MAINSTREAMING SUSTAINABLE LANDSCAPES IN THE EAST BAY MUNICIPAL UTILITY DISTRICT

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the requirements for
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In

Geography: Resource Management and Environmental Planning

by

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San Francisco, California

May 2019

CERTIFICATION OF APPROVAL

I certify that I have read Mainstreaming Sustainable Landscapes in the East Bay Municipal Utility District by Jessica Anne Woodard, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Arts in Geography: Resource Management and Environmental Planning at San Francisco State University.

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2019

Water suppliers in arid and Mediterranean regions of the United States have invested heavily in incentive programs to replace water-thirsty lawn with climate-appropriate plants and landscapes. These "sustainable landscapes" can thrive on a fraction of the water required by lawns and reap water savings that increase with time, representing an important opportunity for water conservation. Yet even the most successful lawn conversion program cannot expect to replace the largest irrigated crop in the United States with rebated lawn conversions alone. Underlying the design of and heavy investment in lawn conversion programs is an ambitious end-goal: to transform the landscaping market away from lawns, and mainstream sustainable landscapes.

Using a market transformation framework, this study investigates the geographic variation of reported attitudes (aesthetic preference and willingness to replace lawn) and lawn conversion rates, as indicators of landscape transformation, across the East Bay Municipal Utility District (EBMUD). The difference between 2014 and 2017 customer acceptance and lawn conversion rates show growth during drought years, especially in cities with higher rebates participation rates. This research provides a method evaluate landscape transformation indicators to develop strategies to hasten the adoption of region-wide sustainable landscaping.

I certify that the Abstract is a correct representation of the content of this thesis.

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Chair, Thesis Committee Date

PREFACE AND/OR ACKNOWLEDGEMENTS

Thank you to my advisors, Nancy and Jerry; without their easy patience and warm support, this project would have stayed buried in the dusty archives of my GIS folders. Once I listened to their advice, things started to fall in place. I owe a huge thanks to all my friends and colleagues in water conservation, not only for generously allowing me to use their data, but for trusting that this year, for real, I would finish – and giving me the time off to wrap things up. My friends, family and sister-like creatures have been wonderfully kind, especially considering that my Geography master's is *fully* responsible for an overly enthusiastic curiosity surrounding California native plants, making me a very distracted companion in our increasingly (I hope) species-rich urban neighborhoods. Finally, thanks to my mom, who typed when my hands hurt, and who – entirely without me catching on until recently, has had everything to do with my love for native and water-wise gardens, and my respect for the gardeners who tend them.

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Introduction

The problem with lawns and drought

Grass lawns are the largest irrigated crop in the United States (Milesi et al. 2005) and dominate our urban and suburban environments completely (Nassauer, Wang, and Dayrell 2009). More suited to humid climates, in California's arid and Mediterranean climate turf grass demands 70% more water than climate-appropriate plants (Hayden et al. 2015), and inefficient irrigation practices lead to an additional 50% water loss (Alliance for Water Efficiency 2018; Glenn et al. 2015). The issue is not limited to the United States: globally, residential gardens represent 70% of urban water demand, primarily due to the global expansion of a preference for lawns and ornamental plants with high water requirements (Reyes-Paecke et al. 2019). Irrigated gardens and green spaces provide ecosystem services important for human health and quality of life, but if we examine the impact of lawns, we find that the superficial benefits of the green spaces they create are outbalanced by their harmful effects. The amount of carbon released through a lawn's installation and maintenance exceeds a lawn's potential carbon sequestration by as much as 100%; urban lawns thus act as net carbon emitters (Gu et al. 2015): in fact, "we could reduce far more greenhouse gases by paving over lawn with concrete – with concrete!" (Sutton 2013). Besides carbon emissions, lawn maintenance practices are associated with numerous negative environmental impacts: the use of lawn chemicals and over-fertilization pollutes local watersheds, while the heavily maintained

monoculture of lawns negatively impact local pollinator biodiversity (Burr, Hall, and Schaeg 2018).

In California, water supplies are under pressure from climate change which is triggering severe droughts and hotter and drier summers (Williams 2015), and from population growth and development, which is disproportionally faster in hotter inland counties, where turf requires much more water than in cooler coastal communities (Hanak and Davis 2006). The issues inherent to maintaining lawns become especially noticeable during water shortages; considered discretionary to direct human health, landscapes become subject to drastic mandatory reductions. California recently experienced its longest and most severe drought on record, from 2011-2017. When the Governor declared the first-ever mandatory reduction in potable water usage throughout the state, Californians were very responsive, meeting or exceeding mandated drought reduction targets in most regions (Park et al. 2015). Green lawns and runoff from wasteful irrigation became a lightning rod for negative attention for water-conscious Californians, and drought messaging campaigns played a part in the transmission of this idea: for example, “Brown is the New Green” was a marketing campaign adopted by several water agencies (Hogue and Pincetl 2015). However, letting lawns die was not without consequences: a large number of trees died in residential areas, unprepared for deficit irrigation on top of stressful drought conditions (Save Our Water, n.d.). The negative impact of lawn maintenance practices does not prevent the benefits of urban green spaces.

Sustainable landscapes

Urban areas can still conserve water while increasing vegetation cover. Water agencies have invested heavily in incentive programs to do just this, replace thirsty lawns with climate-appropriate plants and landscapes. Water-conserving landscapes provide direct water savings that persist or even increase with time, especially compared to turf lawns. The Alliance for Water Efficiency (AWE) measured detectable water savings across 10 different utilities and types of sustainable landscaping programs across diverse geographies, with a 7-39% reduction in water use average annual savings and peak demand reduction. Furthermore, they confirmed that savings increased over time, once landscapes were well-established. Trees and shrubs can access deeper soil moisture than turf grass with their extensive root systems and typically need less water to maintain plant health, thus reducing overall irrigation needs (Reyes-Paecke et al. 2019). When suited to the local climate, these landscapes support local biodiversity and human health by providing ecosystem services such as temperature regulation, carbon sequestration, and urban runoff regulation (Cook, Hall, and Larson 2012). Living landscapes are not only important for the people and local ecosystems - we also know that green space, and vegetation cover are important climate change adaptation by providing temperature regulation, carbon sequestration, and urban runoff regulation. By modifying existing irrigation, and selecting a well-designed mix of shading trees, shrubs, and flowers to improve soil water retention (Litvak and Pataki 2016), urban areas can increase green spaces using a fraction of the water needed for lawn. The investment by water agencies to replace lawn with these kinds of landscapes is in line with necessary climate adaptation:

"in an era of worsening water scarcity and droughts, we can no longer afford to promote traditional high-water use landscape designs that don't support resilient communities or reflect changing climates" (Alliance for Water Efficiency 2018).

One of the greatest barriers to transition is that people are being asked to resist the status quo of the water-intensive landscape. This means not only changing an existing landscape, a labor-intensive project by itself, but also changing deeply ingrained sentiments and connotations that might be attached to lawns: the smell of grass, childhood memories, the sound the lawnmower, etc. We also face resistance from the cultural status symbol of the lawn an indicator of wealth and stability, which are values strongly reinforced by neighborhood peer pressure. Neighborhood norms can be so influential that they override personal environmental values and aesthetics preferences in some places (Burr, Hall, and Schaeg 2018). For this reason, Nassauer et al. 2009 recommend that individuals inclined to introduce ecologically beneficial front yard designs should enlist a neighbor on the block to create a threshold of "cultural sustainability". Lawn conversion rebate programs have a strong challenger in social norms, but also a potential ally: just one rebated lawn conversion on a block leads to a 7-fold increase in the likelihood of more (Torpey 2017). This is especially valuable when considering that by some estimates, lawn conversion programs are reaching only 1.4-2% of existing lawns (Navigant Consulting 2015b; Torpey 2017).

"Landscape transformation" framework

To support and help coordinate efforts to make sustainable landscapes mainstream, water utilities and their partners, the Alliance for Water Efficiency (AWE) and California Water Efficiency Partnership (CWEP), have borrowed from the economic theory of market transformation to create a working "landscape transformation" framework. The goal of landscape transformation is to strategically transition customers (and suppliers) from a partiality for traditional high-water use landscape designs and products to a preference for sustainable landscapes. While traditional water-conservation incentive programs focus on accelerating a market by subsidizing the cost of a desired behavior or sustainable technology, they typically only reach early adopters and imitators, falling short of complete market saturation (Figure 1).

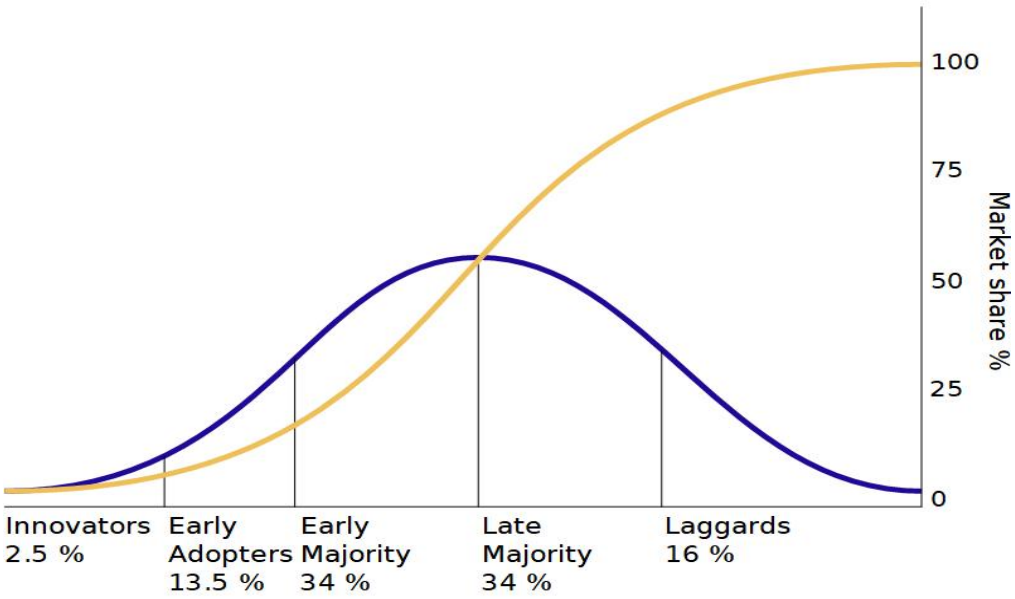


Figure 1. Diffusion of innovations. With successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level (Rogers 2005).

By contrast, landscape transformation is a strategic process to intervene in a market, create lasting change by removing barriers, and accelerate the adoption of sustainable landscape as a matter of standard practice (Alliance for Water Efficiency 2018; Navigant Consulting 2015a). Once comprehensive landscape transformation becomes an explicit goal for a water conservation program, strategies that correspond to specific regional barriers can be more easily incorporated. For example, a landscape design element of a lawn conversion rebate program may not result in significant additional direct water savings for an individual front yard, but it serves to market attractive and functional sustainable landscapes in that neighborhood. The extra investment in landscape design is more likely to inspire spillover lawn conversions than an unattractive and poorly designed project that saves water, but also runs the risk of stigmatizing water-conserving landscapes (Seapy 2015).

Quantifying landscape transformation success as conservation program metric is a daunting challenge. To investigate the multiplier/spillover effect in their service area, Irvine Ranch Water District staff drove down streets identifying those drought-friendly gardens, conducted phone surveys, online surveys, and analyzed satellite and street-level imagery. While the results were valuable and demonstrated cost-effectiveness in their service area -- customers were 5 times more likely to convert without a rebate -- the evaluation process was labor intensive (Irvine Ranch Water District 2016). Another option for evaluating landscape transformation is to do a landcover change analysis with infrared or LIDAR imagery that captures turf and other irrigated areas at the residential lot scale and re-evaluate at different time scales. However, to capture landscape change at

the residential scale, the imagery and analysis needs to be flown at intervals, and to-date, this is still cost prohibitive. There is a clear need for a cost-effective way to evaluate landscape transformation.

Method

This research examines the current state of "landscape transformation" in the East Bay Municipal Utility District (EBMUD) service area. We first analyze indicators of success across the service area using survey results to determine whether 1) customers "accept and prefer water efficient services and products", and 2) whether sustainable landscapes are the market outcome. Then we examine the impact of drought on these positions, and how lawn conversion rebate participation patterns relate to landscape transformation.

Study area

Approximately 1.4 million people along the east shore of the San Francisco Bay receive water from the Mokelumne River watershed of the Sierra Nevada, with service provided by East Bay Municipal Utility District (EBMUD) (Figure 2). Separated by the Oakland-Berkeley hills, on the same day in spring communities on the west may be cooled by marine air flowing inland through the San Francisco Bay, with temperatures in the 50s, while cities inland and over the hills may be sweltering at 100 degrees. Besides climate, income, housing age and property lot size are important factors driving irrigation demand, largely because of lawns (Harlan and Yabiku 2009; Chang et al. 2017; Mustafa et al. 2010).

Figure 2 . East Bay Municipal Utility District water spans a 332-square-mile area in Alameda and Contra Costa counties, extending from Crockett in the north, southward to San Lorenzo, eastward from San Francisco Bay to Walnut Creek, and south through the San Ramon Valley. (East Bay Municipal Utility District 2013)

History of development

The current distribution of lawns is partially a result of the Bay Area's history of urban and suburban development. Housing and lot size are larger in the more recently developed and urbanized regions on the east of hills (East Bay Municipal Utility District 2002). The largest cities in the region, Oakland and Berkeley, were established urban centers by the late 19th century, and population increased following the 1906 San Francisco earthquake. At the outset of World War II, population in neighboring urban areas grew again with the war-time activity in the Richmond Shipyards, which employed

thousands of workers who lived in specially constructed, smaller homes along the shoreline of the Bay (City of Richmond 2019). While lawns were already part of the urban landscape, they really took hold in the United States, as well as the Bay Area, with the post-World War II suburban development that accompanied the population boom of the 1950s (Harlan and Yabiku 2009). Suburban development expanded inland with the completion of the Caldecott Tunnel through the Berkeley-Oakland Hills in 1937, and most new development and housing these days is focused inland.

History of sustainable landscaping

Familiarity with the benefits of a sustainable landscape and environmental values are known to have a positive influence on an individual's perception of landscape aesthetics and their preferences (Hurd 2013; Hoyle, Hitchmough, and Jorgensen 2017). The San Francisco Bay Area has a long history of progressive environmental values and is home to institutions that have long recognized and promoted water-conscious, climate-appropriate gardening. Sunset Magazine, originally based in San Francisco, has constantly addressed the water problems facing the West, both directly and indirectly, "beginning in 1930 with such articles as 'Gardening in the Land of Little Rain'--to water conservation-oriented techniques, encouraging its readers not to waste water, but to garden with nature rather than against it" (Keller 1998). Water-wise native gardening has long been showcased in regional botanical gardens, including University of California Berkeley Botanical Gardens (established in 1890), and the East Bay Regional District Botanic Garden (established in 1940) located in the Berkeley hills, "devoted to the collection, growth, display, and preservation of the native plants of California" (East Bay

Regional Park 2019). The region's first severe drought in recent history (1976-1977) marked the entrance of EBMUD into the landscaping picture; in the 1980s, EBMUD started working with the community and landscaping industry to promote water conservation with its first demonstration gardens, release of "Water Conserving Plants and Landscapes for the Bay Area", and in 1988, the formation of the Landscape Advisory Committee (LAC), a partnership between EBMUD and members of the landscape industry to promote sustainable landscape design, installation, maintenance and management practices (East Bay Municipal Utility District 2015).

EBMUD water supply reliability is increasingly contingent upon water conservation and reducing customer water demand (East Bay Municipal Utility District 2015). The service area is expecting a population increase of 1.8 million people and one million jobs by 2040, and severe drought conditions and a modeled climate change scenario anticipating 20% reduction in Mokelumne River runoff threaten water supply reliability. Across the service area, around 30% of residential water consumption is estimated to be outdoor water use, but inland, outdoor water use accounts for a much larger proportion of demand. This is partially due to differences in climate and the size or irrigated area, but it is also due the prevalence of lawn and related irrigation practices (East Bay Municipal Utility District 2015).

Lawn conversion rebate program

To motivate outdoor water conservation, EBMUD launched a comprehensive landscape rebate program in 2009 which continues to the present day as a key strategy in

water demand management. An earlier assessment of water conservation behaviors and attitudes made it clear that while most customers were willing to take indoor conservation measures, fewer than 40% were willing to take outdoor conservation measure and would need great motivation to reduce lawn area, change plant materials, and improve irrigation efficiency (EBMUD 2002). The landscape rebate program is typical of most lawn conversion incentives: customers are reimbursed per square foot of lawn that is converted to a low water-use landscape. To participate, they must first demonstrate an existing lawn with a discernable seasonal pattern of lawn irrigation. To receive the rebate, their final lawn conversion must adhere to water-conserving landscaping principles, soil must be covered by a 3-inch layer of mulch to retain soil moisture, and 50% of the former lawn area must be covered with low water use plants. The recent 2011-2017 drought was an important driver of EBMUD's program participation during drought years, but after heavy rains in the winter of 2016-2017 and the official end to the drought emergency on April 7, 2017, the lawn conversion program lost momentum.

Data collection

The survey questions used in this analysis come from a pre- and post-program evaluation for EBMUD's "Home Water Report" program, which was launched in 2014. Surveys were sent to randomly-selected single-family households, 71% of which were flagged by EBMUD as likely irrigators based on their seasonal water consumption patterns. Survey invitations were sent to 55,000 EBMUD single-family residential customers between August and November 2014 to with a 13% response rate; a re-survey in March 2017 went to 60,000 customers with an 11% response rate.

Table 1 Survey questions

Question 1: Are you willing to replace your lawn with a low-water use garden?	Question 2: Rate your agreement: A water conserving landscape looks as nice as a landscape that uses a lot of water.
• not applicable • will not do it • unlikely to do it • do not know • might do it • definitely will do it • already done it	• strongly disagree • somewhat disagree • neither agree nor disagree • somewhat agree • strongly agree

Surveys are an effective instrument to evaluate conservation attitudes, actions, and potential actions, yet they always have certain limitations, including self-selection bias. The survey invitations were randomly distributed across the EBMUD service area, and delivered primarily by e-mail, so results could not evenly capture EBMUD customers without e-mail addresses on record (around half of water accounts do not have email addresses associated). All cities except Emeryville had enough survey responses to use in the analysis; with only seven respondents, Emeryville was excluded from analysis. Approximately 1,526 respondents (13%) answered the survey in both years, out of 11,560 total survey responses. When the survey results are combined, the 2017 results were used for those who answered the questions in both years.

In this study, survey data and rebate participation patterns are analyzed by city. There are several unincorporated cities and communities in the service area, so postal code city boundaries were used to present results. With 28 cities in the service area, this scale is easier to interpret, and actionable.

Indicators of landscape transformation

Landscape transformation success is indicated by customer acceptance: whether customers prefer water efficient services and products, and whether sustainable landscapes are the market outcome. The following section will go over how survey questions were used a indicators of landscape transformation.

Lawn conversion rates

The desired outcome of landscape transformation is to replace lawns with water-conserving landscapes. Lawn conversion rates are not only a measure of success, but they can also be viewed as a marker of customer acceptance and a new social norm. This influence can also be a force for change. By 2015 in California, California Water Efficiency Partnership notes, "social norms are changing, and peer pressure is becoming a driver of landscape change". When customers see the result of neighbor/nearby lawn conversions they will often act on their own. This may be a stronger motivational factor than environmental concern.

To determine whether sustainable landscapes are the market outcome in the EBMUD service area, this study uses lawn conversion rates from the reported presence or absence of lawn derived from survey responses to the question "Are you willing to replace your lawn with a low-water use garden?" Absence of lawn is determined by combining response options "already done" and "not applicable." Figure 3 shows the distribution of responses across the service area, revealing a 41% lawn conversion rate, or that 59% of lawns remain.

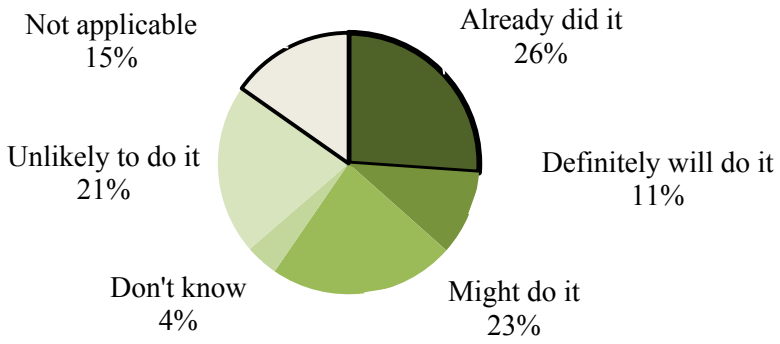


Figure 3 Distribution of responses to the question "Are you willing to replace your lawn with a low-water use garden?" This question had a total of 10,799 responses.

Willingness to convert lawn

Still using the same question, the remaining Likert scale response choices, "definitely will do it," "might do it," "will not do it," and "not sure" are used to assess willingness of respondents with lawns to convert their lawns. By excluding "not applicable" and "already converted" respondents from the response rate calculation, willingness to convert lawn can be examined as an independent variable from the first lawn conversation rates. Figure 4 shows the distribution of responses across the service area, 18% of respondents "definitely will" convert their lawn, once all "not applicable' and "already converted" response rates were excluded.

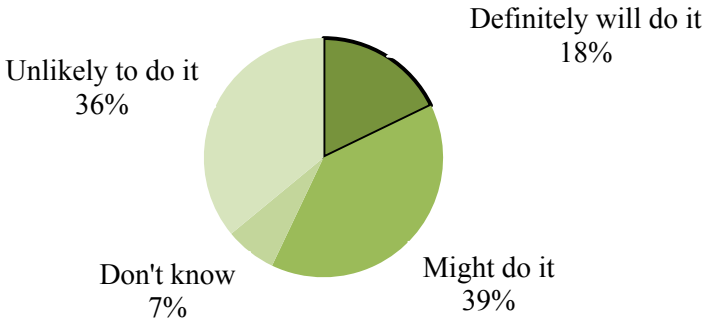


Figure 4 Distribution of responses to the question "Are you willing to replace your lawn with a low-water use garden?" excluding "not applicable" and "already converted" from analysis. These answer choices had a total of 6,329 responses.

Aesthetic preferences

The second survey question in this study allows us to capture aesthetic preferences, i.e. whether respondents like water conserving landscapes. This is important because aesthetic preference override most other drivers, including environmental or social values. Aesthetics contend with and are influenced by neighborhood norms. Aesthetic preferences can be both a key driver and potential barrier to broad market adoption of sustainable landscapes (Navigant Consulting 2015a; Alliance for Water Efficiency 2018; Mustafa et al. 2010; Hayden et al. 2015).

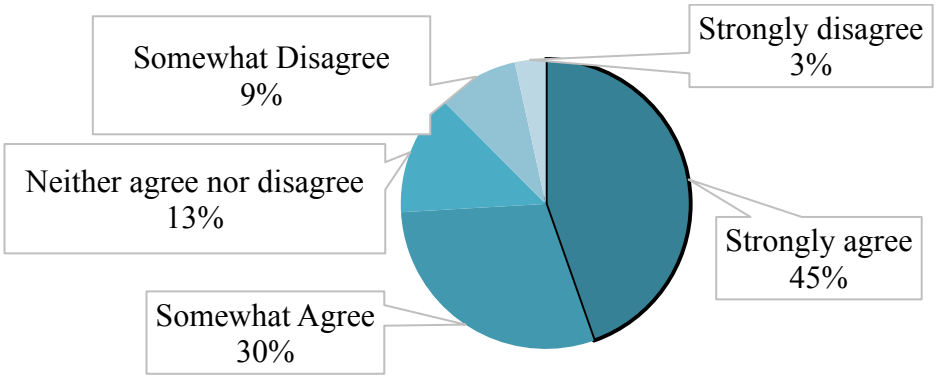


Figure 5 Distribution of responses to the agreement statement question "A water conserving landscape looks as nice as a landscape that uses a lot of water." This question had a total of 11,560 responses.

When we include survey respondents who "somewhat agree," these survey results correspond with AWE findings: 74% of residential households think that water efficient landscaping can be beautiful. Only 15% of AWE survey respondents stated that low water use landscaping would look unattractive in their yards and believed that it must include cactus, gravel, or artificial turf to be water efficient (Alliance for Water

Efficiency 2018). The phrasing of the question relates aesthetics in clear terms relating to water conservation, which allows us to gauge perception of water-conserving landscapes in relationship to lawns, however it also encompasses water-conserving landscape types that may not be sustainable. Without describing a "water conserving landscape," the survey question simply asks respondents to rank it against a "landscape that uses a lot of water." This risks possible misinterpretation of "water-conserving" landscapes as nothing more than rocks, also known as hardscaping, which might indeed save water but is not sustainable since hardscaping can have a net-negative effect on the health of humans and local ecosystems (Navigant Consulting 2015a). We know from a separate survey of EBMUD customers with lawns that they perceive water-conserving landscapes to entail gravel/rocks (75%), native plants (70%), mulch (60%), and cactus (50%). Fewer respondents associate trees, flowers, vegetable gardens with water-wise landscaping (California Water Efficiency Partnership 2018).

Effect of drought and patterns of lawn conversion rebate participation

The timing of the two surveys was providential for evaluating the effect of the drought on landscape transformation. The first survey was sent in August and November of 2014, the same year that Governor Brown declared a Drought and State of Emergency. The follow-up survey was sent on March 2017, after a record-breaking wet winter, just weeks before the Governor declared an official end to the drought. Despite research showing the importance of aesthetics and norms, it's indisputable that during drought, saving water was an important motivator. Rebate participation was strongly impacted by

the drought. In 2015, immediately after the Governor declared mandatory reduction targets, applications for EBMUD's lawn conversion rebate program more than tripled.

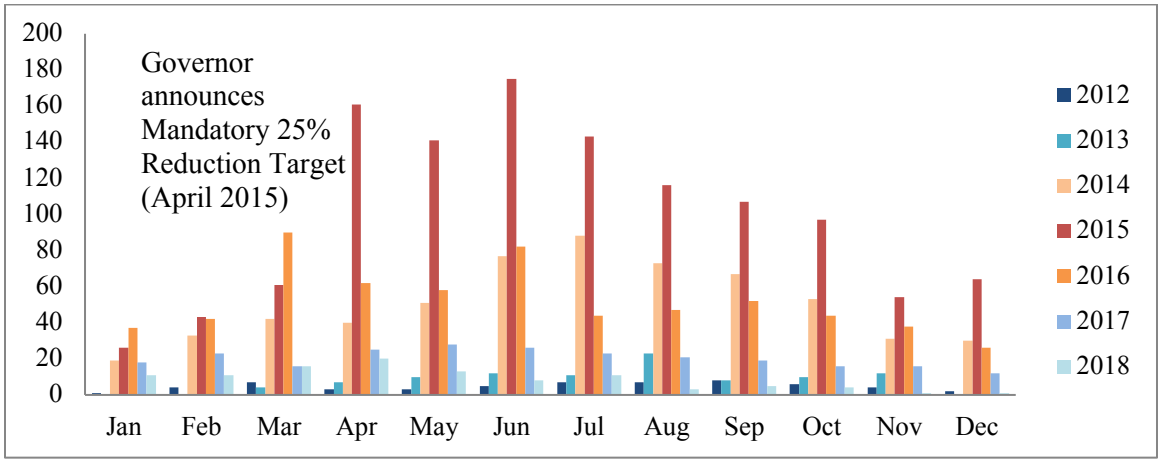


Figure 6 EBMUD Lawn Conversion Rebate Applications (completed projects only).

Completed lawn conversion rebates for single-family residential customers from 2012 to 2018 were used to understand the geographic distribution of program participation. To get rebate rates by city, this study aggregated rebates to city and normalized the count by each city's population of irrigators. Irrigators are single-family residential accounts with seasonal water consumption pattern or high year-round water use and represent approximately 66% of total single-family residential water service accounts.

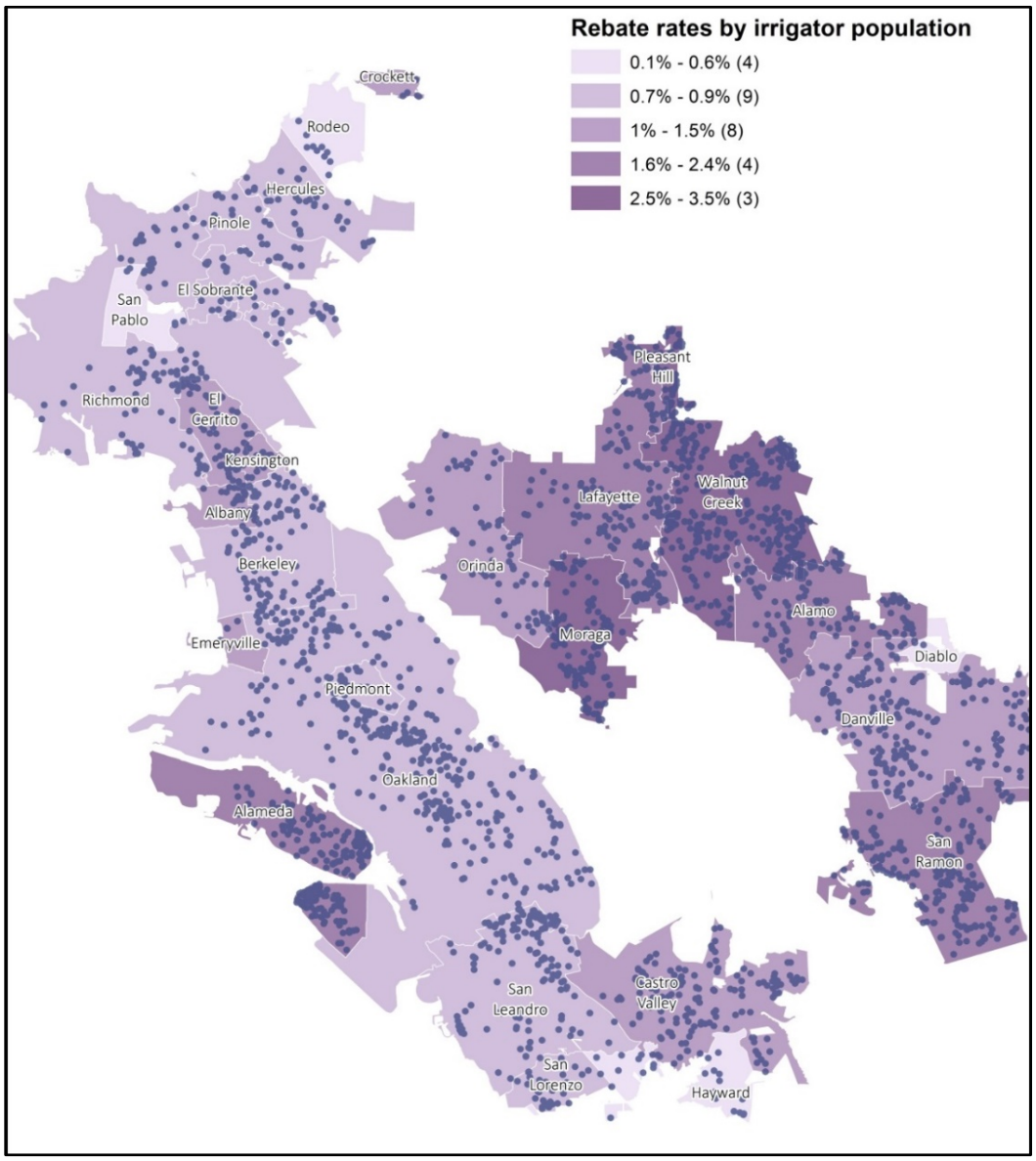


Figure 7 Points represent completed rebate projects, and rebates rates by city were classified using Jenks natural breaks.

Results

Geographic variation of landscape transformation indicators

Lawn conversion saturation rate map

Across the EBMUD service area, 41% of respondents have either already converted their lawns or indicated that the question was not applicable, suggesting they did not have lawns. Rates vary widely by city from a low of 24% in San Ramon, to a high of 67% in Crockett. Using Jenks natural breaks to classify the results into four distinct classes, Figure 8 reveals that cities with the highest saturation rates are grouped together in the more urban, densely populated region west of the East Bay hills. The cities with the lowest saturation rate are generally east of the East Bay hills.

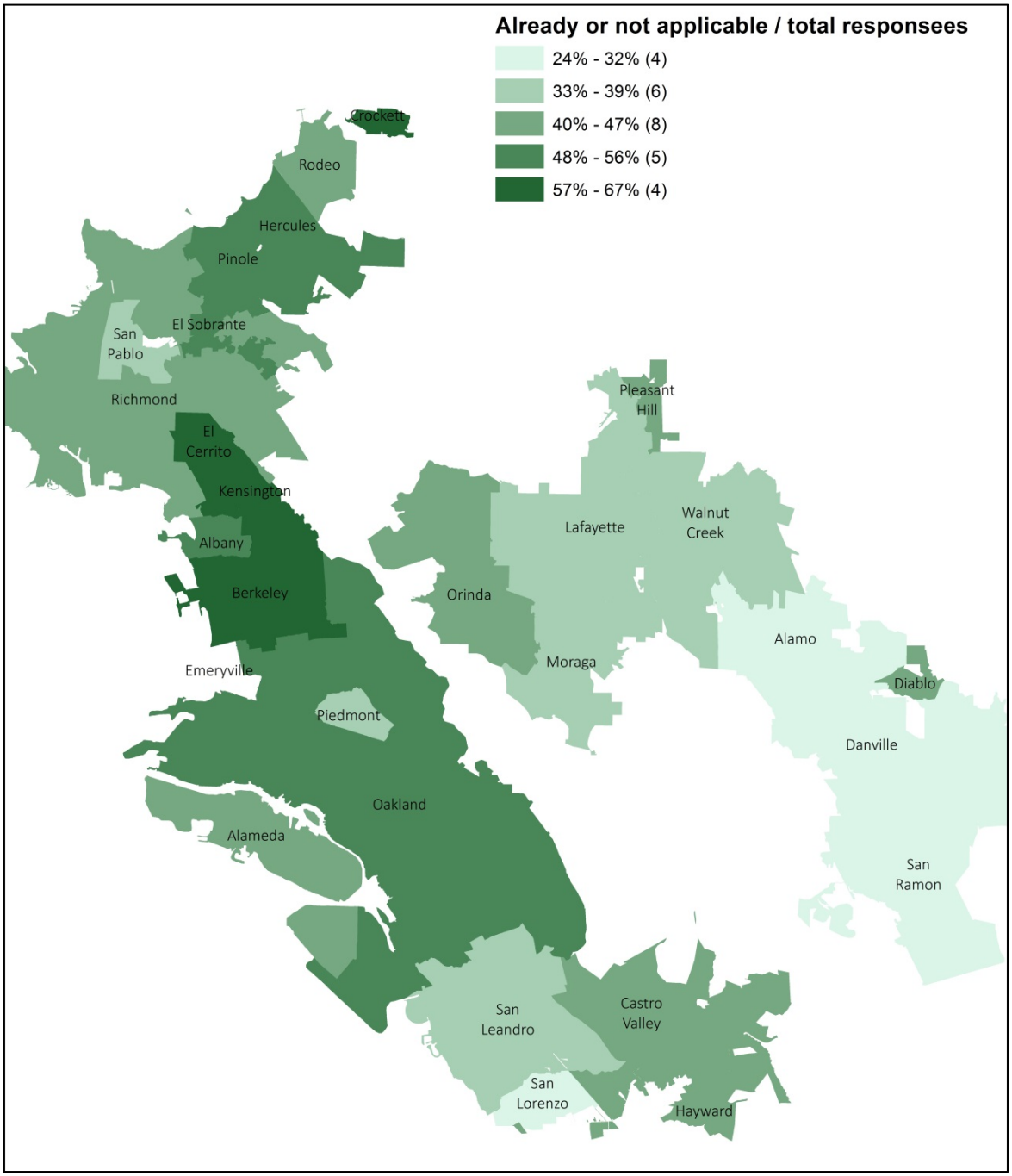


Figure 8 Map shows rate of lawn conversions, based on respondents who have either "already converted" their lawn, or reported that converting lawn was "not applicable".

Aesthetic preferences and willingness to convert lawn

Survey respondents strongly agree that a water-conserving landscape can look just as nice as one that uses a lot of water. Across the study area, aesthetic preferences closely follow "already converted" rates, as shown in Figure 9. There is also a strong positive relationship between aesthetic agreement and willingness to convert lawn. Initial cross-tabulation analysis of the two questions (Appendix Table 9) revealed that, of the respondents who "already converted" their lawns, 87% agreed that a water conserving landscape looked just as nice as one using a lot of water. Similarly, of those who responded that they "will not" replace their lawns, 61% disagreed or felt neutral about the appearance of water-conserving landscapes. In the middle, 75% of respondents who "might do it" still agreed with the statement, but nearly half of them only "somewhat" agreed with the statement.

Overall certainty regarding plans to convert their lawn is much lower than agreement with the aesthetic acceptability of water-conserving landscapes. For example, 70% of Albany respondents "strongly agree" that a water-conserving landscape is aesthetically pleasing but only around 25% expected to convert their lawns.

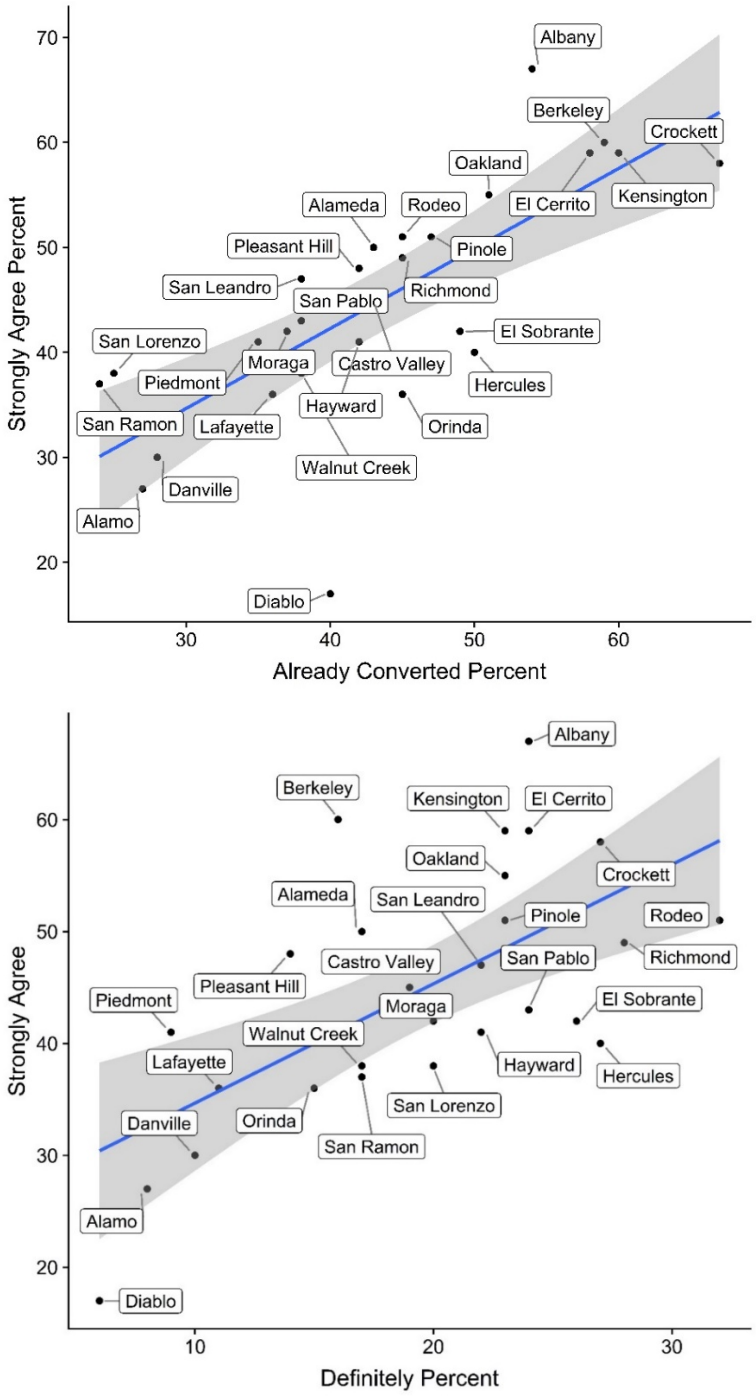


Figure 9 Linear models of aesthetic agreement against lawn conversion rates (top) and aesthetic agreement against "definitely will" convert lawn rates (bottom).

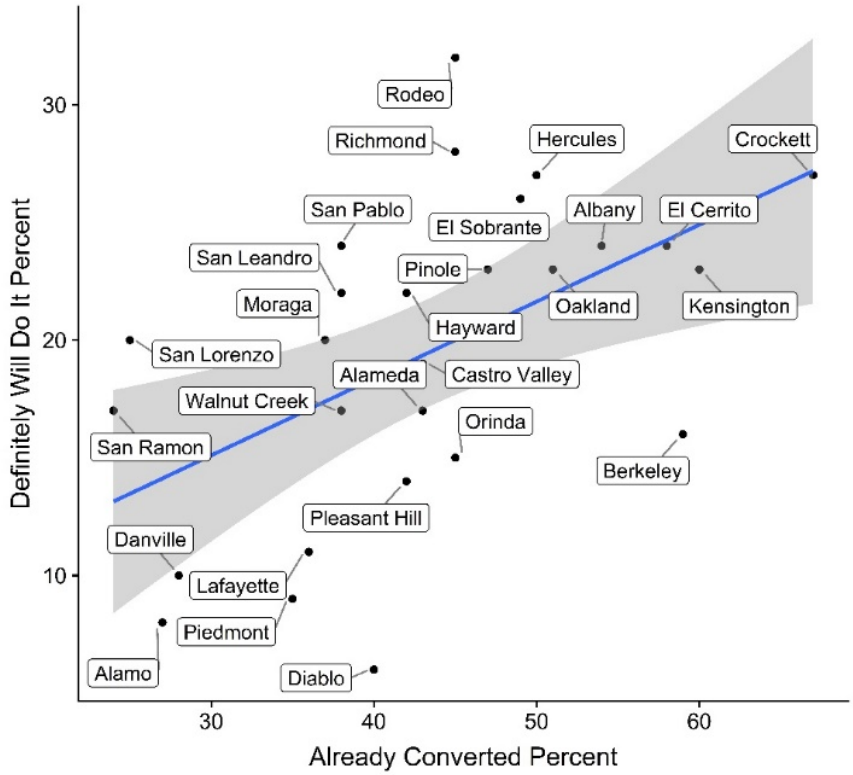
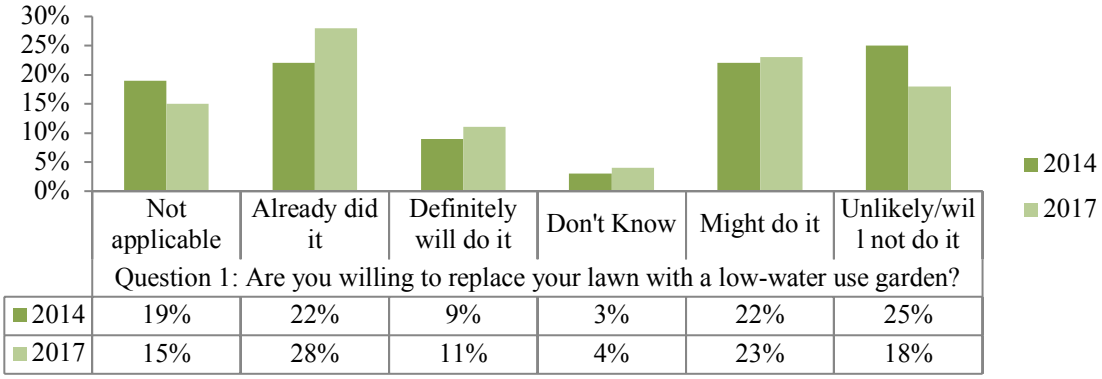


Figure 10 Linear model of "definitely will" convert lawn rates against lawn conversion rates.

Drought effect on landscape transformation indicators

The difference between 2014 and 2017 survey responses reinforces the idea that drought is an important driver of landscape transformation. By March 2017, the proportion of respondents reporting to have already converted lawns increased 6%, and those unlikely to convert lawns decreased by 7% (Figure 11). Mapping this change (Figure 12) reveals that the greatest change in survey responses was in cities with lowest saturation rate in the east of hills area.



	Not applicable	Already did it	Definitely will do it	Don't Know	Might do it	Unlikely/wil l not do it
	Question 1: Are you willing to replace your lawn with a low-water use garden?					
2014	19%	22%	9%	3%	22%	25%
2017	15%	28%	11%	4%	23%	18%

Figure 11 "Are you willing to replace your lawn with a low-water use garden" response rates in 2014 and 2017

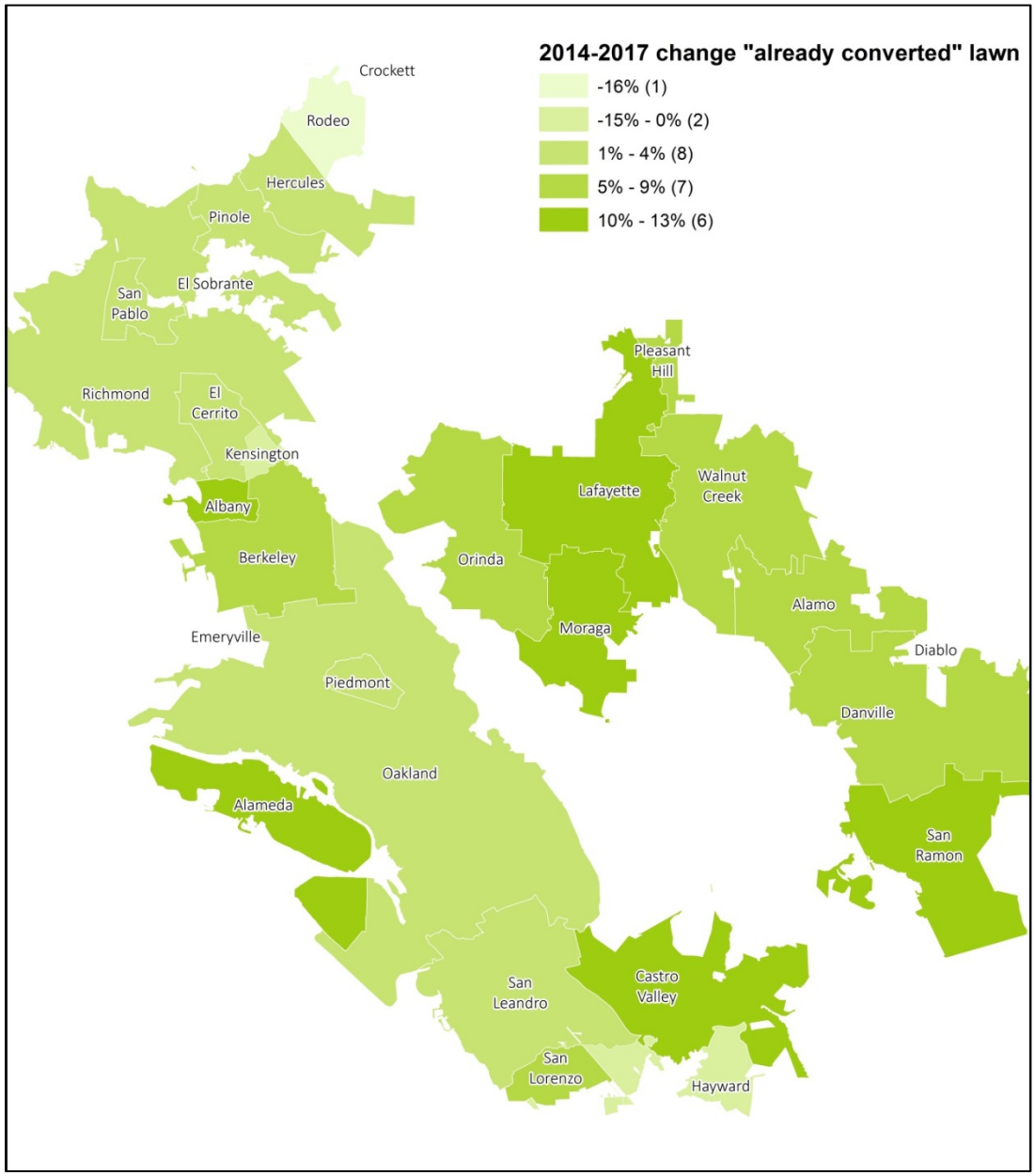
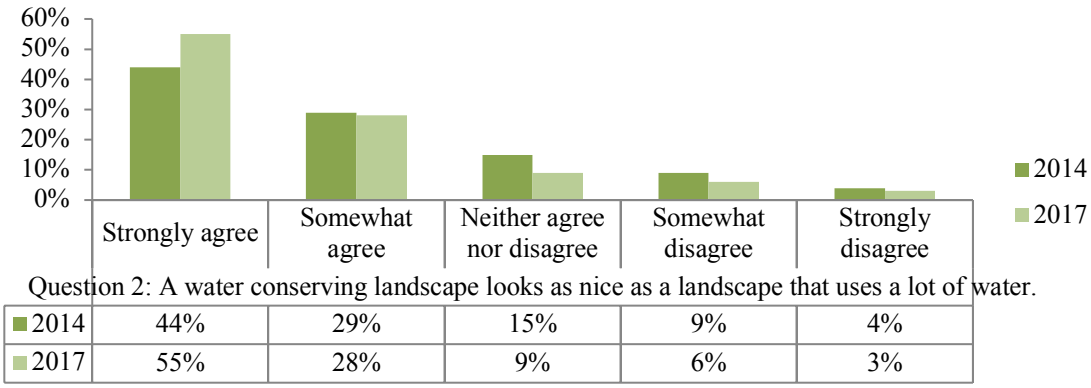


Figure 12 Map shows change between 2014 and 2017 for rate of lawn conversions, based on respondents who have either "already converted" their lawn.

Similarly, by March 2017, 11% more respondents strongly agreed that a water-conserving landscape looked as nice as one that used a lot of water, while overall there was a decrease in negative opinions about the aesthetic value of water conserving landscapes (Figure 13).



Question 2: A water conserving landscape looks as nice as a landscape that uses a lot of water.

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
2014	44%	29%	15%	9%	4%
2017	55%	28%	9%	6%	3%

Figure 13 "A water conserving landscape looks as nice as a landscape that uses a lot of water" response rates in 2014 and 2017.

Given the recent drought conditions, the underlying reason for increased aesthetic agreement in 2017 could be that water-conserving landscapes tend to look much better compared to water-stressed lawns; it is also possible that increased exposure garnered a greater appreciation for water conserving landscapes during drought. These first two options are in line with findings from a 2009 study on landscape preferences, where under a simulated drought conditions (5-weeks with no irrigation), homeowners preferred the low-water use, sustainable garden compared against gardens with traditional high-water use and moderate water use plants. Under well-watered conditions, homeowners preferred the traditional landscape unless they were familiar with the benefits of sustainable landscaping (Mccammon, Marquart-pyatt, and Kopp 2009). There is no doubt

that drought increased local familiarity with water-conserving landscapes: in fact, residents began conserving water long before they were ordered to, largely because they responded to media coverage of the drought. According to Quesnel et al. 2017, an increase of 100 drought-related articles in a bi-monthly period resulted in an 11–18% drop in water use for single-family residential sector.

Cities with the highest rate of completed rebates also report lowest rates across all landscape transformation indicators. Interestingly, there is a positive relationship between cities have changed the most during drought years in terms of aesthetic preferences and rebate participation (Figure 14 Linear model of change in reported aesthetic preferences between 2014 and 2017, and Figure 14).

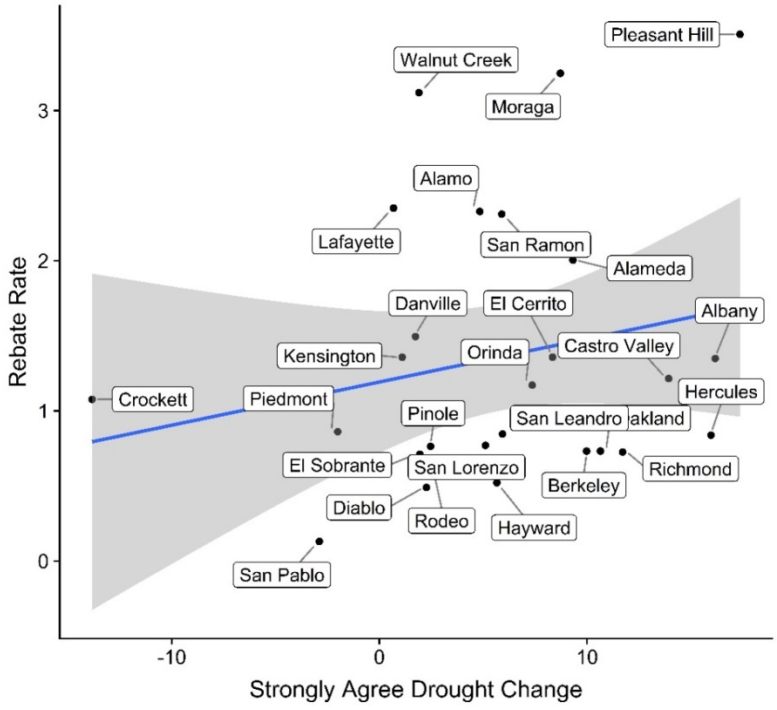


Figure 14 Linear model of change in reported aesthetic preferences between 2014 and 2017, and rebate participation rates by city.

Stages of landscape transformation in the EBMUD service area

The linear models and maps of the survey results show consistent positive relationships between positive agreement with the aesthetics of water-conserving landscapes, willingness to convert lawns, and lawn conversion saturation rates. They also reveal patterns in how respondents vary away from this trend by city, either falling above or below average for the indicators of landscape transformation. For example, Walnut Creek, Pleasant Hill and Moraga – communities east of the hills with large lot sizes -- appear as a group of outliers with higher than average rebate participation in Figure 14 and appear again close together on the lower end of the curve comparing aesthetic agreement and willingness to convert lawn in Figure 9. To group cities by similar relationships to EBMUD's average landscape transformation trends, each of the indicators of landscape transformation was divided into categories, higher or lower than each indicator's median (Table 2). Lawn conversion rates were divided into three groups to distinguish those cities with over 50% saturation rate. According to market transformation theory, 50% is the tipping point when a sector market is transformed and a behavior spreads to the "late majority" (Irvine Ranch Water District 2016). Table 3 shows cities group together by which indicators of landscape transformation were above or below average district wide.

Table 2 Survey question response rates group categories based on median response rate.

Indicator	Median	Below median	Above median	
Lawn conversion rate (LCR)	43%	Low LCR	Medium LCR	High LCR >50%
Definitely will convert lawn (WCLR)	23%	Low WCLR	High WCLR	
Aesthetic agreement rate (AAR)	48%	Low AAR	High AAR	

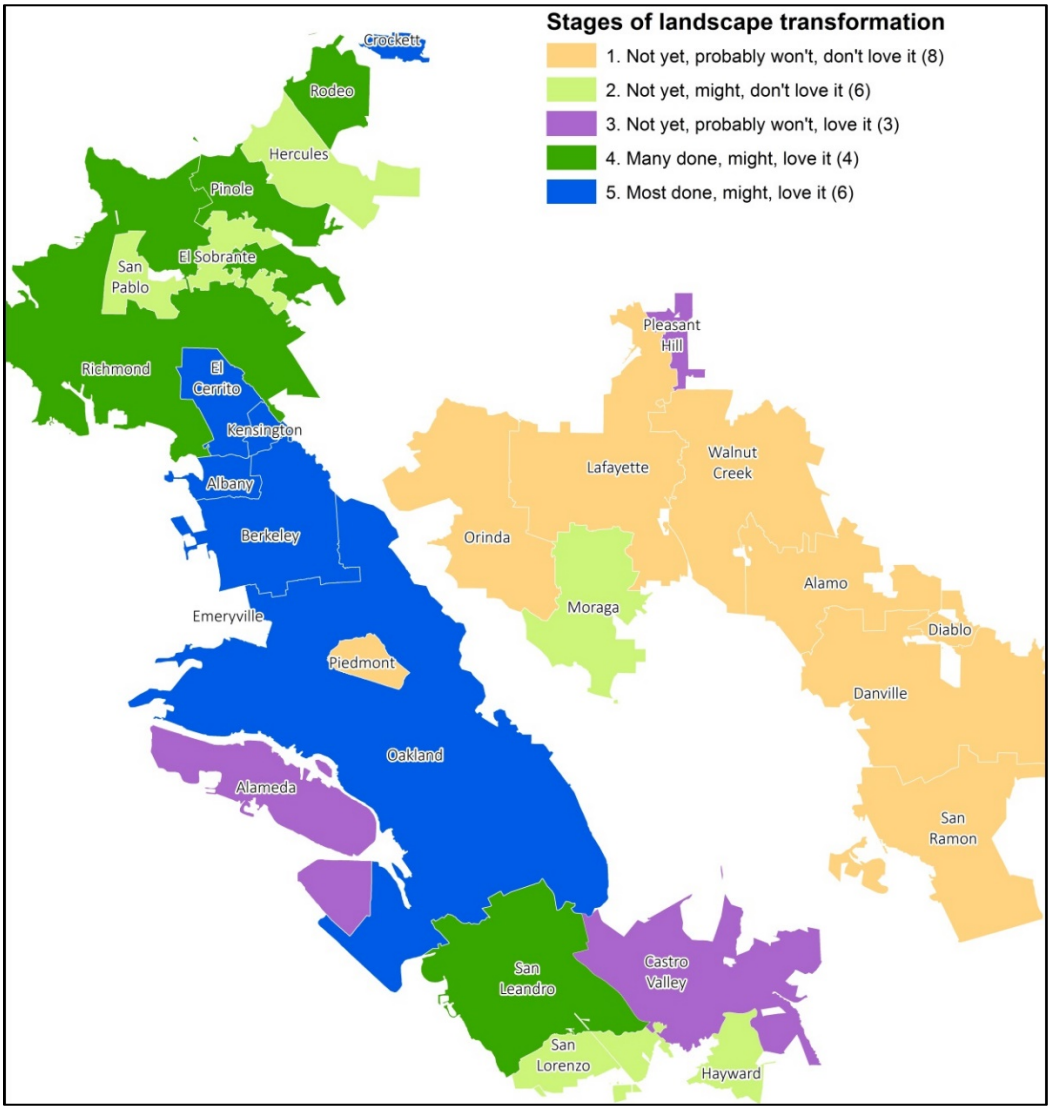


Figure 15 Stages of landscape transformation. Cities are classified based on whether each landscape transformation indicator fell above or below EBMUD median.

Table 3 Cities are classified based whether each landscape transformation indicators fell above or below the EBMUD median.

			Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys***	
Market Transformation Associated S-curve	Group	Cities East West	Lawn conversion (LCR)	"Definitely Will" convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn conversion	Aesthetic agreement
Early Adopters* & Early Majority	1. Low LCR, Low WLCR, Low AAR	Alamo*, Diablo, Danville*, San Ramon*, Lafayette, Walnut Creek, Orinda Piedmont	34%	12%	33%	1.8%	+7%	+3%
	2. Low LCR, High WLCR, Low AAR	Moraga Hercules, Hayward El Sobrante, San Lorenzo*, San Pablo	40%	23%	41%	1.0%	+4%	+6%
Early Majority	3. Low LCR, low WLCR, High AAR	Pleasant Hill Alameda, Castro Valley	42%	17%	48%	2.2%	+11%	+14%
	4. Med LCR, High WLCR, High AAR	San Leandro, Richmond, Rodeo, Pinole	44%	26%	50%	0.7%	-4%	+7%
Late Majority	5. High LCR, High WLCR, High AAR	Oakland, El Cerrito, Berkeley**, Kensington, Albany, Crockett	58%	23%	60%	1.1%	-3%	+9%
		Service Area Median	43%	19%	45%	1.4%	5%	+7%

*Early adopters < 34% market saturation
**Berkeley ranked lower than average on the question "definitely will" convert lawn, but as the only city in that category, was kept with group 5.
*** Cities excluded from drought change 2014 and 2017 analysis because of too few respondents (under 20): Diablo, El Sobrante and Crockett

These groupings are easily associated with general phases of the market transformation curve but are more detailed, and based on actual variations within the EBMUD service area. This next section will describe these groups in more detail, investigate any variation within the groups, and provide recommendations for strategic targeting.

Group 1: Low lawn conversion rates: aesthetic perception is a barrier

Table 4 Group 1 Survey response and rebate participation rate by city and drought effect

Group 1	Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys		
Cities	Lawn conversion (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn con-version (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)
San Ramon	24%	17%	37%	2.3%	+10%	+3%	+6%
Alamo	27%	8%	27%	2.3%	+9%	+4%	+5%
Danville	28%	10%	30%	1.5%	+8%	+3%	+2%
Piedmont	35%	9%	41%	0.9%	+2%	-3%	-2%
Lafayette	36%	11%	36%	2.4%	+11%	-1%	+1%
Walnut Creek	38%	17%	38%	3.1%	+7%	+3%	+2%
Diablo	40%	6%	17%	0.5%	--	--	--
Orinda	45%	15%	36%	1.2%	+5%	+1%	+7%
Group Average	34%	12%	33%	1.8%	+7%	+1%	+3%
Service Area Median	43%	19%	45%	1.4%	+5%	+7%	+43%

Respondents in these suburban cities, largely concentrated east of the hills, report significantly lower rates of lawn conversion, less aesthetic appreciation for low-water use landscapes, and little willingness to convert their lawns. Above-average rebate participation implies that lawn conversion rebates are reaching “early adopters” and “early majority” of sustainable landscaping in these cities. While drought improved lawn conversion rates, it had little impact on improving the aesthetic perception of low-water

use landscapes. Within this group, the lowest aesthetic rating was in the most affluent suburban cities in the east of hills region (Alamo, Danville, and Diablo). Weiser 2017, in studying the effect of drought messaging in the Bay Area, suggests that wealthier people were less receptive to conservation messages: "we think – and this is just speculation – that this might be because some of these higher-income communities hire landscapers and basically outsource some of their outdoor water use…. They just don't interact with their water use the way other people do" (Weiser 2017). Given this, the recommendation for these cities is to focus on improving aesthetic appreciation for water-conserving landscapes so that it becomes an inherently desirable commodity. To take better advantage of the spillover effect, EBMUD may want to consider investing resource in public-facing front yard conversions that showcase examples of attractive lawn conversions, to influence local perceptions and social norms regarding sustainable landscaping.

Group 2 and 4: Driven by drought, relatively more willing to convert lawn, but comparatively low aesthetic appreciation and rebate participation

Table 5 Group 2 Survey response and rebate participation rate by city and drought effect

Group 2	Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys		
Cities	Lawn conversion (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn con-version (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)
San Lorenzo	25%	20%	38%	0.8%	+6%	+5%	+5%
Moraga	37%	20%	42%	3.2%	+10%	-1%	+9%
San Pablo	38%	24%	43%	0.1%	+2%	+9%	-3%
Hayward	42%	22%	41%	0.5%	-2%	+10%	+6%
El Sobrante	49%	26%	42%	0.7%	--	--	--
Hercules	50%	27%	40%	0.8%	+3%	+6%	+16%
Group Average	40%	23%	41%	1.0%	+4%	+5%	+6%
Service Area Median	43%	19%	45%	1.4%	+5%	+7%	+43%

Table 6 Group 4 Survey response and rebate participation rate by city and drought effect

Group 4	Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys		
Cities	Lawn conversion (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn con-version (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)
San Leandro	38%	22%	47%	0.8%	+3%	+4%	+6%
Rodeo	45%	32%	51%	0.6%	-16%	-4%	+3%
Richmond	45%	28%	49%	0.7%	+2%	+4%	+12%
Pinole	47%	23%	51%	0.8%	+1%	0%	+2%
Group Average	44%	26%	50%	0.7%	-2%	+1%	+6%
Service Area Median	43%	19%	45%	1.4%	5%	+7%	+43%

Although group 4 has higher rates of lawn conversions than group 2, overall these cities share important similarities. Respondents are comparatively more willing to convert their lawns than other cities, despite lower appreciation of the aesthetics of lawn

conversions. Rebate participation was significantly lower in these two groups, despite their relatively higher willingness to convert. The drought had a strong influence on these areas, so it appears that water savings was an important motivator here. EBMUD has an opportunity to leverage relatively high interest in lawn conversion for saving water, and can focus outreach efforts in these cities to improve participation rates and showcase benefits of lawn conversion for saving water. Outreach efforts should also focus on inspiring more attractive lawn conversions to improve aesthetic perception overall.

Group 3: Landscape transformation in progress: keep it up

Table 7 Group 4 Survey response and rebate participation rate by city and drought effect

Group 3	Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys		
Cities	Lawn conversion (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn con-version (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)
Pleasant Hill	42%	14%	48%	3.5%	+8%	0%	+17%
Castro Valley	43%	19%	45%	1.2%	+12%	+5%	+14%
Alameda	43%	17%	50%	2.0%	+13%	+1%	+9%
Group Average	42%	17%	48%	2.2%	+11%	+2%	+14%
Service Area Median	43%	19%	45%	1.4%	+5%	+7%	+43%

Within this group, lawn conversion rates are still low, but rebate participation and aesthetic appreciation are notably high. Furthermore, drought had a significant impact on lawn conversion rates and was a remarkably positive influence on aesthetic appreciation for low-water use landscapes. It would be interesting to study the differences between this group and group 1, which saw similar surge of "already converted" lawn rates, but a

much lower increase in aesthetic appreciation. It appears that momentum is growing for sustainable landscaping in this group.

Group 5: Sustainable landscapes are the norm and preference

Table 8 Group 5 Survey response and rebate participation rate by city and drought effect

Group 5	Average survey response and rebate participation rate				Drought Effect: Change between 2014 and 2017 surveys		
Cities	Lawn conversion (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)	Rebate Participation	Lawn con-version (LCR)	Will convert lawn (WLCR)	Aesthetic agreement (AAR)
Oakland	51%	23%	55%	0.7%	0%	+5%	+11%
Albany	54%	24%	67%	1.3%	+11%	-3%	+16%
El Cerrito	58%	24%	59%	1.4%	+1%	+3%	+8%
Berkeley	59%	16%	60%	0.7%	+7%	+3%	+10%
Kensington	60%	23%	59%	1.4%	-3%	-1%	+1%
Crockett	67%	27%	58%	1.1%	--	--	--
Group Average	58%	23%	60%	1.1%	+3%	+1%	+9%
Service Area Median	43%	19%	45%	1.4%	+5%	+7%	+43%

Rates of lawn conversions and corresponding aesthetic agreement were highest in areas with longer histories of embracing low-water use landscaping, and more urbanized and populous regions. Rebate participation rate was below the EBMUD average, but higher than in Group 2 and 4, and while drought appeared to influence aesthetic preference positively, it did not appear to significantly increase the rate of "already converted" landscapes. Within the group, there is also a cluster of cities with comparatively lower willingness to convert their lawns, such as Berkeley. The remaining customers with lawns in these areas are apparently not yet moved by their local norms or aesthetic preferences to make change, so will probably need other motivation. Sustainable landscaping programs can focus more narrowly on the quality of well-

designed lawn conversions, to ensure that best practices regarding water-savings are showcased, and test out new ideas with less risk of rejection. Since low-water use landscapes are normalized, there is less of a need to take advantage of a spillover effect in these areas. To motivate program participation with the late majority, EBMUD could focus efforts on aligning customers' perception of their water use with their actual water use through education on outdoor water use.

Recommendations

Benchmark landscape transformation with surveys

The survey questions used in this analysis provide a cost-effective tool for assessing landscape transformation outcomes. Continuous surveys could inform program refinements and track efforts sustain landscape transformation. The identified stages of landscape transformation in the EBMUD service area can be used for developing geographically targeted strategies for hastening the adoption of sustainable landscaping.

Strategies for geographically targeting landscape transformation

Promote aesthetics value of sustainable landscapes

During non-drought years, when urgency of saving water is less acutely felt, a stronger preference for the look of water-conserving gardening is a more reliable driver of landscape transformation. By investing in improved perception of water-conserving landscape aesthetics, EBMUD can continue to build the desirability of sustainable landscaping in advance of the next drought. A cost-effective strategy might be to focus

resources on public-facing lawn conversion projects in areas where aesthetic appreciation for water-conserving landscapes is lowest.

Messaging drought resilience while preparing for drought

While the 2011-2017 drought dramatically increases interest in converting lawns, if the goal is truly to support a market transition to sustainable landscaping, it is important to continue to build appreciation for the benefits and aesthetics of a water-conserving landscape. It is possible many EBMUD customers may still be moved by the simple aim of saving water and armoring against the next drought emergency, given the incredible media attention to drought, combined with growing acceptance and concern about climate change (Quesnel and Ajami 2017).

Yet water agencies may not be able to rely on media attention to fuel enthusiasm during the next emergency; a wiser strategy is to encourage aesthetically attractive lawn conversions during non-drought years. In areas more sensitive to water savings motivations over aesthetic perception, one way to effectively leverage water saving motivations is to correct the common misperception that residents use more water indoors than outdoors. At the very least, water agencies should be prepared for a surge of interest in conservation programs and incentives during the next drought emergency; they should use the next wave of drought-fueled interest to ensure new lawn conversions are attractive and environmentally beneficial, to maintain the momentum towards sustainable landscaping.

Future research at the neighborhood scale

Efforts to introduce lawn conversions in urban residential landscapes should approach change at the neighborhood scale, in order to enhance "initial success and long-term cultural sustainability" (Nassauer, Wang, and Dayrell 2009). A similar analysis at the neighborhood and block-level in the EBMUD service area would allow for refined geographic targeting of blocks where neighborhood norms are still dominated by lawn, and there have been no lawn conversions. The powerful influence of neighborhood-scale social norms can be the most cost-effective strategy for targeted landscape transformation (Nassauer, Wang, and Dayrell 2009; Sisser et al. 2016; Uren, Dzidic, and Bishop 2015; Larson et al. 2009).

Conclusion

This geographic analysis provides a simple method for evaluating landscape transformation that can be used as a data-driven targeting strategy. We confirm the important relationship between lawn conversion rates and aesthetic appreciation of water-conserving landscapes but found a weaker relationship with reported willingness to convert lawn. Drought years had an overall positive effect across the indicators of landscape transformation, though drought influence varied geographically. Rebate participation rates were highest in areas with low levels of landscape transformation (e.g. Walnut Creek), and even higher in cities that saw the biggest change during drought (e.g. Pleasant Hill, Alameda). Below-average rebate participation correlates with below-average aesthetic ratings. Water agencies seeking to promote sustainable landscaping can use this method to create a baseline of landscape transformation unique to their

population and geography, to help inform targeting strategies for effective landscape transformation.

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Appendix

		Question 2: A water conserving landscape looks as nice as a landscape that uses a lot of water.						
Question 1: Are you willing to replace your lawn with a low-water use garden?		**Strongly Agree**	**Somewhat Agree**	**Neither Agree Nor Disagree**	**Somewhat Disagree**	**Strongly Disagree**	**No Response**	**Grand Total**
	Already did it	1,638	617	213	119	37	53	2,677
	Definitely will do it	701	253	76	43	19	11	1,103
	Don't know	126	127	106	34	25	8	426
	Might do it	909	947	357	209	56	11	2,489
	Unlikely to do it	373	650	419	381	144	15	1,982
	Will not do it	78	100	107	107	59	-	451
	Not applicable	889	536	285	125	54	22	1,911
	No response	31	25	17	9	2	437	521
	Grand Total	**4,745**	**3,255**	**1,580**	**1,027**	**396**	**557**	**11,560**

Table 9 Cross tabulation analysis of survey questions used in this research to assess indicators of sustainable landscaping.