Legalization of Cannabis Home Cultivation and Residential Water Use

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Key words: cannabis, marijuana, home cultivation, water

Executive Summary

In early April 2021, cannabis consumption for adults 21 and older became legal in New Mexico in April 2021. Home cultivation of up to 6 plants per person and 12 plants per household following on June 29, 2021. The implications for residential water use were unknown due to a lack of information on the prevalence of home cultivation and the water requirements of growers.

This project studied the effects of legalization of home cultivation on water use using data from the Santa Fe Water Division of the Santa Fe Public Utilities Department and from a small fielded survey on home cultivation experience and preferences.

Results from analyses of the water utility data indicated an average monthly increase in water use of 36 gallons per household or 1.27 million gallons overall following legalization of home cultivation. Significant variation in the predicted effects existed across households and increased water use was concentrated in Fall 2021 and April 2022. The analyses also show a substantial increase in water use, presumably from COVID, in 2020. Limiting the implications of this study, it is possible that COVID-related increases in water use continued to a more limited degree in 2021 and could be confounding estimates of the effects of home cultivation.

The pilot survey fielded generated 27 responses, disproportionately from experienced growers. Key takeaways included a preference for indoor growing, use of public utility water, and that home-cultivated cannabis can readily compete with dispensary-sourced cannabis on quality and cost.

Policy recommendations include educating growers on low-water growing methods, e.g., indoor growing, evaluating relative water use between commercial and residential growers, identifying the limitations of current testing requirements for ensuring quality, and tracking and publicly sharing the dispensary price and quantity data necessary to understand New Mexico’s cannabis market.

1. Introduction

In April 2021, adult-use, recreational cannabis became legal in New Mexico. The state's House Bill 2 (The Cannabis Regulation Act) anticipated use by 20% of adults, a rate similar to that of other states with legal adult-use cannabis. Although approved by the legislature and signed by the governor in March and April of 2021, dispensaries did not open until April 2022. Home cultivation, however, became legal on June 29, 2021. With no open dispensaries through April 2022 and plant counts of up to 6 plants per person or 12 plants per household among individuals, a boom in home cultivation was expected in 2021.

Home gardening rates in the broader population and medical cannabis personal production licensing rates in New Mexico support that many New Mexicans will cultivate cannabis at home. The National Gardening Association estimates that 35% of U.S. households grow food,[1] supporting that many New Mexicans possess the necessary gardening skills for basic home cultivation of cannabis. Among medical cannabis patients, all certified as suffering from severe, debilitating diseases, rates of personal production licensing ranged from 0.37 licenses per medical patient in the fourth quarter of 2012, the first year for which data are available, to 0.064 licenses in April 2021.[2] Recreational cannabis consumers are likely to be physically healthier than medical cannabis patients and do not have to complete a licensing process, meaning home cultivation by recreational users may exceed the rates seen for personal production licenses through the medical program, especially prior to dispensary entry. The decline in rates of personal production licensing among medical cannabis patients correlates with the availability of medical cannabis dispensaries, so home cultivation rates may be highest prior to dispensary entry in April 2022 with one major caveat – June 29th is a late start to the growing season and may have been too late for outdoor cultivators to grow in 2021 as cannabis plants take 3-6 months to mature. For comparison, California's five-month, outdoor cannabis growing season ranges from June to October (Madhusoodanan, 2019).

Cultivating cannabis requires water and energy with water the dominant resource in outdoor growing and energy the dominant resource for indoor growing. Little research exists on how much water is used by commercial or residential growers. As summarized by a 2017 report on water and energy usage associated with cannabis cultivation in Colorado's Pueblo County, "Searching for credible information on water and energy use in refereed journal articles and from other sources resulted in a significant and frustrating waste of time."[3] The report goes on to report a widespread but largely unsubstantiated estimate of 22 liters or around 6 gallons per day per plant along with their own estimate of ½ gallon per day, based on interviews with six commercial growers. A 2019 article in *Nature* reported commercial outdoor growing uses six gallons of water per day but only for about three months of the five-month California growing

[1] https://www.farmerfoodshare.org/farmer-foodshare/2017/6/15/gardening-boom-1-in-3-american-households-grow-food. Accessed 05/06/2021
[2] https://www.nmhealth.org/about/mcp/svcs/rpa/. Accessed 05/06/2021.
[3] https://mountainscholar.org/handle/10217/192586. Accessed 05/06/2021.

season from June through October, and water conservation methods can reduce commercial per plant water use to only about ½ gallon per plant per day (Madhusoodanan, 2019). This is the first study to estimate water use following HCL. As our estimates are at the household level, they offer particularly policy-relevant results by accounting for actual household water use rather than requiring an estimate of both per plant water use and plants per household as in the existing literature.

To evaluate whether or not HCL led to an increase in residential water consumption, the authors of this study obtained data on residential water use in Santa Fe, New Mexico, and conducted a pilot survey on home cultivation preferences. Comparing water consumption prior to and following HCL, this study found evidence of a modest increase in water use following HCL. Responses to a small pilot survey on home cultivation experience and preferences suggests home-cultivated cannabis can substitute for dispensary-sourced cannabis and may even increase in popularity with increased expertise in the community.

This work supports the goal of the New Mexico Legislature to create a sustainable adult-use cannabis market, while protecting the limited water resources in the state. In addition to its policy relevance, this work contributes to a nascent academic literature on cannabis home cultivation.

2. Data and Methods

Our primary analysis uses water utility consumption data from Santa Fe to analyze the effect of HCL on residential water use. We supplement these data using data obtained from a pilot survey on home cultivation preferences.

Santa Fe Residential Water Use Data

For our primary analysis we are seeking to assess the effect of the June 29, 2021, legalization of home cultivation on water consumption. Thus our "treatment" variable measures whether water consumption occurred before or after June 2021. We cannot ignore the potential influence of the COVID-19 and the associated policy responses, which dramatically affected all aspects of life. Pandemic infection rates were associated with increased interest in home gardening (Lin et al., 2021), the stay-at-home orders have been linked to increased residential water use (Irwin, McCoy, and McDonough, 2021)[4], and the first year of the pandemic showed a large surge in summer and fall residential water consumption in Denver, Colorado (Eastman, et al. 2022). To disentangle the effects of HCL versus COVID, we also measure the effect of COVID-19 on water consumption. We measure the influence of COVID in two ways. In our simple pre/post analyses, we further control for whether water consumption occurred before or after March 2020,

[4] New Mexico shut down all non-essential businesses on March 24, 2020. Businesses began reopening May 16, 2020. Some businesses, including restaurants, were periodically closed and opened, e.g., restaurants were closed three times – 03/20/2020 to 05/27/2020, 07/13/2020 to 08/29/2020, and 11/16/2020 to 03/24/2021.

which coincides with onset of COVID and the first stay-at-home orders.[5][6] For our more detailed month-level analyses, we track monthly water use beginning in January 2020, in addition to any changes which occurred more proximate to HCL in June 2021. Our sample includes 36 months pre-January 2020, 28 after January 2020, and 9 after June 2021.

We obtained data on monthly household-level water consumption from the Santa Fe Public Utilities Department for the sample period from January 2017 through April 2022. By using overall water consumption rather than attempting to estimate per-plant water use as in prior studies, we are able to measure any changes in water use net of any pre-existing water use from, for example, growing other types of plants. The original data set included 2,214,106 observations from 35,978 households. We dropped the 98,132 observations reporting zero or less water consumption in a month. In line with the literature (Price, Chermak and Felardo, 2014), we trimmed the bottom and top 1% of our data to remove outliers that might bias our results, which reduced our sample by another 42,215 observations. After these adjustments to the data, the analysis sample included 2,073,751 observations from 35,351 households. The average household in our sample consumed 4,573 gallons of water per month.[7] We use three measures of water consumption as outcome variables. For our main specification, we use 100s of gallons per day to simplify interpretation of the results. We run two robustness checks on this outcome variables. First, we calculate the natural log of water consumption to potentially better account for outliers. (Histograms suggest the natural log of water use is distributed more normally than the total consumption in gallons, which includes large outliers.) Second, we calculate whether or not the household crossed the threshold between lower and higher cost per gallon consumed. (The base residential water consumption charge for September to April is $6.06/1,000 for first 7,000 gallons and $21.72/1,000 for gallons thereafter, for May to August is $6.06/1,000 for first 10,000 gallons and $21.72/1,000 thereafter.[8])

To improve our estimates, we include time-invariant, household-specific variables, i.e., household fixed effects, that control for differences between households which do not change during our sample period. We also adjust our estimates for consistent differences in water

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[6] We chose not to include alternative COVID measures, such as vaccination rates or cases, hospitalizations and deaths, due to measurement issues with such variables. Vaccines were initially offered to only certain subsections of the population, scientific understanding of the ability of the vaccines to prevent infection and transmission evolved over time, increasing availability of home testing affected case counts, and with the onset of Omicron, many COVID-related hospitalizations and deaths were with COVID rather than due to COVID. Policies might offer cleaner measures, but heterogeneity in those affected by and compliant with policies, the short-term (just weeks) nature of many of the policies, and that only subsectors of the economy were affected and at varying rates make it unlikely that specific policies beyond the general lockdowns in summer 2020 drove multi-month cultivation decisions. We present a month-level event study specification, which allows readers to compare our outcomes with COVID-related policies and outcomes occurring simultaneously.

[7] The United States Geological Survey data indicates that the average New Mexican used 81 gallons of water per day in 2015, the most recent year data are available, making the average in the sample data approximately the average water use for a family of two. National Water Information System: https://nwis.waterdata.usgs.gov/nm/nwis/water_use/. Accessed 07/12/2022.

[8] https://www.santafenm.gov/water_rates. Accessed 07/26/2022.

consumption across months using month-level indicator variables, year-level differences in water consumption, and variation in total monthly precipitation and average monthly high temperatures. The latter two variables are averaged across all reporting weather stations at the city-level, so we further adjust them by "zone", which roughly translates into elevation and allows the effects of these variables to vary with elevation. (Santa Fe elevation averages 7,198 feet above sea level, but can be as low as around 6,348 ft at the airport.) The city is split into 11 different pressure zones ranging from the northeast of the city to the southwest, with higher numbered zones generally corresponding to higher elevation areas. Zone is not available for a subset of households and including it in our regressions reduces our sample size by 2,758 observations (51 households) to 35,300 households and 2,070,993 observations. During our sample period, total monthly precipitation and average monthly high temperatures were 1.07 inches and 61 degrees, respectively.

Lastly, we run specifications assessing whether population density or per capita income affects our results. We obtained these data for each of Santa Fe's 35 Census Tracts from 2019 American Community Survey administered by the U.S. Census Bureau.[9] Population density ranges from 4 persons per square mile to 6,541, while average annual per capita income ranges from $18,309 to $95,198. Table 1 below shows descriptive statistics for the variables.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Treatment Variables				
HCL	0.16	0.37	0.00	1.00
COVID-19	0.42	0.49	0.00	1.00
Outcome Variables				
Water Use (100's of Gallons)	4,674	6,184	6	68,292
Ln(Water Use)	7.92	1.17	1.76	11.13
High-Use Pricing	0.12	0.32	0.00	1.00
Control Variables				
Total Precipitation (Inches)	1.07	0.89	0.02	3.59
Maximum Temperature (Fahrenheit)	60.88	14.67	38.39	84.22
Month	6	3	1	12
Year	2019	2	2017	2022
Population Density (Persons per Square Mile)	2,802	1,741	4	6,541
Per Capita Income (USD)	42,789	19,676	18,309	95,198

Notes: Data cover period from January 2017 through April 2022 and include 2,070,933 observations from 35,300 households. HCL=Home Cultivation Legalization.

We use two estimation methods. Our first uses Least Squares regressions techniques to estimate the effect of being pre- versus post-HCL on water consumption, controlling for the effect of

[9] Data are available at https://www.census.gov/programs-surveys/acs/data.html. Accessed 07/26/2022.

COVID-19; household-level, time-invariant differences; month-level variation in water use across all households; annual differences in water consumption common to all households; and total precipitation and average high temperature, both adjusted for elevation. Because observations within households may be arbitrarily correlated, we cluster our standard errors at the household level to avoid underestimating our standard errors and overestimating the statistical significance of our results. Our standard errors are further corrected for heteroskedasticity, which means the precision of the estimates varies systematically with the value of the independent variables, leading to inaccurate estimation of the standard errors, and thus, erroneous conclusions about the statistical significance of the estimates.

$$WaterUse_{ht} = \alpha + \beta * HCL_t + \gamma * COVID_t + \vartheta * Weather_t * Zone_h + \tau_y + \theta_m + \omega_h + \varepsilon_{ht}$$

Our outcome variables are measured for household *h* at time *t*, where *t* refers to the month *m* and year *y* in which the water use occurred. Our HCL and COVID variables are measured at the month-year level. We further control for the weather variables, adjusted by elevation (Zone), obtaining main estimates for total precipitation and average daily maximum temperature, as well as relative effects of these weather variables by elevation. As the Zone variable does not vary at the household level and we control for time-invariant household characteristics, the main effect of the Zone variable is perfectly collinear with the household fixed effects and drops out of the equation, leaving only the relative effects of the weather variables by zone, with Zone = 1 the omitted zone. The remaining variables capture a constant term α, the year fixed effects τ_y, the month fixed effects θ_m, the household fixed effects ω_h, and the error term ε_{ht}.

For our second estimation method, we use the following event study specification, in line with work on the COVID-19 pandemic by Bacher-Hicks, Goodman, and Mulhern (2021) and Goda et al. (2022).

$$WaterUse_{ht} = \alpha + \sum_{t=-17}^{-1} \beta_t * PreHCL_t + \sum_{t=1}^{10} \beta_t * PostHCL_t + \varphi * Pre2020_t + \vartheta * Weather_t * Zone_h + \tau_{y(2017-2019)} + \theta_m + \omega_h + \varepsilon_{ht}$$

Our outcome variables do not change, but we substitute a series of month-year-level pre- and post-HCL variables for the HCL and COVID indicator variables, tracing out the entire period from January 2020 through April 2022 with June 2021 as the omitted or baseline period relative to which the other periods' water use is estimated. In other words, in January 2020, *t*=-17; in June 2021, *t*=0; and in April 2020, *t*=10. Observations occurring prior to January 2020 are included in a dummy variable *Pre2020,* capturing that the water use occurred pre-2020. As in our difference-in-differences approach, we adjust the estimates for seasonal differences using month fixed effects, for annual differences in years 2017-2019 using year fixed effects, for precipitation and temperature differences (adjusted by elevation) not captured by the month fixed effects, and for time-invariant household characteristics using household fixed effects. We only include year fixed effects for 2017 through 2019 and drop the year fixed effects for 2020-2022 as all months between 2020-2022 are traced out using the period-level variables.

The β_t's measure how much water use differs from predicted water use in each period t relative to use in June 2021. In other words, but for HCL, predicted water use in each period pre- and post-HCL should be equal to use in June 2021 after adjustment, i.e., the coefficients (β_t's) measuring the difference should be statistical indistinguishable from zero. Differences for predicted values in the pre-period could arise from anticipatory effects or be driven by other events entirely, e.g., COVID-19. Similarly, abnormal water use in the post-period could consistent of immediate and lagged effects of HCL or could be capturing the effects of other events unrelated to the HCL.

Home Cultivation Survey

Our survey sample included 27 participants, who responded to 38 questions on home cultivation, ranging from experience to growing methods, and cost- and quality-based preferences for dispensary versus home cultivated cannabis. We provide simple summaries of these data following our main analyses of the Santa Fe water utility data. Participants were recruited through Kurple Magazine, a news publication focused on medical cannabis and headquartered in Albuquerque.[10] The survey recruitment flyer was posted on the Kurple Magazine Facebook page and the survey was administered through Opinio. Of the 26 respondents who reported their current zip code, all resided within New Mexico. The University of New Mexico Institutional Review Board approved the survey design. The survey was intended to serve as a pilot survey to establish the instrument's validity for future larger sampling efforts.

3. Results

Santa Fe Residential Water Use Data

We begin our analysis of the effect of HCL by graphing the raw data by month for the pre-COVID (January 2017 – January 2020), COVID (February 2020 – April 2022), and HCL (July 2021 – April 2022) periods, as shown in Figure 1.

[10] https://kurplemagazine.com/. Accessed 08/09/2022.

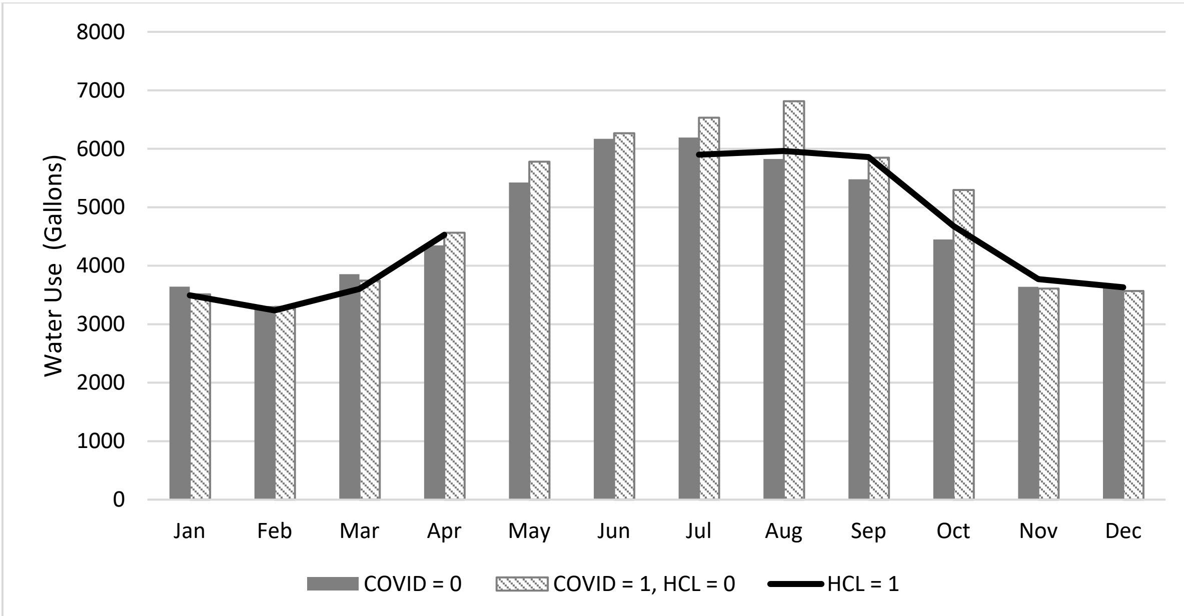

Figure 1: Residential Water Consumption by Time Period – Raw Data

Notes: The graph depicts average monthly household water consumption in gallons for three periods: COVID = 0 and HCL = 0 from January 2017 through January 2020, COVID = 1 and HCL = 0 from February 2020 through June 2021, HCL = 1 and COVID = 1 from July 2021 through April 2022.

Throughout seasonality is evident with higher water consumption in the summer and fall. During the winter months, COVID water use is lower than pre-COVID, but during the summer months, COVID water use is distinctly higher. Water use after HCL tracks similar to prior periods during the winter months but falls between pre-COVID and post-COVID water use during the summer months.

Table 2 shows the results from the regressions for our three outcome variables.

Table 2: Regression Results

	(1) Water Use (100s of gal)	(2) Water Use (100s of gal)	(3) Ln(Water Use)	(4) High-Use Pricing
HCL	-0.913***	-0.799***	-0.025***	-0.005***
	(0.143)	(0.014)	(0.003)	(0.001)
COVID		1.162***	0.033***	0.013***
		(0.177)	(0.004)	(0.001)
Observations	2,070,993	2,070,993	2,070,993	2,070,993
R-squared	0.125	0.125	0.112	0.058
Number of households	35,300	35,300	35,300	35,300
Outcome Mean	0.000	46.740	7.919	0.119

Notes: Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. HCL changes from zero to one in July 2021; COVID changes from zero to one in March 2020. All regressions control for precipitation, maximum temperature, zone x precipitation, and zone x maximum temperature, and include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The estimates in Columns 1 and 2 can be directly interpreted as changes in 100's of gallons of water consumed. In Column 1, the effect of HCL is measured without controlling for COVID. A negative coefficient corresponding to a reduction of 91.3 gallons is evident. However, the magnitude of the coefficient is too large due to the positive impact of COVID on water use in 2020. After controlling for the large surge in water use during summer 2020, i.e., comparing the HCL period with the pre-COVID period, we estimate an HCL coefficient of -0.799, which indicates a reduction of 80 gallons per month from HCL, while the COVID coefficient indicates an increase of 116 gallons. Although the coefficients together suggest an increase of 36 gallons per month in the HCL period, we cannot reject that the joint effect differs from zero (p=0.091) at standard levels of statistical significance (p≤0.05). Although not precise, this analysis suggests an aggregate effect of approximately 36 gallons times 35,300 households or 1,270,800 gallons. In Column 2, the HCL coefficient of -0.025 can be interpreted as showing that legalization of home cultivation reduced average monthly water consumption by 2.5 percent or 117 gallons per month.[11] This reverses an increase of 3.4 percent or 159 gallons during COVID. The combined coefficients for HCL and COVID are not statistically significantly different from zero (p=0.146). Although the outcome variable may better account for outliers in the natural log specification in Column 2, the model's explanatory power (R-squared) is lower than for the model using hundreds of gallons in Column 1. The third column's results show that HCL is associated with a 0.5 percentage point reduction in the likelihood of crossing into higher price-per-gallon consumption, with approximately 12 percent of households crossing the price threshold each month. COVID was associated with a 1.3 percentage point increase in the likelihood of crossing into higher price-per-gallon consumption. Jointly, the probability of crossing into higher price-per-gallon consumption was lower following HCL relative to COVID, but remained elevated relative to pre-pandemic levels (p<0.001). Combining the information in Columns 1 and 3, one can derive a rough estimate of $10,228 increase in monthly payments from households post-HCL relative to pre-COVID.[12] Dividing by the number of households yields an average per household increase in monthly payments of $0.29.

In Table 3, we interact the HCL variable with Population Density in thousand persons per square mile and with per capita income in ten thousand USDs in order to evaluate whether the small,

[11] The average effect of HCL on the natural log of water consumption is calculated as [exp(β)-1], where β is the reported coefficient.

[12] $ChangeAggregateMonthlyWaterUse = [(BaselineHighUsePricing + ChangeHighUsePricing) * N\ Households * Price\ per\ 1{,}000\ gallons * IncreaseWaterUsePostHCL] + [(1 - HighUsePricedProportion) * N\ Households * Price\ per\ 1000\ gallons * IncreaseWaterUsePostHCL] = \left[(0.119 + 0.0.013 - 0.005) * 35{,}300 * \$21.72 * 36\frac{gallons}{1000}\right] + \left[(1 - 0.119 - 0.013 + 0.005) * 35{,}300 * \$6.06 * \frac{36gallons}{1000}\right] = 0.127 * \$27{,}602 + 0.873 * \$7{,}701 = \$10{,}228.$

marginally statistically significant aggregate estimate is masking underlying variation in the effects by population density and per capita income. We adjust the original population density and per capita income variables by 1,000 and 10,000, respectively, to improve interpretation of coefficients given small effect sizes.

Table 3: Regression Results Interacting Population Density and Per Capita Income

	(1) Water Use (100s of gal)	(2) Ln(Water Use)	(3) High-Use Pricing
HCL	-2.252***	-0.049***	-0.015***
	(0.569)	(0.015)	(0.004)
COVID	1.161***	0.033***	0.013***
	(0.177)	(0.004)	(0.001)
HCL x Population Density (1,000 persons per sq. mile)	0.184**	-0.001	0.001**
	(0.087)	(0.002)	(0.001)
HCL x Per Capita Income (10,000 USDs)	0.219***	0.006***	0.001***
	(0.084)	(0.002)	(0.001)
Observations	2,070,993	2,070,993	2,070,993
R-squared	0.126	0.113	0.058
Number of households	35,300	35,300	35,300
Outcome Mean	46.740	7.919	0.119

Notes: Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. HCL changes from zero to one in July 2021; COVID changes from zero to one in March 2020. All regressions control for precipitation, maximum temperature, zone x precipitation, and zone x maximum temperature, and include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In Table 3, we explore heterogeneity in the effects of HCL by population density and by per capita income. The main coefficients for HCL and COVID can be interpreted as baseline levels to which the coefficients for the interaction effects should be added. Despite the prior that cannabis cultivation requires sufficient space, census tracts with denser populations experienced more water use post-HCL, even after controlling for weather differences. Per capita income was also associated with greater water use post-HCL. It may be that these variables are proxying for other factors affecting the decision to home cultivate, such as race and education which are highly correlated with income. Adding the HCL and COVID coefficients, baseline water use is 1.091 gallons lower post-HCL. For HCL to not decrease water use, based on the point estimates in Column 1 above, population density would have to be more than 5,930 persons per square mile, which is not true of any Census Tract in Santa Fe or income would have to be at least $49,818, which is true for 9 of the 35 Census Tracts in Santa Fe. A combination of high enough population density and income would also yield positive effects. Figure 2 below shows estimates of the effect of HCL on water use by Census Tract, where we base our estimates on Census

Tract-level population density and per capita income. Clearly, substantial heterogeneity exists across Census Tracts as shown in Figure 2 below. Most Census Tracts experience an increase in water use, but a handful of counties experience a decrease post-HCL. The magnitudes also vary substantially across counties from a decrease of 60 gallons near the airport (Census Tract 1304) to an increase of 100 gallons in the large rural area on the northwest side of the city near the pueblos (Census Tract 10204).

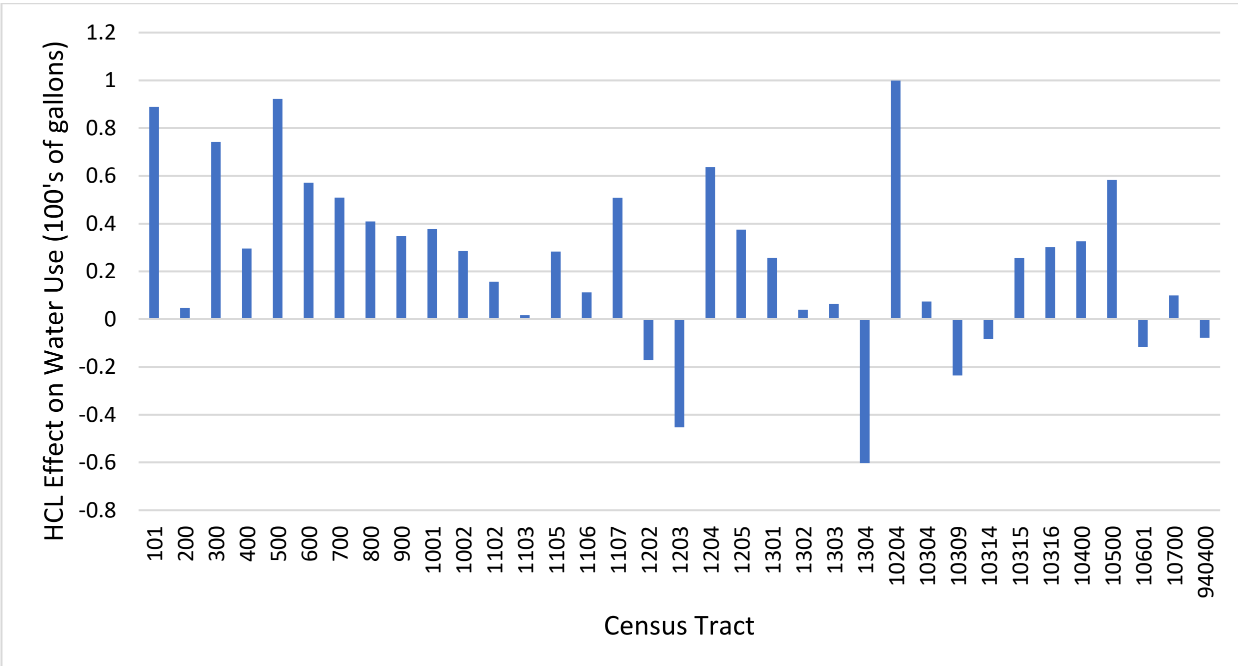

Figure 3: Census Tract-Level Changes in Water Use Based on Population Density and Per Capita Income

Notes: The estimated HCL effect on water use (in 100's of gallons) by Census Tract are calculated from the coefficients reported in Table 3 as follows: $-2.252 * (HCL = 1) + 1.161 * (COVID = 1) + 0.184 * persons\ per\ sq.\frac{mile}{1000} + 0.219 * per\ capita\frac{income}{10000} = Water\ Use\ Change\ (100's\ of\ gallons)$.

To better tease out the relationship between HCL, COVID, and residential water consumption, we use our second specification to generate the event studies in Figures 3-5. The reported outcomes are the average effect of being in that period relative to June 2021, the last month before HCL, adjusted for month-, year- (for 2017-2019), and household-level characteristics, precipitation, and high temperature.

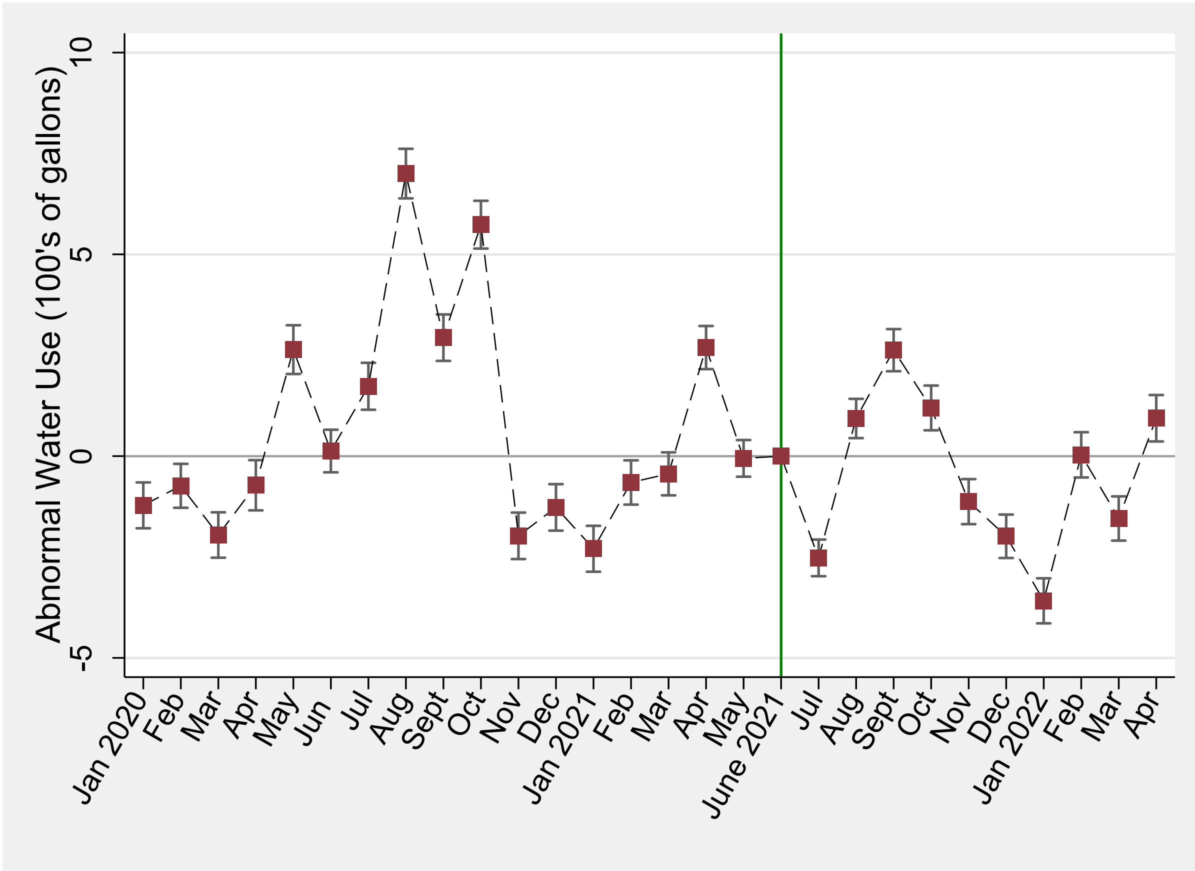

Figure 3: Event Study of Effect of HCL on Water Use (100’s of gallons)

Notes: The y-axis measures change in water use in 100’s of gallons relative to June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

Figure 4: Event Study of Effect of HCL on Natural Log of Water Use

Notes: The y-axis measures change in the natural log of water use relative to June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

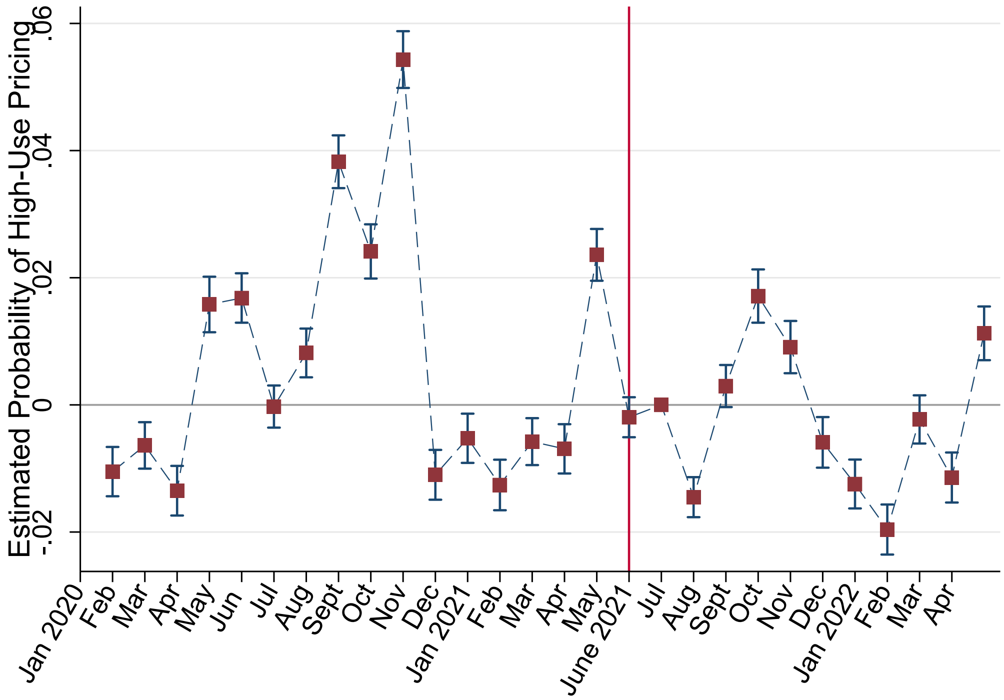

Figure 5: Event Study of Effect of HCL on the Probability a Household Crosses into Higher Priced Use

Notes: The y-axis measures the probability that a household exceeded the price threshold relative to the probability that they did in June 2021, the month prior to HCL. Periods prior to January 2020 are coded as occurring pre-2020. The underlying regressions control for precipitation, high temperature, zone x precipitation, and zone x high temperature, as well as month, year (2017-2019), and household fixed effects. Standard errors are clustered at the household level with 95 percent confidence intervals reported in the graph.

All three figures show much higher levels of water consumption in summer 2020 than any time before or thereafter. This coincides with a period in which COVID lockdowns were most prevalent. An inexplicable higher level of water use occurs in April 2021, around the time of the passage of HB2. In July 2021, the first month in which cannabis home cultivation for adult use was legal, water use is abnormally low. August, September, and October 2021 show water use that exceeds water use in June 2021, but is lower than during the first summer of COVID. (Appendix Table A1 reports the estimated coefficients underlying these regressions.) These results are in line with the overall results, that water use increased post-HCL relative to pre-COVID, but was lower than during COVID, and show that the increase in water use was driven by water use in September, October, and November of 2021 as well as possibly April 2022. September generally marks the end of the harvest season, suggesting that the increase in October and November may be driven by indoor grows begun at the end of June 2021 approaching maturity approximately 3-5 months after planting. A 3-5 month growing season falls within estimates of 3-8 months from a popular cannabis information aggregator.[13]

Home Cultivation Survey Data

The home cultivation survey respondents are fairly representative of the New Mexico population from a demographic perspective.[14] As shown in Table 4, the average age was 44 and respondent ages ranged from 20 to 69, respondents were 81% white (4% Native American, 15% other race) and 56% Hispanic or Latino, and 48% came from households earning $40,000 or less per year.

Table 4: Survey Respondent Demographics

Variable	Number of Respondents	Mean	Std. Dev.	Min	Max
Age:	27	44.25	14.78	20	69
Race:					
Native American	1	0.04	0.19	0	1
Other Race	4	0.15	0.36	0	1
White	22	0.81	0.40	0	1
Ethnicity:					
Hispanic or Latino	15	0.56	0.51	0	1
Not Hispanic or Latino	12	0.44	0.51	0	1
Income:					
Less than $20,000	3	0.11	0.32	0	1
$20,000 - $40,000	10	0.37	0.49	0	1
$40,000 - $60,000	4	0.15	0.36	0	1
$60,000 - $80,000	4	0.15	0.36	0	1
$80,000 - $100,000	3	0.11	0.32	0	1
Over $100,000	3	0.11	0.32	0	1

Notes: The sample included 27 respondents. All variables except Age are coded as {0,1}. For Race, no respondents selected options "Black or African American" or "Asian," so these are not included in the table above.

As shown in Table 5 below, when questioned regarding past, current, and future cannabis growing, 68% had home cultivated previously (on average, for almost 8 years), 72% grew currently, and 96% anticipated growing in the future. These high rates of cannabis growing may have been facilitated by widespread broader growing experience. Around 78% had experience home gardening and 52% had lived on property where crops were grown. When questioned why

[13] Leafly: 4 Stages of Marijuana Growth. https://www.leafly.com/learn/growing/marijuana-growth-stages Accessed. 08/03/2022.

[14] Per the United States Census Bureau, 81.3% of New Mexicans identify as White, 11.4% as Native American, and 2.7% two or more races. 2.7% and 1.9% identify as Black or African American, or Asian, respectively. 50.2% identify as Hispanic or Latino and 35.9% identify as White Alone. Per capita income was estimated at $27,945 (median = $51,243). https://www.census.gov/quickfacts/NM. Accessed 07/26/2022. Median age is 38.1 years. https://datacommons.org/place/geoId/35?utm_medium=explore&mprop=age&popt=Person&hl=en#. Accessed 07/26/2022.

they grew cannabis, 55% grow because home grown cannabis is cheaper than dispensary cannabis, 25% because it is higher quality, 5% in order to have cannabis to share with friends, and 15% sold it for profit. Among those not growing, the most common reason was lack of know-how. Potentially reflecting the high level of expertise in this sample, five respondents anticipate applying for commercial cultivation licenses.

Table 5: Growing Experience & Expectations

Variable	Observations	Mean	Std. Dev.
Growing Experience (Select All That Apply)			
Home Garden	27	0.78	0.42
Crops	27	0.52	0.51
Cannabis - Past	25	0.68	0.48
Cannabis - Current	25	0.72	0.46
Cannabis - Future	24	0.96	0.20
Cannabis - Years of Experience Growing Cannabis	22	7.73	9.18
Why Grow? (Select One)			
Cheaper than Dispensary Cannabis	20	0.55	0.51
Higher Quality than Dispensary Cannabis	20	0.25	0.44
Share with Friends	20	0.05	0.22
Sell for Profit	20	0.15	0.37
Why Not Grow? (Select All That Apply)			
Too Expensive to Grow	5	0.20	0.45
Product Range Is Better at Dispensaries	5	0.20	0.45
I Don't Know How	5	0.80	0.45
Applying for a Commercial License (Current or Future)?			
Yes	23	0.22	0.42
Will Dispensary Access Affect Decision to Home Cultivate? (Select One)			
More Dispensaries => Less Like to Home Cutlivate	24	0.04	0.20
More Dispensaries => More Likely to Home Cultivate	24	0.13	0.34
No Effect on Decision to Home Cultivate	24	0.83	0.38

Notes: The full sample included 27 respondents. All variables are coded as {0,1} except for the years of experience growing cannabis. Other response options not selected for "Why Grow?" include "I don't consume cannabis," "Too expensive to grow," "I do not live where I am allowed to grow," and "I am afraid of legal liability."

A primary focus for the survey was to understand how cannabis is grown and which water sources are used with responses reported in Table 6. Among those respondents who grew cannabis, 56% grew indoors, 31% outdoors, and 17% in a greenhouse. In terms of water sources, 53% used public utility water, 21% used a private well, and 26% used another source. Plans for future cannabis growing predict an increase in greenhouse growing and potentially a slight shift away from public utility water. While there was some disagreement, half of respondents felt indoors with artificial lighting yielded the highest quality product. Responses were more mixed for the highest quantity growing method with 35% favoring greenhouses, 26% favoring indoors, and 17% favoring outdoors without a structure. The remaining respondents felt all produced similar quantities.

Table 6: Growing Methods and Quality/Quantity Expectations

Variable	Observations	Mean	Std. Dev.
Cannabis Growing Method (Select All That Apply)			
Current:			
Indoors with Artificial Lighting	23	0.56	0.50
Outdoors with Natural Light in a Structure (e.g., Greenhouse)	23	0.17	0.38
Outdoors with Natural Light and No Structure	23	0.31	0.47
Water Sources (Select Primary Source)			
Current:			
Public Utility	19	0.53	0.51
Residential Well	19	0.21	0.42
Ditch/Rural Surface Water	19	0.00	0.00
Other Water Source	19	0.26	0.45
Past:			
Public Utility	19	0.47	0.51
Residential Well	19	0.21	0.42
Ditch/Rural Surface Water	19	0.05	0.23
Other Water Source	19	0.26	0.45
Highest Quality & Quantity Growing Methods (Select One)			
Highest Quality Method:			
All Methods Are Similar	22	0.32	0.48
Indoors with Artificial Lighting	22	0.50	0.51
Outdoors with Natural Light in a Structure (e.g., Greenhouse)	22	0.14	0.35
Outdoors with Natural Light and No Structure	22	0.05	0.21
Highest Quantity Method:			
All Methods Are Similar	23	0.22	0.42
Indoors with Artificial Lighting	23	0.26	0.45
Outdoors with Natural Light in a Structure (e.g., Greenhouse)	23	0.35	0.49
Outdoors with Natural Light and No Structure	23	0.17	0.39
Highest Quality Source (Select One)			
Home-Cultivated and Dispensary Cannabis Are Similar in Quality	25	0.60	0.50
Dispensaries	25	0.04	0.20
Home Cultivators	25	0.36	0.49

Notes: The full sample included 27 respondents. All variables are coded as {0,1}.Under water sources, no respondents selected "Commercial Well."

The survey also sought to assess preferences for home cultivated versus dispensary-sourced cannabis in order to gain insight into the likely popularity of home cultivation post-dispensary entry in April 2022. As shown in Table 5, 80% home cultivated because they perceive home cultivation to yield a cheaper or higher quality product. A similar percentage also responded that dispensaries will not affect their decision to home cultivate. As shown in Table 6, with respect to quality, the majority (60%) felt that home cultivators and dispensaries produced similar quality products, while 36% favored home cultivation over dispensary-sourced cannabis.

4. Results Summary and Discussion

The Santa Fe water use data indicate a possible increase in residential water use in response to HCL. Households in Santa Fe are spending about $0.29 more per month on average for an additional 36 gallons and Santa Fe Water Utility can expect just over $10,228 more per month. Significant variation in water use exists across households and across Santa Fe more generally. Complicating the identification of causal effects, COVID caused an enormous perturbation in water use patterns in 2020 and it is possible that a spillover or continued COVID effect could be driving the results in 2021 rather than HCL. Reducing the risk of contamination from spillover COVID effects, the COVID context changed substantially between the summers of 2020 and 2021. Although case counts and hospitalizations did not differ significantly across summers in 2020 and 2021, during the first summer stay-at-home orders were prevalent, while by summer 2021, most of those who wanted to be vaccinated were vaccinated and businesses were open. Labor market analyses (e.g., Goda et al. (2022)) show a general trend towards a resumption of normal labor market outcomes, suggesting that individual policies and COVID-related cases, hospitalizations, and deaths may have done little to perturb a general trend back to normal over the course of the pandemic. Data from the New Mexico Department of Health show peak cases in November 2020 and January 2022, peak deaths in December 2020, December 2021 and February 2022, which, apart from November 2020, are not months with particularly high water use.[15] Further analysis of a longer period of post-HCL water use is necessary to more definitively disentangle the effect of HCL from COVID. In addition, the data sample extends only through April 2022, meaning that the effect of dispensary entry in April 2022 on HCL-related water use remains to be assessed. Additional survey questions could be used to identify mechanisms through which HCL reduced water use relative to during the first summer of COVID, such as substitution away from growing more water-intensive plants cultivated during COVID towards cannabis and delaying the onset of the growing season to accommodate legalization at the end of June 2021.

A major limitation of the water use data is the lack of household-level information. While we do control for household fixed effects to capture time-invariant household characteristics, we are do not have household-level information on factors such as age, race, number of household members, employment status, education, and income. Although we are unable to analyze these variables at the household level, we are able to evaluate Census Tract-level differences in the effect of HCL. We focused on population density to approximate lot size and per capita income to capture financial resources and because income is correlated with employment status,

[15] New Mexico Department of Health COVID Dashboard. https://cvprovider.nmhealth.org/public-dashboard.html. Accessed 08/09/2022.

education, and health. Unfortunately, the positive coefficient on population density does not have an obvious explanation. Less space seems unlikely to drive increased water use, so factors such as more private wells in less densely populated areas or increased population density in more fertile growing areas might be driving the effect. Future analyses should drill deeper into the heterogeneity across Census Tracts to attempt to identify the underlying factors leading to greater changes in water use in more densely populated areas. Similarly, the positive coefficient on per capita income could be directly due to greater availability of resources or might arise because per capita income is correlated with other factors, e.g., health and education. Ultimately, Census Tract-level heterogeneity can only capture the general context in which a household lives and not the precise circumstances of an individual household. Another issue with the lack of individual information is that it limits our ability to generalize the results beyond Santa Fe, as we do not know which underlying household factors specific to Santa Fe could be driving the results. For example, survey data indicates that cannabis consumers 45 and older are more likely to home cultivate than cannabis consumers under 45 (Azofeifa, Pacula, and Mattson, 2021). With the U.S. Census reporting that the average age in Santa Fe is 44[16] versus 38[17] for the rest of New Mexico, it may be that Santa Fe residents are more likely to cultivate than in cities with younger populations. The survey data thus clearly complement the water use data by providing insight into individual factors affecting cannabis growing that cannot be captured by Census Tract-level variables.

The Home Cultivation Survey data are limited by the small sample size but provided a proof-of-validity for the survey questions and suggestive evidence of potential trajectories in cannabis home cultivation in the future. In particular, the main reported barrier to home cultivation, lack of know-how, can easily be addressed; more respondents intend to grow cannabis in the future than grow now; and home cultivated cannabis is a cheaper, potentially higher quality product as compared to dispensary-sourced cannabis. Expected growing methods point towards lower water-use methods, i.e., indoor growing, but the majority of water used for home cultivation is likely to come from public water utilities. Furthermore, the dominance of indoor growing could relate to the late legal start date of the 2021 growing season on June 29, 2021, i.e., we may see more outdoor cultivation in summer 2022. Potentially further expanding home cultivation in Summer 2020, although dispensaries that began entering in April 2022 provide a substitute product, they also sell seedlings, which can greatly simplify the growing process for novice growers.

5. Policy Implications

The data analyzed suggest that home cultivation occurs in New Mexico and it is likely to increase in the future, even if dispensary access is widespread. Home cultivation could lead to an increase in water use, but the popularity of indoor growing methods likely mitigates the potential impact and overall impacts so far are relatively small at less than 1% of average monthly use.

[16] https://censusreporter.org/profiles/16000US3570500-santa-fe-nm/. Accessed 08/09/2022.
[17] https://censusreporter.org/profiles/04000US35-new-mexico/. Accessed 08/09/2022.

Dispensary entry after our sample period may reduce home cultivation-related water use, but the overall effect of cannabis legalization on water resources in New Mexico remains unknown because the relative water use of commercial versus residential cultivation is unknown.

While policymakers might prefer that cannabis be sourced through regulated dispensaries for public health and tax revenue reasons, dispensaries seem unlikely to drive out home cultivation for the foreseeable future. Dovetailing with the findings from our pilot survey, perceptions in the popular press in April were that prices in New Mexico, particularly for more processed products, continue to be relatively high as compared Colorado and quality is comparatively lower (Hooper, 2022; Porter, 2022), i.e., dispensaries are not seen as offering a particularly high value product, even compared to dispensaries in competing markets, despite regulations. More recent price data are not available from the Cannabis Control Division, only aggregate sales by city.[18]

Policy Recommendations:

1. Educate and encourage growers to use low-water growing methods, with indoor growing a clear option for conserving water.
2. Continue to monitor the evolution of New Mexico's cannabis market with respect to the interplay between unregulated home cultivated cannabis and dispensary-sourced cannabis and the relative water use of each approach to cannabis cultivation.
3. Identify why regulations do not necessarily ensure positive perceptions of dispensary-sourced products, even at newly opened recreational dispensaries in New Mexico. It may also be that current testing protocols are inadequate to ensure that products sold are free from contamination, e.g., from pesticides, mold, mites, or even just seeds.
4. Ensure that the Cannabis Control Division tracks detailed data on prices and quantities sold overall and by product type and makes this data available to researchers. Such data are crucial for understanding substitution patterns between home-cultivated and dispensary-sourced cannabis and the implications for water use across types of products sold.

6. Future work

We anticipate continuing this research into next year. Doing so will enable to us to extend our sample period for the water use data to capture a longer period post-HCL, in order to better disentangle the effects of COVID from those of HCL. We will further analyze the effect of proximate recreational dispensary entry on household-level, home cultivation-related water use. The additional funding will also enable us to field a much larger survey with respondents from across New Mexico, in order to capture information necessary for understanding the prevalence and incidence of home cultivation throughout New Mexico, including predictions of future home cultivation rates.

[18] https://www.rld.nm.gov/cannabis/for-media/press-releases/. Accessed 07/27/2022.

Expanding beyond the existing project, we expect to produce preliminary evidence on the extent of water use by commercial cultivators using water utility data and data on commercial cannabis cultivation licenses. We also plan to leverage the survey results to create an undergraduate data analysis project for use across courses and faculty with the goal of improving the data analysis skills and economic understanding of our undergraduates, as well as connecting our teaching curriculum to real issues occurring in New Mexico right now.

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Appendix Tables and Figures:

Table A1: Event Study Regression Results

	(1) Water Use (100s of gal)	(2) Ln(Water Use)	(3) High-Use Pricing
January 2020	-0.046***	-1.218***	-0.010***
	(0.007)	(0.290)	(0.002)
February 2020	-0.042***	-0.734***	-0.006***
	(0.006)	(0.278)	(0.002)
March 2020	-0.057***	-1.953***	-0.014***
	(0.006)	(0.287)	(0.002)
April 2020	-0.034***	-0.720**	0.016***
	(0.007)	(0.318)	(0.002)
May 2020	0.020***	2.641***	0.017***
	(0.006)	(0.308)	(0.002)
June 2020	-0.002	0.128	-0.000
	(0.005)	(0.269)	(0.002)
July 2020	0.010*	1.732***	0.008***
	(0.006)	(0.297)	(0.002)
August 2020	0.088***	7.003***	0.038***
	(0.006)	(0.313)	(0.002)
September 2020	0.053***	2.937***	0.024***
	(0.006)	(0.294)	(0.002)
October 2020	0.120***	5.737***	0.054***
	(0.006)	(0.302)	(0.002)
November 2020	-0.025***	-1.973***	-0.011***
	(0.006)	(0.294)	(0.002)
December 2020	-0.036***	-1.269***	-0.005***
	(0.006)	(0.294)	(0.002)
January 2021	-0.055***	-2.294***	-0.013***
	(0.006)	(0.290)	(0.002)
February 2021	-0.004	-0.652**	-0.006***
	(0.006)	(0.280)	(0.002)
March 2021	-0.000	-0.438	-0.007***
	(0.006)	(0.272)	(0.002)
April 2021	0.065***	2.691***	0.024***
	(0.005)	(0.273)	(0.002)
May 2021	-0.005	-0.054	-0.002
	(0.004)	(0.232)	(0.002)
July 2021	-0.055***	-2.521***	-0.015***
	(0.004)	(0.232)	(0.002)
August 2021	0.006	0.934***	0.003*

	(0.005)	(0.248)	(0.002)
September 2021	0.023***	2.627***	0.017***
	(0.005)	(0.266)	(0.002)
October 2021	0.022***	1.195***	0.009***
	(0.005)	(0.283)	(0.002)
November 2021	-0.007	-1.127***	-0.006***
	(0.006)	(0.285)	(0.002)
December 2021	-0.036***	-1.985***	-0.012***
	(0.006)	(0.275)	(0.002)
January 2022	-0.093***	-3.584***	-0.020***
	(0.006)	(0.285)	(0.002)
February 2022	-0.022***	0.033	-0.002
	(0.006)	(0.286)	(0.002)
March 2022	-0.056***	-1.545***	-0.011***
	(0.006)	(0.280)	(0.002)
April 2022	0.009	0.940***	0.011***
	(0.006)	(0.293)	(0.002)
Observations	2,070,993	2,070,993	2,070,993
R-squared	0.113	0.126	0.059
Number of households	35,300	35,300	35,300
Outcome Mean	46.740	7.919	0.119

Notes: Each column represents a separate regression. The outcome variables are total water consumption in 100's of gallons, the natural log of total water consumption in gallons, and whether or not the household crossed into high-use pricing. June 2021 is the omitted period. All regressions control for precipitation, maximum temperature, and zone x precipitationand include month, year, and household fixed effects. Standard errors clustered at the household level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The Authors:

Sarah Stith is an expert on the medical and regulatory effects of cannabis legalization with eighteen cannabis-related, peer-reviewed publications. She has had her work cited in testimony before the U.S. Congress, has testified herself on the subject before the New Mexico Legislature's Economic Development and Policy Committee, and has experience managing policy-related grant work for the Social Security Administration. Dr. Stith has conducted research related to New Mexico's medical cannabis program with a focus on particularly vulnerable New Mexicans, including chronic pain patients and veterans with PTSD. Her work has been cited in both the national press, e.g., *U.S. News and World Report* and *Forbes*, and local news outlets, e.g., *KRQE, KKOB,* and the *Santa Fe New Mexican*.

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