Research Report

Estimating the Reversion Rate for the Turf Removal Rebate Program: 2020 Update

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Tasks Addressed in this Study

Task 1.1 Estimate Rate of Reversion from 2018 to 2020 for both 2014-2016 and 2016-2018 Rebate Participant cohorts

Task 1.2 Improve Confidence Rate of 2014-2016 Reversion cohort Study to 99%

Task 1.3 Analysis of Select Factors influencing Reversion Rate for 2014-2016 and 2016-2018 cohorts

1. Executive Summary

This study finds that there is a small, but consistent rate of parcels that replant natural turf to the same area in which they received a rebate from Metropolitan's Turf Removal Rebate Program. This study estimates that between 1% and 1.5% of rebate participants perform a major reversion every two years, defined as replanting turf on more than 50% of their rebate area. And only 0.6% of all rebate participants reverted 100% of their rebate during the study period. More than half of the parcels that perform a major reversion are also sold, supporting anecdotal evidence of real estate turf or that some new homeowners prefer turf.

It remains unclear why the remaining parcels that did not sell performed a major reversion. These parcels do not vary significantly across counties, in the age of the home or when they participated in the rebate program. They could be unhappy with the landscape conversion or possibly represent a demographic shift away from water conservation. But at just 25 of the more than 2,320 sampled parcels, this represents a very small group.

This study continues research on the impact of the Turf Removal Rebate Program over time. A previous study established that for every 100 rebate participants, a multiplier effect caused an

additional 132 parcels to convert to drought-tolerant landscaping[1]. So while there are participants reverting to natural turf, the rebate program continues to have a net positive affect on landscape conversion.

Full results are presented in Appendix A by cohort, period and county.

2. Data

2.1 Imagery

The U.S. Department of Agriculture's (USDA) National Agricultural Imagery Program (NAIP) aerial imagery was the primary data source of this study. Nationwide, multispectral imagery is collected during the late summer every two years since 2003[2]. Imagery is collected in four wavelengths – blue, green, red and near-infrared (NIR) allowing for the discrimination between artificial lawns and natural green turf. High-quality GeoTiffs are purchased from the USDA's Aerial Photography Field Office (APFO) Aerial Photography Field Office for 2014, 2016, 2018 and 2020[3]. The 2014 and 2016 imagery data are 1 square meter (m[2]) spatial resolution and 0.6 m[2] for 2018 and 2020 (Figure 1).
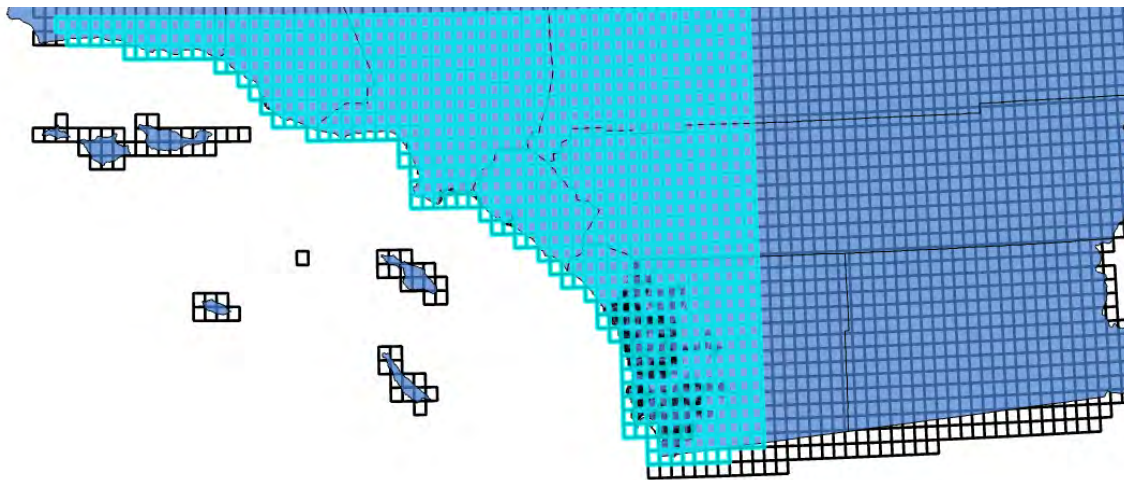

Figure 1. A U.S. Geological Survey (USGS) Application Programming Interface (API) used to order and download all NAIP imagery required is available at: https://m2m.cr.usgs.gov/api/docs/json/

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[1] Marx, A., 2020. "Quantifying the Multiplier Effect of Southern California's Turf Removal Rebate Program with Time-Series Aerial Imagery." *Journal of the American Water Resources Association*. Under Review.

[2] Grant, Simone, 2018. "National Agriculture Imagery Program: FY2019 Plan Update." GeoPlatform, Federal Geographic Data Committee. Accessed November 20, 2019. https://communities.geoplatform.gov/ngda-imagery/naip-fy2019-plan-update/.

[3] NAIP, 2018. U.S. National Agricultural Imagery Program. United States Department of Agriculture. https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/, accessed 20 November 2019.

2.2 *Rebate Participant Data*

Metropolitan provided two groups of rebate program participant data. Data for cohort 1 (rebate participants between 2014 and 2016) contained 64,513 program participant records, which included addresses, dates of turf conversion, and total amount of turf replaced[4]. Data for cohort 2 (rebate participants between 2016 and 2018) contained 9,226 program participant records including address, date of rebate, landscape contractor in some cases and total amount of turf replaced (Table 1). This was provided in two files[5]. After removing duplicate records there were 7,593 unique program participant records for cohort 2.

Parcels were geocoded, providing a latitude and longitude via the Bing Maps geocoder available at www.gpsvisualizer.com/geocoder. Rebate records are then spatially joined to a parcel database containing a polygon of their location. This processing of the data resulted in 85% of cohort 1 remaining for the study (54,901 participants) and 76% of cohort 2 remaining for the study (5,798). Rebate records that did not geocode had incomplete or erroneous addresses which could not be matched to addresses in the parcel database.

Because this study relies on time-series imagery analysis taken in the late summer every two years, only rebate participants who received the rebate after 1 August 2014 and before 1 April 2016 were analyzed for cohort 1. And only parcels who received the rebate after 1 August 2016 and before 1 April 2018 were sampled cohort 2. Of these remaining, 1.7% (cohort 1) and 0.99% (cohort 2) had either very small rebates (less than 100sqft) or very large rebates (greater than 10,000sqft) and were removed from the study population. Rebates under 100sqft were removed because landcover changes are too small to detect with NAIP imagery, and rebates greater than 10,000sqft were removed because they were large apartment complexes or other collections of properties recorded under a single parcel number.

Preprocessing Step	Cohort 1 (2014 to 2016)	Cohort 2 (2016 to 2018)
1) Total Records	64,513	9,226
2) Remaining after Removing Duplicates	N/A	7,593
3) Remaining after Geocoding	54,901	5,798
4) Remaining Records within Period	51,840	4,902
5) Records with Correct Rebate Area	50,952	4,848

Table 1. Processing data participant resulted in 79% of total unique records used for cohort 1 sampling and 64% of records used for cohort 2 sampling. Most unused records had incomplete or corrupted addresses.

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[4] MWD, 2018. Internal Dataset on Rebate Participants from 2012 to 2017.
[5] MWD, 2021. Internal Dataset on Rebate Participants from June 2016 to December 2018.

3. Approach

3.1 *Sampling Rebate Participants*

To estimate overall and by-county reversion rates for both cohorts at a 99% confidence level, a stratified random sampling was conducted of the 50,952 and 4,848 participants respectively. The formula used to determine the number of samples per county is an estimate of a proportion with a finite population (Equation 1)[6]. In Los Angeles County, cohort 2 had 2,406 rebate participants in the study population (Appendix A). With an expected proportion of 10% reversion and a 5% margin of error, 219 parcels were required to be analyzed (Table 2) (Figure 2)[7].

$$n_0 = \frac{\hat{p} \times (1 - \hat{p}) \times z^2}{MOE^2} \qquad n_0 = \frac{0.1 \times 0.9 \times 2.58^2}{0.05^2}$$

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \qquad n = \frac{240}{1 + \frac{240}{2,406}}$$

$$= 218.231 \to 219$$

Equation 2. The sampling required for each county is an estimate of a proportion with a finite population where n_0 is the sample size, **p** is the sample proportion, **z** is found using a z-score table, **MOE** is margin of error, **n** is sample size and **N** is population size (left side). In the case of Los Angeles, cohort 2, with 2,406 rebate participants, 219 samples are required (right side).

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[6] Bartlett, James E. "II, Kotrlik, JW, & Higgins, CC, 2001. Organizational research: Determining appropriate sample size in survey research." *Information Technology, Learning, and Performance Journal* 19.1 (2001): 43-50.

[7] The expected proportion of 10% and margin of error of 5% were chosen to guarantee a robust sample size.
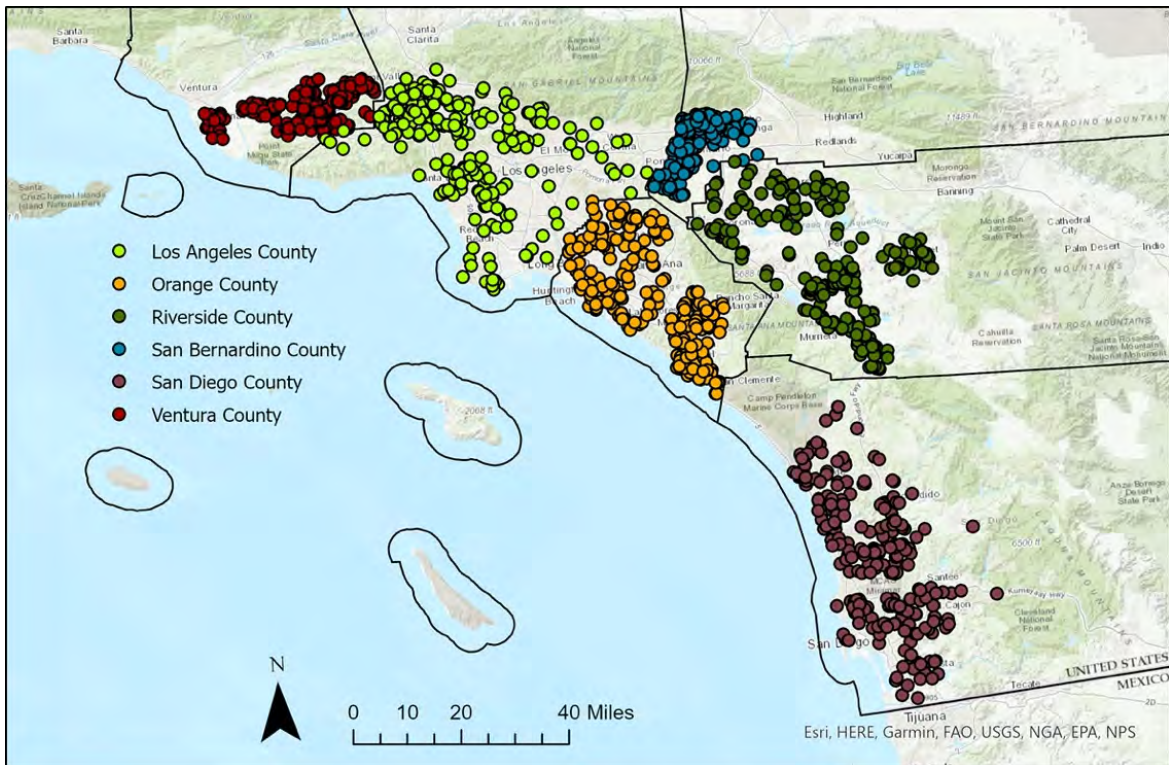
Figure 2. Using stratified random sampling, 1,347 rebate participants were analyzed from across Metropolitan's six counties to detect if they had replanted natural turf on areas in which they had received a rebate for cohort 1 (shown here). An additional 973 rebate participants were analyzed for cohort 2.

	Cohort 1		Cohort 2	
	Population	Samples for 99%	Population	Samples for 99%
Los Angeles	28,442	238	2,406	219
Orange	5,030	230	666	177
Riverside	4,037	227	487	161
San Bernardino	943	192	167	99
San Diego	8,850	234	843	187
Ventura	3,650	226	279	130
	50,952	1,347	4,848	973

Table 2. A total of 1,347 and 973 samples were analyzed from the study population for cohorts 1 and 2 respectively.

3.2 *Imagery Analysis*

For samples across both cohorts, the parcel's boundary as well as the 2014, 2016, 2018 and 2020 NAIP imagery was loaded in a geographic information system (GIS) platform. For cohort 1, visual analysis was conducted on the multispectral imagery (near-infrared, red and green) to identify 1) where turf was removed for the rebate between 2014 and 2016 and 2) if that same area was replanted during the next period (Figure 3). A second period from 2018 to 2020 was also analyzed for a reversion cohort 1. For cohort 2, the area of rebate was detected between 2016 and 2018, and a reversion was recorded if found between the 2018 and 2020 NAIP images.

NAIP is the primary imagery source because all imagery is taken within a few weeks over the entire study area every two years and because the near-infrared band provides the ability to detect artificial from natural turf. In cases where trees, vehicles or other objects obscured the NAIP imagery, a combination of Google Street View and high-resolution imagery in Google Earth is also used. If the location of turf removed in the rebate could not be identified or other obstructions prevent analysis, the parcel was removed as a sample and replaced with another randomly selected parcel for that county.
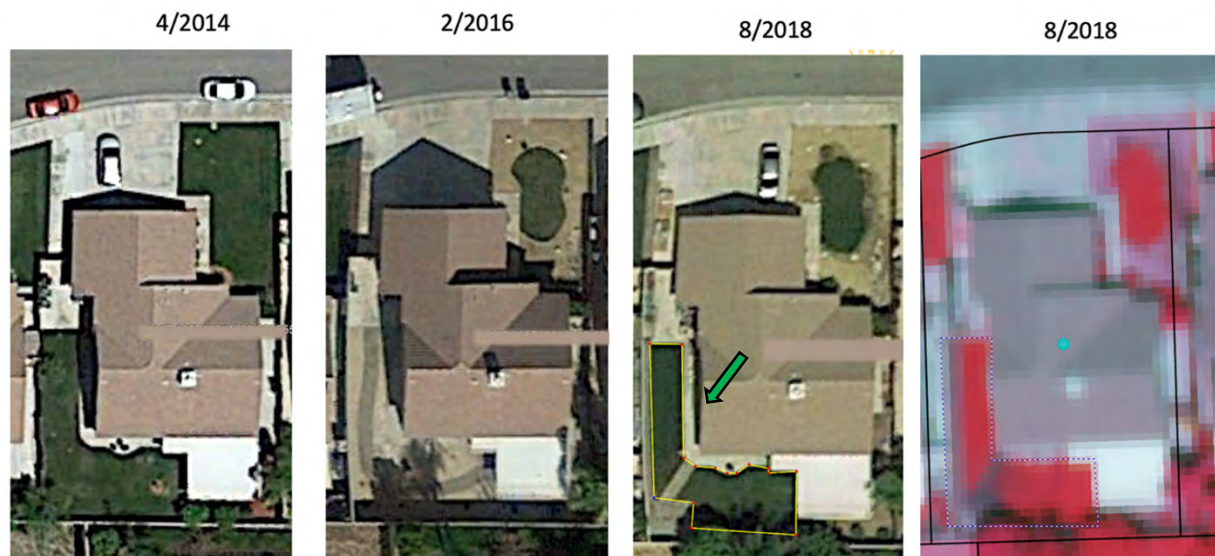

Figure 3. A combination of multispectral NAIP imagery, historic high-resolution imagery and Google Street View is used to detect and measure how much area a parcel reverted. In this case, a participant received a rebate for 1,176 sqft as a part of cohort 1 and converted their front and back yard (second image from left). By 2018 they reverted 800 sqft (68%) of their rebate highlighted with the green arrow and outlined in yellow (third image from left). Multispectral imagery (far right) confirmed that this was not artificial turf.

4. Results

4.1 *Reversions by Participant*

This study finds that 88 out of the 2,326 samples performed some kind reversion. These reversions were split up relatively evenly between cohort 1's first period (2.5% reversion rate), cohort 1's second period (2.7% reversion rate) and cohort 2 (4.2% reversion rate) (Appendix A). The reversion rates vary by county slightly, from as low as 0.4% for Riverside and San Diego in cohort 1's second period, to as high as 6.4% for Los Angeles County for cohort 2 (Appendix A).
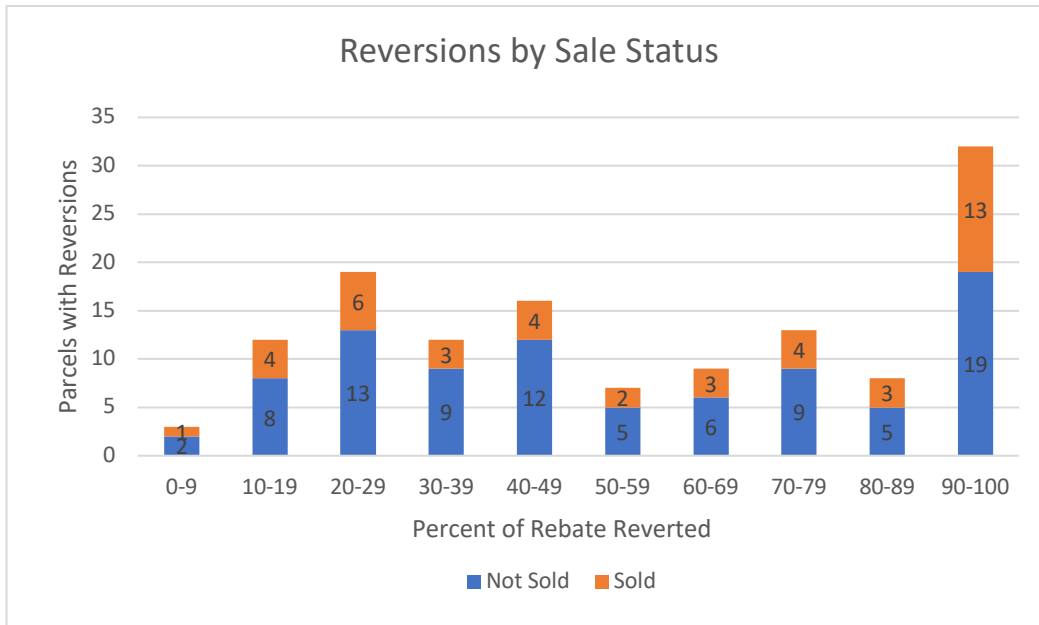

Figure 4. Of the 88 reversions in the study, 44 reverted less than 50% of their rebate. 19 reversions (22%) were for at least 90% of their rebate. Of these 19 near total reverters, 13 (68%) also changed ownership (See Section 5.3).

Reversions ranged from areas as small as 70 sqft to as much as 3700 sqft. This corresponds to between 8% and 100% of the participant's rebate area (Figure 4). 44 of the 88 reversions were for 50% or more of their rebate, with the highest number of reversions in the 90-100% bracket (22%). The average reversion by percent of rebate was similar across the cohorts and periods, ranging from 60% for cohort 1 to 53% for cohort 1, period 2 (Table 3).

	Average	Standard Deviation
Cohort 1, Period 1	60.4%	29.1%
Cohort 1, Period 2	53.6%	31.8%
Cohort 2	55.5%	29.4%

Table 3. Percent of Rebate Reverted by Cohort and Period

44 of the 2,326 sample parcels (1.9%) performed a major reversion. 16 of these were from cohort 1, period 1 (1.2%), and 13 were from cohort 1, period 2 (1.0%). The remaining 15 were from cohort 2 (1.5%).

Oct 2016   Dec 2017   Aug 2019

Aug 2015

Figure 5. 'Minor Reverter'. Between October 2016 and December 2017 this parcel converted their front lawn as part of their 1,500 sqft rebate. Imagery from Aug 2019 shows that 360 sqft reverted by Aug 2019 (24%). This was confirmed as natural turf with multispectral imagery and this property did not sell during the study period. Google Street View is unavailable for this parcel after the conversion, but the area of the rebate (outlined in red) and approximate area of the reversion (outlined in yellow) are indicated in the bottom panel.
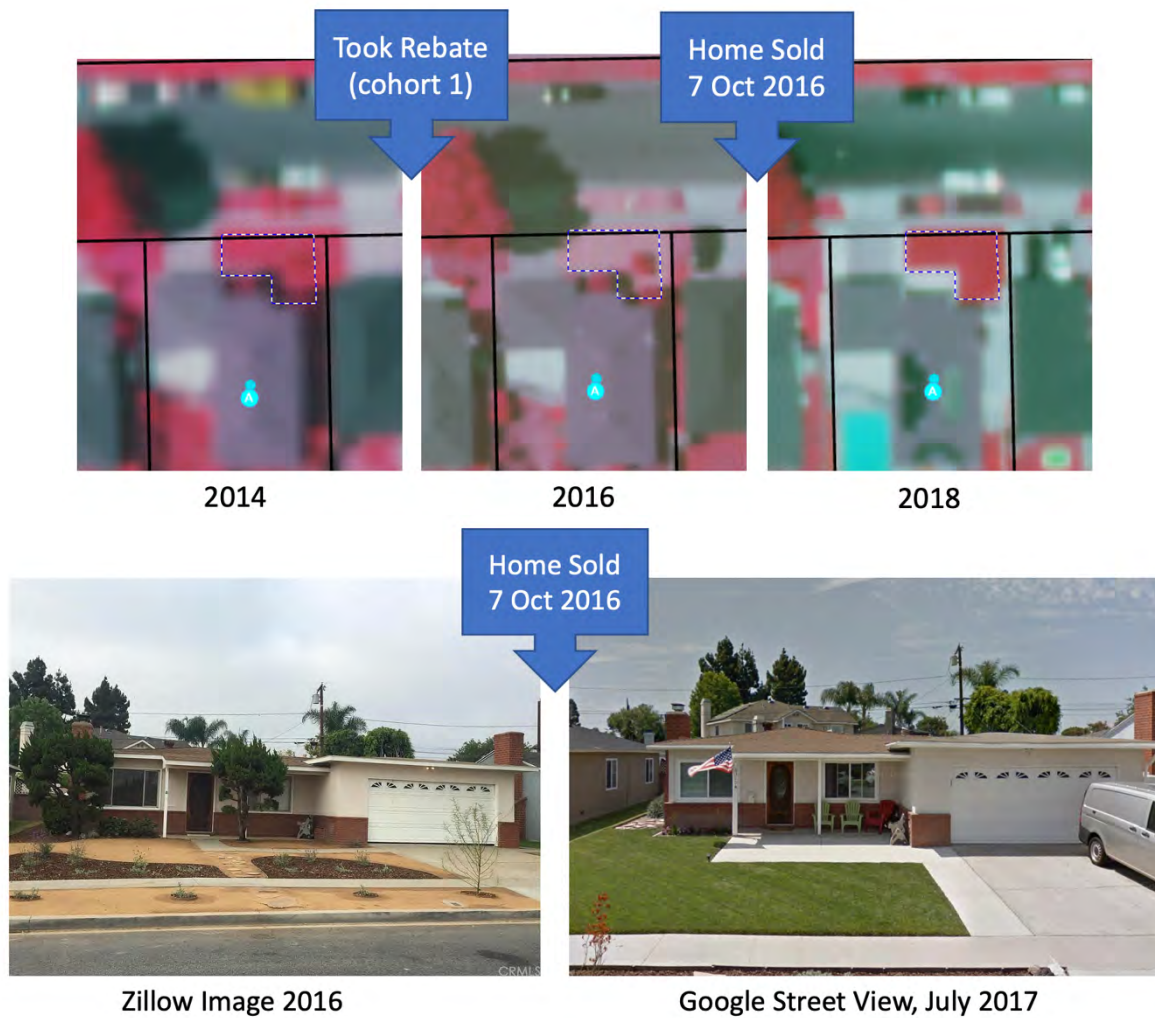
Figure 6. 'New Homeowner'. Multispectral imagery (top panel) and Google Street View (bottom panel) show a parcel in Los Angeles that converted their front lawn as part of cohort 1, but then reverted within two years. Because the reversion coincides with change in home ownership, either the outgoing owner reverted to help sell the property (real estate turf) or the new homeowner replaced the drought tolerate landscaping to natural turf. Note the new pool in the top right panel is not recorded as a reversion – only natural turf replanted on the area in which the rebate was taken.
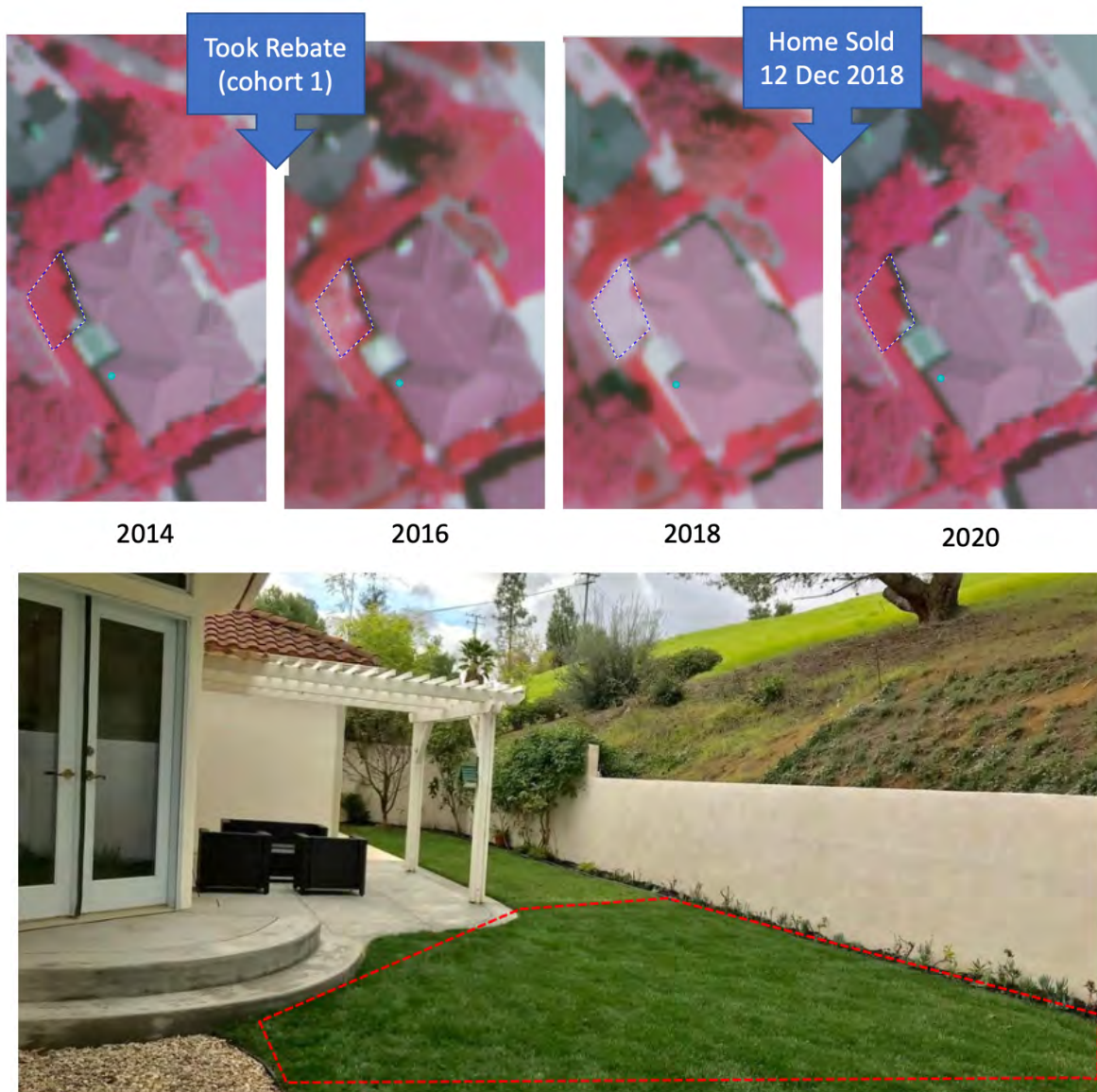
Figure 7. 'Real Estate Turf'. This parcel in Thousand Oaks, Ventura converted a significant portion of their backyard turf (520 sqft) (highlighted by dashed area in top figures) between 2014 and 2016 as part of cohort 1. They maintained this through 2018, but by 2020 had reverted 465 sqft (89%) of their rebate. Records show this parcel was sold in December 2018 and real estate photos of the parcel at this time show new sod (outlined by red dash in bottom panel).

Figure 8. 'Unhappy Converter'. While this parcel in Los Angeles converted both the front and back lawns between 2016 and 2018, they only received a rebate for the back lawn (2,295 sqft). As of Fall 2020, they kept the drought tolerate landscaping in the front lawn but reverted most of their backyard (2,025 sqft or 88%) outlined in red. This parcel did not change ownership during this time and represents the third group of major reverters that did not sell but still performed a major reversion.

4.2 *Examples of Reversions*

Parcels that performed reversions tended to fall into three groups. The most common were parcels that reverted a contiguous, small section of their rebate (example shown in Figure 5). Figures 6 and 7 show the next most common group – those major reversions that coincided with a home sale. Figure 8 shows the last group – parcels that converted a major portion of their rebate but did not sell their home.

4.3 *Estimation of total Area reverted*

For reverters of each county, the total area of their turf rebate and the total area of their rebate that they reverted was calculated (Appendix B). For example, the eight parcels that reverted in Los Angeles County in cohort 1, period 1 had claimed a total rebate of 8,613 sqft. Imagery analysis showed that 6,277 rebates reverted to turf, or 72.9%. With an estimated number of 956 reverters across the study population of Los Angeles, and an average rebate size of 1,443, we can estimate the total area of reversion for the cohort 1 study population to be 1,005,396 sqft reverted between 2016 and 2018. Combining the two cohorts and two time periods (Table 3) shows an estimated 2.5 million sqft reverted. This represents 2.9% of the total rebate area of more than 85 million sqft.

Sample	total rebate	est. Reverted
cohort 1, time 1	78,707,700	1,292,113
cohort 1, time 2		1,031,774
cohort 2, time 1	6,451,105	133,739
	85,158,805	2,457,626

Table 3. The less than 2.5 million sqft of area reverted across the study population represents a small fraction of the total area that received a rebate (2.9%).

5. Analysis of Factors influencing Reversions

5.1 *Variables Analyzed*

Task 1.3 performs an analysis of how 1) age of home, 2) if the property was sold and 3) landscaping contractor effects participants reverting. Data for age of home and property sale status was collected from Parcel Quest (parcelquest.com). This fee-based site provides data updated daily on these and other parcel attributes. Parcel Quest did not return either sales and/or age data for 144 parcels in cohort 1 and 77 in cohort 2. Redfin and Zillow were then used to manually record age and the last sale date for these parcels with missing information. Along with Parcel Quest, these websites found data for 2320 of the 2326 samples in the study. An additional six properties were removed from the regression because their date-built field was later than 2015, bringing the regression samples to 2,314. Landscape contractor was not used in the analysis because of lack of

data. No landscape contractor data was available for cohort 1 and only 2.1% landscape contractor data was available for cohort 2.

The age of the property was a scale variable, ranging in years built from 1899 to 2015 and a mean of 1976. Property sale status was treated as a nominal variable (1=sold, or 0=not sold). Sale status was determined if there was a sale date after the rebate award date. Of the 2314 samples, 634 (27%) had been sold after the rebate date.

5.2 Regression Analysis

A logistic regression was performed to ascertain the effects of sale status and year built on the likelihood that parcels did a major reversion, defined here as reverting 50% or more of their rebate

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	418.411	.011	.063

Table 4. While statistically significant, Year Built and Sale Status only explain 6.3% of the variance of why parcels revert.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1a	YRBLT	-.018	.006	7.572	1	.006	.982	.970	.995
	Sold(1)	1.278	.306	17.415	1	.000	3.590	1.970	6.544
	Constant	30.501	12.682	5.784	1	.016	17643552721961.610		

a. Variable(s) entered on step 1: YRBLT, Sold.

Table 5. Parcels that were sold were 3.59 times more likely to revert than properties that did not sale. Additionally, newer properties were slightly less likely to do a major reversion.

(Table 4). The logistic regression model was statistically significant, $p < .0005$, with both variables (sale status and year built) included in the model. The model explained 6.3% (Nagelkerke R^2) of the variance in major reversions (Table 4). Parcels that were sold were 3.6 times more likely to revert than properties that did not sell (Table 5). Increasing build year was associated with a small reduction in the likelihood of doing a major reversion. In other words, newer properties were slightly less likely to do a major reversion.

6. Discussion and Conclusion

5.1 Discussion

This research establishes a small but consistent pattern of reversions for rebate participants. An estimated 1.2% of cohort 1 performed a major reversion in the first two years after their rebate, we

saw an additional a group of parcels from this study sample perform a major reversion in the second period (1.0%). This doesn't seem to be a result of how the rebate program was designed because those that participated in cohort 1's rebate (1 August 2014 to 1 April 2016) had, and continue to have, a major reversion rate like cohort 2 (1.5%) (1 August 2017 to 1 April 2019). Cohort 2 included minimum plant coverages, sustainability elements and other design features.   These additional requirements did not seem to impact the reversion rate for cohort 2.

The regression analysis reveals that this is in part a function of properties changing hands with parcels sold being 3.6 times more likely to revert than properties that did not sell. However, using the age of the home and if the property sold after the rebate can only predict 6.3% of parcels that will perform a major reversion, with property sold having most of the predicative power. This is because there were 642 parcels in the 2,326 samples that were sold without reversion. So, while we can't predict what parcels will revert from their sale status, we can say that among those that do a major reversion, its 3.6 times more likely that they were also sold.

In other words, of the 44 major reversions 26 (58%) also sold after their rebate was awarded. This supports the notion of a 'real estate' lawn, where a seller will place turf to appeal to more buyers. Or it could also be that new buyers didn't like the drought-tolerate landscaping and chose to replace it with turf.

What is left is a very small percent of parcels, which didn't sell, that took the rebate but still did a major reversion. In our study, of the 2,326 parcels, 19 parcels (0.8%) didn't sell and still did a major reversion. And of these 19, four replaced 100% of their rebate. It's a small percent but likely represents those that were unhappy with how their drought-tolerate landscaping was installed, or those who feel the drought is over and don't feel the need to conserve water. Additional research is needed to assess why these rebate participants reverted.

5.2 Future Study

In response, we recommend a study to analyze the residential landcover trends in Metropolitan's service area from 2014 to 2020. Such research will reduce uncertainty by understanding trends in customer behavior. Using imagery from 2014 to 2020, the research would analyze the landcover of a representative selection of parcels over time, and thereby also the parcel owner's conservation attitudes. Specifically, it will calculate the amount of irrigated turf on their parcel and track how those change over time. This study will utilize the California Irrigable Landscape Algorithm (CILA)[8] which has been evaluated by the California Department of Water

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[8]   California Data Collaborative 2017 CaDC Statewide Efficiency Explorer Methodology (http://californiadatacollaborative. org).

Resources and found to have an 89% accuracy rate for error—adjusted landscape estimates (Olofsson et al 2013)[9].

5.3 Conclusion

This study establishes a reversion rate for two cohorts of participants in Metropolitan's Turf Removal Rebate Program. The approach analyzed time-series, multispectral aerial imagery to identify if and how much of the rebate was reverted or replanted with turf. This study finds that there is a small and consistent rate of parcels reverting more than 50% of their rebate - between 1% and 1.5% every two years. Regression analysis shows that home sales are a significant factor in parcels performing a major reversion, supporting anecdotal evidence that turf reversion is often done by new homeowners or during the sale process. Over the four-year period, less than 1% of all parcels performed a major reversion without a home sale representing a small, but possible shift in demographic attitudes toward water conservation.

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[9] Olofsson P, Foody G M, Stehman S V and Woodcock C E 2013. Making better use of accuracy data in land change studies: estimating accuracy and area and quantifying uncertainty using stratified estimation Remote Sens. Environ. 129 122–31.

Appendix A: Participant reversions by cohort, period and county.

2014-2016 Cohort; First Time Period						
County	Participants	Sample (99%)	Reversion Cases	Reversion Case %		Est. Number of Rev
Los Angeles	28,442	238	8	3.4%	->	956
Orange	5,030	230	3	1.3%	->	66
Riverside	4,037	227	5	2.2%	->	89
San Bernardino	943	192	6	3.1%	->	29
San Diego	8,850	234	2	0.9%	->	76
Ventura	3,650	226	3	1.3%	->	48
Total	50,952	1,347	27			1,264

2014-2016 Cohort; Second Time Period						
County	Participants	Sample (99%)	Reversion Cases	Reversion Case %		Est. Number of Rev
Los Angeles	28,442	238	9	3.8%	->	1,076
Orange	5,030	230	2	0.9%	->	44
Riverside	4,037	227	1	0.4%	->	18
San Bernardino	943	192	6	3.1%	->	29
San Diego	8,850	234	1	0.4%	->	38
Ventura	3,650	226	10	4.4%	->	162
Total	50,952	1,347	29			1,366

2016-2018 Cohort						
County	Participants	Sample (99%)	Reversion Cases	Reversion Case %		Est. Number of Rev
Los Angeles	2,406	219	14	6.4%	->	154
Orange	666	177	4	2.3%	->	15
Riverside	487	161	4	2.5%	->	12
San Bernardino	167	99	4	4.0%	->	7
San Diego	843	187	2	1.1%	->	9
Ventura	279	130	5	3.8%	->	11
Total	4,848	973	33			207

Appendix B: Area of Reversions by cohort, period and county.

Cohort 1, Period 1

County	Sample					Study Population Estimate				
	Sample (99%)	Reversion Cases	Turf Rebate (SQFT)	Turf Reverted (SQFT)	Turf Reverted %	Est. Reverters	Ave Turf Rebate (SQFT)	Ave. Reverted (SQFT)	Total Turf Rebate (SQFT)	Est. Area Reverted (SQFT)
Los Angeles	238	8	8,613	6,277	72.9%	956	1,443	785	41,041,806	1,005,396
Orange	230	3	15,114	7,978	52.8%	66	1,713	2659	8,616,390	59,324
Riverside	227	5	5,386	3,556	66.0%	89	1,771	711	7,149,527	103,972
San Bernardino	192	6	14,621	5,001	34.2%	29	2,139	834	2,017,077	21,560
San Diego	234	2	1,008	558	55.4%	76	1,548	279	13,699,800	64,819
Ventura	226	3	6,437	2,905	45.1%	48	1,694	968	6,183,100	37,041
Total									78,707,700	1,292,113

Cohort 1, Period 2

County	Sample					Study Population Estimate				
	Sample (99%)	Reversion Cases	Turf Rebate (SQFT)	Turf Reverted (SQFT)	Turf Reverted %	Est. Reverters	Ave Turf Rebate (SQFT)	Ave. Reverted (SQFT)	Total Turf Rebate (SQFT)	Est. Area Reverted (SQFT)
Los Angeles	238	9	12,847	6,663	51.9%	1,076	1,443	740	41,041,806	804,934
Orange	230	2	3,898	1,625	41.7%	44	1,713	813	8,616,390	31,235
Riverside	227	1	1,222	850	69.6%	18	1,771	850	7,149,527	21,908
San Bernardino	192	6	9,979	4,156	41.6%	29	2,139	693	2,017,077	26,252
San Diego	234	1	540	540	100.0%	38	1,548	540	13,699,800	58,546
Ventura	226	10	17,991	5,846	32.5%	162	1,694	585	6,183,100	88,900
Total									78,707,700	1,031,774

Cohort 2

County	Sample					Study Population Estimate				
	Sample (99%)	Reversion Cases	Turf Rebate (SQFT)	Turf Reverted (SQFT)	Turf Reverted %	Est. Reverters	Ave Turf Rebate (SQFT)	Ave. Reverted (SQFT)	Total Turf Rebate (SQFT)	Est. Area Reverted (SQFT)
Los Angeles	219	14	19,584	9,449	48.2%	154	1,312	675	3,157,298	97,383
Orange	177	4	5,999	3,403	56.7%	15	852	851	567,432	7,274
Riverside	161	4	9,403	4,813	51.2%	12	1,578	1203	768,486	9,773
San Bernardino	99	4	7,475	3,300	44.1%	7	1,638	825	273,546	4,879
San Diego	187	2	3,670	2,290	62.4%	9	1,510	1145	1,272,930	8,495
Ventura	130	5	12,122	4,546	37.5%	11	1,475	909	411,413	5,934
Total									6,451,105	133,739