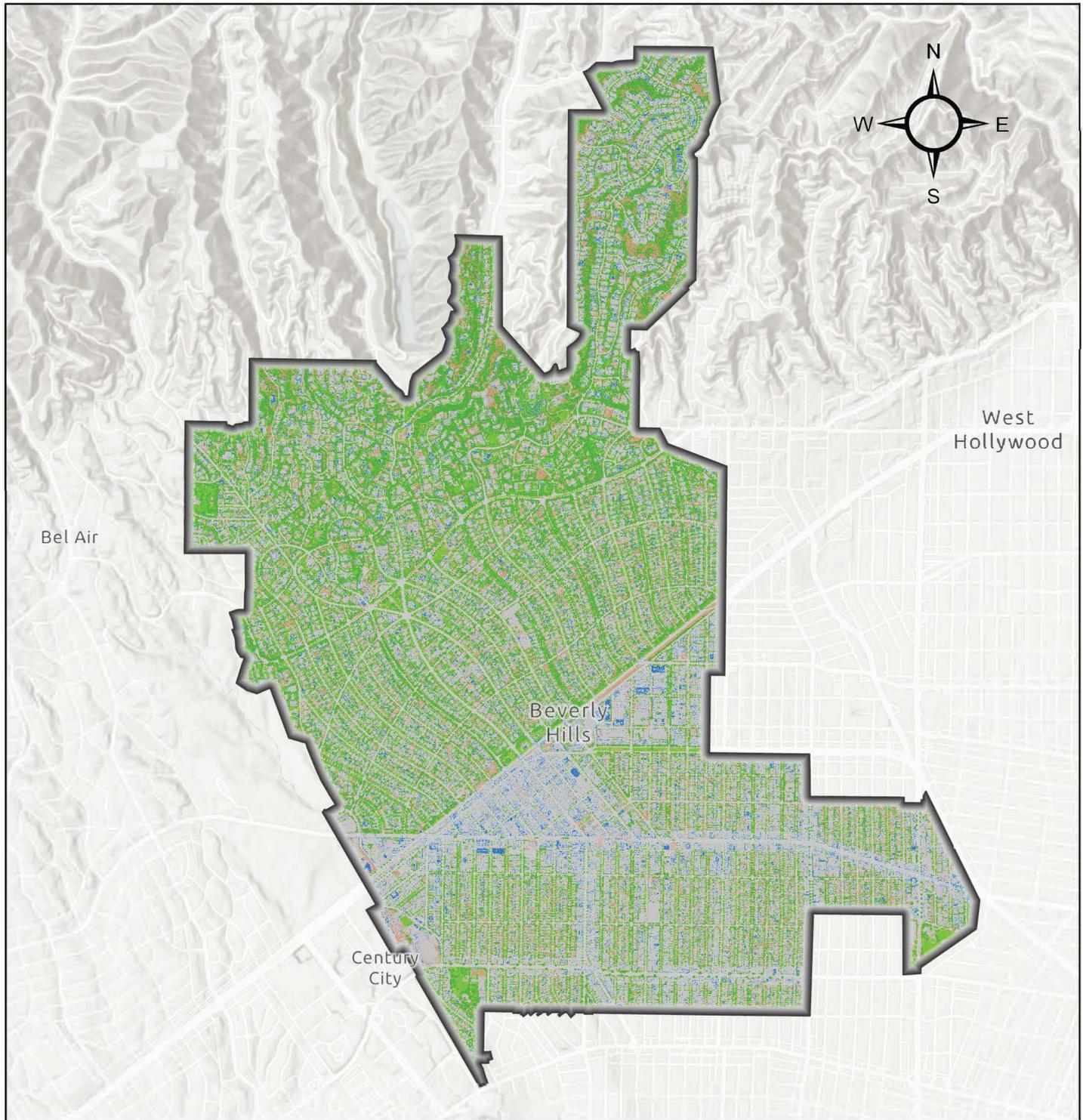
Surface Classifications

- Turf
- Trees
- Non-irrigated
- Impervious
- Water

2020 Surface Features

City of Beverly Hills, California

Supervised, Pixel-Based Classification



0 0.25 0.5 1 Miles
|-----|-----|-----|-----|-----|

Cartography by: Shane Clement

Sources: NAIP Imagery - Earth Explorer, City of Beverly Hills

Surface Classifications

- Turf
- Trees
- Non-irrigated
- Impervious
- Water

Discussion

The results indicating that there was a 27% reduction in turf area may be inaccurate for several reasons. First, seasonal differences in the collected NAIP images could present errors. For example, June is typically cloudier than May, which may present spectral differences in the images. The 2009 image is noticeably lower quality and contains more shadows than the 2020 image. This created challenges in accurately classifying the pixels. Secondly, the 2007-2009 drought may have biased the classifications in the 2009 image. If the grass was dry due to the drought, turf, trees, and non-irrigated areas could be misclassified, as noted in the methodology. Lastly, water was misclassified in impervious areas in the 2020 image. All these errors affected the accuracy of the classifications for the surface features and contribute to the low Kappa scores in the Confusion Matrix.

Sovocool et al. developed the turf-to-xeriscape conversion factor based on studies conducted in Southern Nevada. The study estimates that 55.8 gallons per square foot per year is the equivalent of 89.6 inches of precipitation per year. The Mediterranean climate in Beverly Hills is milder, with more rainfall than Southern Nevada. Las Vegas is a desert climate that receives an average annual rainfall of 4.5 inches (Sovocool et al., 2005). In comparison, Beverly Hills receives 15.7 inches of rainfall per year (Mini et al., 2014). The conversion factor is potentially lower in the Los Angeles area. Regardless, this conversion factor was applied due to the broad support in the academic community.

Furthermore, the water service area of Beverly Hills includes parts of West Hollywood and is excluded from this analysis. Therefore, those areas of West Hollywood included in Beverly Hills water consumption reports should be included in future studies when assessing water usage. Figure 1 shows the areas of West Hollywood served by the City of Beverly Hills.

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