Final Report

Licensed and Unlicensed Cultivation Across Ban and Permit Jurisdictions

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ABSTRACT

This project aimed to: a) provide the first empirical assessments of unlicensed production amounts and geography over time; b) identify what policies are correlated with growth or diminution of unlicensed cultivation; c) estimate unlicensed market product, including leakage from the licensed to unlicensed market; and d) test whether cultivation bans or permits are more effective at preventing unlicensed cultivation and environmental harms. It does so through a mixed method approach involving a first-in-kind mapping approach (using SWRCB's Cannavision platform), license data, consumer surveys, point-of-sale, supply chain and pricing data, interviews, observations, and secondary material research.

Keywords: Cannabis cultivation, bans, permits, California, enforcement, local government, agriculture.

EXECUTIVE SUMMARY

This project, entitled "Licensed and Unlicensed Production Across Ban and Permit Jurisdictions," aimed to assess the evolution of unlicensed cannabis cultivation since legalization. We approached this with four objectives in mind: (1) empirically assess changes in unlicensed cultivation amounts and geography over time; (2) identify what policy, social, economic, and geophysical factors drove those changes across ban and permit counties; (3) compare unlicensed cultivation changes with proximate changes in the licensed market; and (4) assess whether local bans or permits demonstrably prevented environmental harms from unlicensed cultivation.

Over 30 months, six core researchers from environmental, data, and social sciences, along with 22 undergraduate researchers and two additional graduate students, addressed these objectives through multiple methods including ethnography, interviews, data modeling, analysis of energy records, license data, and policy. There are several top-tier takeaways:

1) *The boom is over:* After a post-legalization boom, cultivation levels have returned to 2018 levels.

2) *Licensed farms are the best deterrent for unlicensed cultivation*: The presence of a licensed farm best predicts declines in unlicensed cultivation nearby.

3) *Local Permit programs reduce the environmental impact of unlicensed cultivation:* Over time, counties with bans showed more negative environmental outcomes than permit counties.

4) *Bans do not have any consistent effects on unlicensed cultivation:* Bans correlated to increases and decreases in unlicensed cultivation.

5) *Eradication-oriented enforcement lost its deterrent effect, while civil regulation showed increasing efficacy:* While eradication-oriented enforcement initially discouraged unlicensed growing, it lost efficacy over time. Civil regulations (e.g. administrative fines, liens, landlord liability, hemp registrations) showed increasing efficacy as they stabilized and fostered norms.

6) *Unlicensed cultivation is diverging from licensed cultivation:* Unlicensed cultivators are persisting in more remote areas, far from licensed farms.

7) *Persistence of unlicensed cultivation is driven by socioeconomic factors:* As market conditions worsened, unlicensed cultivators who persist have few alternative livelihood options.

Stated strongly, our analysis concludes that permitting – particularly of numerous farms, dispersed over broad territories – can do more to address unlicensed cultivation and its attendant environmental outcomes than any other policy choices, including bans and eradication efforts. Bans have no consistent impact on unlicensed cultivation and eradication-focused enforcement has declining efficacy, particularly when cultivators are driven by socio-economic concerns, and lack of other opportunities. Conversely, licensed farms were the strongest localized deterrent of unlicensed cultivation and local permit programs in general were correlated with fewer environmental impacts.

Our analysis points to a number of important but less-appreciated points contained in our findings. The "whack-a-mole" dynamics referenced in enforcement efforts occur more often in ban counties. Licensed cultivation grew faster than unlicensed cultivation. Among unlicensed cultivators, there was a notable shift from outdoor to mixed-light methods. Indoor unlicensed cultivation grew while the total amount of unlicensed outdoor and mixed-light shrank (2020-2023). State regulations and permit programs can create norms that shape how unlicensed cultivation occurs and what kinds of effects it has on society and the environment. Persistent unlicensed cultivators are commonly "stuck in place" either for economic or social reasons. Surprising and counterintuitive results also abound, such as the increase of cannabis cultivation in 2022-24 in counties that are conservative, have bans, and have intensive histories of eradication-based enforcement. We invite readers to investigate the numerous results and findings detailed in this report and in the raw data reported in the Appendices.

Together, these findings point to a substantial remaking of unlicensed cultivation after legalization. Though patterns of cannabis cultivation changed numerous times over 50 years of prohibition, post-legalization patterns are distinct and divergent. A crucial difference is the application of a suite of new policy measures, from bans to hemp programs to fines to permits. This project is the first-in-kind to test how different policies affect – or do not affect – unlicensed cultivation. In doing so, it offers to California policymakers and to legalizing jurisdictions in the US and beyond, empirical feedback on policy efficacy.

Another key difference in this new landscape of unlicensed cultivation is economic: the unlicensed market is not the lucrative market of prior eras. Cultivators are responding to cost pressures by exiting cultivation, becoming more efficient, or just persisting because other viable options do not exist. These dynamics intensify in the remote geographies where cannabis was traditionally grown and among the marginalized populations that have found livelihoods and social stability in cultivation, before and after legalization.

At the conclusion of this report, we recommend several specific policies and policy approaches. Derived from our findings and takeaways, we recommend measures that strengthen and expand permitting in ways that foster normalization but do not worsen market conditions. Permitting is the key policy associated with declining unlicensed cultivation. Policies include:

maximizing the number and dispersion of licensed farms, creating new pathways for small-farm local permits, and protecting the right to personal cultivation. We also encourage the reform of enforcement and ban policies to ensure responsiveness to the drivers of unlicensed cultivation, demonstration of efficacy, and parity between cannabis and other forms of agriculture. We encourage broader developmental policies for areas affected by declines in cannabis markets and, finally, reform of track-and-trace programs to improve data quality and facilitate and increase optimal use. eliminate barriers to proper use.

INTRODUCTION

This project, entitled "Licensed and Unlicensed Production Across Ban and Permit Jurisdictions," aims to provide an assessment of unlicensed cannabis cultivation since legalization. This includes the amount, modality, and geography of unlicensed cultivation, the policy and social factors that drive its development (e.g. bans and permit programs), and its relation to the licensed market. As such, this project addresses longstanding challenges in the measurement of unlicensed cultivation and the understudied impacts of post-legalization policy and societal factors on it.

The project pursues four primary objectives. First, it seeks to utilize innovative tools and methods to assess the amount and geographical variation of unlicensed cannabis cultivation over time, specifically since the establishment of state regulations in 2018. We rely on a first-in-use modeling of CannaVision (a product of California's State Water Resource Control Board) to identify outdoor and mixed light production. We also innovated methods to assess indoor production by modeling and analyzing Investor-Owned Utility Company records.

Second, we analyzed what, if any, relation unlicensed cultivation might have to California's legal supply chain. To do this we obtained data from California's Track-and-Trace Program, specifically data on cultivation licensing, harvests amounts, and the development of cannabis supply chains across the state. We then compared these findings with data on unlicensed cultivation.

Third, we correlated this spatiotemporal evaluation of unlicensed cannabis cultivation to a fine-grained analysis of local policy and social dynamics. This involved a thorough review of local ordinances and governmental dynamics, in-person qualitative methods to assess on-the-ground dynamics that may not be obvious, and reincorporation of these findings into Cannavision modeling. As suggested in the title, we specifically investigated differences between cultivation ban and permit policies, though not exclusively

Fourth, we sought to assess the environmental impacts of shifts in unlicensed cannabis cultivation and what policy or social factors are associated with their increase or decrease. To do this, we created models that drew upon Cannavision and geophysical data to determine overlays of environmental sensitivity and cannabis cultivation.

In sum, this project a) provides the first empirical assessments of California's unlicensed cultivation amounts and geography over time; b) identifies what post-legalization policies and/or non-policy factors are correlated with growth or diminution of unlicensed cultivation; c) analyzes the harvest, transfer, sales and consumption data to detect relational trends between legal and unlicensed production; and d) tests whether cultivation bans or permit programs (among other factors) are more effective at preventing unlicensed cultivation and environmental harms.

Through the multiple mixed methods described – mapping, energy records, supply chain analysis, policy analysis, ethnography – we aimed to deliver the most comprehensive assessment possible of shifts in cultivation since legalization. As such, this project assesses progress toward the first purpose and intent of Proposition 64 – to transition cannabis production out of the hands of the illegal market. Has this been accomplished and what factors have impeded or facilitated this transition?

The project emerges out of our prior findings. First, restrictive zoning has pushed unlicensed cannabis out of agricultural lands and onto marginal and more environmentally sensitive lands (Butsic et al 2018; Dillis, Petersen-Rockney & Polson 2024), but licensing programs have been effective in driving licensed cultivation toward less environmentally sensitive areas (Dillis et al 2021a; Dillis et al 2021b). At the local level, bans can worsen environmental and social impacts by impeding education, outreach, regulation, and beneficial adaptation (Polson & Petersen-Rockney 2019; Polson 2019), even as local permitting programs can erect barriers for farmers hoping to become licensed (Bodwith et al 2021; Biber et al 2023). Together, these findings suggested directions in how to understand licensed and unlicensed cultivation across varied local policy regimes, though they have been limited to licensure, permit and policy data, localized mapping efforts, and qualitative methods.

The project is conducted by a team of researchers with nearly 60 years of combined cannabis-related research experience. The researchers' expertise has resulted from investigations of: cannabis cultivation geographies before and after legalization; resource use in cannabis cultivation; regulatory compliance; policy design; ban policies; studies of cannabis use; and social and historical dynamics of non-legal cannabis cultivation. The research team includes experts in anthropology, legal studies, public health, water ecology, political ecology, environmental ethics, and energy resources.

LEGAL AND POLICY BACKGROUND

In this section we summarize the history of California cannabis law and policy, the issue of local control, and the background on how counties choose to regulate cannabis cultivation through bans, permits, and other correlated measures. We also discuss market and social dynamics relevant to this research (i.e. the spatial-temporal development of cannabis cultivation).

2.1 CANNABIS LAW HISTORY

1913 Poison Act: California banned cannabis by amending the Poison Act, and in 1915, the State restricted cannabis to pharmacies (Gieringer 1999).

1937 Marihuana Tax Act: Federal government prohibited cannabis and hemp by requiring a special tax stamp to sell these products. Distribution of stamps was limited, and sellers were

wary of obtaining them as they would then be identified as sellers of these products by the government.[1]

1970 Federal Controlled Substances Act: Federal government deemed cannabis an illegal narcotic, designated it Schedule I and established serious criminal consequences for violation.[2]

1975 The Moscone Act (SB 95): California decriminalized possession of one ounce or less of cannabis and deemed it a civil rather than criminal offense.

1991 Proposition P, San Francisco: San Francisco voters approved Proposition P with an 80% vote, recommending that California and the California Medical Association include medical hemp preparations on the list of available medicines (*Proposition P*, n.d.).

1996 Proposition 215: California voters passed Proposition 215, the "Compassionate Use Act", which decriminalized medical cannabis for seriously ill patients but was silent on the issue of local control and unified state regulation.[3] It allowed patients to obtain a doctor's recommendation for the medical use of cannabis to be used as a defense in court thereby exempting patients from criminal penalties associated with possessing cannabis.

2003 SB-420: In 2003, the California Legislature passed the "Medical Marijuana Program Act", which gave local governments the power to regulate medical cannabis consistent with state law[4] and created a cooperative and collective structure.

2008 Attorney General Guidelines: In August 2018, Attorney General Brown published the "Guidelines for the Security and Non-Diversion of Marijuana Grown for Medical Use.[5] The memo created guidelines for non-profit cannabis cooperatives and collectives.

2011 AB-1300: In 2011, the California Legislature further refined local control by giving local governments the power to regulate the "location, operation, or establishment of a medical marijuana cooperative or collective."[6]

2011 - 2014 Case Law: Case law between 2011 and 2014 clarified that local governments' land use powers authorize them to prohibit cannabis activities and designate cannabis activities as a nuisance.[7]

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[1] 50 Stat. 551 (Pub. Law 75-238).
[2] Controlled Substances Act, 21 U.S.C. §§ 801 et seq.
[3] Cal. Health & Saf. Code § 11362.5.
[4] Section 11362.83 stated "Nothing in this article shall prevent a city or other local governing body from adopting and enforcing laws consistent with this article."
[5] Brown, E. G., Jr. & California Department of Justice. (2008). *California Attorney General's Guidelines for the Security and Non-Diversion of Marijuana Grown for Medical Use*. https://www.placer.ca.gov/DocumentCenter/View/15072/bosd_100406_032_p26_p37-PDF.
[6] Cal. H&S Code § 11362.83(a).
[7] *See* City of Riverside v. Inland Empire Patients Health & Wellness Center (200 Cal. App. 4th 885 (Cal. Ct. App. 2011)); Browne v. County of Tehama (213 Cal. App. 4th 704, (Cal Ct. App 2013); and Maral v. City of Live Oak (221 Cal. App. 4th 975 (Cal. Ct. App. 2014)).

2015 Medical Marijuana Regulation and Safety Act ("MMRSA"): In 2015, the California state legislature passed the Medical Marijuana Regulation and Safety Act ("MMRSA") to regulate commercial medical marijuana (S.B. 643, Reg. Leg. Sess. 2015-2016 (Cal. 2015))

2016 Proposition 64: In November 2016, California voters passed Proposition 64 (The Control, Regulate and Tax Adult Use of Marijuana Act, known as AUMA). AUMA legalized cannabis consumption for adults 21+ and created a robust, detailed regulatory structure to govern the issuance of cannabis licenses across the supply chain (Cal. Bus. & Prof. § 19300.7(a)–(j)). Proposition 64 was based on the structure defined in the MMRSA, but also included new provisions.

2017-18 State Emergency Regulations and Issuance of State Cannabis Licenses: In April 2017, state agencies responsible for cannabis regulation (BCC, CDFA, CDPH) released Emergency Regulations for the medical cannabis industry. In November 2017, the agencies released Emergency Regulations for the adult-use and medical industry. The State began accepting applications in December 2017. In 2018, state regulatory agencies, including the Bureau of Cannabis Control, the California Department of Food and Agriculture, and the California Department of Public Health, began issuing licenses to businesses involved in legal cannabis activities. In 2018, the state began issuing "temporary" cannabis licenses, which did not require access to METRC's track-and-trace system but required keeping paper records. In Q4 2018, the state started issuing "Provisional" licenses, which required operators to use METRC. California commenced its relationship with METRC to conduct track-and-trace in June 2017.[8]

2017 SB-94, Budget Trailer Bill: In 2017, the State Legislature combined AUMA and MMRSA into one unified bill, called the Medicinal and Adult-Use Cannabis Regulation and Safety Act ("MAUCRSA"), which regulated adult-use and medicinal cannabis under one legal umbrella (S.B. 94, 2017–2018 Reg. Leg. Sess. (Cal. 2017)).

2018 AB-2164: In 2018, AB 2164 amended California Government Code Section 53069.4 to allow local governments to impose immediate fines for illegal cannabis cultivation without providing a prior "reasonable time period" for correction.[9] In general, local governments must provide a reasonable period to correct for violations of building, plumbing, electrical, or other similar structural, health, and safety, or zoning requirements. However, when those same violations are related to cannabis cultivation, a fine or penalty can be issued immediately under AB-2164

2020 California State Public Health Officer List of Essential Critical Infrastructure Workers: In 2020, cannabis was deemed an "essential" business and could continue operating during the COVID-19 pandemic stay-at-home order.[10]

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[8] Prior, A. (2025, April 4). *Metrc California | Official Cannabis Tracking & Compliance*. Metrc. https://www.metrc.com/partner/california/.

[9] *Bill Text - AB-2164 Local ordinances: fines and penalties: cannabis.* (n.d.). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2164.

[10] Schroyer, J. (2021, December 18). Amid coronavirus pandemic, California gov classifies cannabis industry as 'essential' during state's effective lockdown. *MJBizDaily*. https://mjbizdaily.com/california-gov-classifies-cannabis-industry-as-essential-during-lockdown/.

2021 AB-141, Budget Trailer Bill: In 2021, AB-141 amended state law to consolidate the three agencies regulating cannabis under the MAUCRSA, the BCC, CDPH, and CDFA, into a newly created agency: The Department of Cannabis Control within the Department of Consumer Affairs (Cal. Bus. & Prof. § 26010.7(a)).

2023 AB-1684: In 2023, the California legislature passed AB-1684, expanding on AB-2164 to include not just cannabis cultivation but all unlicensed commercial cannabis activity, including manufacturing, distribution, and retail. It expanded state law to authorize local ordinances that deem unlicensed commercial cannabis activity a public nuisance. It prohibited local governments from issuing fines or penalties exceeding $1,000 per violation or $10,000 per day. It allowed local governments to hold property owners, as well as each owner of a business entity engaging in unlicensed commercial cannabis activity, jointly and severally liable for fines. Finally, it allowed local jurisdictions to refer unlicensed cannabis nuisance cases to the Attorney General.[11]

2025 SB-141: SB-141 amended local grant rules for the Board of State Community Corrections cannabis public-safety grants by repealing the prior prohibition on awarding grants to local jurisdictions that ban both indoor and outdoor cultivation, or ban retail sales. Instead, to receive state grant funding for law enforcement, fire protection and other public-safety related programming, local governments must either allow cannabis retail, and the Board must prioritize applications that include illicit cannabis enforcement. This allows local governments to receive grant funding, despite banning cultivation.

2026 - Sunsetting of Provisional State Licenses: Provisional state licenses expire on January 1, 2026, with the exception of some social equity retailers.

2.2 LOCAL CONTROL

California consists of 541 local governments, comprising 58 counties[12] and 483 cities.[13] Although counties may ban commercial cannabis cultivation, the cities located within a county have the authority to establish their cannabis regulations, and many cities take a different approach from the county that surrounds them. For instance, while Fresno County prohibits commercial cannabis cultivation, the City of Mendota allows it. Local governments generally possess powers to determine land use policy – how, where, and when activities can take place within their jurisdictions. County boards of supervisors govern unincorporated areas of counties,[14] whereas a City Council and Mayor govern cities. "Local control" is enshrined in the California Constitution, Article XI Section 7, which grants local governments the authority to enact local ordinances to the extent that they do not conflict with state law. Proposition 64 granted cities and counties "local control" to regulate and tax cannabis businesses or ban them

[11] *Bill Text - AB-1684 Local ordinances: fines and penalties: cannabis.* (n.d.). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB1684&search_keywords=%22cannabis+cultivation%22.

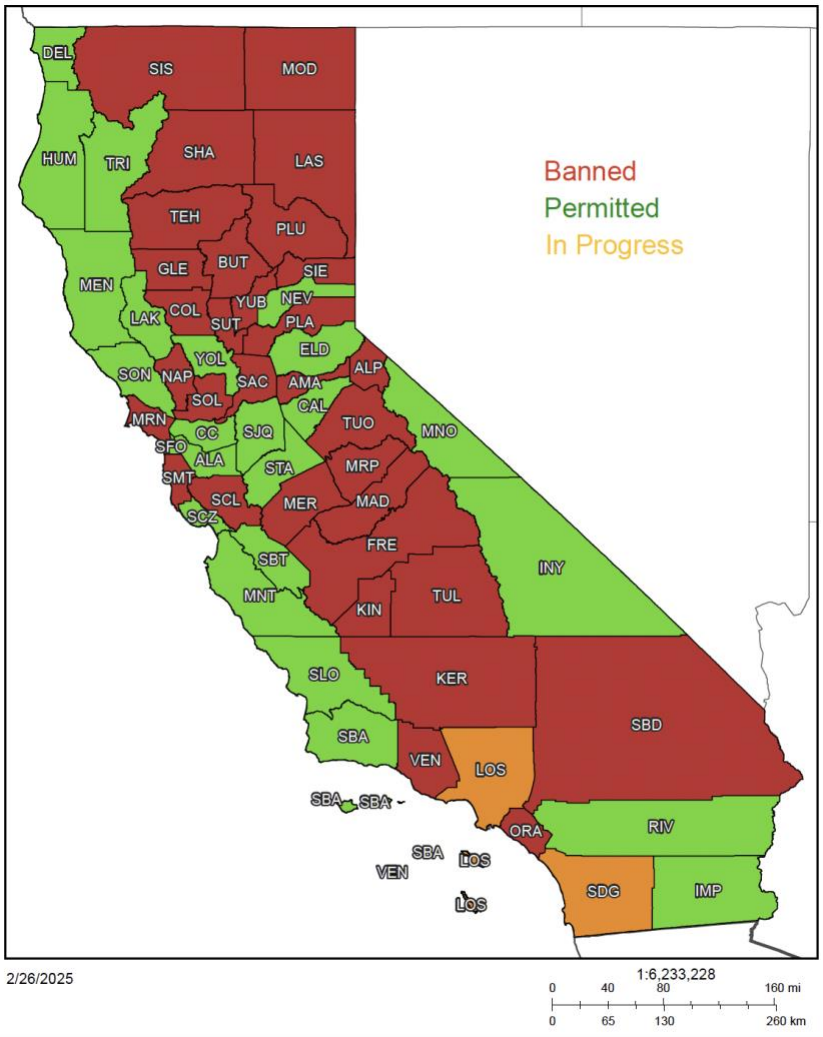
[12] *What do counties do? - California State Association of Counties*. (2015, May 26). California State Association of Counties. https://web.archive.org/web/20240125030912/https://www.counties.org/californias-counties.

[13] *Mountain House officially becomes California's 483rd city*. (2024, July 2). CBS News. https://www.cbsnews.com/sacramento/news/mountain-house-officially-becomes-california-city/.

[14] *How Counties are Structured - California State Association of Counties*. (2015, May 26). California State Association of Counties. https://web.archive.org/web/20240125031517/https://www.counties.org/county-structure.

entirely.[15] Local control has resulted in a patchwork of local cannabis ordinances across California. As of January 1, 2026, thirty (30) counties ban outdoor[16] commercial cannabis cultivation, and twenty-eight (28) counties permit outdoor commercial cannabis cultivation. Figure 1 shows a map of the patchwork of local regulation at the county level. This study does not examine cannabis rules in California's 483 cities, except through county case studies.

Most ban counties adopted their ordinances before January 1, 2018. Many others began regulating cannabis cultivation before California voters passed Proposition 64 in November 2016. Most permit counties adopted ordinances between 2016 and 2018, with some exceptions, such as Nevada, Riverside, and Calaveras (2019), Ventura (2020), and San Diego (2022). Nineteen counties have exclusively regulated cannabis since 2016, without imposing bans.



Local control is enshrined in California's constitution, but California is not the only state that allows local governments to prohibit cannabis entirely. Of the states that have legalized cannabis, 81.25% have allowed localities some ability to bar cultivation (Getz et al., 2024).**Figure 1: Map of California Counties' Regulatory Status**

3. COMMERCIAL CANNABIS CULTIVATION BANS

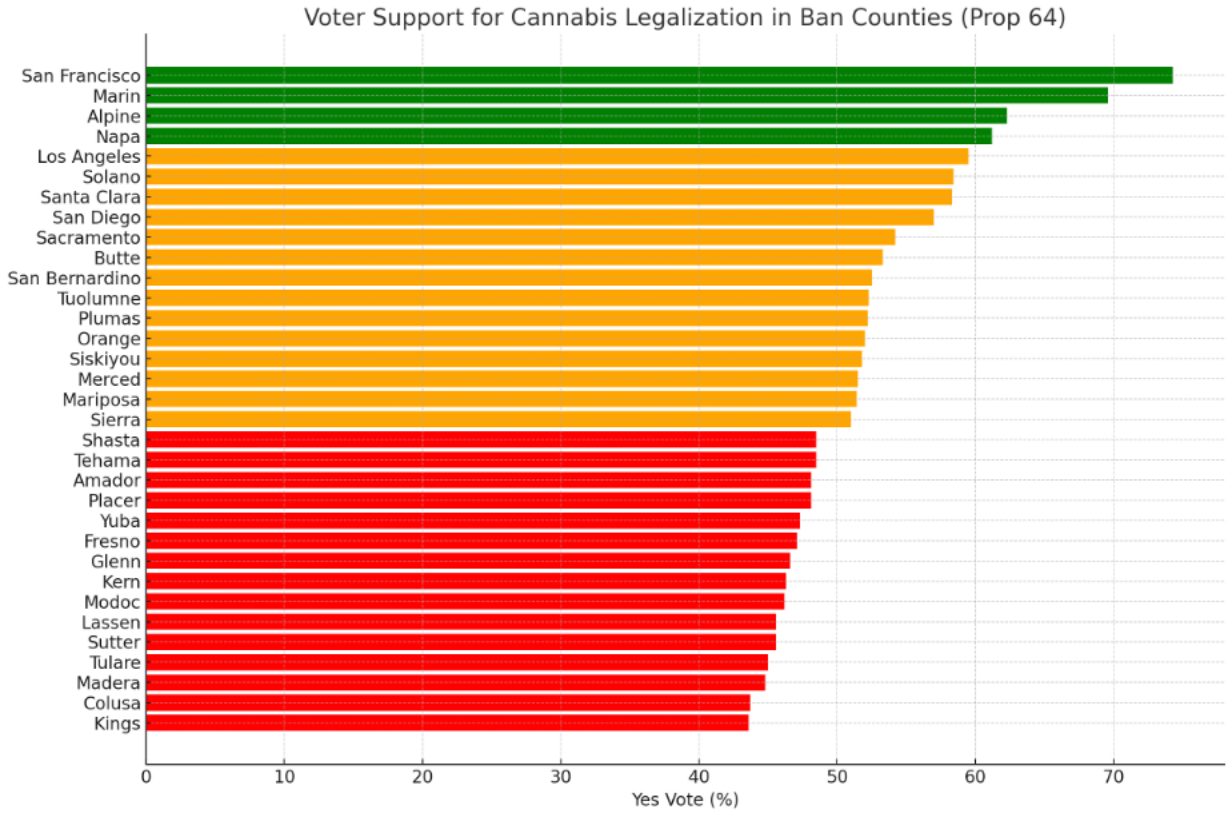
Counties where voters supported Proposition 64 still ban commercial cannabis cultivation. Although a majority of California voters generally supported cannabis legalization, many residents and/or county supervisors

[15] ATTORNEY GENERAL & LEGISLATIVE ANALYST. (n.d.). *PROPOSITION 64 MARIJUANA LEGALIZATION. INITIATIVE STATUTE.* https://slper.senate.ca.gov/sites/slper.senate.ca.gov/files/Background%20Supplemental%20-%20Prop%2064%20Text.pdf.

[16] Although a county bans outdoor commercial cannabis cultivation, it may permit indoor cultivation.

still oppose having cannabis cultivation in their communities. Figure 2 shows voter support for cannabis legalization in ban counties. Most ban counties that ban cultivation had electorates that supported legalization (56.25%). Eighteen (18) counties registered majority votes for legalization yet have banned cultivation. Marin, Alpine, and Napa had overwhelming support for legalization, but have not allowed commercial cannabis cultivation. San Francisco allows indoor cultivation but prohibits outdoor and mixed-light cultivation, mainly due to the city's limited space available for outdoor cultivation.

Figure 2: Voter Support for Cannabis Legalization in Ban Counties[17]



Bans are Intended to Stop Unlicensed Cultivation, Reduce Environmental Impacts, Protect Quality of Life, and Reduce Crime. County governments indicate many reasons for banning commercial cannabis cultivation, including safeguarding the quality of life for residents, mitigating public health risks, preventing criminal activities, and preserving environmental integrity (Getz et al 2024). Some counties ban cannabis cultivation because financial limitations prevent them from establishing permitting programs, which can be expensive to create and staff.[18] County governments may implement bans because of "related or unrelated political or

[17] State of California. (n.d.). *Supplement to the Statement of Vote Statewide Summary by County for state ballot measures*. https://elections.cdn.sos.ca.gov/sov/2016-general/ssov/ballot-measures-summary-by-county.pdf.

[18] For instance, Lassen County's commercial cannabis cultivation ad hoc committee found that developing a commercial cannabis cultivation permitting ordinance would be costly, time-consuming and take up considerable county resources, particularly due to CEQA review (*See* Recommendations from the Commercial Cannabis

institutional agendas, as from other industries, governmental agencies, political leaders, or residential groups" (Getz et al. 2024).

After Proposition 64, Unlicensed Cannabis Cultivation is Addressed as a Nuisance. Statewide, cannabis legalization reclassified commercial cultivation from a felony to misdemeanor. Local cannabis regulation is framed as a land use and nuisance issue. The landmark lawsuit, *City of Riverside v. Inland Empire Patients Health & Wellness Center* (200 Cal. App. 4th 885 (Cal. Ct. App. 2011)), decided in 2011, held that local jurisdictions retain inherent land use powers, including the right to ban cannabis entirely under their public nuisance rules. The case of Maral v. City of Live Oak (221 Cal. App. 4th 975 (Cal. Ct. App. 2014) held that if cannabis activity threatened public health, welfare, and security, it would qualify as a nuisance that could be banned. Local cannabis bans have shifted focus from criminal penalties, such as imprisonment, to civil penalties related to land use. Counties punish cultivators by issuing fines, asset forfeiture, and property liens that can result in forced tax sales. In 2023, the legislature passed AB 1684, further bolstering local governments' ability to use nuisance laws to enforce against unlicensed cannabis. Attorney General Rob Bonta supported the bill, stating, "This important bill will encourage an administrative enforcement approach that will create a more efficient means to discourage and eradicate unlicensed commercial cannabis activities, while avoiding many of the harms inherent in traditional criminal enforcement."[19] Although civil enforcement is undoubtedly less punitive than criminal sanctions, it nevertheless has significant consequences for those enforced against and can result in unfairly applied penalties, particularly against marginalized communities (Getz et al 2024).

County abatement processes involve: notifying the nuisance, giving property owners opportunities to abate or attend a hearing, and ultimately destroying the cannabis. While non-cannabis violations often are subject to warnings and abatement periods, cannabis-related violations (including matters like unpermitted structures) can be abated immediately and can involve elevated fines atypical for other violations. Civil fines may be assessed on a per-occurrence basis (irrespective of number of plants) (Table 1), or per-plant basis (Table 2).

Cultivation Ad Hoc Committee regarding possible direction to staff and the Planning Commission concerning development of a commercial cannabis cultivation ordinance. File 300.18.01.60, 2/22/2022).

[19] AB-1684, Bill Analysis, 09/12/23- Assembly Floor Analysis, available at:https://leginfo.legislature.ca.gov/faces/billAnalysisClient.xhtml?bill_id=202320240AB1684#.

Table 1: County Fines for First Cannabis Violation (Per Day)	
Fine for First Cannabis Violation (per day)	**Counties**
$50-$500	Alpine, Inyo, Napa, Solano, Ventura
$100	Amador, Colusa, Contra Costa, Del Norte, Glenn, Modoc, Madera, Merced, Plumas, Sacramento, San Luis Obispo, Santa Barbara, Stanislaus, Tuolumne, Yuba
$250-$1000	Alameda, Kern, Kings, Lake, Lassen, Mendocino, Mono, Riverside, Sutter, Tulare
$500	Butte, Siskiyou (before 2024)
$1,000	Calaveras, Fresno, Kings, Lake, Lassen, Mendocino, Mono, Nevada, Plumas, Riverside, San Joaquin, San Luis Obispo, San Mateo, Sierra, Sutter, Tehama, Trinity, Tulare
$2,500	Marin, Monterey, Orange, Santa Clara, Santa Cruz
$5,000	El Dorado, Placer, Siskiyou (after 2021)
$10,000	Humboldt, San Benito, Shasta, Sonoma, Yolo
$30,000	Los Angeles
$100-$3000 depending on number of plants	San Bernardino
$1000-$19,722	San Mateo

Table 2 County Fines Per Plant	
COUNTY	**DAILY FINE PER CANNABIS PLANT, PER DAY**
EL DORADO, SISKIYOU (after 2021)	$5,000
CALAVERAS, FRESNO, PLACER, SACRAMENTO, SAN JOAQUIN, STANISLAUS, SISKIYOU (after 2024)	$1,000
KERN	$25-$300 (depending on the number of plants)
MENDOCINO	$200
SAN LUIS OBISPO, SANTA CRUZ, YUBA	$100

When deciding whether to implement per-occurrence or per-plant fines and whether to allow a grace period, counties assess the deterrent effect of the penalties and the ability of growers to illicitly relocate their operations during a grace period and avoid fines. For instance, Sacramento County initially fined illegal cannabis cultivation sites $100 per day, regardless of the number of plants, and provided a grace period to avoid penalties. Staff realized that cannabis cultivators exploited the grace period by removing plants before reinspection, either harvesting them or moving them to another location. To create a more substantial deterrent effect, Sacramento County amended its ordinance in 2019 to introduce a per-plant penalty of $1,000 per day imposed immediately with no grace period.[20] Sacramento, Stanislaus, Siskiyou, Shasta, and Los Angeles County, among others, authorize the immediate imposition of penalties, with no warning period or grace period before fines accrue. Immediate administrative fines were enabled by state law, AB 2164 (Gov. Code § 53069.4), to strengthen local enforcement powers against unlicensed cultivation (see above). AB 2164 caps immediate administrative penalties at $10,000 per day, however local jurisdictions may cite additional local nuisance, cost recovery or civil penalty authorities to exceed the maximum of $10,000 per day.

[20] Sacramento County Code, Title 6, Chapter 6.88.060(B)(1)).

Some counties ban personal outdoor/mixed light cannabis cultivation. Although Proposition 64 allows adults to cultivate up to six plants at home indoors, many counties impose stricter regulations or outright bans. Some counties prohibit all outdoor cultivation for personal use (Alpine, Amador, Colusa, Contra Costa, Fresno, Glenn, Imperial, Kern, Kings, Lassen, Madera, Marin, Merced, Modoc, Napa, Orange, Riverside, Sacramento, San Benito, San Bernardino, San Diego, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara (only in Montecito), Santa Clara, Santa Cruz, Shasta, Siskiyou, Solano, Stanislaus, Sutter, Tehama, Tulare, and Yuba). Many counties restrict the scope of state-allowed indoor cultivation by requiring permits, inspections, and permissions, including electrical permits, landlord consent, or registration.

Counties Have Resorted to Compelling Landlords to Monitor Their Property for Unlicensed Cannabis Cultivation Proactively. Tenants, property owners, or both can be liable for fines, which can compel landlords to monitor tenant activities diligently. Counties may impose property liens to recover abatement costs and fines. Many counties require property owners to oversee their tenants' activities to ensure they aren't renting to unlicensed cultivators. Some ordinances make property owners, tenants, and permit holders jointly liable for fines and abatement costs. Any unpaid fees may result in property liens. To avoid liability, landowners in some counties often must demonstrate that their lease explicitly prohibits cannabis cultivation.

Some Counties Charge Unlicensed Cannabis Cultivation Associated with "Aggravating" Factors as a Felony. Proposition 64 made unlicensed cultivation of more than 6 plants a misdemeanor, punishable by 6 months incarceration and a fine of $500.[21] However, when certain prior convictions and the presence of "aggravating" factors are associated with cannabis cultivation, charges can become "wobblers", meaning DA's can charge them as a felony or a misdemeanor, based on prosecutorial discretion. Aggravating factors include unlicensed cannabis cultivation that results in environmental violations (including illegal water diversion, wastewater discharge violations, violating fish and game code relating to waters, rivers, streams and lakes, and endangered or threatened species, violations of penal code about hazardous substances, or "intentionally or with gross negligence causing substantial environmental harm to public lands or other public resources").[22] Each District Attorney has prosecutorial discretion on whether or not to charge felonies for unlicensed cultivation with associated environmental violations. For example, the San Bernardino District Attorney prosecutes cannabis related environmental crimes as felonies.[23] Law enforcement is also charging unlicensed cannabis

[21] California Code, Health and Safety Code - HSC § 11358(c).
[22] California Code, Health and Safety Code - HSC § 11358(d).
[23] *District Attorney prosecutes conspirators in massive subterranean illegal marijuana grow - San Bernardino County District Attorney*. (2022, May 25). San Bernardino County District Attorney. https://da.sbcounty.gov/2022/05/25/district-attorney-prosecutes-conspirators-in-massive-subterranean-illegal-marijuana-grow/.

cultivators with felonies related to grand theft of utilities[24] related to illegally siphoning electricity (described as power stealing).[25]

Ban Counties Take Hardline and "Soft" Enforcement Approaches. Ban county enforcement varies. Some counties take a hard-line approach, marshalling law enforcement, state-federal-local law enforcement collaborations, special operations, steep fines, and felony charges. Prior research has found that bans only enforced by law enforcement are limited in efficacy and often counterproductive (Getz. et. al, 2024). Other counties take a softer enforcement approach by relying on code enforcement, complaint-driven investigations, civil nuisance abatements, and fines, and an ad hoc and inconsistent enforcement (e.g. some years but others). Some counties combine these methods, utilizing code enforcement and law enforcement approaches.

2.4 COMMERCIAL CANNABIS CULTIVATION PERMITS

Twenty-eight (27) counties in California issue permits for commercial cannabis cultivators to operate outdoors or in mixed-light setups. Significant variation exists in how these counties structure their cannabis permitting programs, including differences in definitions, approval processes, eligibility for farmers, and environmental considerations. California's approach to cannabis legalization and regulation results in a patchwork of local regulation, with little uniformity in how counties regulate cannabis cultivation. Each county's ordinance is based on a foundation of state law, but has unique characteristics reflective of the county's landscapes, ideologies, and politics. We focus on local permitting below, in order to highlight within-state policy variations relevant for this study, but summaries of state licensing systems can be read elsewhere (Biber et al 2023; Bodwitch et al 2021).

Permit Types Key regulatory elements differ across jurisdictions, including permit eligibility, approval pathways, zoning, application process, and California Environmental Quality Act (CEQA) compliance. Some counties provide incentives and opportunities for existing operators ("legacy cultivators") to transition from the unregulated market to the legal market by giving them priority registration or allowing them to operate while completing their permit application. In a typical land use process, a business cannot start operating until it has obtained a permit and approval from the building department, often referred to as a certificate of occupancy. In contrast, in the cannabis context, some counties allow cannabis cultivators to operate while they complete the lengthy permit process, to transition them from the unregulated market.

Counties regulate cannabis cultivation through various permit types, including ministerial, administrative, and discretionary permits, which involve different levels of public notice and public hearings. Some counties, such as Stanislaus, require a Development Agreement —a long-term contract between a property owner and a local government that outlines how to develop a property, including the conditions for approval. Development Agreements typically span 10-years or more; they are generally used in commercial real estate to give developers certainty about developing their property, even if local regulations change. Counties regulate

[24] Gilmour, J. (2018, August 14). Prolific pot growers stole $200,000 in power for their 7,000 illegal plants, Calif. cops say. *Sacramento Bee*. https://www.sacbee.com/news/california/article216698405.html.
[25] Bryce, R. (2020, April 21). How cannabis farms steal megawatts to grow Mega-Weed. *Forbes*. https://www.forbes.com/sites/robertbryce/2020/04/20/an-epidemic-of-stealing-watts-for-weed/.

cultivators based on their size, measured in square footage, and cultivation method (outdoor, indoor, or mixed-light). Additionally, counties apply unique conditions to farms due to their location, zoning, natural resources, business model, and property conditions.

Local application processes vary. Counties utilize different departments to oversee cannabis applications, and the process timeframe can vary significantly. Prior research found that the mean approval timeframe across eleven permitting counties was 2 years (Biber et al. 2023). Applications require extensive documentation about business operations and ownership, as well as application fees and materials that need professional assistance, such as site plans, water management plans, and security plans. The lengthy application process often involves inspections and meetings with various county officials.. Navigating the complex web of applications, consultants, attorneys, and the gauntlet of local scrutiny can be too much for operators who don't have extensive permitting or land use experience, leaving more prominent operators who can afford to weather the process or have expertise in land use development at an advantage.

Permit Caps Many counties place a limit on the total amount of cannabis cultivation allowed in the county ("permit caps"), either by (a) capping the total number of cannabis permits that the county can issue, (b) the total acreage of cannabis cultivation that can be approved countywide, (c) the number of permits an individual or firm may obtain; or (d) by limiting individual farm sizes. Permit caps limit the maximum size of the cannabis market in a county and often leave many unlicensed cultivators with no entry point to the licensed market. In counties where permit caps are reached, legacy and new operators cannot enter the legal market, resulting in a semi-monopolistic structure for those who have obtained a license. When a county issues all the available permits, permit counties can be functionally equivalent to ban counties. Appendix 4 contains a list of the permit counties with a permit or acreage cap of some nature.

Environmental Regulations Many counties impose environmental regulations on cannabis cultivation, addressing factors such as water source and usage, energy consumption, wastewater disposal, protection of sensitive species, and preservation of prime agricultural soils.[26] Additionally, zoning restrictions dictate the permissible locations for cannabis farms. These restrictions may include minimum parcel size requirements, opt-out zones, setback regulations, and limitations on proximity to sensitive land uses or cities.[27] Approaches to CEQA vary. Some counties use a programmatic approach with Programmatic Environmental Impact Reports, or Programmatic Mitigated Negative Declarations (MNDs). In contrast, others issue ministerial permits that are not subject to CEQA or rely on CEQA exemptions. Permit and approval pathways also vary. Methods range from staff-approved ministerial permits to extensive conditional use permits, competitively graded applications, and hybrid approaches. Appendix 4 contains a comparative analysis spreadsheet, showing the different permit types and CEQA process across each permit county.

[26] Humboldt County prohibits cultivation sites from using more than 20 percent of the Prime Agricultural Soil on the Parcel and the cultivation must occur only in native soil unless an exemption is acquired with a Conditional Use Permit (Humboldt Cty., Cal., Cty. Code § 55.4.6.4.3.).

[27] Humboldt County requires cultivation sites located within 1,000 feet of an incorporated city to obtain a Conditional Use Permit (Humboldt Cty., Cal., Cty. Code § 55.4.6.7.).

Legal and Political Challenges Statewide, counties that permit cannabis cultivation have faced legal challenges from environmental groups, local communities, Native American tribes, competing agricultural industries, and residential communities. Local cannabis ordinances are not static and constantly evolve in response to changes in state laws, political pressures, litigation, shifts in county governance and leadership, and refinements to the regulatory structure.

Permit Maintenance After obtaining a local permit, cultivators must comply with ongoing compliance requirements, including annual permit renewals, inspections, paying cannabis taxes, and adhering to any conditions outlined in their permit. Some of these conditions require continued site improvements that can take years to complete (Biber et al. 2023). Additionally, cultivators must continually adapt to evolving local regulations, ordinance changes, and enforcement patterns, leaving them constantly running a gauntlet of regulatory hurdles and shifting goals. Many operators have failed to maintain compliance with their permits, have let their permits expire, and have left the licensed market, either moving elsewhere, leaving the cannabis industry entirely, or reverting to the unlicensed market. At the state level, the expiration of provisional license allowances and Lake and Streambed Alteration Agreements (from CDFW), among other shifts, have pushed cultivators out of licensure (and hence permits).

2.5 ENFORCEMENT AGAINST UNLICENSED CULTIVATION

Both permit and ban jurisdictions have unlicensed cultivation within their borders and take enforcement action against those unlicensed entities. Counties take different approaches to enforcement. Some adopt a proactive approach, meaning they proactively seek out, identify, eradicate, and abate unlicensed cannabis cultivation sites. Others take a reactive approach, relying primarily on citizen complaints to conduct enforcement. Enforcement has significant limitations, including cost, staffing, legal challenges, and the sheer volume and geographic area of unlicensed cannabis can overwhelm the county. The following sections describe the two primary approaches to enforcement: the civil approach, which involves code enforcement, fines, and civil judgments, and the criminal approach, which involves law enforcement, criminal penalties, and jail or prison time.

2.5.1. LOCAL CIVIL ENFORCEMENT

Some counties use a (primarily) code enforcement approach, relying on citizen complaints about unlicensed cultivation or using satellites or drones to identify unlicensed cultivation sites. These counties send code enforcement officers to abate nuisances and issue notices, citations, and fines. This can involve efforts not only by code enforcement, but by environmental health, public health, agricultural agencies, and other entities. Civil approaches seek to address issues like zoning, building, environmental and other violations and differ from criminal approaches, primarily, by working through economic sanctions to discourage activity. Generally, civil enforcement is responsive to problems, rather than proactively pursuing violations. Further, civil enforcement generally seeks to enlist violators in changing their behaviors prior to punishment via warnings and abatements. With cannabis, however, the State has allowed localities to eliminate and abridge abatement periods, elevate fines well beyond what

is customary for other violations, and enable the immediate (see AB-2184 and AB-1684 above). (At the state level, the Cannabis Administrative Prosecutor Program (CAPP), launched in 2023 by Attorney General Bonta, uses a civil strategy to quickly shut down unlicensed operations, using tools such as citations and cease-and-desist orders.) Therefore, civil approaches can be more or less punitive or lenient, depending on local codes and practices (Getz et al 2024).

The emergence of technological advancements to have an "eye in the sky" allows enforcement agencies, including code enforcement, to identify unlicensed cultivation without a site visit. Unmanned aircraft systems (drones), are currently being used in Nevada, Lake, Sonoma and Solano counties, among others. Deploying drones in potentially hazardous situations minimizes risk to law enforcement officers by providing information without direct exposure to danger (Marijuana - California Central District Drug Threat Assessment, n.d.). Satellite detection is being used in Humboldt and El Dorado counties and have multiplied the amount of administrative actions by "tenfold" according to the California State Association of Counties (Kemp 2020). In Humboldt, this resulted in significant revenue raised via fines and citations (Kramer 2019). Satellite and drone programs can be expensive to implement and maintain, though, and have raised complaints and incited lawsuits over civil liberty protections, like due process, privacy expectations, and concerns over excessive fines and infringement on property rights (Kemp 2024).

2.5.2. CRIMINAL ENFORCEMENT

Local Law Enforcement

County Sheriffs and City Police Departments typically enforce against unlicensed cultivation, and several counties have established specialized task forces and regional drug units to specialize in cannabis enforcement, listed in Table 3. Some of these task forces focus solely on cannabis, others concentrate on narcotics and drugs, including cannabis. Local law enforcement often conducts inter-agency collaborations with neighboring law enforcement and state and federal agencies to conduct raids and investigations. Twenty-two counties have specialized Sheriff units or divisions dedicated to cannabis enforcement, or drug-related enforcement that includes cannabis as one of the priorities. They typically utilize specialized equipment and have dedicated staff focusing on cannabis investigations and enforcement. Sheriff's Departments have taken different approaches to enforcing against unlicensed cannabis cultivation, including emergency declarations on cannabis cultivation in Yuba, Siskiyou and Tehama calling for federal, state and regional assistance to tackle unlicensed cultivation, and special enforcement campaigns in Riverside and San Bernardino.[28]

[28] In 2021, San Bernadino Sheriff's Marijuana Enforcement teams conducted "Operation Hammer Strike" which resulted in 34 arrests and the execution of 26 search warrants across various locations, including Twentynine Palms and Rancho Cucamonga (McGee, 2021).

Table 3: Sheriff Specialized Cannabis Enforcement Units	
Task Force	**Enforcement Team**
● Amador County Combined Narcotics Task Force (Amador) ● Glenn Interagency Narcotics Task Force (Glenn) ● Narcotics Task Force (Kern, San Diego)	● Special Enforcement Unit (Butte) ● Marijuana Enforcement Team (Calaveras, Humboldt, Mariposa, Mendocino, San Bernardino, Santa Clara, Stanislaus) ● Marijuana Safety Team (Fresno) ● Narcotics Enforcement Team (Mono) ● Marijuana Eradication Team (Monterey, Shasta) ● Sheriff Special Investigations Unit (SIU) (Nevada) ● Sheriff Cannabis Compliance Team (Santa Barbara) ● Special Enforcement Team (Santa Cruz) ● Siskiyou Interagency Marijuana Investigation Team (SIMIT) and North State Marijuana Investigation Team (NSMIT) (Siskiyou) ● Tulare Area Gang Narcotics Enforcement Team (Tulare)

Proposition 64 Public Health & Safety Grant Program

Proposition 64 allows counties that permit cannabis cultivation and retail to receive state funding from cannabis tax revenue to support law enforcement, including programming to address public health and safety associated with implementing Proposition 64. Grant projects include environmental remediation, compliance and enforcement, and cannabis public health education programs (The Board of State and Community Corrections, n.d.). Prior to 2025, counties that banned commercial cannabis cultivation and retail were ineligible for the Public Health & Safety Grant Program, though recent legislation (AB-141 in 2025) allowed counties that ban cultivation to receive these funds if they allow retail.

State & Federal Law Enforcement

Several state agencies conduct enforcement against unlicensed cannabis, described in Table 4. In 2024, the United Cannabis Enforcement Task Force seized 480,991 plants (Crofts-Pelayo 2025) and the State destroyed a total of 1.7bn lbs of cannabis between 2019 and 2025

(Marissasaldivar, 2025). The Drug Enforcement Administration ("DEA") is the primary federal agency involved in cannabis enforcement. Between 2019 and 2022, the DEA eradicated an average of 4.2 million plants and 480 thousand pounds of product per year in the US with 82% of that total coming from California alone (ERA Economics, 2025). The Federal Bureau of Investigation (FBI) and the Department of Homeland Security (DHS) investigate organized crime and interstate trafficking of cannabis.

Table 4: State Law Enforcement Agencies Enforcing Against Unlicensed Cannabis	
The California Department of Fish and Wildlife (CDFW)	CDFW's Marijuana Enforcement Team (MET) is made up of CDFW Law Enforcement Officers tasked with eliminating unauthorized cannabis cultivation on state and federal lands. MET's core mission is to apprehend trespass cultivators and restore public lands damaged by illegal marijuana sites (*Cannabis Cultivation Law Enforcement*, n.d.). CDFW works with CDFA and the SWRCB on its Watershed Enforcement Program to enforce against environmental damage from unlicensed cannabis cultivation on private land.
State Water Resources Control Board (SWRCB) Cannabis Enforcement Section	The SWRCB collaborates with CDFW, DCC, and the California Department of Pesticide Regulation on enforcement initiatives (State Water Resources Control Board, n.d.).
Department of Cannabis Control	The DCC's Law Enforcement Division collaborates with local sheriffs and police departments to conduct enforcement against unlicensed operators.
California's Unified Cannabis Enforcement Task Force (UCETF)	The Unified Cannabis Enforcement Task Force (UCETF), created in 2022 by Governor Newsom, coordinates multiple agencies to target illegal cannabis operations and disrupt illicit financial networks. UCETF is co-chaired by the Department of Cannabis Control (DCC) and CDFW.[29]

[29] Department of Cannabis Control - State of California. (2025, April 10). *Unified Cannabis Enforcement Taskforce (UCETF)*. Department of Cannabis Control. https://cannabis.ca.gov/about-us/about-dcc/unified-cannabis-enforcement-taskforce-ucetf/,

Department of Justice's Campaign against Marijuana Planting (CAMP)	Established in 1983, the Campaign Against Marijuana Planting (CAMP) is a California DOJ–managed, multi-agency task force involving over 110 local, state, and federal partners, dedicated to eradicating illegal cannabis cultivation and trafficking.
Eradication and Prevention of Illicit Cannabis (EPIC)	Led by the California DOJ, EPIC is a multi-agency partnership between the USDA Forest Service, BLM, and National Park Service; CDFW; DEA; California National Guard Counter Drug Task Force; Central Valley HIDTA; State Parks; and local law enforcement. EPIC investigates and prosecutes illicit cultivation, with a focus on environmental and economic harms and labor exploitation.

NON-POLICY DYNAMICS INFLUENCING CANNABIS CULTIVATION

3.1 MARKET DYNAMICS

Cultivation is heavily influenced by market dynamics. Prior to rule issuance in 2018, many cultivators grew a significant amount, thus leading to a price drop. Prices stabilized amidst a general downward trend until Covid in 2020, when a price spike was followed by a significant crash in the Winter of 2020-21. This depression has persisted, defining a new price equilibrium that has pushed operators throughout the supply chain to the edge of solvency. Partly in response, the logic of investment has switched from capacity-building and market share capture to return-on-investment. With dropping prices, ROI was difficult to demonstrate, leading investment to become scarce across California. Very recent signs of new investment on discounted firms, following federal rescheduling orders in 2025 (Black 2026).

Since medical decriminalization in 1996, cannabis supply chains have been transforming, largely with the effect of diminishing the power of cultivators to establish prices and capture value (Polson 2017). Since legalization this diminishment of the cultivation sector's power has been amplified in California, a state with large numbers of cultivators and farms. Even before the 2021 price drop, cultivators were under tremendous cost pressures as they became legal, largely due to significant compliance, licensing, and tax burdens (Bodwitch et al 2021). In recent years, the State has taken measures to ease licensing procedures and eliminate the cultivation tax, though structural issues in California's supply chain have prevented the sector from rebounding.

Based on ethnographic work, some of us have argued that the cannabis market is oversaturated and cannabis operators are failing due to a lack of retail opportunities (Polson et al, 2024). The oversaturated market has several root causes. The first is overproduction. California places no controls on legal supply, farm license amounts, or farm size (the latter of which was undermined by an allowance for "license stacking"). As a result, the licensed market produces

too much cannabis to be consumed by the California market (ERA Economics 2025; Polson et al, 2024). As a result, many unlicensed cultivators decided not to enter the market, where they would have to compete with large firms. Also because of oversaturation, many legal firms sold on the unlicensed market to stay solvent and realize returns on significant amounts of debt they had incurred to operate, become compliant, and achieve licensure. On the consumption side, there are not enough California retailers to sell the cannabis produced in California. This is due to local bans on cannabis retail and permitting restrictions that limit retailer locations and numbers. Another factor is overinvestment: large, venture-backed cultivation companies, and a plethora of investors swarmed California after legalization. They tried to capture as many licenses and square feet of cultivation as possible, leading to oversupply, particularly when investors demanded returns. Oversupplied legal markets – within and beyond California – flooded unlicensed markets, pushing many unlicensed cultivators out of business (Polson et al, 2024). In sum, overproduction, overlicensing, underconsumption, and overinvestment all led to significant declines and price that drastically affected the structure and character of licensed and unlicensed cultivation. In 2017 California Growers Association estimated there were approximately 68,000 cultivators in California (Roberts 2020). State records show that 12,889 entered the licensing process. As of January 13, 2026, there are 4,416 active cannabis cultivation licenses, many of them owned by the same person or entity.[30]

Before legalization, collectives and cooperatives, storefront and delivery, provided patients with cannabis. None of these retailers had state licenses because they were not available until 2018. Now, licensed retail permits are limited, due to permit bans, caps, zoning restrictions, not to mention the prohibitive cost of obtaining a license in a market yielding low prices and margins and lacking investment. The Humboldt Institute of Interdisciplinary Marijuana Research estimated that there were 2,174 medical cannabis dispensaries (both storefront and delivery) in California in 2015, though they could only confirm that 37% were active (Eschker 2015). As of January 13, 2026, there are 1,208 active retailer licenses in California.[31] As a comparison, Alcoholic Beverage Control has 48,078 on-sale licenses.[32] The opportunities to purchase alcohol are endless, but cannabis is limited to storefront or delivery sales.

3.2 SOCIAL AND ECOLOGICAL DYNAMICS

Social and ecological dynamics affect where, how and to what extent cultivation occurs. There are many areas of environmental concern around cannabis agriculture (Wartenberg et al 2022), as there are with any new land use in post-climate change California. Fires, droughts, floods, and other climactic events likely affect the decisions cultivators make about siting and production (e.g. Martin et al 2022). The expansion of cannabis cultivation has triggered significant social and legal conflicts, particularly between cultivators and various stakeholders. These tensions have resulted in many legal challenges across multiple counties, such as Trinity (Trinity Action Assoc. v. Cty. of Trinity, 2019), Yolo (Yocha Dehe Wintun Nation v. Cty. of Yolo, 2021), Humboldt (Friends of the Eel River v. Cty. of Humboldt, 2018), Santa Barbara

[30] *DCC Cannabis Unified License Search* (n.d.). https://search.cannabis.ca.gov/results?searchQuery=.
[31] *1225 Results found for*. (n.d.). https://search.cannabis.ca.gov/results?searchQuery=.
[32] California, S. O. (n.d.). *State Totals | Alcoholic Beverage control*. https://www.abc.ca.gov/licensing/licensing-reports/annual-report-archives/license-summary-counts-for-fy-2021-22/state-totals/.

(SBCRBC, Inc. v. Cty. of Santa Barbara, 2020), and Siskiyou (Ger Chong Ze Chang et al. v. County of Siskiyou et al., No. 2:22-cv-01378-KJM-AC, Doc. 85 (E.D. Cal. Aug. 21, 2024). The friction often stems from concerns over environmental impact, land use conflicts, and perceived regulatory deficiencies in cannabis ordinances. Residents, non-cannabis farmers, tribes, and environmental groups have been active in stalling and opposing cannabis cultivation across the state. This has contributed to the pushing of cannabis into more marginal, environmentally sensitive areas and away from traditional agricultural landscapes (Dillis et al 2024).

Social dynamics also shape cultivation decisions about siting and production amounts. Cannabis cultivators have formed trade associations to lobby and shape policy in their county, such as the Humboldt County Growers' Alliance, the Nevada County Cannabis Alliance, and the Trinity County Agriculture Alliance. These organizations shape county responses to both licensed and unlicensed cultivation. Non-cannabis land users are often resistant to cannabis cultivation (Dillis et al 2024; Valakovic et al 2019), leading to struggles over zoning, land use, environmental, and nuisance policies. Some areas, however, are accustomed to cannabis cultivation historically and provide zones of allowance for unlicensed cultivation to occur (Polson et al 2024).

OBJECTIVES

This project measures the degree to which the first Purpose and intent of Proposition 64 – to transition cannabis "production…out of the hands of the illegal market" – has been accomplished and what factors facilitate that transition effectively. As defined in Proposition 64, we also address issues related to cannabis' "criminal justice impacts," "environmental issues related to cannabis production," and which agencies and approaches might achieve AUMA's purpose "more effectively" (see RTC 34019(b)(7-10)). As listed in the project proposal, the study objectives were:

1) Assess Unlicensed Production Amounts and Geography;
2) Identify factors influencing the observed extent of unlicensed cultivation;
3) Compare Licensed and Unlicensed Production and Estimate Leakage of Licensed Product into Unlicensed Market;
4) Assess Potential for Environmental Impacts of Unlicensed Production in Ban and Permit Counties.

METHODS AND RESULTS

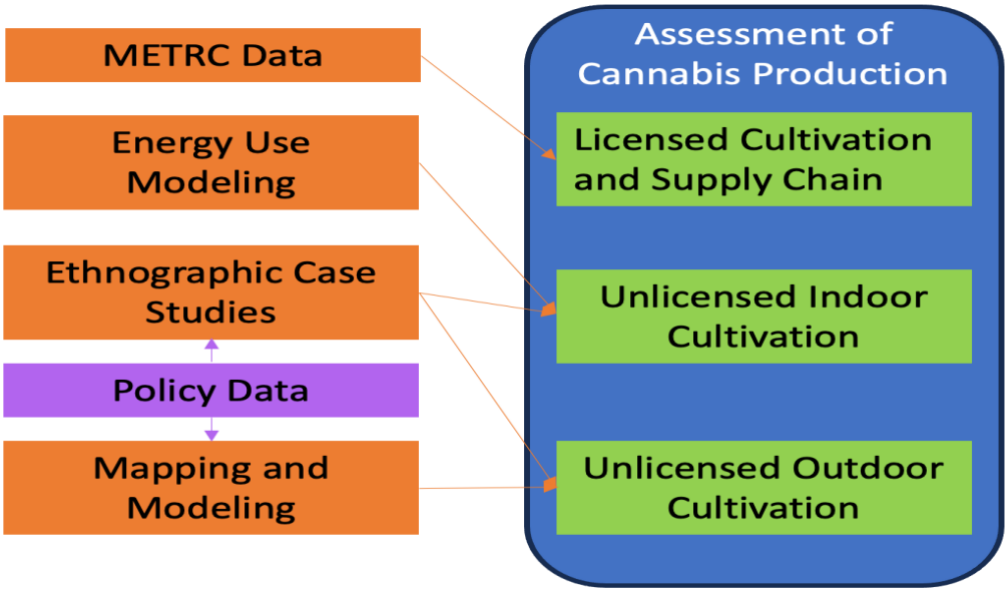
This research employed a mixed-methods approach and involved collaboration with experts in anthropology, political ecology, energy resources, environmental ethics, environmental science, and legal studies. Quantitatively, we utilized statewide mapping data, licensing data, and energy use records to understand indoor, outdoor and mixed-light cultivation

trends across the legal and unlicensed markets. Qualitatively, we conducted policy analyses at state and local levels and six (6) in-depth case studies of select counties. We met biweekly for 2.5 years to coordinate and harmonize research across these methodological domains and aimed to establish feedback loops between different research approaches, to ensure robust and integrated findings. We found that quantitative, policy, and qualitative data each offered different yet complementary takes on what is happening and why. By summing and integrating them, this study comprehensively assessed California's state of unlicensed cultivation.

Mixed-methods research approaches are valuable in answering policy-focused questions and addressing social problems because they combine broad, generalizable insights of quantitative data with the meaningful, person-centered understanding gained through qualitative inquiry. The combination allows researchers to explore both *what* is happening and *why*, thereby covering the gaps or weaknesses in using singular approaches alone (Martin et al., 2023; Tzagkarakis & Kritas, 2022). This integration is beneficial because qualitative data can reinforce the reliability of big data by ground-truthing the findings (Bamberger, n.d.).

All researchers are affiliates of UC Berkeley's Cannabis Research Center (CRC), established in 2017. The CRC is dedicated to interdisciplinary cannabis research, focusing on cultivation, policy, and environment. CRC researchers include ecologists, wildlife and conservation biologists, hydrologists, geographers, anthropologists, and policy experts in agriculture, law, and land use. This research expands upon prior studies conducted by CRC-affiliated researchers on bans (Getz et al., 2024), local control (Biber et al., 2023), unlicensed cultivation (Polson et al., 2024), cannabis water use (Dillis et al., 2023) and fire risk (Martin et al 2022), and barriers to entry in the legal market (Bodwitch et al., 2021).

Figure 3: Diagram of Methodological Approaches



5.1 LOCAL ORDINANCE ANALYSIS

5.1.1. ANALYTICAL FRAMEWORK & DESIGN FLOW

What is the effect of local policies and social dynamics on cannabis cultivation and commerce? Prior studies have pointed to the importance of local policies (Biber et al 2023; Heddleston 2012; Holmes 2019; Matthay et al 2022; Moiseeva 2023; Polson 2015; Polson & Petersen-Rockney 2019) in influencing the development of legal cannabis markets and in shaping the unlicensed market. Our recent work on cannabis bans (Getz et al 2024) indicates that ban policies may be consequential in shaping unlicensed cultivation. Similarly, the design of local permitting programs can affect unlicensed cultivation (Polson et al 2024) as well as legal market involvement and development (Biber et al 2023).

Building from this prior work, our team analyzed local and state policy timelines. We then integrated these timelines with spatial modeling based on the CannaVision mapping data, which identifies unlicensed cultivation (see below). Through this, we aimed to correlate local policies with the growth or decline of local unlicensed cultivation and the roll-out of state policies with the growth or decline of statewide unlicensed cultivation. The first step in this process was to create a policy analysis of California's 58 counties. We analyzed cannabis-related policies and practices across all counties to assess their impact on the unlicensed market. We examined whether counties had bans or permit ordinances, the specifics of those programs, and the enforcement mechanisms utilized to curb unlicensed cultivation. Our review included county ordinances, zoning codes, public nuisance provisions, enforcement procedures, environmental reports, and litigation related to cannabis cultivation. In this phase, we sought to compile, index, and compare cannabis policies across all 58 counties.

Then, these policies were sorted into typologies. The first tier typology was "ban" and "permit." Within these two categories, we identified other policy typologies to characterize the varied policy measures in ban and permit counties (e.g., presence/absence of sanctions for landowners or properties where unlicensed cultivation occurs). These policies were then placed on a timeline according to when they were passed. This policy analysis was then converted into a spreadsheet that can be integrated into the mapping analysis of cultivation across the state (via CannaVision) and over time. This resulted in a model that offers insight into how local and state policy measures may have affected the growth or decline of unlicensed production. We did this by looking across counties for statistically significant patterns

Through this, we were able to identify policies that are effective and ineffective at addressing unlicensed cultivation, including whether bans or permits are more effective in this effort. By simultaneously considering terrain-based factors, including remoteness and ruggedness measures, we could estimate their effects independently and therefore more

effectively isolate policy factors with our models. After the CannaVision model was run incorporating the policy variables, we analyzed the trends and tried to ascertain if any local policy changes may have impacted the growth or diminution of unlicensed cultivation and drafted an analysis of the dataset.

Policy analyses were also used to inform case studies of select counties. For these counties, more in-depth policy histories and social analyses were compiled utilizing secondary sources, including census data, local news, reports from local and regional nonprofits, etc. Qualitative researchers utilized these policy and social analyses to inform interview scripts and participant prompts. They were also used in compiling the full case studies in the Appendices.

5.1.2. DATA USED

Policy analyses were conducted using the following sources: cannabis ordinances, zoning ordinances, local cannabis tax measures, environmental impact reports, Board of Supervisor meeting minutes and agendas, cannabis application documents, county cannabis websites, county sheriff websites, litigation, and grand jury reports. For more in-depth analyses of case study counties, we accessed news sources, census data, and reports on various aspects of county life.

5.1.3. METHODS FOR POLICY ANALYSIS

For each California county, we generated a planning code summary. To prepare the summary, we analyzed county cannabis-specific ordinances, including the zoning code and code provisions applicable to public nuisances, administrative abatement, and civil fines and penalties. After conducting legal research on the county code, we reviewed county staff policy documents, regulations, and county websites dedicated to cannabis. We also reviewed the County Sheriff's website to learn about specific cannabis enforcement teams. In some counties, we supplemented our understanding of the code by reviewing minutes from the Board of Supervisors' public meetings. For permit counties, we reviewed environmental documents for each cannabis program, including Program Environmental Impact Reports and Program Mitigated Negative Declarations. We analyzed Grand Jury investigations of commercial cannabis programs in Humboldt, Nevada, Monterey, and Santa Barbara.

For permit counties, summaries include significant dates, permit and acreage caps, types and sizes of allowable cultivation, site conditions, CEQA pathways, types of permits, standard conditions, and enforcement mechanisms. For ban counties, we examined enforcement approaches, investigation strategies, fines, property liens, owner liability for unlicensed cultivation, Sheriff's office enforcement teams, and criminal penalties.

5.1.4. RESULTS

After completing 58 planning code summaries, we created a comparative analysis spreadsheet comparing notable policies across all counties. Table 5 includes the key questions examined in our comparative analysis. The spreadsheet is included in Appendix 4.

Table 5: Key Variables in Permit and Ban Counties

Permit County Factors	Ban County Factors
● When was the first commercial cannabis cultivation ordinance passed? ● Is there a permit or acreage limit, and when was it reached? ● Are new applications for cultivation being accepted? ● What are the conditions for cultivating properties? ● What type of CEQA documents were prepared for the cannabis ordinances? ● Are there application processes requiring discretionary review? ● What types of permits are available, and who reviews them? ● Is outdoor and mixed-light cultivation allowed? ● How many approval terms and conditions apply to cultivation sites? ● Tax rate information.[33]	● The date that commercial cannabis cultivation was banned. ● If personal outdoor cultivation is prohibited. ● If satellite investigation is used. ● If a drone investigation is used. ● The fine amount per occurrence per day. ● The fine amount per plant per day. ● If fines are capped. ● If each day constitutes a separate offense for fines. ● If the property owner is held responsible for fines. ● If property liens are available for failure to pay fines. ● What type of special enforcement team exists, separate from the Sheriff? ● What criminal penalties are applicable?

[33] Both ban and permit counties were examined for cannabis business tax information, including: The date tax measures were passed, tax structure (gross receipts, square footage, or production), and any changes to the cannabis business tax rate, including a reduction or waiver of the tax for a time period.

• What are the fines (per plant or occurrence)?	• What criminal penalties apply to environmental crimes associated with cannabis cultivation?

The policy variables listed above and outlined in the comparative analysis spreadsheet were isolated and fed into the CannaVision model. Variables that had no statistical impact were excluded from the model, and several variables remained, as listed in **Table 5**, including: whether a ban existed, fine amount, fine per plant, landowner responsibility, enforcement task force, and code enforcement.

Planning code summaries were used as a framework for ethnographic projects to explore the relationship between policy factors and changes in local cultivation dynamics. They were also referenced in drafting a synthetic summary for each county of interest (see Section 5.5).

5.2 CANNAVISION MAPPING OF UNLICENSED CULTIVATION

5.2.1. ANALYTICAL FRAMEWORK

For decades, reliable data on cannabis cultivation, aside from qualitative ethnographic data (Corva 2014; Polson 2021), has been difficult to ascertain. They often derive from limited, unreliable, and potentially biased law enforcement estimates (Kalacska & Bouchard 2011; Leggett & Pietschmann 2008) or from remote sensing techniques, which requires significant amounts of inference (Dillis et al 2020; Gianotti et al 2017; Franklin et al 2017; see Meisel 2017 for discussion). Innovative cross-disciplinary approaches to estimating cultivation have grown alongside liberalization of cannabis policy, as cultivators and cultivation become more visible (e.g. Bouchard 2008; van der Giessen et al 2016; Werb et al 2012). At UC Berkeley, researchers innovated an empirical method to estimating cultivation via satellite and aerial imagery (Butsic et al 2017; Butsic & Brenner 2016), however this approach is time- and resource-intensive.

The ability to accurately estimate unlicensed cultivation impedes the assessment and design of interventions in the unlicensed market. A lack of methods for assessment can leave policymakers and the public uninformed about the existing scale of cultivation, potentially leading to inappropriate or ineffective responses. If assessments overestimate cultivation, punitive and overzealous responses can result, which may be motivated by other institutional or social agendas (Getz, Petersen-Rockney & Polson 2024). This can undermine the transition to cannabis legalization by amplifying re-criminalizing and stigmatizing approaches above other more proportional approaches (Adinoff & Reiman 2019; Polson 2019).

To address the lack of consistent data on cultivation amounts, this project provided first-in-use modeling of CannaVision, a product of California's State Water Resources Control Board (SWRCB). This model was used to identify outdoor and mixed-light cannabis cultivation across thirty counties, utilizing advances in aerial surveillance data and object detection modeling. The SWRCB has trained this model extensively, investing significant time in not only tool design, but in ground-truthing its identified objects for accuracy.

CannaVision was used to identify outdoor (including mixed-light) cannabis cultivation sites. Licensed cultivation was removed using Department of Cannabis Control (DCC) license data. The model is a custom-trained Detectron2 system developed by the State Water Resources Control Board (SWRCB) and trained on approximately 100,000 labeled examples using National Agricultural Inventory Program (NAIP; USDA) imagery. CannaVision summary data can be generated biennially following the NAIP acquisition schedule.

Although CannaVision provides consistent spatial coverage, several methodological constraints limit the reliability of absolute area estimates. The model identifies objects by locating and outlining them within satellite imagery. This process can miss small or partially visible features or detect them inconsistently, which introduces sensitivity-related errors that affect total area calculations. The training data, while extensive, do not fully capture the full range of visual variation found across California, and this can lead to inconsistent detection rates in different settings. Detection accuracy is also affected by lighting conditions, shadows, vegetation cover, and background complexity, all of which vary across NAIP imagery and cannot be fully corrected after detection has occurred. Small errors in identifying or outlining objects accumulate when results are aggregated across thousands of images, which produces total area estimates that may differ substantially from the true extent of cultivation. For these reasons, absolute values are not reliable indicators of the actual scale of cultivation activity.

Given these constraints, the analysis emphasizes *relative* measures, which provide more stable and interpretable results at regional scales. Relative deviations, normalized values, and year-to-year comparisons offer more robust indicators of the spatial distribution of cultivation activity and its temporal dynamics. These metrics form the basis for identifying hotspots, characterizing geographic patterns, and assessing changes in cultivation concentration over time.

Using this framework, all available CannaVision datasets from 2018 through 2024 were compiled and analyzed. Identified cultivation features were converted to area estimates and aggregated within grid cells, and county-level summaries were generated to assess the distribution and evolution of unlicensed outdoor and mixed-light cultivation across 30 counties. Analyses focused on three outcomes: (1) county-level summaries of unlicensed cultivation across years, (2) trends in the relative expansion or contraction of cultivation activity within and across counties, and (3) evaluations of spatial and environmental characteristics associated with cultivation patterns.

5.2.2. DATA USED

Source data for cannabis mapping using CannaVision were acquired from the US Department of Agriculture's National Agricultural Imagery Program (NAIP). Imagery is produced and publicly released every two years. The years included in this project were 2018, 2020, 2022, and 2024.

A comparative analysis spreadsheet was created using planning code summaries to generate variables to be analyzed as predictors of unlicensed cannabis cultivation. Additional socioeconomic and demographic variables in our models were generated using data from the California State Franchise Tax Board (CSFTB), the US Census Bureau (USCB), and voting records from the California Secretary of State (CSoS). Additional geographical and terrain-based variables required the use of data from the Microsoft Buildings Footprint Layer (Microsoft), CALTRANS, the US Geological Survey's (USGS) National Hydrography Dataset, the USGS National Land Cover Database, the USGS National Elevation Dataset, CALFIRE, the California Department of Cannabis Control (DCC), the California Department of Food and Agriculture (CDFA), and the California Division of Water Resources (CDWR). All model variables and their data sources are outlined in **Table 6** below. Our assessments of potential environmental impact used data from the National Land Cover Database (USGS), the National Hydrography Dataset (USGS), and species distribution data from the National Oceanic and Atmospheric Administration (NOAA).

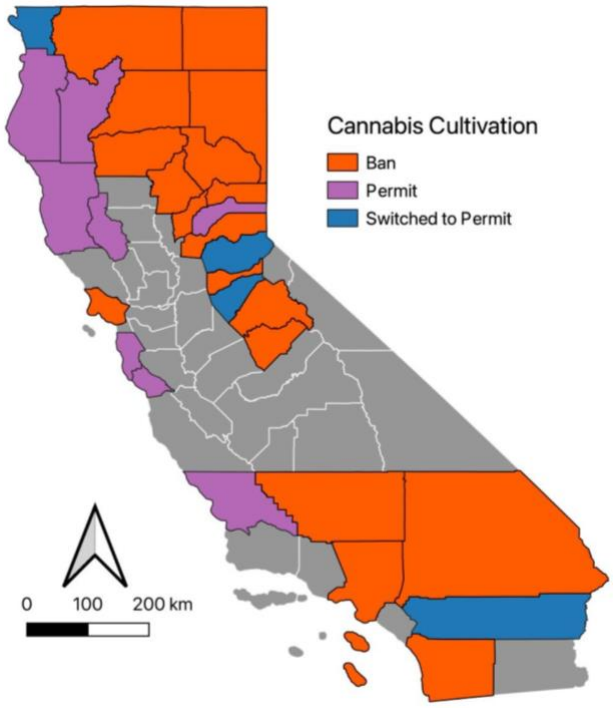
5.2.3. METHODS

The CannaVision computer vision model was applied to aerial imagery to produce the outcome variables used in the analysis. The study area for the model's application was initially limited to 17 counties that could offer reliable accuracy of object detection. Some of the excluded counties included significant centers of cultivation, including all of Southern California. Since Cannavision was largely trained on the North Coast and its particular land type, application to other parts of the state were tenuous. To address this, we partnered with SWRCB to expand the geographic applicability of Cannavision from 17 to 30 counties and to increase the reliability of object identification in each of these counties to an acceptable range. To refine and expand the model, we supervised approximately 30 undergraduate researchers over two semesters to identify and validate objects. All students were trained in appropriate methods and given supervision by project personnel and SWRCB liaisons.

The final modeling based on Cannavision data was limited to 30 counties in which sufficient training data were available. This included: Amador, Butte, Calaveras, Del Norte, El Dorado, Humboldt, Kern, Lake, Lassen, Los Angeles, Marin, Mendocino, Modoc, Nevada, Placer, Plumas, Riverside, San Bernardino, San Diego, San Luis Obispo, San Mateo, Santa Cruz, Shasta, Sierra, Siskiyou, Tehama, Trinity, Tuolumne, and Yuba. Analyses were restricted to

private lands, since public land trespass grows are not subject to the same landowner penalties and disincentives, however we did analyze polygons that included public and private land to analyze cultivation trends at this public-private interface.

Figure 4: Study Area Map. *Counties included in the study (n=30) are colored either orange if cannabis cultivation is banned, purple if cannabis cultivation is permitted, or blue if cultivation changed from banned to permitted during the study period.*



The CannaVision model produced polygons representing predicted outdoor and greenhouse cannabis cultivation gardens. Prior to distribution, the State Water Resources Control Board (SWRCB) aggregated these polygons to a generic sampling grid with a typical cell size of 9 km² to protect anonymity. The sampling grid was aligned to county boundaries to allow for county-level summarization. When county borders split grid cells, a minimum cell size of 2.25 km² was maintained by merging adjacent cells when necessary.

Cannabis density, expressed as square meters per square kilometer, was calculated for each grid cell for the years 2018, 2020, 2022, and 2024. Differences between consecutive years (2018 to 2020, 2020 to 2022, and 2022 to 2024) were then used as outcome variables in the statistical models. Consult Appendix 4 link to see variables.

Predictors of Unlicensed Cultivation

All models were Generalized Additive Models (GAMs) that account for spatial clustering through the use of smoother functions, in this case, applied to the latitude and longitude of the spatial unit (i.e., grid cells). They were also hierarchical models, which included county as a random effect variable to control for unmeasured county-specific factors. For each model, we paired the full model matrix (i.e., all variables) using stepwise AIC to prioritize useful variables. Because the data were zero-inflated (i.e., many grid cells showed no change in cultivation density between time points), the hierarchical GAMs were fit as hurdle models. This is accomplished by fitting separate component models: a binary model to predict whether or not the change in cultivation density is non-zero and a second conditional model to predict the amount

of change, assuming it is non-zero. Hurdle models are appropriate when there is presumed to be a particular reason for values being zero. In this dataset, values of zero were almost always present due to a complete lack of cannabis cultivation, rather than a complete lack of change in mapped cultivation between time points. Because this analysis was focused on the predictors of change in cannabis cultivation, the presentation of the analysis will focus exclusively on the conditional model in which only non-zero values are included in the model fitting data.

Table 6. Predictor variables for GAMs

Variable	Description	Source
Cultivation Ban	Binary; presence/absence of cultivation ban during time period	Planning Code Summaries
Fine Amount	Integer; Dollar value of daily fine for unlicensed cultivation	Planning Code Summaries
Fine Per Plant Basis	Binary; whether/not fines are assessed on a per-plant basis	Planning Code Summaries
Land Owner Responsibility	Binary; whether/not landowners are responsible for tenant cannabis cultivation violations	Planning Code Summaries
Personal Cultivation	Binary; whether/not personal cultivation allowances (up to six plants) were present	Planning Code Summaries

Enforcement Rank	Rank; rank among study counties of lbs of cannabis seized since 2011	ERA Economics
Public Land Boundary	Binary; presence/absence of public land within the sampling grid cell	CALFIRE
Presence of Licensed Farm	Binary; presence/absence of a licensed cannabis farm within the sample cell	DCC
Presence of Hemp	Binary; presence/absence of a hemp license within the sample cell	CDFA
Proportion Conservative	Continuous, bounded (0-1); proportion of county registered voters identifying as Republican	CSoS
Median Income	Continuous; county median income	CSFTB
Proportion Retirement Age	Continuous, bounded (0-1); proportion of county population aged 65 or older	USCB
Building Density	Continuous; number of buildings per km^2	Microsoft
Road Network Density	Continuous; length of paved public roads per km^2	CALTRANS
Stream Network Density	Continuous; length of streams per km^2	USGS NHD

Proportion Forest	Continuous, bounded (0-1); proportion of sample cell that is covered in forest	NLCD
Proportion Planted	Continuous, bounded (0-1); proportion of sample cell that is cultivated (non-cannabis agriculture)	NLCD
Proportion Barren	Continuous, bounded (0-1); proportion of sample cell that is barren rock	NLCD
Average Slope	Continuous, bounded (0-1); average hill slope of the sample cell	USGS DEM
Remoteness	Continuous; distance from sample cell to nearest incorporated area	CALFIRE
Groundwater Present	Binary; presence/absence of SGMA groundwater basin within the sample cell	DWR
High Fire Hazard Severity	Binary; presence/absence of area mapped as either “high” or “very high” fire hazard severity within the sample cell	CALFIRE

Intra-County Volatility

This analysis assessed how patterns of unlicensed cannabis cultivation changed over time within counties. Data were organized into spatial cells nested within counties, and variables used to predict unlicensed cultivation (as described above) were adapted, where necessary, to reflect county-level characteristics. For instance, the presence of a licensed farm in a cell was aggregated to represent the proportion of cells in a county containing licensed farms. The goal was to understand whether hotspots of activity (i.e., areas with higher levels of unlicensed cultivation) tended to persist in the same places across multiple years, or whether they shifted over time.

To measure this, a nonparametric, rank-based approach was used. For each county, cell-level cannabis cultivation values were converted to within-year ranks for four time points: 2018, 2020, 2022, and 2024. These ranks were then compared across three adjacent year-pairs (2018 to 2020, 2020 to 2022, and 2022 to 2024) using Spearman correlation coefficients. Each coefficient captures the degree to which the relative ordering of cells (from highest to lowest cultivation) was maintained between two time points. A high correlation indicates that cells with high cultivation levels in one year tended to remain high in the next; in other words, the spatial pattern was stable. A low correlation, by contrast, suggests that hotspots moved or were replaced by other areas, indicating instability in the spatial distribution of activity.

To summarize these temporal comparisons, the three Spearman correlation values were averaged to produce a single rank stability score for each county. This score reflects how consistently cultivation intensity was distributed across space over time. Counties with high stability scores exhibit persistent hotspots, where the same areas remain high in cultivation across years. Counties with low scores show more dynamic, shifting patterns, consistent with a "whack-a-mole" effect in which enforcement, policy, or other pressures displace activity from one place to another rather than eliminating it outright. The outcome variable was bounded between 0 (no correlation between time periods- maximally dynamic) and 1 (perfect correlation between time periods- absolute stasis) and was modeled using a beta regression with a logit link function.

Environmental Impact Analysis

In order to assess the potential environmental impacts of unlicensed cultivation since legalization, we compared the expansion and contraction of unlicensed cultivation in the study counties, relative to the county's environmental sensitivity. Environmental sensitivity was scored based on the composite of three metrics:

1) Proportion of county watersheds containing critical salmonid habitat, as outlined by the National Oceanic and Atmospheric Administration (NOAA);

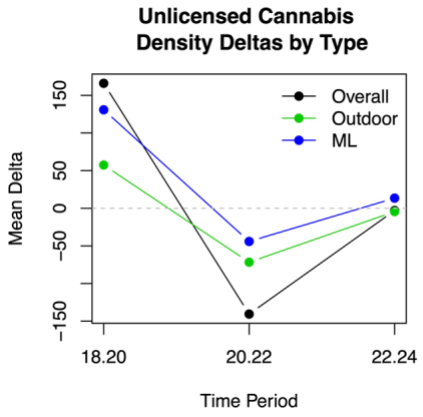
2) The amount of aquatic habitat, as measured by the length of perennial streams per km^2 of county land area, using the USGS National Hydrography Dataset (NHD)

3) The proportion of land area undeveloped and uncultivated, as identified by the National Land Cover Dataset (NLCD).

Each metric was calculated for every county in the state, and rankings were summed to produce a composite rank for each county. Cannabis cultivation data were acquired for each of the 30 study counties using CannaVision. Separate OLS models were run for permit and ban counties (and altogether,) comparing county environmental sensitivity rank to the average change in cannabis cultivation during the time periods 2018-2020, 2020-2022, and 2022-2024.

Table 7. Ranking Metrics for Environmental Impact Analysis.		
Variable	Description	Data Source
Proportion Undeveloped	Continuous, bounded (0-1); the proportion of private land in a county that is not classified as developed or cultivated	USGS
Stream Network Density	Continuous; the length of streams on private land within a county, divided by the area of said land	USGS
Proportion of Watersheds Sensitive	Continuous, bounded (0-1); the proportion of watersheds within a county that contain critical habitat for protected fish species	NOAA

5.2.4. RESULTS



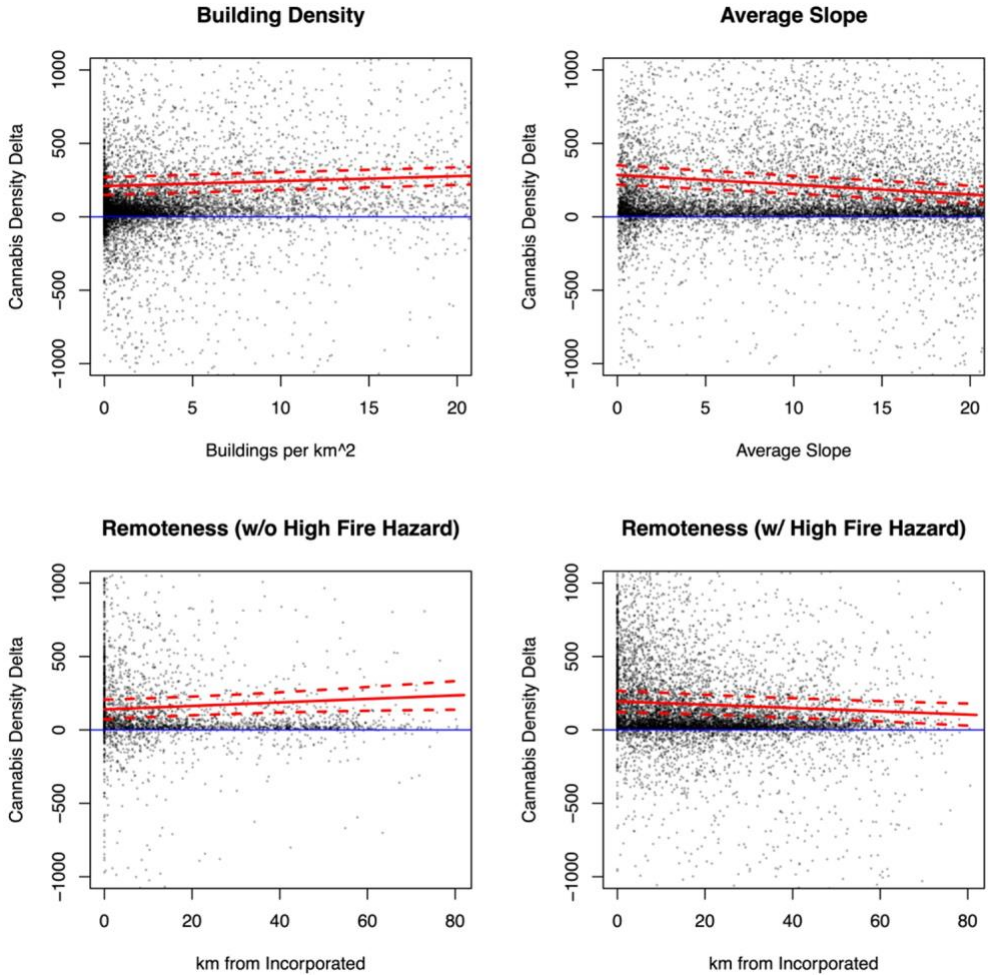
From 2018 to 2020, unlicensed cannabis cultivation expanded markedly (mean = 165.99 m^2 / km^2; SD = 507.24). Among cultivation types, mixed-light operations exhibited greater expansion than full-sun outdoor cultivation. During the second time period (2020 to 2022), the extent of unlicensed cultivation decreased substantially, effectively reversing the relative gains observed in the previous period (mean = -140.59 m^2 / km^2, SD = 456.05). Reductions in outdoor unlicensed cultivation slightly exceeded that of mixed-light during this time. In the final time period (2022 to 2024), overall unlicensed cultivation remained relatively stable (mean = -3.06 m^2 / km^2, SD = 190.68). However, during this period, mixed-light cultivation continued to increase slightly, while outdoor unlicensed cultivation decreased slightly.

Predictors of Unlicensed Cultivation

Physical and Terrain-Based Variables

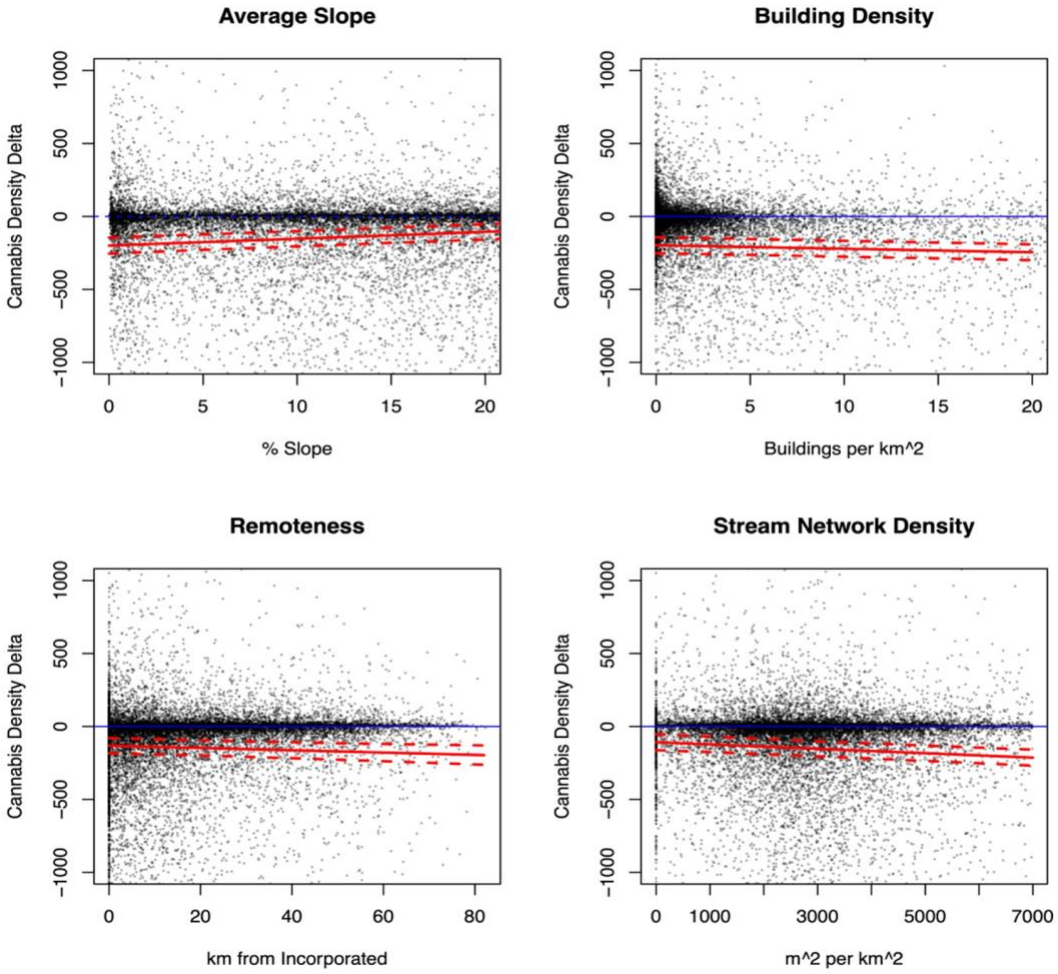
Between 2018 and 2020, cultivation densities increased most significantly in areas characterized by flatter terrain (average slope: MLE = -6.67, SE = 0.83) and more buildings (building density: MLE = 3.40, SE = 0.16). Expansion was sensitive to fire hazard, in that remoteness (MLE = 1.19, SE = 0.60) was only associated with increasing cannabis density in the absence of high fire hazard; in the presence of high fire hazard the effect was negative (remoteness × high fire hazard interaction: MLE = -2.32, SE = 0.63). Fire-prone areas were widespread during this period, with over 60% of all cells containing at least one region classified as high fire hazard severity.

Figure 6: 2018-20 Physical/Terrain Predictors



From 2020 to 2022, reductions in unlicensed cultivation were most pronounced in flat areas (average slope: MLE = 4.69, SE = 0.64), while cells with steeper average slopes showed smaller declines. Areas with lower building density (MLE = -2.39, SE = 0.13) also experienced smaller reductions, as did cultivation in the public/private boundary areas (MLE = 68.36, SE = 9.14), although the magnitude of these changes was relatively modest. Decreases were smaller in less remote areas (remoteness: MLE = -1.05, SE = 0.42), suggesting cultivators valued proximity to infrastructure, but the cover of hills and the absence of neighbors. Finally, there was also an effect of stream network density, with cells containing more streams seeing a larger decrease in cannabis density (MLE = -0.015, SE = 0.003).

Figure 7: 2020-22 Terrain/Physical Predictors

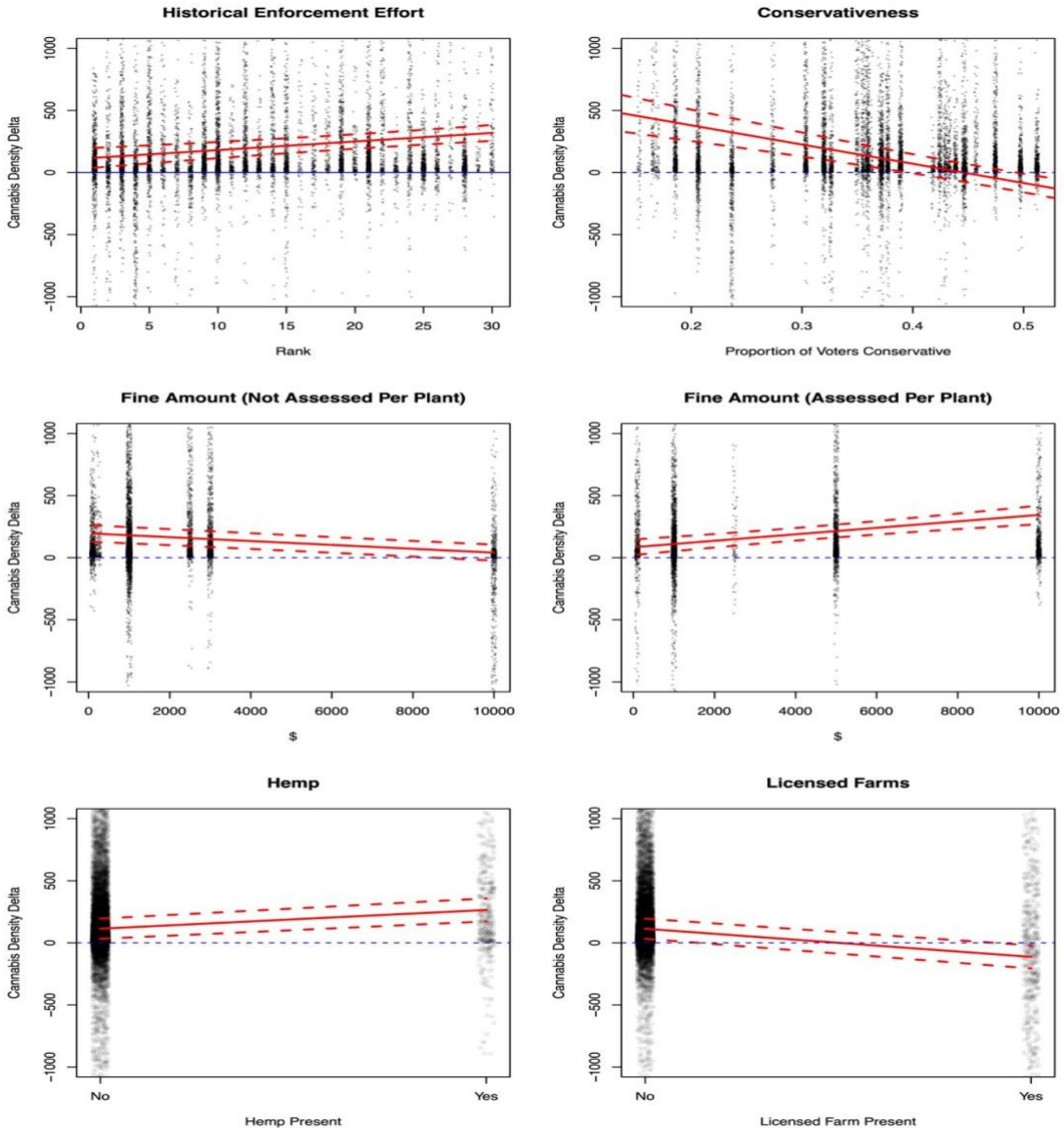


From 2022 to 2024, there was no strong positive or negative trend in cannabis cultivation, although there was still substantial spatial variation. Somewhat paradoxically, both remoteness (MLE = 0.29, SE = 0.11) and building density (MLE = 0.65, SE = 0.06) were positively associated with small increases in cannabis density. Also, cells with denser stream networks experienced increases of cannabis density (MLE = 0.005, SE = 0.0011) in an unexpected reversal of the prior trend, potentially reflecting shifting enforcement focus or adaptation strategies by cultivators. The effect sizes of these variables were substantially smaller than those seen in prior time periods however, indicating that while they were statistically significant, they are not necessarily meaningful.

Socio-Political Variables

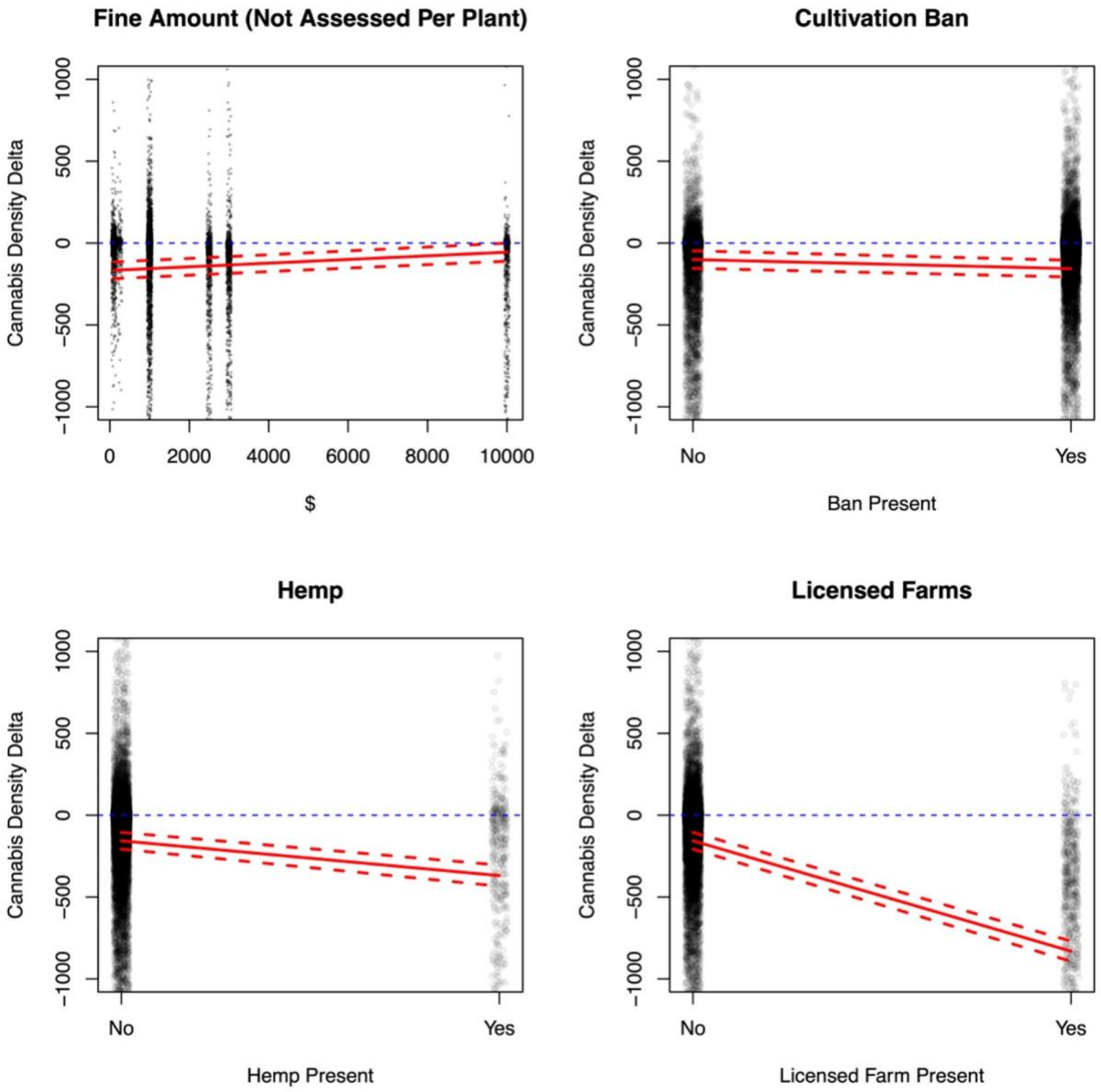
During the first time period (2018–2020), counties with historically lower enforcement efforts showed larger increases in cannabis cultivation (MLE = 7.09, SE = 2.89). Counties that assessed fines on a per-plant basis experienced smaller increases (MLE = -111.97, SE = 28.45), and higher fine amounts were negatively associated with cannabis cultivation (MLE = -0.01554, SE = 0.0017). The interaction between fine amount and per-plant fines was positive during this period (MLE = 0.042, SE = 0.0054). Among social variables, conservatism had a pronounced influence, with the proportion of conservative voters negatively associated with cannabis density change (MLE = -1548.39, SE = 202.42). Hemp presence was positively associated with cannabis cultivation (MLE = 151.17, SE = 23.28). The presence of licensed farms had a negative effect on cannabis density (MLE = -227.20, SE = 22.26).

Figure 8: 2018-20 Socio-Political Predictors



Policy variables had more muted effects during 2020–2022. Fine amounts were associated with declines in cannabis density only when not assessed per plant (fine amount: MLE = 0.011, SE = 0.0011; interaction with per-plant fine: MLE = -0.012, SE = 0.004). Cultivation bans were associated with somewhat larger declines (MLE = -55.40, SE = 14.53). The presence of licensed farms was the most influential factor, with cannabis density declining three times more in their presence (MLE = -674.52, SE = 17.11). In areas without licensed farms, the model estimated continued increases. Hemp presence was now associated with reductions in cannabis cultivation (MLE = -212.96, SE = 19.85).

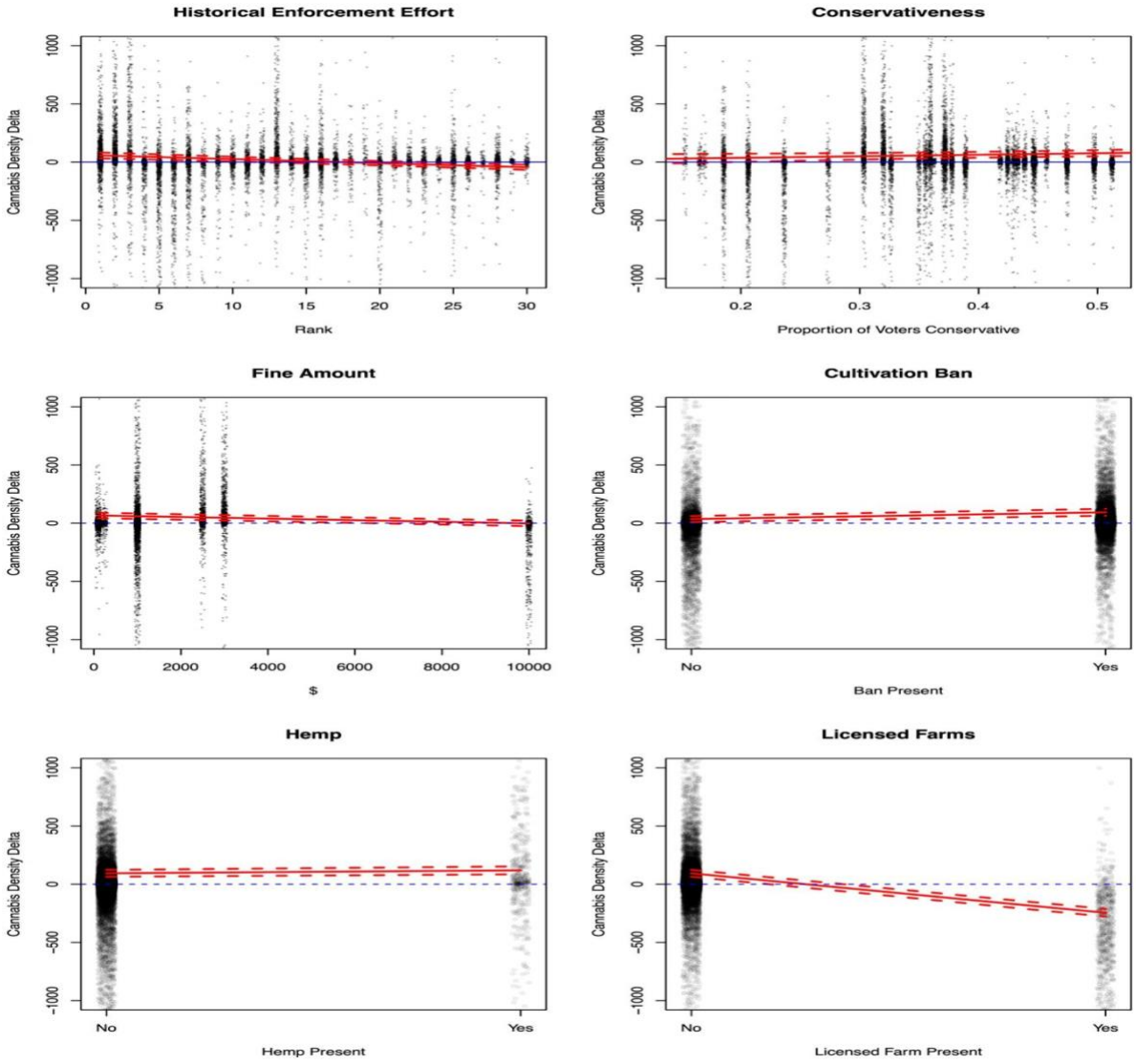
Figure 9: 2020-22 Socio-Political Predictors



In the third time period (2022–2024), enforcement history was negatively associated with cannabis density change (MLE = -2.45, SE = 0.70), indicating historically enforcement-heavy counties saw larger increases. Fine amounts were negatively associated with cannabis cultivation (MLE = -0.007, SE = 0.0005), regardless of per-plant fine structures, which were not significant (MLE = -0.002, SE = 0.0019). Cultivation bans reversed their association and were estimated to have a small positive effect on increasing in cannabis density (MLE = 59.03, SE = 10.13). Social patterns flipped, with the proportion of conservative voters positively associated with cannabis

density change (MLE = 131.68, SE = 56.46), indicating increases in more conservative counties, while more liberal areas experienced declines. The presence of licensed farms remained the strongest factor, with a continued negative association with cannabis density (MLE = -339.10, SE = 7.74).

Figure 10: 2022-24 Socio-Political Variables

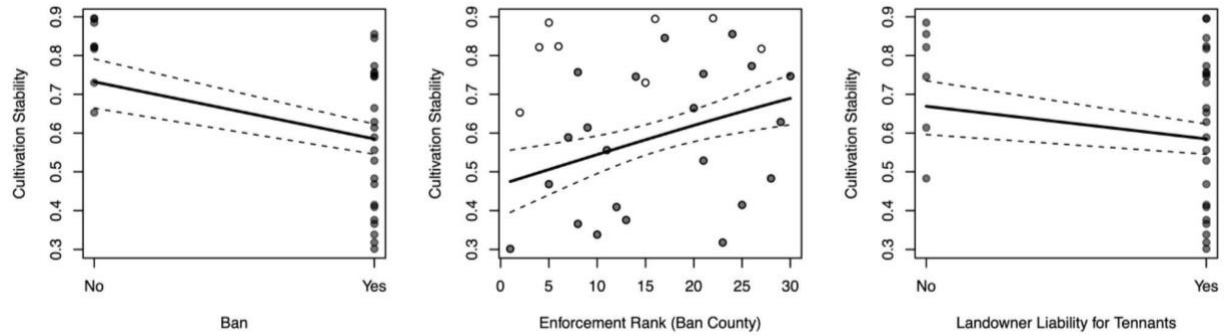


Intra-County Volatility

Over the study period (2018-2024), the distribution of cannabis cultivation was significantly more volatile in counties with local cannabis bans (MLE = -1.65, SE = 0.32). That is, cultivation exhibited more "whack-a-mole" dynamics in these counties. Cultivation stability was also lower in counties with stronger historical enforcement reputations, as measured by enforcement rankings (MLE = -0.034, SE = 0.019). However, this association was only reliably

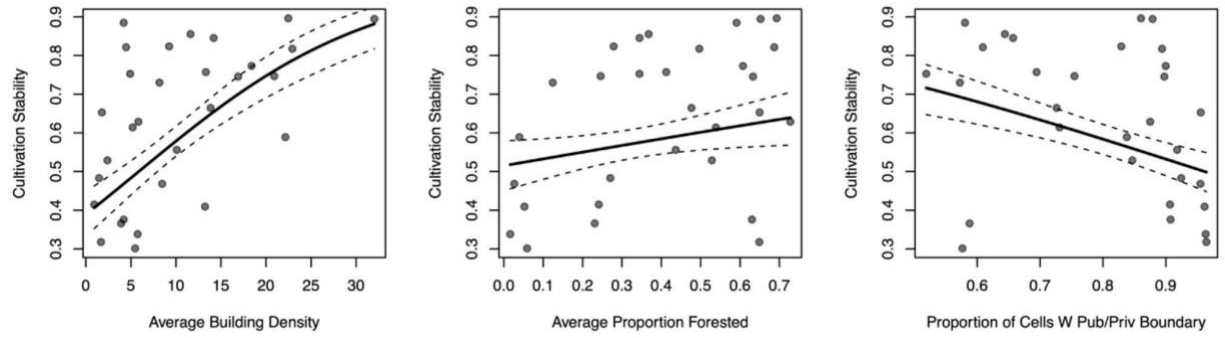
associated with reduced cultivation stability in counties where a ban was in place, as indicated by a statistically significant interaction (MLE = 0.065, SE = 0.022). Policies holding landowners liable for tenant cultivation were also associated with lower stability (MLE = -0.36, SE = 0.18), suggesting these measures may be linked to more mobile or short-lived cultivation activity.

Figure 11: Within-County Cultivation Movement - Policy Factors (2018-24)



Several spatial and environmental characteristics were significantly associated with cultivation stability. Counties with greater average building density showed higher levels of stability (MLE = 0.077, SE = 0.011), as did those with more forest cover (MLE = 0.70, SE = 0.33). In contrast, cultivation was significantly less stable in counties with a higher proportion of grid cells containing both public and private land (MLE = -2.09, SE = 0.46), a pattern that may reflect uncertainty or complexity in land access or enforcement.

Figure 12: Within-County Cultivation Movement - Terrain Factors (2018-24)



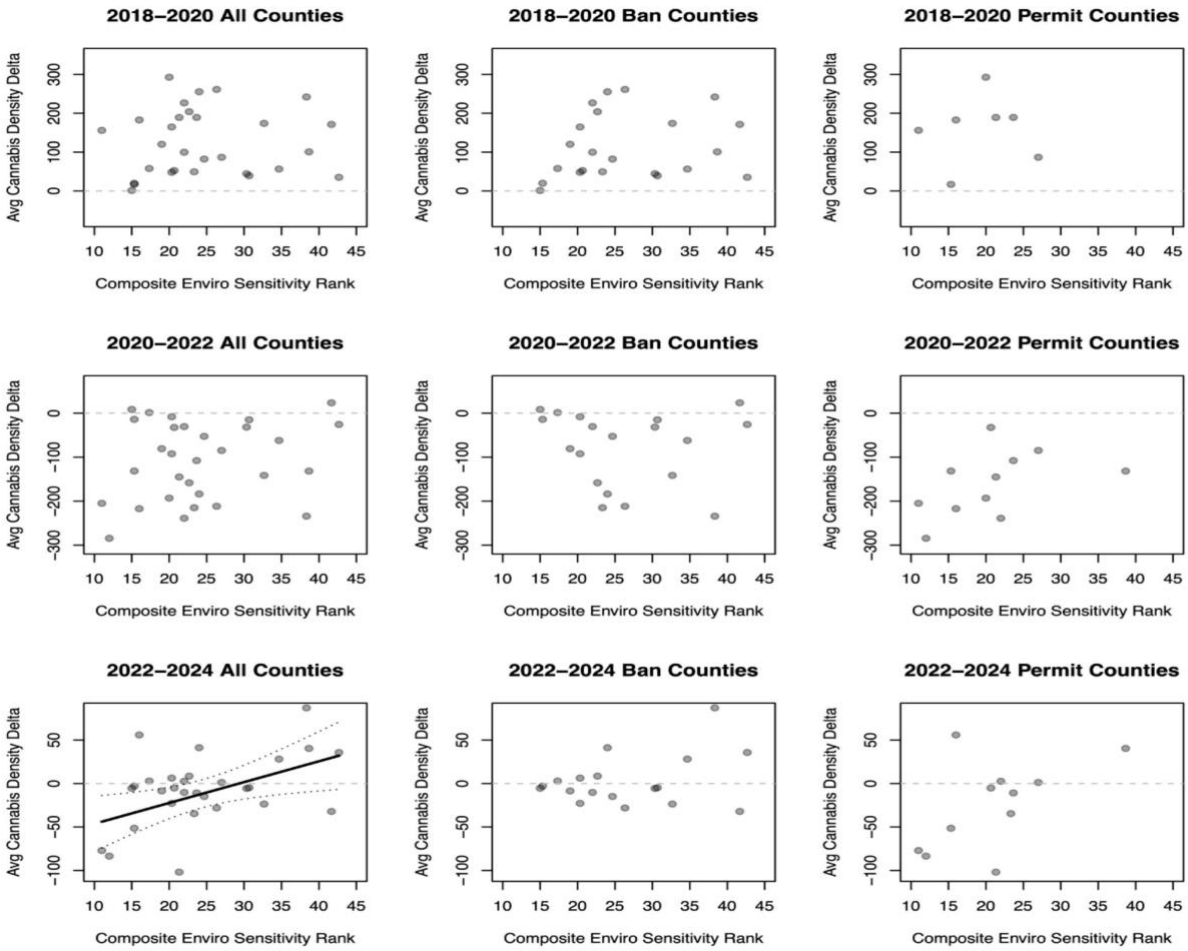
Environmental Impact Analysis

In the first two time periods (2018–2020 and 2020–2022), there was no significant relationship between environmental sensitivity rank and cannabis density delta. However, by the second time period (2020–2022), a trend appeared to be emerging specifically among permit counties of a positive relationship between the change in cannabis density and environmental sensitivity rank. That is, more environmentally sensitive counties experienced greater declines in

cultivation, while less sensitive counties saw smaller decreases (the overall trend was universal decreases during this time period). The sample size in this group (n = 12) was too small to detect a statistically significant effect despite a large R^2 value of 0.22, reflecting limited power (~43%) to reach statistical significance. By the third time period (2022–2024), the relationship was strong enough in permit counties (and somewhat emerging in ban counties), that when all counties were analyzed together there was a statistically significant relationship (MLE = 2.40, SE = 0.94). In the third time period, environmentally sensitive counties experienced decreases in unlicensed cultivation, while the least sensitive counties experienced unlicensed increases.

During this third period, it remained clear that the relationship was primarily driven by permit counties ($R^2 = 0.21$), rather than ban counties ($R^2 = 0.09$), with the small sample size of permit counties limiting statistical significance due to low power (~43%). Observation of this pattern *among* permit counties specifically suggests that ban/permit status alone was not solely responsible for reductions in cultivation relative to environmental sensitivity.

Figure 13: Cultivation x Environmental Sensitivity - All, Permit & Ban Counties



5.3 INDOOR PRODUCTION ESTIMATION

5.3.1. ANALYTICAL FRAMEWORK & APPROACH

This project component uses electricity consumption data as a proxy to estimate the distribution of unlicensed indoor cannabis cultivation in California. The primary objective was to determine the extent of such activity by analyzing distinctive patterns of energy usage, particularly in indoor cultivation facilities.

The analytical framework was built on the premise that indoor cannabis cultivation exhibits identifiable energy usage characteristics due to its high energy demands and regimented light cycles. Mills (2012) found that indoor cannabis production requires approximately 2,000 kWh per pound of finished product, with lighting accounting for the majority of energy consumption. More recent work by Summers et al. (2021) confirmed that indoor cultivation's greenhouse gas emissions stem primarily from high-intensity lighting systems operating on strict 12-hour on/off cycles during the flowering phase when plants produce harvestable flower. Research on cannabis photobiology demonstrates these rigid photoperiod requirements, Chandra et al. (2008) and Bilodeau et al. (2019) documented that cannabis is a photoperiod-sensitive plant whose growth stages are triggered by specific light durations, with the flowering phase universally requiring a 12-hour light/12-hour dark cycle to stimulate bud production. This concept is supported by consultations with plant biologists, cannabis cultivators, regulatory enforcement officials, and energy utility representatives who all noted these distinctive diurnal flowering patterns in indoor cultivation operations. The research draws upon a diverse set of sources, including public regulatory data, anonymized utility records, and documented enforcement actions. The process of obtaining and integrating these datasets involved significant coordination and institutional engagement over the length of the project.

The methodology began with the acquisition of data on licensed indoor cannabis cultivation sites from the California Department of Cannabis Control (DCC). This data was used to establish a reference energy profile for legal commercial operations. A machine learning model was then trained using this profile to detect similar patterns in a broader dataset of commercial energy users to enable the identification of likely unlicensed indoor cultivation facilities.

To obtain training data for unlicensed cultivation occurring in residential settings, the project utilized records from warrant-based inspections and requested records from blocks where media-reports indicated indoor cannabis cultivation in homes. Following the identification of specific locations, corresponding historical energy usage data (specifically for the 12 months preceding enforcement action) was requested and analyzed. This analysis produced a representative energy profile of residential indoor cultivation, which was subsequently used in the development of the machine learning model. The model was applied to a randomized sample

of residential energy customers across California to estimate the incidence and geographic distribution of unlicensed residential indoor cultivation.

In summary, the analytical process followed these key steps:

1. **Identification of Known Cultivation Sites**: Data on licensed and unlicensed indoor cultivation operations were obtained from DCC records and documented law enforcement actions, respectively.

2. **Acquisition of Utility Data**: Energy usage data from these known cultivation sites were collected from Pacific Gas & Electric.

3. **Energy Signature Analysis**: The data were analyzed to extract a distinctive energy signature characterized by (a) high energy intensity and (b) a recurring 12-hour on / 12-hour off usage cycle—an operational pattern atypical of most other energy-intensive commercial activities.

4. **Machine Learning Implementation**: These signatures were used to train machine learning models that were then applied to large-scale datasets of commercial and residential utility customers to identify probable unlicensed indoor cannabis cultivation activity.

Institutional Review and Ethical Oversight: Given the sensitivity of the subject, particularly the consideration of potentially unlicensed cannabis operations, we sought to update our existing protocol and obtain Institutional Review Board (IRB) approval from the University of California, Berkeley for this specific portion of the project. The approved protocol outlined data privacy measures, legal boundaries, and public interest value, and was a prerequisite for engaging with utilities and requesting proprietary data.

5.3.2. DATA USED

To develop an energy-based model of indoor cannabis cultivation, datasets were integrated from three primary sources:

- **Licensed Commercial Cultivation Facilities:** Publicly available licensing data from the California Department of Cannabis Control (DCC) was used to identify commercial indoor cultivation sites. This included facilities operating under indoor and mixed-light cultivation licenses, which, while operationally distinct, collectively represent the spectrum of electricity usage patterns typical of licensed indoor cannabis production. The dataset contained spatial information, license type and status, facility type, and operational size, enabling the establishment of energy usage benchmarks based on the scale of cultivation activities.

- **Suspected Unlicensed Cultivation Sites:** Two key efforts were undertaken to identify properties potentially involved in unlicensed indoor cultivation. First, a manual review of police and media sources—including online news archives, local newspapers, court records, and law enforcement press releases—was conducted to compile addresses linked to past enforcement actions related to indoor cannabis cultivation. Second, a confidential list of residential and warehouse addresses was obtained from the DCC, representing sites where unlicensed cultivation had been confirmed through enforcement activity. These locations had been subject to energy-related warrant inspections, indicating that anomalous energy signatures were a factor in investigative efforts.

- **Anonymized Electricity Consumption Data:** Anonymized electricity usage data was requested through the California Public Utilities Commission (CPUC)'s Energy Data Request (EDR) Program from the state's three major investor-owned utilities: Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). Each utility required a separate application process under the EDRP, including submission of Institutional Review Board (IRB) approval, a detailed project proposal outlining data use and rationale, data protection and encryption protocols, and signed legal agreements. Although requests were initiated in late 2023, as of October 1, 2025, only PG&E had fulfilled the data request.

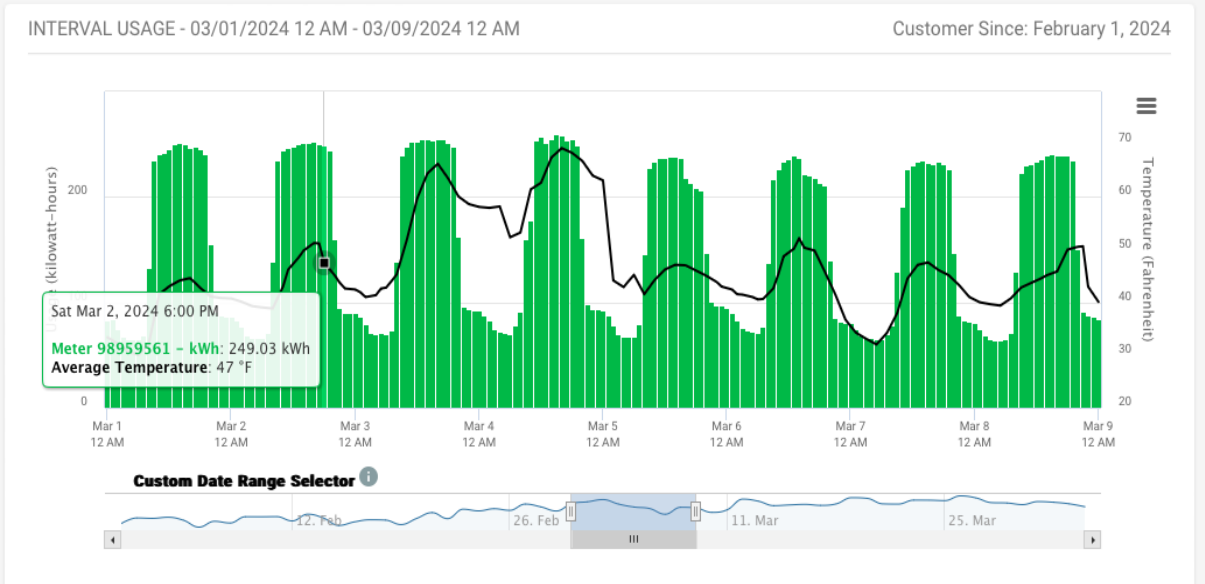
5.3.3. METHODS

Identifying Indoor Cultivation Energy Signature: Cannabis is a photoperiod-sensitive plant, meaning its growth stages are triggered by the duration of light exposure. Indoor cultivators replicate these natural cycles using artificial lighting systems, which creates highly predictable patterns of electricity consumption. Specifically, cannabis is typically grown in two phases: a vegetative phase, during which plants grow from seedlings to maturity under an 18 to 24 hours on, 0 to 6 hours off light cycle; and a flowering phase, during which plants begin producing flower buds, which are harvested and sold as cannabis flower or processed into other products. This stage almost universally occurs on a 12 hours on, 12 hours off cycle, which mimics the shortening photoperiods of late summer and early fall (Moher et al., 2022). These consistent lighting schedules produce a distinctive diurnal load shape in electricity usage data, characterized by sharp, repeating peaks and troughs (Figure 2). This pattern is widely recognized in both industry reports (e.g., Mills 2012; Summers et al. 2021) and in discussions with utility analysts and enforcement personnel as a strong indicator of indoor cannabis cultivation.

Figure 2 shows an example of this load profile. Between March 1 and March 9, 2024, the cultivation facility displayed regular evening spikes in electricity demand, consistent with lighting schedules used during the flowering stage. The green bars represent hourly kilowatt-hour (kWh) usage, while the black line shows average outdoor temperature. The pattern repeats across multiple days, with sustained nightly use and temperature-driven variation linked to

HVAC activity. Based on this energy signature, it was hypothesized that the load profiles of known cannabis cultivation facilities could be used to develop a machine learning model capable of identifying similar energy usage patterns across a broader sample of user accounts.

Figure 14: Indoor Cultivation Energy Signature



Data was obtained from Pacific Gas & Electric (PG&E) consisting of hourly kilowatt-hour (kWh) readings for approximately 300,000 customer accounts, covering the period from January 1, 2020, to December 31, 2023. This dataset included electricity usage for both residential and commercial addresses identified as known cannabis cultivation sites through a records review process. In addition to these known cultivation operations, addresses associated with other high-energy-use facilities, such as data centers, laundromats, hospitals, and agricultural processing facilities, were also submitted for inclusion in the sample.

Given the large dataset of hourly intervals, we aggregated hourly values to daily values to first identify the 30-day period within each year of the maximum amount of energy use. These 30-day windows were then characterized using the following criteria (i.e., variables) to identify a signal of cannabis cultivation:

1) Proportion of hourly intervals in which kWh remained constant (within 5%, 10%, and 20% of total variation) for at least 6 hours

2) Proportion of hourly intervals in which kWh remained constant (within 5%, 10%, and 20% of total variation) for at least 8 hours

3) Proportion of hourly intervals in which kWh remained constant (within 5%, 10%, and 20% of total variation) for at least 12 hours

4) Proportion of hourly readings within 5%, 10%, and 20% of the max overall reading

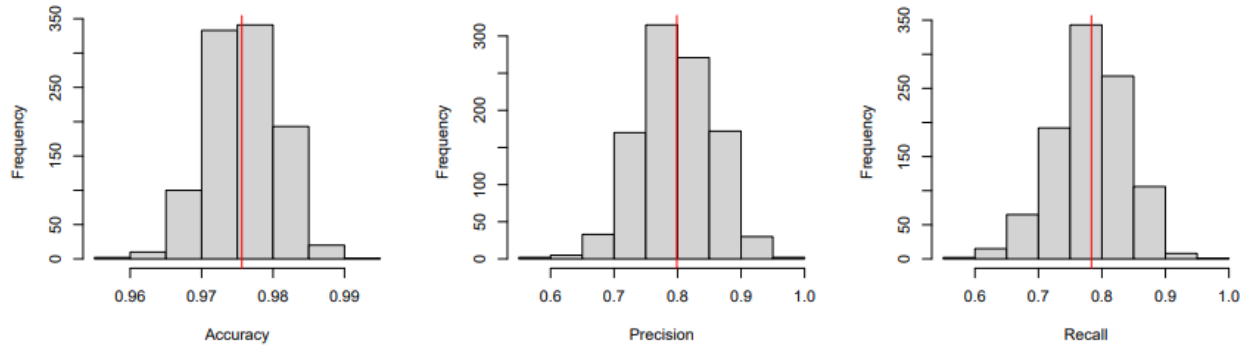
5) Proportion of hourly readings within 5%, 10%, and 20% of the minimum overall reading

6) Periodicity of readings, as determined by the correlation of hourly readings to the daily average reading at each hour

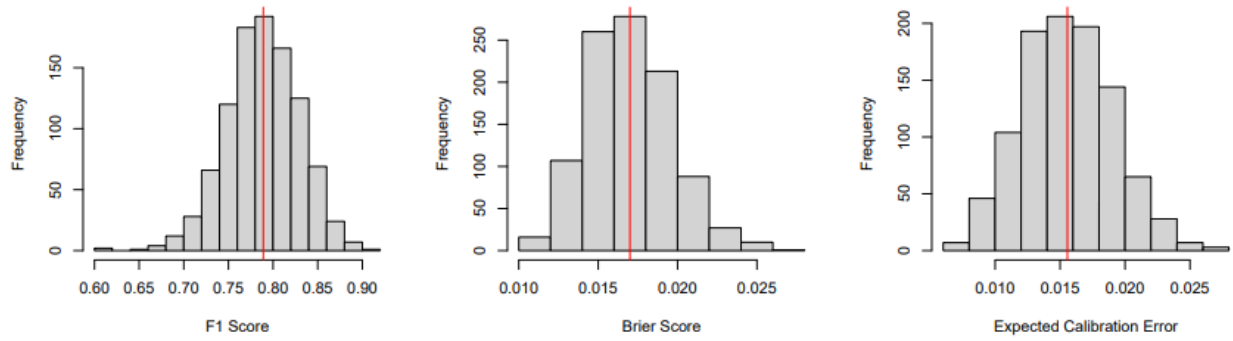
These 16 variables were then used as predictors of cannabis cultivation in a random forest machine learning model implemented using the ranger package in R (citation). In total, there were 223 accounts in the sample confirmed to have been cultivating cannabis. Of the random sample of utility accounts (125,000), approximately 20% were used for model training. Aside from accounts that were specifically identified as high-energy-use facilities, any other account using more than an average of 2 kWh during the 30-day sample period were excluded following the conservative assumption that growing cannabis would require more than this threshold. The same principle was applied in reverse to cannabis accounts, with any "cannabis" account using less than an average of 10 kWh, excluded from the analysis. These "cannabis" and "non-cannabis" accounts were aggregated into a single "labeled" dataset to be used for model training.

The reliability of the model was assessed by evaluating both its predictive performance and the accuracy of its probability estimates. The labeled dataset was divided into training and testing portions, and subjected to 1000 iterations of cross validation to measure model performance. The model's mean precision, recall, and F1-scores indicated strong predictive performance, and calibration tests, using measures such as the Brier Score and Expected Calibration Error (ECE), showed that the predicted probabilities were consistent with observed outcomes in the test data (i.e., the model was well calibrated).

Figure 15: Random Forest Model Performance Metrics



The prevalence of cannabis in the training set (5%) was necessarily arbitrary, given the lack of data with which to make a true population estimate. Therefore, an important consideration was whether the model's predictions were biased toward the 5% cannabis prevalence in the training data. This issue, known as prior probability shift, occurs when the



proportion of positive cases differs between the data used to train the model and the population to which it is later applied. If the underlying prevalence changes, the model's predicted probabilities may no longer correspond to the true likelihood of a case. To test for this, the model was applied to simulated datasets with different known prevalence levels. These simulated datasets were generated prior to and separate from model training, using a reserved 20% of the entire labeled dataset. These simulated tests (with known prevalence) showed that the model tended to slightly overestimate prevalence when applied to very low-prevalence populations and underestimate it when applied to higher-prevalence ones, confirming that the model's predictions were affected by the training data's baseline rate.

To account for this, a Bayesian prior adjustment was applied to the model's predicted probabilities. This statistical correction adjusts the model's outputs so they reflect a population with a different overall prevalence, without requiring the model to be retrained. The method, which is well established in both epidemiological and machine learning research (Saerens et al., 2002; Forman, 2008), is based on Bayes' theorem and assumes that the relationship between predictors and outcomes remains stable, while the overall prevalence may differ. In practical terms, the Random Forest model produces a probability of cannabis presence for each observation, but those probabilities are influenced by the 5% prevalence of the training data. To account for this, a Bayesian prior adjustment is applied to the model's predicted probabilities. This method modifies the model's outputs to reflect a different overall prevalence than that seen in the training data, without changing the model itself. It draws on Bayes' theorem, which provides a way to combine the model's predictions with prior information about how common the outcome is in a given population. In this context, the adjustment reweights the probabilities so that they align with an assumed new overall rate of cannabis presence. The approach assumes that the relationships between the predictors and the outcome remain stable across populations, while allowing the total number of cases to differ. In practical terms, this means the model's estimated prevalences are scaled to what would be expected if the population's true prevalence were lower or higher than in the data used to train the model.

Because the true prevalence of cannabis in the target population cannot be known from available data, predictions were made over a range of assumed prevalence values from 0.25% to

1.75%, in increments of 0.25%. For each assumed level, the Bayesian adjustment was applied to the model's predictions to produce adjusted probabilities for every observation. These adjusted probabilities were then averaged within each subgroup (region by year) to generate prevalence estimates under each assumed scenario. This approach provides a transparent and statistically grounded way to explore how estimated prevalence might vary across a plausible range of true population rates. Because of inconsistencies and missing data at the county level, results are reported at the aggregated regional level. This aggregation reduces the influence of local data gaps and improves the stability of estimates, allowing for more reliable regional-level comparisons across years.

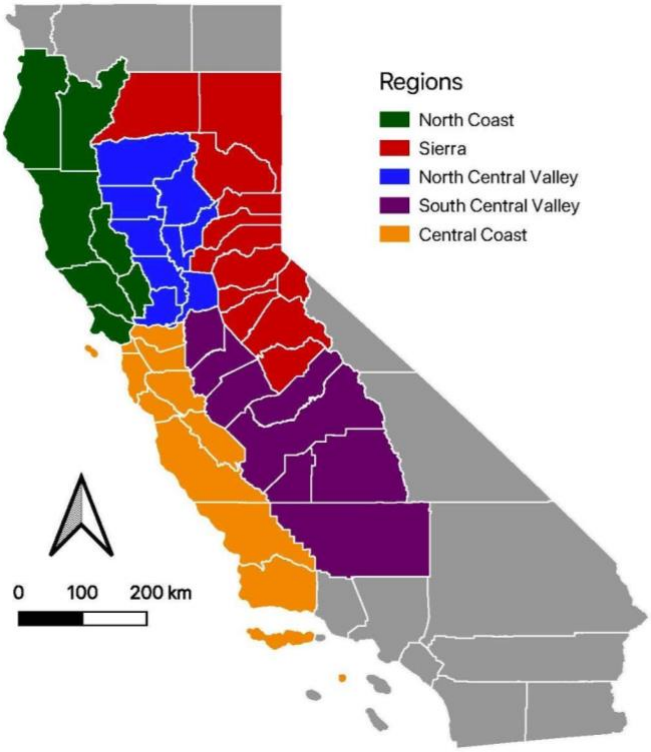


Figure 16: Counties and Regions Included in Data Record Analysis

4. RESULTS

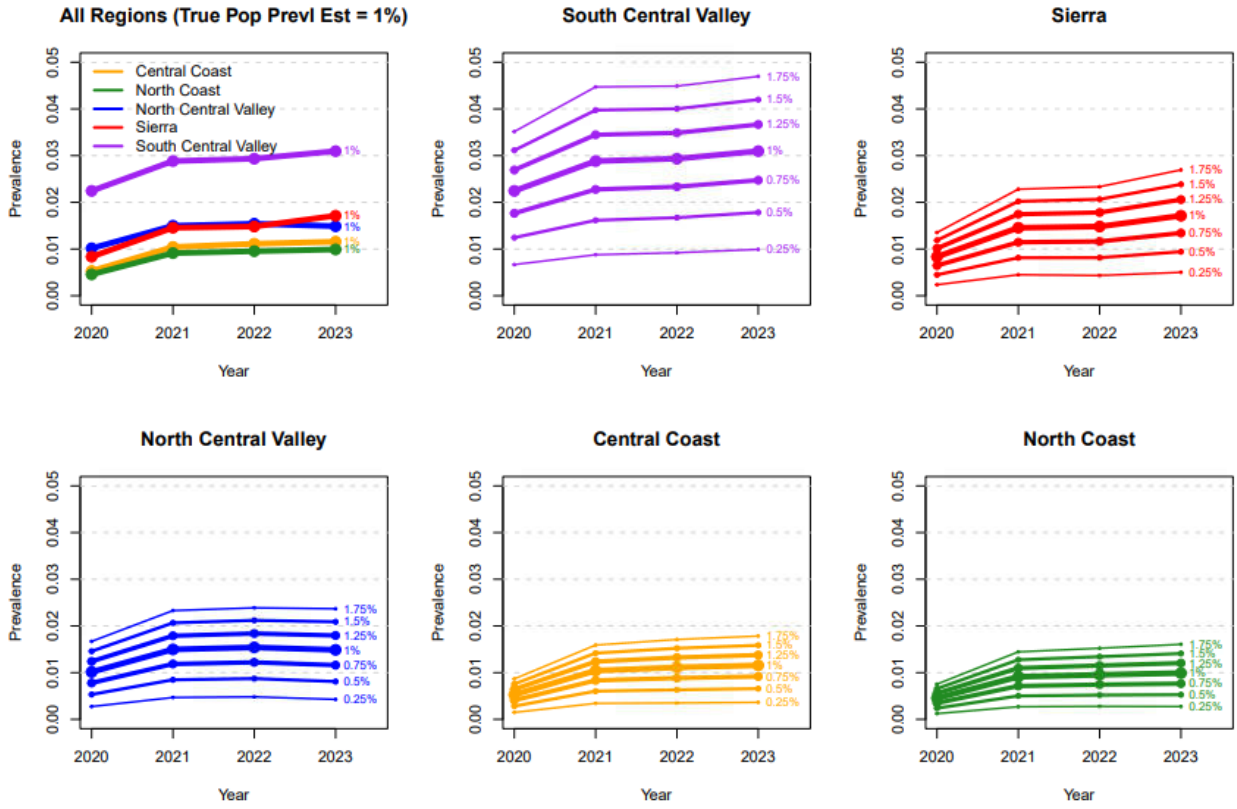
Across all regions, adjusted cannabis prevalence estimates were evaluated under a range of assumed true overall population prevalence levels (0.25–1.75%). For reporting clarity, results are expressed as percentages corresponding to the lower, midpoint, and upper bounds of this range. Each estimate is presented as x% (y–z%), where x% represents the value under the 1% assumption, bracketed by the 0.25% and 1.75% assumptions.

Overall, the most dramatic increase in estimated prevalence across all regions occurred between 2020 and 2021, followed by more gradual changes in later years. The South Central Valley and Sierra regions continued to show sustained growth through 2023, while the other regions appeared to have largely plateaued after the initial increase in 2021.Prevalence in the North Coast region remained comparatively low, but showed steady increases across the four-year period, beginning at 0.46% (0.12%–0.76%) in 2020 and rising to 0.96% (0.28%–1.51%) in 2021, 0.98% (0.29%–1.57%) in 2022, and 1.04% (0.29%–1.69%) in 2023. The Central Coast exhibited a similar upward trend, but at slightly higher levels, with estimates of 0.53% (0.15%–0.86%) in 2020, 1.05% (0.34%–1.59%) in 2021, 1.12% (0.36%–

1.72%) in 2022, and 1.16% (0.36%–1.79%) in 2023. Both regions show incremental year-over-year increases, with the most substantial gains occurring between 2020 and 2021.

The North and South Central Valley regions displayed higher overall prevalence levels, particularly in the South. In the North Central Valley, estimates increased from 1.00% (0.27%–1.64%) in 2020 to 1.49% (0.47%–2.30%) in 2021, 1.54% (0.48%–2.39%) in 2022, and 1.48% (0.43%–2.36%) in 2023. The South Central Valley exhibited by far the highest values observed across all regions, beginning at 2.24% (0.67%–3.50%) in 2020 and rising steadily to 2.87% (0.88%–4.44%) in 2021, 2.95% (0.93%–4.50%) in 2022, and 3.09% (0.99%–4.68%) in 2023. In the Sierra region, prevalence rose more gradually, but consistently from 0.70% (0.20%–1.14%) in 2020 to 1.26% (0.39%–1.97%) in 2021, 1.31% (0.38%–2.07%) in 2022, and 1.46% (0.42%–2.30%) in 2023, reflecting steady year-to-year growth.

Figure 17: Indoor Cultivation Prevalence (2020-23)



5.4 LICENSED MARKET ANALYSIS

5.4.1. ANALYTICAL FRAMEWORK

For our analysis, we looked at the harvest data contained in the METRC track and trace system and entered by cultivators to reflect the number of plants per harvests, number of harvests per year, and weight of each harvest. This allowed us to note differences in plant counts, harvest numbers and weight for various license types, as well as specific counties and geographical regions. This differs from the methods used in a recent report prepared by ERA Economics, which analyzed cultivation tax data to estimate licensed production from 2018-2021 (the cultivation tax program was suspended in 2022). This method relied on reporting done by cultivators as to how much cannabis they produced and then stratified by the plant material (e.g. leaves vs. flowers) with each plant component charged a different amount of tax. The ERA report also looked at sales receipts on the retail side to track backwards to estimate production levels.

For methods deployed by ERA and methods used for this study, a major limitation was data quality. This is expounded upon in the Limitations section. The directionality of the analyses impacted the estimates from both groups, as diversion at the cultivation level can happen prior to tax payments, resulting in our harvest estimates being higher than ERA's post tax estimates. Furthermore, product sold at the retail level does not include diverted product, product that is brought to retail and never sold, or is used for promotional purposes, further shrinking the estimates of licensed production made by ERA.

We aimed to present a fuller picture of how the amount of licensed product produced compared to the amount of whole flower sold in dispensaries as reported through PoS systems. We also used self-reporting of flower amounts consumed annually by CA cannabis consumers. To do this, we used a sample of PoS data as well as a consumer survey administered to a national sample, including California.

We also used Transfer Data from the CTTP database to track the most common manifest origins and destinations. This allowed us to compare where the most cannabis is grown, to where most transfer manifests originate and end up.

5.4.2. DATA USED

We utilized consumer and point-of-sale data from New Frontier Data (NFD), and inferences from California Track and Trace Program (CTTP) data to produce average estimates of production for each license type and indoor unlicensed output as well. (California has 20 different licenses available for cultivation categorized by size: large, medium, small, specialty, and specialty cottage. These categories are then divided based on cultivation method (outdoor[34],

[34] Outdoor licenses grow cannabis outside without using any artificial lighting.

mixed-light[35], or indoor[36]).) NFD utilized CTTP data to analyze total production amounts. These figures from 2022-2023 were compared with consumer survey and POS data to evaluate these data sources as indicators of cannabis flower purchased and consumed through the regulated system. Consumer data was analyzed to assess reliance on the licensed and unlicensed markets and to compare differences in acquisition and consumption patterns across licensed and unlicensed markets. These figures allowed us to compare licensed vs. unlicensed production and consumption and to cross-check our production estimates with trends in consumer sourcing and potential diversion from the licensed supply chain. It also highlighted the issues with using multiple data sets to triangulate data with vulnerabilities in reliability and validity. The CTTP data was also used to track the origin and destination of cannabis manifests.

Obtaining METRC Data: To assess licensed cannabis harvests in California from 2018 to 2024, harvest data from the seed-to-sale tracking program METRC were received from the Department of Cannabis Control. We intended to document trends from 2018, but the earliest data available from the DCC was from January 2019.

5.4.3. METHODS

We referred to the CTTP data to estimate the amount of cannabis grown in the licensed market in 2022-2023. This data is reported in weight from harvested plants. We calculated the weight of the flower being produced for whole flower sales and compared it against the weight of whole flower sold through retailers (minus prerolls) according to the CTTP.

Analyzed Retail Sales: To triangulate the sales data, we examined a sample of 419 licensed retailers in California and determined the volume of cannabis flower sold for the 2022-2023 period. We then obtained licensing numbers from the DCC for the number of retailers licensed in January and December 2022 and took the average. We removed the lowest and highest 5% of retailers by sales volume to account for outliers, for a final sample of 377. The sample of retailers was generalized to the average number of retailers open during that year to arrive at the final estimate (N=1622.5) While we are able to see the weight of the flower sold in the PoS system, we are not able to see the weight for prerolls sold (preroll weights can vary from .25 grams to 1 gram) so we omitted prerolls in the analysis. In the PoS system, a preroll is entered the same way regardless of weight.

Estimated Consumption: To estimate consumption amounts, we first narrowed our sample of 497 California consumers by selecting those who said they use cannabis flower and those who said they primarily source from regulated sources. We then looked at the range of consumption (from once or twice a year to multiple times per day) as well as the amount of

[35] Mixed-light licenses grow cannabis in a: Greenhouse, Hoop-house, Glasshouse, Conservatory, Hothouse or Other similar structure.

[36] Indoor licenses grow cannabis in a permanent structure using at least 25 watts of artificial light per square foot.

flower reported by consumers as their average monthly intake. From this, we determined the low and high ends of flower consumption per year. To generalize to the entire California population of consumers, we used the consumption rate in California for those aged 18 and above and applied it to the entire population of Californians aged 18 and above. Then, from that sample, we applied the proportion of consumers who said they consume cannabis flower (as opposed to only non-flower products) and those who primarily source from regulated businesses. This gave us a low and high estimate for annual consumption of cannabis flower by weight, for consumers in California 18+. We did the same process for consumers who say they primarily source from outside the regulated market. We included those 18+ in our sample because consumers 18+ can access cannabis retailers with a medical cannabis card.

Analyzing Harvest Data: The data was provided as a series of monthly CSV files. Each CSV covered one month of data, and each file had 25 columns. Data was downloaded and ingested into Snowflake software, which was consolidated into a master table called "DCC_HARVEST" and analyzed in a separate software, Sigma. Regarding the data makeup, columns 1-13 were specific to the harvest batch, while columns 14-25 were specific to each package generated from the harvest batch. These first 13 columns were separated into a table labeled "DCC_HARVEST_FIRST." Unique identifiers (UUIDs) were created for each individual harvest based on the columns "HarvestLicenseNumber" & "HarvestBatchName." From there, the first 13 columns were split into a separate table for analysis. To calculate the number of and weight from harvests, several columns were added to these original 13, including: UUID; Maximum square footage allowed by each Harvester Facility Type; Region each City / County falls under. Regions were selected based on categorization in other areas of the study (Central Coast, North Coast, San Francisco Bay Area, Sierra Foothills/Northern California, San Joaquin Valley); Standardized Unit of Measurement for Harvested Weight; and Packaged Weight Harvested Per Plant.

When analyzing harvests by license type, several license types were filtered because the products they produced were not mature flower, but other plant components like seeds and clones. These included Nurseries & Microbusiness Licenses.

Data Cleaning and Analysis: Some data anomalies were identified and accounted for during the data cleaning and analysis. Several outliers were identified during initial analysis. For example, Harvest Batch "Mendo Breath – 05/10/21", harvested from a small Mixed Light Tier 1 facility in Monterey County, claimed 720 plants produced 413,414,949.36 kg of flower. This was an unrealistic number because Small Mixed Light Tier 1 average weight per harvest is 154kg, with an average of 471 plants per harvest. Lake County data was also excluded due to the vast majority of Harvest Batch UUIDs accounting for a single plant. It is extremely unlikely that a harvest would contain only one plant. The assumption is that this harvest was broken up by plant in the data, and each plant was granted its own entry into METRC. Filters were also applied based on Packaged Weight Per Plant. Several Harvest Batches had negative or null values. On

the higher end, some harvests reported 14+ KG of dried flower per plant. The top 5% of Harvest Batches by Packaged Weight Per Plant were filtered out. (See Limitations and METRC Data Issues in Appendix for additional details).

After the data was ingested, cleaned, and normalized, the following values were calculated by Region / County / License Type:

- Distinct UUIDs
- Total KG Harvested
- Avg Harvested KG by License Type
- Total Harvested Plant Count
- Avg Plants per Harvest
- Avg KG per Plant

Data was reported by license type, county, and region for the state.

Analyzing Transfer Data: While the DCC dashboards can provide data on the amount of cannabis produced for continuation in the supply chain, no data shows where in the supply chain the cannabis goes next. To address this gap in supply chain movement data, we analyzed CTTP manifest data for the study period. Manifest data was reported quarterly for the years 2019-2023. Data for the period of January 2022 – September 2022 was not available. The data was provided as a series of monthly CSVs. Each CSV covered one month of data, and each file had 34 columns. Data was downloaded and ingested into Snowflake, where it was consolidated into a master table called "DCC_TRANSFER" and analyzed in Sigma. Data was reported in April, July and October for each year. We noted the number of manifests by county of origin and county of destination. Before Q3 2022, most transfers included a null value for both "Origin County" and "Destination County" of transfers. These values were updated based on the zip code of the facility in question. Transfers from each Origin Facility Type to each Destination Facility Type were extracted on an annual, monthly, and total time frame. The number of distinct manifests was also specifically identified from Harvest Origin Facilities and their destinations over time. We divided the analyses into four areas: regions, the top ten counties for manifest origin and destination, counties of interest, and counties not included in the counties of interest.

5.4.4. RESULTS

According to CTTP and the DCC, there were approximately 1,680 tons of cannabis harvested for continuation in the supply chain in 2022 (i.e. 3.36m lbs or 1.524m kg). This includes cannabis that went to a manufacturer as well as cannabis that was sold as whole flower

through a retailer. When looking at the PoS data, there were 466.6 tons of cannabis flower sold in 2022, not including prerolls. According to the consumer self-report, there was an average of 1,402 tons of cannabis flower consumed in 2022 by people who state they primarily source from regulated businesses (low end = 756.4; high end = 1316.86). For people who report mainly using unlicensed sources (including dealers and family/friends), there was an average of 1007.68 tons of cannabis flower consumed in 2022 (low end = 744.02; high end = 1271.35).

Table 8: Consumer Self-Reporting on Consumption & Source

Source Category	Average Consumption (tons)	Low End (tons)	High End (tons)
Licensed Retailers	1,402	756.4	1,316.86
Unlicensed Sources (dealers, family/friends)	1,007.68	744.02	1,271.35

As can be seen in the difference between the production data and sales and consumption data, a significant amount of the cannabis being produced in California is going into making manufactured products, meaning it is either packaged into prerolls, or becoming oil, isolate, distillate or other forms of isolated cannabinoids to be used in the making of vape cartridges, gummies and other products. The amount of raw product needed to make a manufactured product will vary based on cannabinoid density and method of extraction. There are not measurements of flower contained in pre-rolls or amounts of flower used to produce manufactured products, so this study was limited to tracing flower and inferring amounts for other kinds of products. The gap between production and consumption data could indicate lost or diverted product, as with “burner distros,” or entities using DCC distributor license numbers that have not been removed from CTTP systems (Reisman, 2025).

Also notable is the difference between self-report measures of consumption and sales data from retailers. Measuring the use of an intoxicating substance via self-reporting has been shown to have reliability and validity issues. Often, people underreport their consumption because they do not remember, or because the vessel they use for consumption varies in size across different consumption sessions (Dawson 2003). There are also limitations in relying on PoS data to calculate the weight of prerolls sold because the weight of the preroll is usually not entered into the PoS system; rather, it is sold as one unit, regardless of weight. Furthermore, just because an individual is buying a certain amount of cannabis, does not mean they are using the entirety of what they buy. Especially prior to COVID, sharing joints was common, so someone may have bought a preroll, but shared it with three other people which makes self-reporting difficult beyond consumption sessions per day. Currently, for cannabis, there has not been an established rate of over/under reporting. When looking at alcohol, more accurate rates have been attempted by having the consumer sample use their own vessels, including ice and mixers and then measuring the amount of actual alcohol that is being added to the glass. Similarly to edibles,

it is easier to estimate consumption with standardized doses like a bottle of beer, but wine and mixed cocktails present barriers similar to raw flower and prerolls.

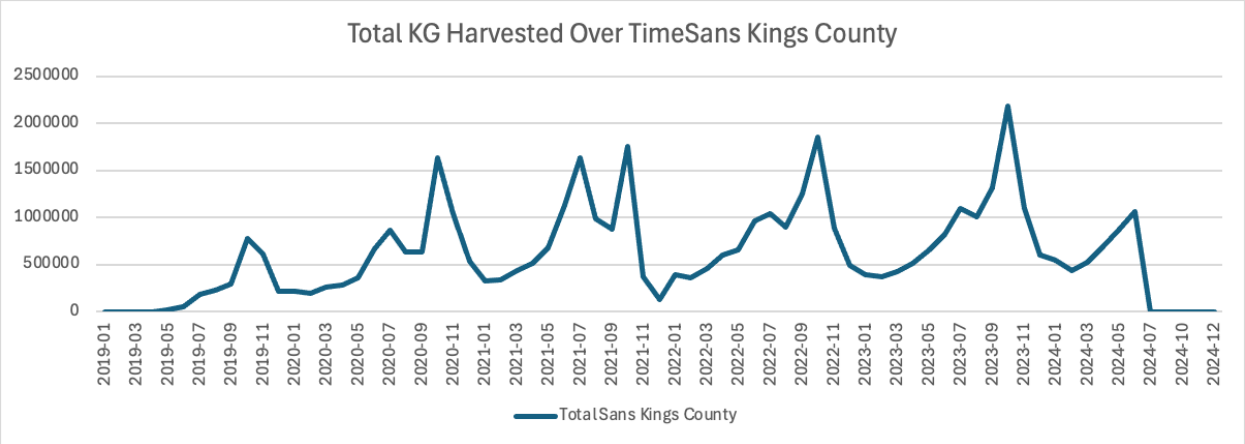
Harvest Data by License Type

Deploying the methods described above total harvest weight (in KG) per license between January 2019 and July 2024 was calculated, as well as average harvest weight (in KG) per license type and average number of plants per harvest.[37] Between 2019 and 2024, 50.4M KG of cannabis was reported by cultivators as harvested in METRC. Small outdoor licensees produced the most (18.2M KG), followed by Small mixed-light tier 1 (13.3M KG). The smallest amount reported came from large mixed-light tier 2 (771 KG) but that was also the category with the fewest harvests reported (16).[38]

The Small mixed-light tier produced the largest number of harvests (86.4K), followed by small indoor (78.6K) and medium indoor (61.9K). Mixed-light and indoor cultivation facilities can produce multiple harvests per year, while outdoor facilities are limited to one, perhaps two if light deprivation is used. Large outdoor cultivation licensees reported the highest average weight per harvest at 763 KG, followed by small outdoor with 315 KG and large mixed-light tier 1 at 284 KG.

Small mixed-light tier one licensees reported growing the most plants over the study period (40.6M), followed by small outdoor (25.9M) and small indoor (17.3M). This tracks with the number of harvests reported, the total weight harvested and the average weight per harvest. However, because of a smaller number of total harvests, the highest number of average plants per harvest was reported by large indoor licensees (1.7K), followed by large outdoor (1.2K), and large mixed-light tier 1 (659). (See Appendix 2.4.1 for full table of harvest data by license type).

Figure 18: Total KG Harvested Over Time: All production in California



[37] See Appendix 2.4 on limitations with Kings and Lake County data irregularities and subsequent exclusion from analysis.

[38] It should be noted that the DCC began issuing Large licenses in 2023.

Figure 18 shows the total KG harvested by licensed facilities over the study period ending in July, 2024. Those licensees that did report a decline in flower production averaged -48% reduction over the study period. Otherwise, there was a small boost during the periods when the outdoor product was harvested, usually September to November. There was a dip in production in November 2021 which was the lowest point of production during the study period. This followed two spikes in production, one in the expected outdoor harvest time of September to November, but another earlier that year from May to July.

Harvest Data by County

Below is a summary of which types of licenses reported harvests in which counties during the study period (including municipalities within counties). (Not every county allows for every type of cultivation license.) No counties reported harvests from large indoor licenses. See Appendix 2.4 for the types of cultivation licenses issued by counties of interest and for the complete harvest data.

Overall, Santa Barbara accounted for the most harvests with just over 72K, followed by Monterey with 63.4K, Los Angeles county with 59.7k, 41k from Humboldt, Sacrament with 30.8k and 26.8K from Mendocino. Marin County reported the fewest harvests (2), followed by El Dorado (13), Siskiyou (32), Mono (73) and Del Norte (125). License types were limited in these counties; for instance El Dorado and Siskiyou only reported one type and Del Norte reported two.Santa Barbara was the top producer by weight, with over 18m kg of cannabis harvested, followed by Monterey with 8.7m, Humboldt with 2.6m kg, Los Angeles and Mendocino, both with 1.4m kg, and Riverside County with 1m kg. On the low side, Siskiyou reported harvesting 501 kg, El Dorado 2.7k kg and Del Norte 4.1k kg.

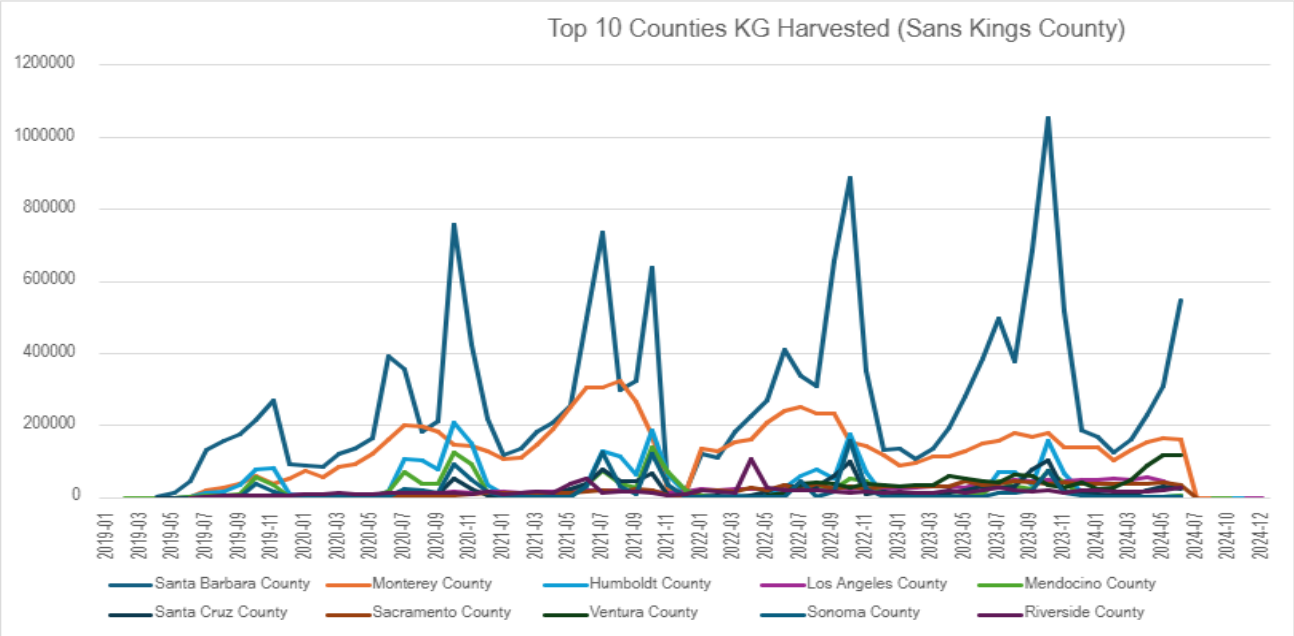
As mentioned in a previous section, Kings County is an anomaly. Although reporting just 1221 harvests, they reported the third highest harvest weight at 7.1M KG, equating to 2333 plants per harvest, a total far above the other counties. Also of note is Inyo County. Reporting just 275 harvests, they also reported 1175 plants per harvest, far above the other counties, with the exception of Ventura County, which reported an average of 1328 plants per harvest from their 2541 harvests (See Appendix 2.4 for the full harvest data by additional counties).

The outdoor nature of harvesting can be seen in counties like Humboldt and Mendocino, which show spikes during the outdoor harvest season (October-November), but remain dormant for most of the year. Overall, Santa Barbara dominates the cultivation landscape in California due to its use of large, all-season greenhouses to produce harvests every few months.

Sub-Sample Analysis: We selected 12 counties (plus Los Angeles) to analyze closely, as these counties aligned with Cannavision and case study analyses. These counties were:

Calaveras, Humboldt, Mendocino, Trinity, Siskiyou, Shasta, San Bernardino, Riverside, Del Norte, San Diego, Nevada, El Dorado and Los Angeles.

Figure 19: Total KG Harvested Over Time: Top 10 producing counties (excluding Kings and Lake County)



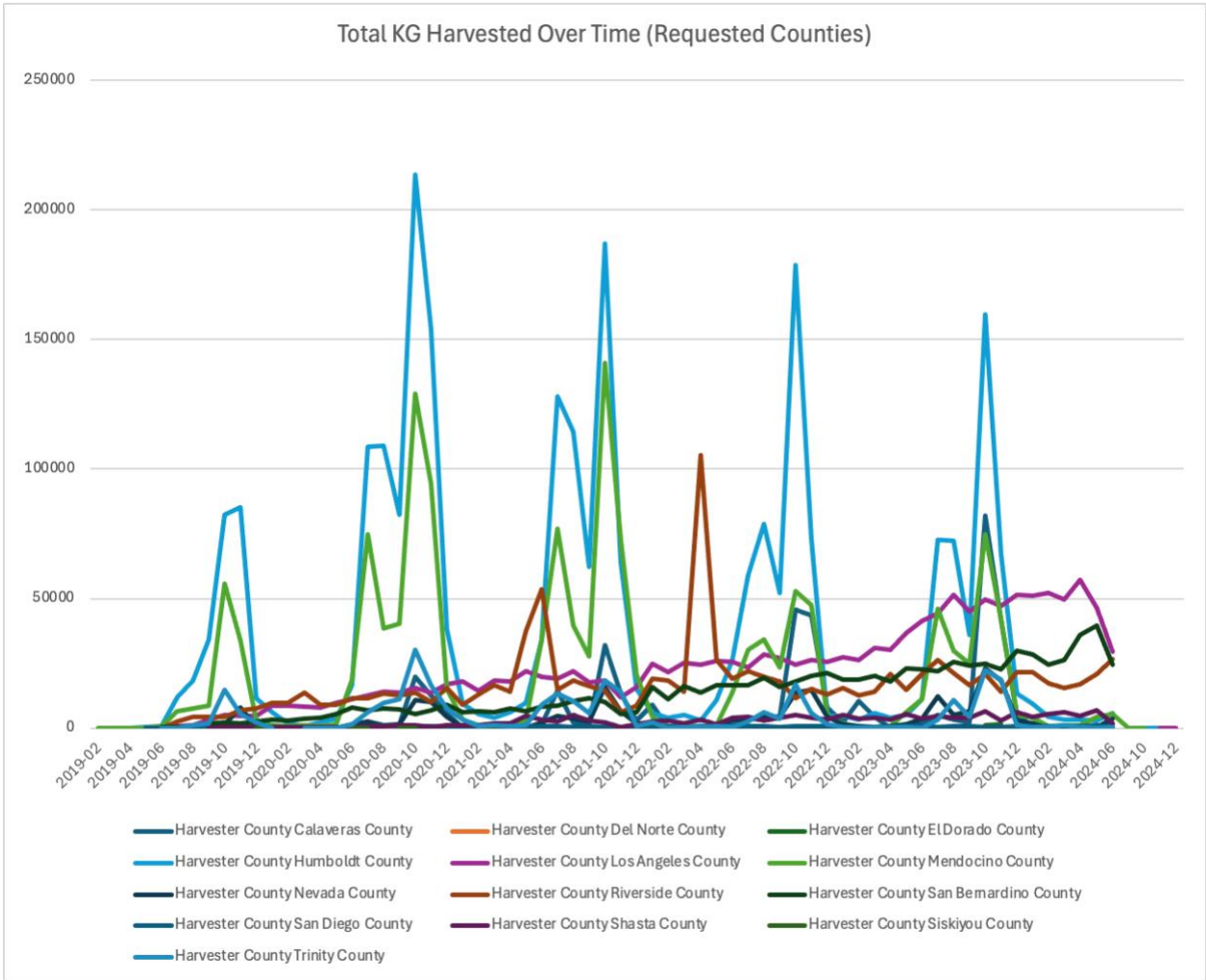
Of the 13 study counties, specialty indoor was reported in all but El Dorado and Trinity counties. Large mixed-light tier 1 was only reported in Calaveras and Humboldt counties and large mixed-light tier 2 was only reported in Humboldt County. Siskiyou only reported harvests from specialty indoor licenses and El Dorado only from medium outdoor licenses. Humboldt County had harvests from the widest variety of license types, reporting for everything except large and medium indoor license types.

Even though El Dorado County only reported 13 harvests from medium outdoor licensees, they also had the largest average weight per harvest at 208 KG. The smallest average weight per harvest came from Siskiyou County at 16KG. Interestingly, Los Angeles County, which has one of the widest ranges of license types and the most overall harvests and harvest weight was on the lower end of average weight per harvest at 24 KG, likely because of the density of indoor licenses

Humboldt County reported the most plants harvested during the study period (14.4M) followed by Los Angeles with 11.5M. Although Mendocino was third in number of harvests and total weight harvested, they were 5th in number of plants (4.5M), suggesting that Mendocino farmers are getting more yielded weight per plant than in other counties. And although Del Norte has harvests reported from only two license types and is on the low end for all other metrics, they had the second highest number of average plants per harvest at 353, topped only by San Diego at

380. El Dorado reported the lowest number of plants per harvest at 118, followed by Mendocino at 169 and Nevada at 190. Counties favoring indoor licenses will have higher number of harvests per year, with more plants per harvest, but likely less weight per plant since indoor plants tend to be smaller. While regions that traditionally grow outdoors may have fewer harvests per year, bigger plants, resulting in higher weights per plant.

Figure 20: Total KG Harvested Over Time: 13 Counties Overlapping with Cannavision Data (Plus Los Angeles)



Harvest Data by Region

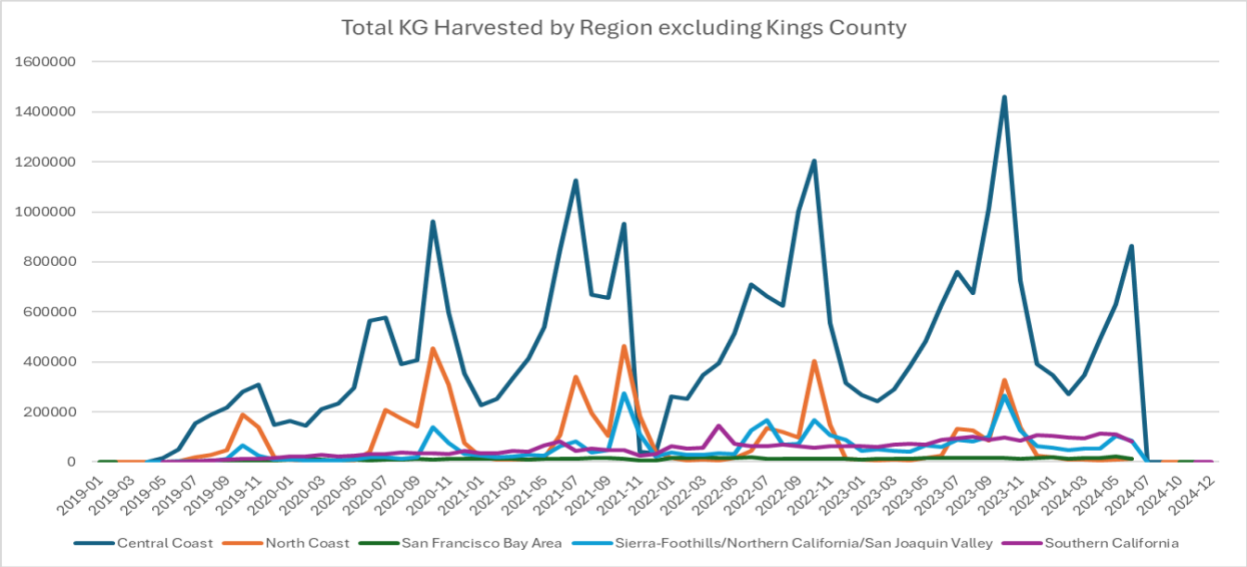
To explore regional differences in cannabis harvests, the counties permitting cultivation were categorized by region based on the US Census. Figure 20 provides harvest data by region.[39]

[39] The data for the Sierra Foothills region contains Kings County, which has already been identified as an outlier and may represent errors in the data. Kings County has been removed from the line graph to better view the trends over time for the regions (See Appendix 2.4 for the complete harvest data by geographical region).

The Central Coast region reported the most harvests during the study period with just over 150K harvests. The San Francisco Bay Area region reported the fewest with just over 27K. The Central Coast also led with total KG harvested with 29.4M KG and the San Francisco Bay Area had the least with 712K. The Sierra Foothills region reported over 1M KG in weight harvested, but their number of harvests was 63.9K, the second lowest out of the five regions. The Central Coast, by far, reported the highest number of harvested plants with 72.4M, followed by the North Coast and Southern California, both with just over 23M. The Central Coast also had the highest number of plants per harvest at 480 and Southern California the lowest with 191.

The data conveys regional differences. Southern California counties like Los Angeles, San Bernardino, Riverside and San Diego mostly license indoor facilities, which harvest multiple times per year and therefore have higher numbers of harvest. Central Coast region has large mixed-light and outdoor operators, allowing both large numbers of harvest and kilograms harvested. Primarily driven by outdoor farms in Humboldt and Mendocino counties, the North Coast reports fewer harvests than the Central Coast and Southern California, likely because outdoor farms only do one harvest a year. The North Coast is second in the number of plants harvested only to the Central Coast. The San Francisco Bay Area has not licensed substantial cultivation and licenses smaller sites, resulting in lower numbers of harvests. Variations between indoor, outdoor, and mixed light harvest times give each region a different harvest rhythm. For instance, Southern California shows consistent harvests while Central Coast and North Coast (largely outdoor) shows seasonal rhythms.

Figure 21: Total KG Harvested Over Time: California geographical regions (excluding Kings and Lake County)



LICENSED MARKET ESTIMATES: TRANSFER DATA

Regional Data

As shown in Figure 22 there were 3.38M manifests created for the products in the state of California between April 2019 and October 2023. Southern California accounted for 47% of these manifests. The San Francisco Bay Area was next with 15%, followed by the Sierra Foothills/Northern California/San Joaquin Valley and Central Coast regions with 13% each, and the North Coast with just 1%, indicating that most supply chain movement occurs in urban areas (See Appendix 2.4 for a table of the manifests by region of origin).

A total of 3.36M manifests were received during the study period. The counties of receipt were in the same order as the counties of origin in terms of % of total manifests received. Los Angeles (49%), San Francisco Bay Area (18%), Sierra Foothills/Northern California/San Joaquin Valley (14%), Central Coast (12%) and the North Coast (<1%). Graph 6 presents this data as a stacked bar chart.

Figure 22: Manifests by Region of Origin

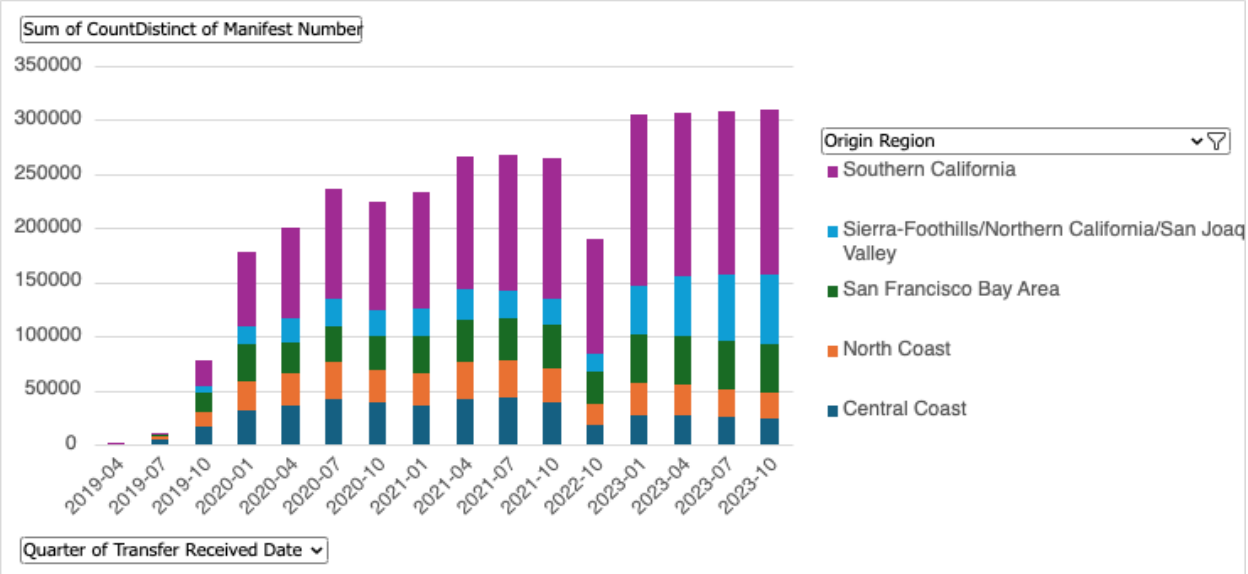
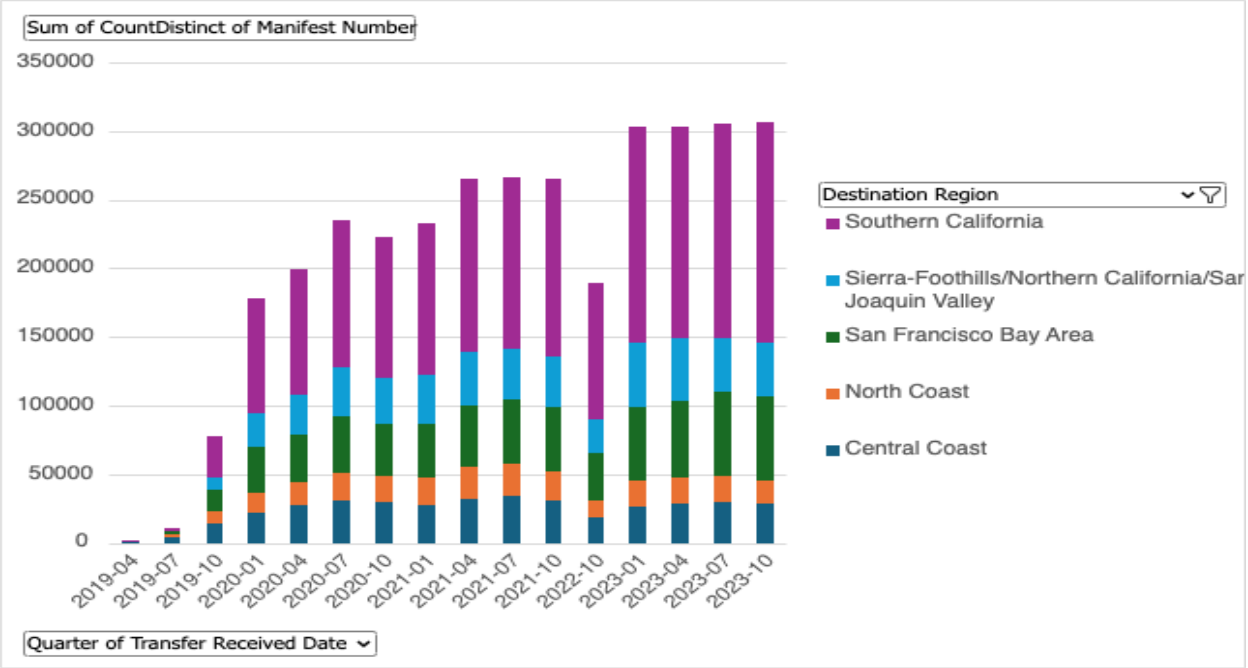


Figure 23: Manifests by Region of Destination



Top 10 Counties

Figure 24 displays the number of manifests for the top 10 counties where they originated for the study period. There were 2.8M manifests sent from their county of origin during the study period. Los Angeles had the most manifests with 39%, followed by Alameda County with 15% and Riverside County with 7%. We see the same dip in October of 2022.

Figure 24: Manifests for Top 10 Counties of Origin

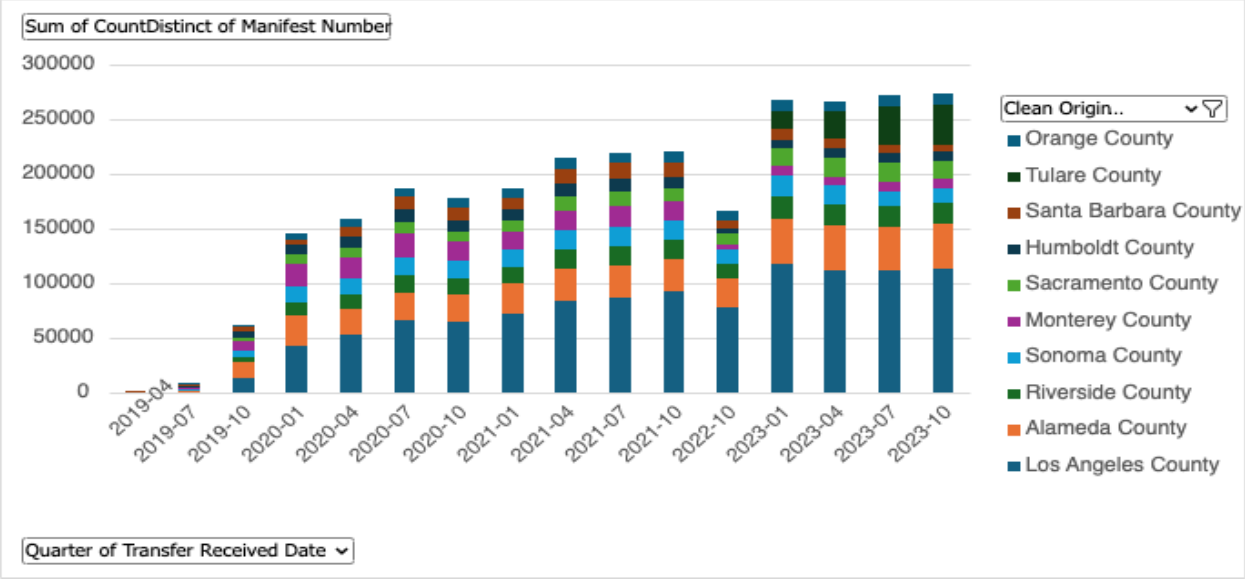
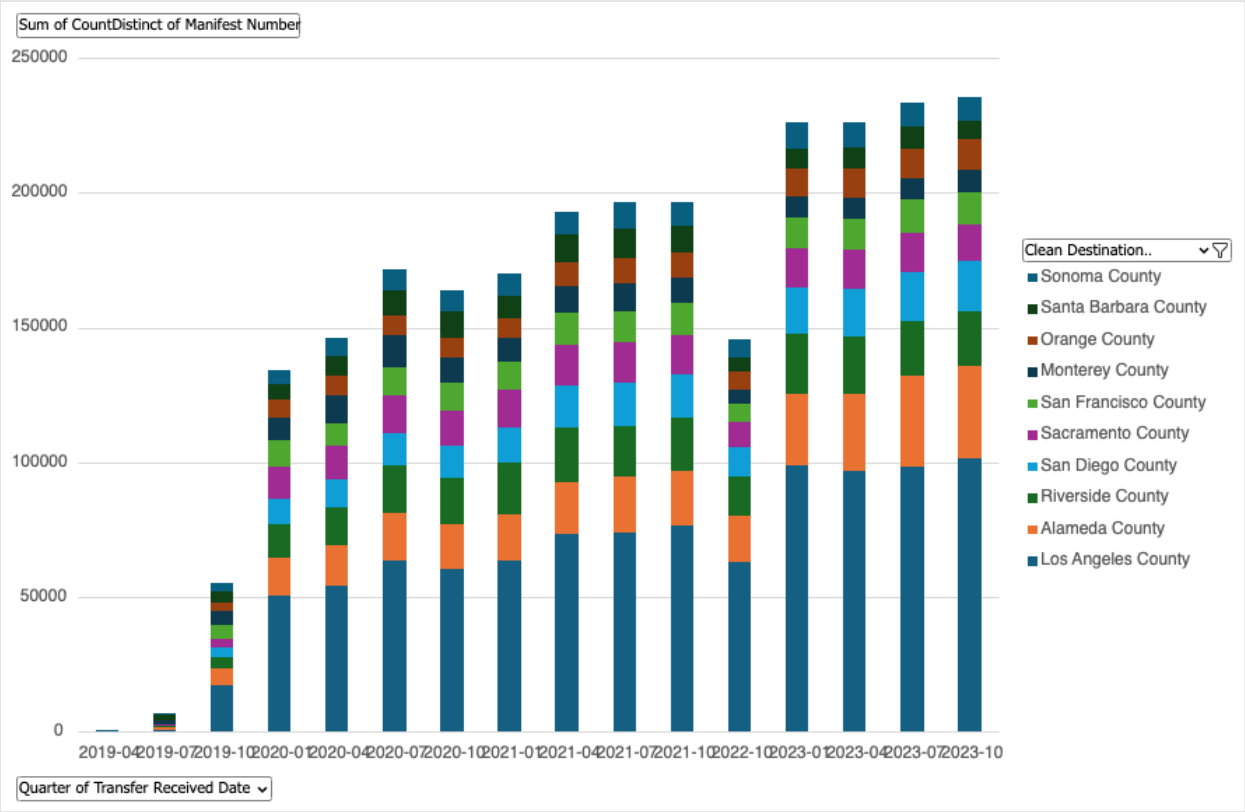


Figure 25 displays the number of manifests for the top 10 counties where they were received for the study period. The top 10 counties sent a total of 2.5M manifests during the study period. Los Angeles county accounted for 40% of manifests received. Alameda County was next with 12%, followed by Riverside County with 10%. When compared to the number of manifests sent from these counties, Los Angeles sent about the same percent as they received. Alameda sent slightly more than they received (15% vs. 12%) and Riverside sent slightly less than they received (7% vs. 12%). This may reflect the level of production in these counties compared to the number of retail outlets. As with the other analyses, there was a dip in October of 2022, but otherwise the number of manifests has grown steadily since 2019. There was a slight decrease in Q3 2020 and Q1 2021 which could have been related to COVID and slowed production.

Figure 25: Manifests for Top 10 Counties of Destination



5.5 CASE STUDY ANALYSIS OF PRODUCTION AND POLICY

While policy, mapping, and market analysis provide important perspectives on unlicensed cannabis cultivation, numerous studies have demonstrated how non-policy factors and unexpected policy effects can play a critical role at local levels in determining patterns of unlicensed cultivation (Corva 2014; Polson 2013; Polson & Petersen-Rockney 2019; Polson et al

2024; Getz et al 2024). A useful approach to assessing these less obvious factors is ethnographic research. Consisting of interviews and in-person observations of everyday environments, ethnographic research can detect factors that may not be apparent through more remote sensing methods and existing data sets, especially around hidden or criminalized activity (Adler 1990; Boeri & Shukla 2019).

Guided by the outputs of our predictive model, we deployed a rapid response interview and ethnography team to investigate policies correlated with significant increases or decreases in unlicensed cannabis production. This included a targeted inquiry into the effects of local cultivation bans and permitting schemes on the geography of unlicensed activity. We conducted qualitative analyses informed by interviews in jurisdictions exhibiting major shifts or anomalies in unlicensed production, alongside a secondary source historical review to contextualize findings and test underlying assumptions. The team pursued in-depth fieldwork in policy-reactive jurisdictions to understand the history, implementation, and social dynamics surrounding key policies, conducting interviews until thematic saturation was reached. Interviewees included over 100 stakeholders such as county supervisors, sheriffs, code enforcement officers, cannabis advocates, licensed and unlicensed cultivators, environmental health officials, and local water agency representatives. Informed by mapping outputs, we focused on hyper-local trends and potential confounding factors, such as the presence of non-cannabis greenhouses, and assessed the influence of events like enforcement actions, elections, and natural disasters. Fieldwork was concentrated in six counties, both ban and permit jurisdictions, where policies were particularly effective or ineffective at mitigating unlicensed activity. This work builds on and integrates findings from Polson and Peteren-Rockney's concurrent DCC-funded research in four ban counties and several permitted jurisdictions. Our benchmark for success is a clear, evidence-based understanding of which local policies reduce unlicensed cultivation and its associated environmental harms.

5.5.1. CASE STUDY SELECTION

We used CannaVision model data to identify the impact of different variables on licensed and unlicensed cultivation in twenty one counties (at the time of county selection, we had model data for 2020-2022 available). We then selected six counties aiming for a balanced representation of permit and ban jurisdictions, geographical and ecological diversity, and a range of policy variables that our ethnography would test. We also looked for counties with dramatic changes in the amount of cultivation. For ban counties, we selected Siskiyou with secondary research in Amador and Shasta and drew on prior research in Napa, Yuba, and San Bernardino. We selected Nevada, Mendocino, Lake, Riverside and Trinity for permit counties. **Table 9** contains county background information.

Table 9: County Background (data from 2020 US Census and 2022 USDA NASS Census)						
	Lake	**Mendocino**	**Nevada**	**Riverside**	**Siskiyou**	**Trinity**
County size (square miles)	1,256	3,506.82	957.76	7,209.27	6,278.77	3,179.27
Population	67,878	89,108	102,037	2,492,442	42,905	15,670
Density (population per square mile)	54.2	26.1	106.8	335.4	7.0	5.1
Median household income	$58,738	$64,688	$84,905	$89,672	$55,499	$53,498
Poverty rate	17.6%	13.9%	10.9%	11.3%	17.1%	20.8%
Racial Demographics (Top 3 listed	-64.9% White alone, not Hispanic or Latino	-62% White alone, not Hispanic or Latino	-83% White alone, not Hispanic or Latino	-31% White alone, not Hispanic or Latino	- 74.1% White alone, not Hispanic or Latino	-81.3% White alone, not Hispanic or Latino

plus Hispanic/Latino	- 4.8% American Indian and Alaska Native - 5.1% Two or More Races - 25.4% Hispanic/Latino	- 6.5% American Indian and Alaska Native - 4% Two or More Races - 28.1% Hispanic/Latino	- 1.7% Asian alone - 3.6% Two or More Races - 10.9% Hispanic/Latino	- 7.6% Black alone - 8.1% Asian alone - 51.9% Hispanic/Latino	- 5.3% American Indian and Alaska Native - 6.0% Two or More Races - 13.7% Hispanic/Latino	- 5.0% American Indian and Alaska Native - 5.6% Two or More Races - 6.4% Hispanic/Latino
Number of farms (non-cannabis)	581	975	620	2,424	655	139
Average size of farm (acres)	238	695	104	149	1027	411
Top Agricultural products (by acre)	Cattle, forage (hay,alfalfa)	Cattle, forage (hay, alfalfa), Grapes	Forage (hay, silage), Cattle, Sheep and Lambs, Greenhouse crops	Cattle, Poultry, Wheat, Cotton, Corn, Forage	Forage, Cattle, Sheep/Lamb, Chicken, Vegetables, Wheat,	Forage (hay/haylage), Grapes, Vegetables harvested, Apples, Land in berries

Average per farm government payment	$2,033	$7,567	$420	$5,505	$7,139	$261
Average per farm net cash income	-$6,338	$6,819	-$11,903	$111,471	$66,115	$1,063

5.5.2. ANALYTICAL FRAMEWORK

Building on an existing array of informants and key stakeholders, this study used interviews, focus groups, and participation observation sessions to gain a qualitative understanding of local policy's impacts on the licensed and unlicensed markets. We analyzed changes in cultivation geography and practices in seven California counties (Nevada, Lake, Siskiyou, San Bernardino, Mendocino, and Trinity) through in-person semi-structured interviews with licensed and unlicensed cannabis cultivators, business owners and industry representatives, cannabis advocates, and local officials responsible for regulation, planning, and law enforcement. By examining "on the ground" experience of cultivators and perceptions about the effects of local policy, ethnographies investigated what policy variables influence the extent of unlicensed cultivation. This qualitative analysis of policy outcomes supplements large-scale data analyses through a localized understanding of the social, political, and economic variables that determine market actor behaviors. Interview questions examined cultivators' policy awareness, decision-making, experiential outcomes, perceptions of the industry, and other stakeholders' perceptions of changes in cultivation and the effects of local cannabis policy. Answers to these questions help explain the decisions of licensed and unlicensed cultivators in both ban and permit counties, nuancing and sometimes balancing data procured through other methods.

5.5.3. METHODS

Summary of IRB Work: We first secured Institutional Review Board (IRB) approval, ensuring that human subject research adheres to the highest ethical standards. Our protocol, classified as Soc-Behav-Ed Non-Exempt, was crafted to outline our study's framework, with a strong emphasis on protecting participant data and handling sensitive information responsibly. Given the multi-method approach, careful consideration was given to protecting human subjects involved in both qualitative interviews and the privacy interface of geospatial technology. Special attention was paid to ethical considerations surrounding our engagement with individuals potentially involved in unregulated activities, ensuring their safety and privacy were prioritized. The IRB protocol detailed research aims, methodology, and data management plans. The IRB protocol was reviewed, revised, and strengthened iteratively, including an update for the energy data request (described above) as outlined in the CPUC guidelines. Our study received IRB approval on January 9, 2024, from Colleen Kohashi, IRB Analyst/Administrator at the University of California, Berkeley's Office for Protection of Human Subjects. For more information on data security refer to Appendix 13.

Ethnographic research protocol: Once county selection was finalized, ethnographers divided up counties for fieldwork and followed a standard protocol. In preparation for fieldwork, the research team meticulously reviewed key county policy variables and planning code summaries. This included analyzing policy timelines related to local cannabis legislation,

discourse timelines of significant events, and other background materials, such as equity programs and existing cannabis reports. By examining spatial and temporal model data, the team identified crucial policy variables, refining their approach to ensure interview questions aligned with emerging patterns. Ethnographers collaborated and agreed upon a set of specific interview types and alternatives, as described in **Table 10**.

Table 10: Cannabis Interviewee Categories	
Interview Type	**Alternative**
Sheriff / Appropriate Sheriff Official	Cannabis Enforcement Team Member/Leader, Enforcement Official/Staff relevant to Cannabis
Pro-Cannabis Supervisor	Neutral Supervisor, County Administrator or equivalent
Pro-Ban / 'Anti'-Cannabis Supervisor	Neutral Supervisor, County Administrator or equivalent
Code Enforcement Official (dealing with Cannabis)	-
Planning Director or Staff (if county regulatory program)	-
Cannabis Program Director/Manager (if county regulatory program)	-
Environmental Health/Services Official	Agriculture Agency Official
Water Official (where relevant)	-

Toxic/Hazardous Waste Official (where relevant)	-
Unlicensed Grower x2	Former Unlicensed Grower
Licensed Grower x2 (new and legacy, if county regulatory program)	-
Grow Store Owner/Operator/Staff	-
Soil Provider	-
Dispensary Owner	-
Pro-Cannabis/Regulation Advocate x2 (knowledge of local policy history)	-
'Anti-Cannabis' / Pro-Ban Advocate (e.g., neighborhood groups, environmentalists)	-
Hemp Official/Staff (if hemp program)	-

To streamline outreach, researchers developed a comprehensive spreadsheet to track informant recruitment. They followed a structured list, leveraging professional networks, government websites, media sources, and referrals from initial contacts. To protect participant confidentiality, each informant was assigned a unique identifier, which was used exclusively in field notes and interview transcripts.

Before beginning interviews, ethnographers read a consent form aloud and obtained verbal consent from participants. They provided information sheets outlining the study's purpose. Ethnographers conducted semi-structured interviews using a standard list of questions (Appendix 5) tailored to specific county conditions and interview type. Each interview ended with a set of "universal questions" that tested initial spatial model data. Whenever possible, interviews were recorded and transcribed using specialized transcription software, ensuring accuracy in data collection.

After interviews, ethnographers composed a two-page summary that included the participant's identifier, relevant geographic details, a summary of key themes, an analysis of findings, and significant quotes.

Team Retreat: To integrate findings, ethnographers convened a retreat in January 2025 and collaborated virtually, aligning case studies with spatial mapping data, policy analysis, and insights into the legal cannabis market. This collective effort ensured that the research provided a holistic and well-contextualized understanding of the evolving cannabis landscape.

Synthetic Summaries: After completing fieldwork, ethnographers drafted a 10-15 page Synthetic Summary for each county, which included a top-level summary, research summary, background information, a historic account of unlicensed cultivation, discussion, findings, and conclusions. The synthetic summaries included references to: planning code summaries, comparative analysis spreadsheet, CannaVision data, and county background summaries. They specifically assessed unlicensed cultivation trends over time and discussed how findings aligned or diverged from spatial analysis. Plausible explanations for discrepancies were explored, culminating in a set of conclusions. See Appendix 6.

5.5.4. DATA USED

We conducted a total of 145 interviews across six counties between July 2024 and March 2025 (with an additional 9 interviews in Amador and Shasta counties). We built contacts with residents, staff, officials, law enforcement, business owners, cannabis advocates, and cultivators, and conducted in-depth interviews. We also conducted remote interviews via Zoom with certain interviewees. Though we did not quantify non-interview ethnographic interactions, we spent time at county meetings, cultivator gatherings and meeting spots, celebratory dinners, farm tours, and in community meetings.

Table 11: Interviews in Each County

Interviewee Category	Trinity	Lake	Mendocino	Nevada	Siskiyou	Riverside
State agency staff	0	0	4	2	4	2
Local government staff & officials	3	6	3	2	5	3
Local law & code enforcement staff	2	3	1	3	0	4

Local business owners & residents	3	3	4	2	12	6
Cannabis advocates	1	1	3	2	6	2
Cannabis cultivators (licensed)	3	3	3	6	0	5
Cannabis cultivators (unlicensed)	3		2	5	20	3
Total per County	**15**	**16**	**20**	**22**	**47**	**25**

5.5.5. LAKE COUNTY RESULTS

The Lake County Synthetic Summary is included in Appendix 6. No informants had good visibility into overall unlicensed production, but law and code enforcement officers observed a decline in unlicensed production, and cannabis industry insiders estimated that 33-50% of legacy growers have dropped out. Respondents attributed this decrease in unlicensed cannabis to saturation of and downturn in the cannabis market, dwarfing other contributing factors. Other factors cited include: law and code enforcement pressure; wildfire risk and effects; and cultural factors (e.g. resistance to licensure), but these factors were not cited nearly as often as market conditions. Additionally, licensed cultivators may report on unlicensed cultivators who they see as perpetuating stigma around cannabis and competing for narrow margins. The pandemic, which led many to stay home and grow cannabis, may be an underappreciated contributor to the market collapse from 2021 to 2022, with significant effects in Lake. See Appendix 6.

CONTEXTUAL FACTORS

- Inland, semi-agricultural county. Population of ~68,000. Second poorest county in CA with a poverty rate of 16.8%. Annual government budget of $417M.
- Prone to flooding and wildfire. Fire has affected 60% of land since 2015.
- Considered by some to form the southern point of the “Emerald Diamond,” Lake has a multigenerational history of cannabis cultivation. From 2003-11, it ranked highest in CAMP eradication statistics.

- Enforcement led to “high risk, high reward” practices like having multiple, large grows on public lands. It also led to polarization and stigmatization around cannabis.
- Under medical cannabis, Lake allowed small growers to “self-certify” that they were growing as part of cannabis collective or “cooperatives” and loosened enforcement on 99 plants or fewer, paving the way for quasi-legalization.
- Lake was an early adopter to legal cannabis. Officials saw it as an opportunity to attract big business and increase the tax base. Measure C (2016) and K (2018) imposed tax structures on cannabis cultivation and retailers. Many license-holders find these onerous.
- Lake aimed to expedite the transition to the licensed market through “early activation” (EA) of self-certified operations. County staff were overwhelmed by the number of applicants they received and EA license holders operated for years without oversight. The EA program ended Summer 2021.
- Under EA, cannabis cultivation was initially permitted in low-lying and densely populated areas of the County.
- Cannabis faced intense oppositional pressure from the agricultural lobby, organized under the Farm Bureau, resulting in passage of “Farmland Protection Zone” (FPZ) ordinance in 2021. FPZ prohibited outdoor cultivation in areas zoned for agriculture and pushed cannabis cultivation indoors and/or to more arid county areas.
- Prior to 2023, applicants were allowed to “stack” up to 15 Type 3 (Medium sized) licenses for outdoor cultivation and unlimited Small licenses. In 2023, the county discontinued new stacking and encouraged cultivators to acquire Large Cultivation licenses. By early 2026, Lake County had the most Large outdoor cultivation licenses (26) of any county in California (70 total) as well as a mix of pre-2023 stacked Medium and Small licenses (outdoor and mixed light).
- In 2022, Lake formed a Cannabis Ordinance Task Force (COTF), charged with making recommendations for updating the county’s ordinance to align with state laws and regulations. COTF meetings were frequently derailed by anti-cannabis activists. BOS disbanded the COTF in March 2025. Community Development planned to summarize COTF’s recommendations and put them before the BOS in 2025.
- Lake does not have a designated Marijuana Enforcement Team. The Sheriff’s office has a robust narcotics division that has historically been involved in cannabis eradication. Two code enforcement officers are dedicated to cannabis (funded by the state). Lake is experimenting with joint campaigns between Planning and Sheriff (previously the Roadmap Task Force and now COPTR). Enforcement campaigns are known to target both large backwoods grows and smaller backyard grows.

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- Most enforcement respondents have the (correct) impression that unlicensed cultivation is in decline based on how many unpermitted plants they encounter and cut down each year

(~200,000). Licensed cultivators and those around the industry believe unlicensed production remains prevalent because county permitting and state licensing procedures are slow, expensive, and onerous. For those fortunate enough to get a permit and license, state and local taxes add another burden.

- Licensed grows are now more visible and prevalent in low-lying parts of the county as farmland becomes available. Some agriculturists are diversifying crops by growing cannabis. Some unlicensed grows are mixed in, but local residents are often aware when this occurs. Many "craft" or "cottage" grows remain in the hills. Some legacy growers may be "straddling the market" with permitted grows in more central areas and unpermitted grows in the hills. Meanwhile, opposition groups are lobbying to expand the Farmland Protection Zone and push licensed cannabis to outlying regions.

- Many legacy cultivators have exited the cannabis market, especially since 2021. Informants estimated between 33% and 50% of legacy growers have dropped out, some after trying to obtain a license and "stalling out" in permitting. Informants did not have a good explanation for those "hanging on." It is possible that cultural factors help to explain the obstinacy of some cultivators who "were never going to get a license" and those who persist despite increasingly narrow profit margins. Cultural factors may also impede best business practices.

- From 2018-20: unlicensed cultivation density increased (matched overall trend), particularly in more densely populated areas and areas with higher proportions of non-cannabis agriculture, despite above-average enforcement.

- From 2020-22: unlicensed cultivation density decreased (matched overall trend), especially near licensed farms and in areas with hemp presence, with some unlicensed cultivation increasing in outlying areas, especially where there were no licensed farms (the absence of licensed farms predicted increase in unlicensed cultivation).

- From 2022-24: cultivation density continued to decrease (more decrease than overall trend), driven most by proximity to licensed farms, with greater declines in areas with fewer roads and higher proportions of population over 65.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

- Permitted cannabis operations set up shop in more visible, flatland areas. Many smaller, unlicensed operations stayed in the hills. Tight-knot communities make it hard for unlicensed operators to "hide in plain sight." Strong oppositional groups, however, are actively lobbying to push cannabis back into the hills.

- Market failure was the overriding variable leading smaller cultivators to stay in the unlicensed market or drop out of the cannabis market altogether.

- According to grow store earnings data, the pandemic may have played a role in cannabis' boom-bust cycle by leading people to stay home and grow cannabis, contributing to market glut that crashed the market.
- County-level policy created barriers to licensure, including onerous tax and regulatory structures (which relate to compliance costs and mandatory infrastructure investments) and an unclear or dysfunctional permitting process, especially with regard to CEQA, burdened permit-seekers and deterred unlicensed growers from permitting.
- In short, the costs and difficulty of licensure and competition from large-scale businesses quashed opportunities for smaller operators.
- Nearly all interviewees believed enforcement efforts were ineffective and not a deterrent, despite sustained efforts to shut down unlicensed operators. Many used the phrase "whack-a-mole" and a law enforcement officer told the fable of "the Boy and the Dike."
- Smaller operators may have succeeded in the licensed market had the state provided more funding and technical assistance to transition legacy growers and helped counties streamline permitting.

5.5.6. MENDOCINO COUNTY RESULTS

Mendocino County experienced a distinct boom-and-bust in cannabis cultivation following legalization, with expansion from 2018 to 2020, followed by significant contraction during 2020-2023. Economic factors, particularly the price collapse below production costs, reduced unlicensed cultivation more than enforcement or regulatory efforts. The county's complex and unstable permitting system, which underwent multiple iterations between 2017-2023, created significant barriers for small operators. Cultivation patterns shifted geographically from traditional mountain hideaways to more accessible valley locations, driven by water access concerns, infrastructure needs, and environmental compliance considerations. See Appendix 6.

CONTEXTUAL FACTORS

- Mendocino County (3,507 square miles) features diverse microclimates ideal for cannabis cultivation, with distinct regional cultivation cultures across coastal areas, valleys, and northern regions.
- The county's economy historically relied on timber and fishing with cannabis becoming a major significant economic force following the decline of these industries.
- Median household income ($65,500) falls below state average with a 19% poverty rate, approximately 1.5 times higher than state and national averages.
- Mendocino attempted multiple regulatory approaches:
    - (1) the Sheriff's "zip-tie" program (2012), (2) a three-phase permitting system (2017) that established size limits ranging from small (≤2,500 sq. ft.) to large

(5,001-10,000 sq. ft.) cultivation on parcels 5-10+ acres, restricted cultivation to agricultural, residential, and industrial zones while prohibiting it on Forest Land and Timber Production zones, and (3) delegation of environmental review to the state (2023).

- Administration of cannabis permitting bounced between departments: Agricultural Commissioner (2017-2019), Planning Department (2019-2021), and a dedicated Cannabis Department (2021-present).
- As of 2024, the county issued 762 state cultivation licenses, with 98.55% remaining provisional (indicating incomplete regulatory (CEQA) compliance). No remaining provisional licenses remain in 2026.
- As of January 2026, of the 1157 permits processed, 462 (40%) remained active.

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- Model data shows unlicensed cultivation increased by +158 m^2/km^2 during 2018-2020, then decreased by -205 m^2/km^2 during 2020-2022, followed by continued decline of -77 m^2/km^2 during 2022-2024, for a net reduction of about -124 m^2/km^2 over six years. These patterns occurred in a permit county with $1,000 per-plant fines and moderate enforcement (rank 3 initially, rising to rank 5).
- Geographic patterns shifted across periods. From 2018-20, cultivation grew in both remote areas (strongest predictor) and areas with more buildings, with hemp presence also strongly linked to growth. From 2020-22, cultivation contracted countywide, with slightly greater declines in remote, built, and flatter areas. From 2022-24, this reversed: cultivation increased substantially in the most remote areas while continuing to decline in more accessible, developed locations.
- Licensed farms had minimal deterrent effect initially (2018-20) despite high licensed farm density, but became increasingly significant, doubling the expected decline in cannabis density by 2020-22 near licensed operations.
- Pre-legalization cultivation methodology of multiple small grows (25 plants each) across different parcels shifted toward larger, more consolidated operations.
- The Sheriff's office estimates dealing with approximately 200,000 unlicensed plants annually, significantly down from peak years.
- From 2018-20: Unlicensed cultivation density increased by approximately 200 m^2/km^2 (matched overall trend), particularly in remote areas and areas with hemp presence, with building density also positively associated with increases. Despite high density of licensed farms, their presence had minimal deterrent effect.
- From 2020-22: Cultivation density decreased substantially (matched overall trend), with strongest contractions in areas with higher building densities and flatter terrain. The

presence of licensed farms became significant, doubling the expected decline in cannabis density compared to areas without licensed farms.

- From 2022-24: Cannabis density continued to decrease, exceeding the overall average decline (diverged from overall trend). Most dramatically, remoteness reversed its prior effect; cultivation increased substantially in the county's most remote areas while declining in more accessible locations.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

- **Market Economics:** The Mendocino experience demonstrates that market forces can drive unlicensed behavior more than enforcement or policy structures.
    - Cannabis prices collapsed dramatically in 2021-2022, falling below $300/lb (often beneath production costs of $250-400/lb).
    - Market forces drove reduction in unlicensed growing. As one legacy cultivator turned permitted operator stated “The economy has been the best enforcer of illegal, black market, unlicensed grows.”
    - Licensed operators face competitive disadvantages due to compliance costs adding $200-300 per pound to production expenses.
- **Regulatory Challenges:** The county's unstable permitting system with multiple iterations created uncertainty that discouraged participation. One-size-fits-all environmental requirements disproportionately burden small operators and can inadvertently encourage consolidation.
    - Complex environmental regulations, particularly CEQA requirements, created significant barriers to legal market entry.
    - Permitting system underwent multiple iterations and department transfers, creating confusion and uncertainty.
    - Many operators attempted to enter legal market but became stuck in permit limbo due to constantly changing requirements.
- **Water and Infrastructure Access:** Environmentalist resistance to cannabis cultivation increases financial, compliance, and locational pressure on cultivators.
    - Environmental activism aimed at protecting oak woodlands effectively limited cannabis industry expansion in Mendocino County.
    - Drought conditions made water access a critical factor in cultivation location decisions.
    - Valley locations offered better road access, proximity to services, and more reliable water sources.

    - Water hauling costs became prohibitive for many remote operations (reported up to $40,000 annually).

- **Enforcement Limitations:** Limited enforcement capacity necessitates strategic prioritization, rather than complaint-based or revenue-focused approaches,
    - County lacks a dedicated cannabis enforcement task force.
    - Complaint-based enforcement system leads to inconsistent actions.
    - Limited resources prevent systematic address of unlicensed cultivation, particularly in remote areas and near tribal lands.
    - Stakeholders considered enforcement ineffective compared to market forces.
- **Blurred Market Boundaries:** Policy approaches that maintain strict distinctions between legal and illegal markets fail to address market realities.
    - Licensed operators often maintain both legal and illegal sales channels to survive economic pressures.
    - Strict categorization between legal and illegal markets breaks down in practice
    - Licensed cultivators face high business failure rates due to compliance costs.
- **Community Economic Impact:** The disappearance of cannabis industry's informal economic support reveals broader challenges in rural development.
    - Traditional "mom and pop" operations (25-100 plants) squeezed out by market forces and regulatory burdens.
    - Local businesses in cultivation dense areas reported sales drops of over 50% as the cannabis economy contracted.
    - Informal economic support system that previously funded community projects largely disappeared.
    - Supervisor assessment: "There's no timber, there's no fish, there's no cannabis, there's really no exports."

5.5.7. NEVADA COUNTY RESULTS

CONTEXTUAL FACTORS

- Relatively small county spanning Sierra Nevada foothills and mountains from the Central Valley to the Nevada state line.
- Population quadrupled from 1970 to 2001 and is concentrated in western foothill region, with 30% in incorporated cities.

- Non-Hispanic white (83%), Democratic-leaning, below average poverty (11%). Half the county is under 300% of poverty line with low rates of workforce participation (53%).
- Economic history of mining and timber but present-day economy dominated by residential growth, service sector, government and retirement/investment incomes.
- Agricultural land has declined precipitously since 1970 and is dominated by cattle.
- Housing prices have risen by approximately 20% since 2020.
- Cannabis has become the county's second most valuable (legal) agricultural product.
- Nevada County was destination for many cannabis cultivators since 1970s.
- In 2016 an outdoor cultivation ban failed and voters approved Proposition 64.
- Supervisors formed community/stakeholder group to inform cannabis permitting program, which was passed in 2018.
- Permitting program delayed until 2019 to conduct CEQA review.
- Permit program excluded cannabis from contentious residential-agriculture areas but allowed it in forested and agricultural areas, which comprised most county lands and land already in use for cannabis cultivation
- Permit limited farm size to 10k square feet and later expanded this to 40,000 square feet if multiple contiguous parcels were obtained.
- County made multiple reforms from 2021-2025 to support permittees.
- County responded to persistent unlicensed cultivation by expanding code enforcement powers, particularly in flatter more populated areas, and expanding Sheriff enforcement in remote areas.

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- Cultivation was historically concentrated in more remote mountainous areas, particularly in county's northwest.
- As medical cannabis cultivation grew, growers moved into flatter lands throughout the county's populated western region, generally growing plots with 99 plants or less.
- 2017 study estimated 3250 county parcels with cultivation covering 303 acres of cultivated area. Most was outdoor, on land with relatively low environmental sensitivity,

and in agriculturally-zoned land. Current licensed cultivation is 1/10th this area, approximately 32 acres.

- Only 5% of pre-existing cultivated area made it into licensure.
- Most pre-existing cultivation (approximately 88%) was on land later zoned for cannabis cultivation (i.e. ag and forest resource land) under county permitting programs.
- From 2018-20: unlicensed cultivation expanded significantly (highest in sample), but in areas not populated by older populations and more populated by younger populations.
- From 2020-22, unlicensed cultivation (particularly outdoor) decreased, especially near licensed farms.
- From 2022-24, unlicensed cultivation decreased most of any sampled county, thus returning to 2018 levels, with outdoor driving declines. Reversing trend, it declined least in areas with older populations and most in areas with younger populations.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

- *Market as Reason for Unlicensed Exit:* Exit from unlicensed cultivation was generally attributed to market challenges, not enforcement risk.
- *Early Move Toward Licensed Areas:* Unlicensed cultivation was initially ('18-20) hidden "in plain sight" in agricultural areas, often near licensed farms. These areas were less remote, closer to amenities, had better weather, and posed less environmental enforcement risk.
- *Later Divergence of Licensed and Unlicensed Cultivation:* After 2020 unlicensed production moved away from licensed farm areas. This was due to intensifying civil/code enforcement, particularly around licensed farm areas in flatter, more agricultural areas as well as persistent cultivation in remote areas, where few other livelihood options existed, particularly for older and jobless populations.
- *Supportive Policies Fostered Small Farm Legal System:* County regulations limited farm size, required on-site residences, and fostered local supply chain. Iterative reforms aimed to reduce barriers to cultivation, generally.
- *Enforcement Aimed to Prioritize Harm Reduction:* In 2022, code enforcement and law enforcement reformed their approach to enforcement. Law enforcement focused on remote regions, prioritizing sites with environmental impacts and large spatial footprints. "Notices of violation" were placed on parcels with persistent cultivation (particularly out-

of-state LLCs) to inhibit sale. Code enforcement tightened inspection and enforcement against unlicensed cultivation, utilizing a range of tools from compliance mandates and education to stringent tactics, as necessary.

- *Unlicensed Cultivators Adapted to Enforcement:* Growers reported avoiding waterways, steep hills, unpermitted road grading, and large grows that would incite enforcement. They also: adopted mixed-light cultivation to avoid aerial detection, used autoflower strains and light-deprivation techniques to shorten cultivation periods to avoid detection (and increase productivity); and kept properties clean to avoid code enforcement fines and inspections. Savvier growers adhered to permit requirements (e.g. having an on-site residence; growing in allowed zones) to blend in.

- *Various Types of Unlicensed Cultivators Exist:* (1) personal cultivators for personal consumption and/or small, supplemental funds; (2) small, legacy cultivators, often older and "stuck" on devalued post-cannabis land, cultivating as sole livelihood; (3) larger-scale unlicensed cultivators in remote areas with cheap land and little investment; (4) larger-scale unlicensed cultivation scattered over multiple parcels, often in ways that mimicked permit conditions; (5) licensed farmers that partially depended on unlicensed market for viability.

- *Economic Decline:* Declining cannabis cultivation has deepened poverty and insecurity for economically and socially marginal growers, as well as working-age populations, with unknown consequences on surrounding ecologies as residents seek new income source and land uses.

- *Cultural and Quality of Life Factors Keep Former Growers Local:* Cannabis market fostered a vibrant culture which now contributes to rising property prices and displacement. Former cultivators report a loss of meaning/direction – and economic stability – but express hope of staying local.

- Local cultivator organization has been key in shaping regulations, supporting farmers, defusing conflict, and promoting shared values among all cultivators.

5.5.8. SISKIYOU COUNTY RESULTS

Siskiyou has positioned itself as a pioneer in cannabis prohibition within California, by developing intensive and innovative enforcement strategies. Despite this, unlicensed cultivation has remained relatively steady. As observed elsewhere in California, cultivation expanded between 2018 and 2020, but slowed from 2020 to 2022, and contracted from 2022-2024. Research participants attributed this plateau primarily to the cannabis market downturn rather than enforcement efforts. Aggressive enforcement paradoxically shifted cultivation's geography and scale, with smaller cultivators leaving, only to be replaced by larger operations, cultivation

spreading across multiple parcels to distribute risk, and more intensive cultivation practices being adopted to harvest before potential raids. The county's enforcement approaches have disproportionately impacted socially marginalized growers, particularly Asian and Asian-American farmers, while consuming substantial local resources and hindering environmental and social protection agencies' ability to mitigate cultivation impacts. See Appendix 6.

Contextual Factors

Siskiyou is a large, rural county in far-northern California with approximately 44,000 residents and a population density of just seven people per square mile (compared to California's average of 250).

County is among California's most economically disadvantaged with a 16.8% poverty rate (compared to 12.2% statewide), 7.5% unemployment, and median household income under $50,000 (about half the state average).

Population is predominantly white (74.2%).

Economy is based on agriculture, forestry, and tourism, with 60% of the county's area comprised of state and federal public lands.

The county faces intensifying wildfire risks and drought conditions that have placed pressure on water resources.

- County's annual budget is approximately $115 million. Primarily conservative voters, who approved Proposition 64 in 2016.
- 2015: county established permissive medical cannabis regulations after extensive public input. County quickly shifted to restrictive policies.
- Sheriff's Office led efforts to restrict cannabis cultivation. After Proposition 64, county quickly placed moratorium on commercial cannabis activity, declared state of emergency, and ultimately banned cultivation. Sheriff also enlisted state agencies into enforcement.
- County innovated enforcement approaches including water restrictions, significant fine penalties, and elimination of abatement periods.
- Multiple civil rights lawsuits allege racial discrimination in county enforcement, resulting in court injunctions against some ordinances.
- County has created no pathways for cultivation permitting, despite wishes by cultivators to comply.

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- Pre-legalization cultivation occurred primarily in remote mountainous regions with limited enforcement against predominantly white cultivators.
- Cannabis cultivation patterns shifted dramatically in mid-2010s as Hmong farmers purchased small, inexpensive parcel in rural subdivisions. Many initial Hmong in-migrants described being refugees and veterans who sought affordable retirement opportunities and return to agrarian roots.
- After legalization in 2016, cultivation further shifted from public lands to private properties in rural subdivisions, bringing cultivation closer to agricultural and residential areas
- By 2017, approximately 6,000 Hmong Americans had moved to Siskiyou since 2014, purchasing approximately 1,500 parcels
- County officials frame cannabis cultivation as primarily conducted by "outsiders" threatening the local "way of life."
- From 2018-20: Siskiyou County saw an increase in unlicensed cultivation on par with the general study average. However, several factors had more dramatic effects: a) flatter areas saw increases in cannabis density more than double the overall study average, with no increases in cultivation density in more hilly areas, b) poorer areas tended to have substantially larger increases in cannabis density (2.5x the study average) relative to the wealthiest areas, which saw very little increase, c) like other counties, increases in cannabis density were more pronounced in areas with more buildings, and d) the increase in cannabis density was greater in more fire prone areas in Siskiyou County.
- From 2020-22: an overall decrease in average cannabis density, which was especially pronounced in areas with increasing building density and in less forested areas
- From 2022-24: average contraction in cannabis density, with the strongest reductions in flatter areas with potentially some increases in cultivation in more sloped areas.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

- Expansion then Plateau: Cultivation expanded during 2018-2020 but plateaued from 2020-22, unlike other counties that saw significant decline.
- *Multiple Causes for Slowing Production:* Slowing production was attributed to declining cannabis prices. In targeted subdivisions, slowing production was also due to social and ecological impacts of the 2021 Lava Fire, and limited access to water (for cultivation as well as basic household needs, livestock care, and subsistence growing) due to cannabis-related enforcement.
- *Cultivation Adapted to Enforcement:* (1) Shift to less visible, mixed-light methods; (2) Distribution of operations across multiple parcels to spread risk; (3) More intensive

cultivation practices to harvest quickly before potential raids; (4) Smaller operations giving way to fewer but larger, better-capitalized operations.

- *Enforcement-First Approach Produces Counterproductive Results*: Siskiyou's ban and intensive enforcement failed to significantly reduce unlicensed cultivation while consuming substantial resources. Enforcement has driven adaptation, consolidation, and increased scale of operations. Adaptation and economic/social insecurity – not elimination – appears to be most significant impact of enforcement.
- *Environmental Justifications Applied Inconsistently:* While environmental protection is a primary justification for cannabis restrictions, intensive enforcement has pushed cultivators onto more marginal land, led to environmentally maladaptive practices, and reduced opportunities for environmental education and amelioration.
- *Ethnic Trajectories of Cultivation:* Many white growers significantly scaled back cultivation due to enforcement concerns, or moved to jurisdictions with permit programs. Hmong and Hmong-American growers remain in Siskiyou due to community ties, poverty, and sunk investments in land. Cultivation is one of few viable economic options on subdivision lands.
- *Racial and Ethnic Disparities:* Asian and Asian-American farmers have been disproportionately impacted by cannabis enforcement. Surveillance and enforcement has been concentrated on rural subdivisions with predominantly Hmong populations. Lack of infrastructure in subdivisions makes primarily low-income residents vulnerable to drought, water restrictions, wildfire, and complaint-driven enforcement.
- *Economic Necessity Drives Persistence:* People continue to grow unlicensed cannabis primarily because they have few other economic options on marginal lands. Siskiyou's cheap land attracted cultivators with limited financial means, many of whom cannot afford to relocate to permit jurisdictions (and otherwise lack necessary capital to seek licensure).
- *No Stakeholders Satisfied with Current Approach:* Not one research participant described the current policy regime as functioning well. County officials face escalating cultivation with limited resources. Cultivators have a narrow path to legal markets and little social and economic stability. Residents concerned with cultivation impacts are denied opportunities for monitoring and addressing concerns through regulated pathways.

5.5.9. TRINITY COUNTY RESULTS

Trinity County is a rural place with a legacy cannabis economy. The county's cannabis program established a cap of 530 licenses—a fraction of the estimated 4,000-6,000 cultivation sites—leaving approximately 90% of the county's cultivators with no legal pathway to licensure. Trinity treats cannabis cultivation as a land use issue with its Cannabis Division housed in the Planning and Building Department. Trinity's permit program made notable efforts to support smaller-scale farms, including limiting permits to one per parcel, requiring residence on farms, restricting large-scale cultivation by allowing only 15 Type 3 licenses (up to one acre), and

reserving licenses for legacy growing regions like Hayfork. Our spatial analysis shows an initial increase in unlicensed cultivation between 2018-2020, followed by a decrease between 2020-2022 and 2022-2024, with most significant reductions occurring near licensed farms. Stakeholders consistently identified the cannabis price collapse as the most significant driver of cultivation decline. Trinity's experience highlights how well-intentioned regulations can create unintended barriers to legal market participation. See Appendix 6.

CONTEXTUAL FACTORS

- Trinity has a population of approximately 16,000 residents and a population density of just five people per square mile, making it one of California's most rural counties.
- Trinity has one of lowest median household incomes in California (just over $40,000) with a poverty rate exceeding 22% (compared to 12.2% statewide).
- Trinity County's steep, mountainous terrain and dense forests create high wildfire risk, with several major fires affecting the region in recent years.
- County budget is approximately $76 million per year, with about $4 million dedicated to law enforcement.
- Approximately 85% of county is public land, with just over 3% zoned for agriculture.
- The economy historically depended on timber before its decline from 1970-1990. Cannabis cultivation became a significant economic force, especially during economic downturns. One resident noted that "the 2008 and 2009 U.S. market crash wasn't even felt here because cannabis provided such a cushion."
- Trinity's cannabis landscape is shaped by distinct communities: especially legacy cultivators (many former timber workers) and ethnic growers, especially since the late 2000s. Approximately 1000 Hmong farmers operate in one especially dense locale.
- Proposition 64 passed by only six votes in the county (50.10% in favor).
- Trinity enacted its first commercial cannabis ordinance in October 2017, establishing enrollment caps (530), zoning restrictions, and property requirements.
- County has generally supported small grower entry into licensed market, by providing educational opportunities to comply, limiting permits to one per parcel requiring residence on farms, restricting large-scale cultivation, and reserving licenses for legacy growing regions
- Trinity Action Association (TAA) filed 2019 lawsuit challenging CEQA compliance, resulting in requirement of CEQA reviews for each farm. This lawsuit effectively shut down the licensing program for two years (2020-2022) and substantially increased permitting costs.

- As of January 2025, approximately 335 cultivation licenses have been issued, over half of the 600 that entered the licensing process. (This latter number does not account for those cut off by county permit caps.)
- While the county does not have a Marijuana Enforcement Team, it employs a multi-agency enforcement approach against unlicensed cultivators that includes the Sheriff's Office, neighboring county law enforcement, EPIC team, State Water Resources Control Board, California National Guard, and CDFW.

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- From 2018-20: Trinity County did not have any reliable predictors of change in cannabis density and experienced a close to zero change.
- From 2020-22: an overall decrease in average cannabis density that was most pronounced in areas with high building density and flatter terrain. Like other counties, the most significant decreases in unlicensed cultivation occurred in proximity to licensed farms that attract enforcement activity.
- From 2022-24: average contraction in cannabis density, with the strongest reductions in flatter areas and places near licensed farms.
- Due to market downturn, many legacy growers exited the industry, while ethnic growers, including Hmong growers, have persisted due to limited economic alternatives, substantial investments in land, and strong intra-community ties.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

- *Market Forces Eclipse Enforcement:* Cannabis price declines held greater explanatory power for reductions in unlicensed cultivation than enforcement or policy measures.
- *Regulatory barriers create unintended consequences:* License caps combined with costly requirements has effectively locked most cultivators out of licensure, creating a de facto ban for 90% of pre-existing cultivators. This has perpetuated unlicensed cultivation despite grower willingness to participate in the legal market.
- *High-profile enforcement can backfire.* Trinity's enforcement experience, particularly when permitting was stalled, demonstrates how targeting growers attempting to enter the legal market (because they are easier to identify) creates disincentives for compliance.
- *Community-tailored approaches show promise.* Policies that accommodate diverse community needs, such as grandfathering legacy operations, opt-out zones for cannabis-opposed communities, and overlay zones for unique areas like Trinity Pines—can reduce overall opposition while supporting existing cultivators.

- *Demographic shifts reshape cultivation patterns:* While market pressures have forced many legacy growers to exit the industry, Hmong cultivators in Trinity Pines have largely persisted due to limited economic alternatives, substantial investments in land, and strong community ties.
- *Environmental and Infrastructure Challenges:* Water access, fire risk, and erosion concerns shape cultivation patterns. Market declines can also place pressure on cultivators to increase scale or face debt and livelihood loss.

5.5.10. RIVERSIDE COUNTY RESULTS

CONTEXTUAL FACTORS

- Riverside is large (7209 square miles), reaching from Arizona to Orange County, and encompasses mountainous, desert and agricultural valleys with 84% public land.
- Large population (2.4m residents) makes it 4th largest California county.
- Economy historically centered on agriculture, defense, and service sector.
- Riverside County and City spearheaded efforts to resist statewide cannabis regulations and ban cannabis under land use laws.
- In 2006 County banned cannabis distribution and in 2015 expanded the ban to cover all cultivation and delivery, except a personal/medical exception of 24 plants per property.
- Limited cannabis enforcement from 2013-17 but, after 2017, intensified enforcement via Sheriff and Planning Department's Cannabis Regulation Task Force (CRTF).
- 2019: County implemented cannabis permitting program with stringent, costly terms.
- Most firms sought permits in cities, which had established permitting programs early, often with less restrictions, easier administration, and lower costs.
- Approximately 52% of cultivation licensees in Riverside County (including cities) were in active status in January 2025

SPATIAL DISTRIBUTION OF UNLICENSED CANNABIS

- History of indoor cannabis cultivation since 1990s, particularly in warehouses and housing tracts of urban/suburban Inland Empire.
- Growth of rural cultivation sites in Anza-Aguauga-Sage area of southwest Riverside in early 2010s.

- Post-2015 growth of suburban and urban backyard cultivation with the passage of personal/medical allowances.
- 2018-2020: cultivation increased, nearly all mixed light, particularly around Anza, Coachella Valley, and eastern desert areas along I-10, with localized declines near southwestern urban/suburban areas of Moreno Valley and along the I-15. Cultivation moved to more open and less remote areas (i.e. toward more building-dense areas, closer to hemp permit sites, and further from public lands);
- 2020-22: cultivation decreased overall, especially in rural/suburban areas of southwest county (Anza and Coachella valleys). Localized cultivation growth around City of Riverside, Perris, and areas near the San Gorgonio Pass on I-10. Cultivation reversed trend by moving toward more concealed areas (i.e. toward areas with lower building density, near public land and further from agricultural areas and hemp permits).
- 2022-2024: Overall increase of cultivation (4th highest), against study-wide trend of decline. Cultivation increased far from permitted farms in areas with higher building density, hemp permits, and traditional agriculture, but declined near permitted farms. 75% of cultivation increase came from mixed-light cultivation.
- Other noted trends:
    - Most small-scale suburban/urban cultivation has stopped, except for some gardens under the personal limit in greenhouses and basements.
    - Public awareness of grow houses combined with high energy and production prices and need for scaling up to drive cannabis away from residential areas, though some sophisticated, scaled-up, multi-house operations have persisted.
    - Little to no growth in indoor cultivation.
    - Virtually no new cultivators. Current operators are trying to remain operational.
    - Cultivation appears to have mostly left the legacy area of Anza Valley.
    - Growers avoid operating on public lands because of elevated consequences.
    - Price declines and profitability challenges have pushed many growers out of operation but proximity to LA markets and inter-state highways, as well as lack of opportunities to become licensed, may explain the modest (and off-trend) growth in cultivation in 2022-24.

ETHNOGRAPHIC SUMMARY: CONTRIBUTING FACTORS TO UNLICENSED CULTIVATION

Permitting Programs Insufficiently Incorporated Most Cultivators:

- Expensive, stringent and delayed county permitting program made cultivation permits inaccessible for most, except those with significant resources.
- County regulations stimulated unlicensed cultivation by categorically excluding most pre-existing cultivators through restrictive zoning and an outdoor cultivation ban.
- Early-starter cities received the most benefit and growth from permitting programs, while legacy cultivation areas saw less cultivation but also declining economies.

Political Conflict Over Cultivation Amplified by Enforcement:

- Exclusion of legacy cultivation areas ensured that those cultivators would become perennial targets for enforcement agencies.
- Vocal rural residents, who drove zoning restrictions and enforcement pushes, disliked cannabis cultivation but benefited from it, via increasing property prices.
- Calls for enforcement by rural residents were part of a larger desire for county resources and investment, which enforcement could not deliver.
- Cultural and racial animus played a role in justifying more stringent approaches.

Code Enforcement and Law Enforcement Approaches Had Mixed Results

- Code enforcement was effective at discouraging smaller-scale residential cultivation in more populated areas, addressing cannabis cultivation near hemp farms, and, across localities, ensuring cultivation did not return once addressed.
- Law enforcement was effective at stopping remote cultivation in the short run
- Despite a reputation for stringent enforcement, cultivation increased in 2 of 3 study periods.
- Enforcement can drive where cultivation occurs (e.g. in more/less remote areas, near/far from public lands; near/far from hemp permitted areas; near/far from agricultural lands) but does not drive *whether* cultivators grow cannabis.
- Market factors appear to determine *whether* cultivators grow

5.6 UNDERGRADUATE RESEARCH

Over 30 undergraduate student research assistants (RAs) assisted with research, writing, data analysis, GIS work, and policy fact sheet creation. RAs worked on:

- Research and writing projects related to: county news summaries, cannabis laws, county use of drones and satellites, state enforcement programs, comparative analysis between county polices, social equity programs, and legislative tracking;

- Creation and design of fact sheets on various topics, including local county fact sheets, permit and acreage caps, infographics, and maps;
- Comparative analysis spreadsheets comparing county political and demographic information, local cannabis tax rates, support of Proposition 64, and county background information, including budgets;
- Research and design of maps;
- GIS & Machine Learning Annotation, where students were trained to annotate machine learning output from the Water Board's CannaVision platform using the Computer Vision Annotation Tool (CVAT).

DISCUSSION

6.1 OVERVIEW

In this section, we discuss and synthesize the results of this study. The section is organized according to the four guiding objectives of the project, as originally proposed. This includes: (1) assessing unlicensed production amounts and geography; (2) identifying influential factors that drive or are correlated with unlicensed production; (3) comparing licensed and unlicensed production; and (4) assessing potential environmental impacts of unlicensed production. This section draws from the "Results" sections of Section 5, including Sections 5.1.4 (Policy Analysis), 5.2.4 (Spatial Modeling), 5.3.4 (Licensed Market Data), 5.4.4 (Energy Data Analysis), 5.5.4-5.5.10 (Ethnographic Analysis). For further detail on results, please consult Appendix.

6.2 OBJECTIVE 1: ASSESSING UNLICENSED PRODUCTION AMOUNTS AND GEOGRAPHY

Finding #1: Since legalization, unlicensed cultivation initially expanded, rapidly retracted, then stabilized.

Between 2018 and 2020, CannaVision data showed a clear expansion in the absolute amount of cannabis cultivation (i.e. outdoor and mixed-light operations). Growth was evident across case study regions. Ethnographic data suggested that this initial surge reflected grower market optimism, combined with delayed and uneven licensing rollouts. Early permitting delays, rule changes, and high entry barriers pushed many growers to begin, continue or expand unlicensed production. Local variation in enforcement and permitting timelines also shaped these early outcomes, with less stringent enforcement and slower program implementation associated with temporary expansion in unlicensed cultivation.

From 2020 to 2022, spatial modeling showed a significant decline in unlicensed cultivation. Ethnographic accounts supported this, describing how collapsing wholesale prices, often below production costs, led to widespread attrition among cultivators. Many smallholders exited the market, unable to sustain operations amid low prices, regulatory uncertainty, and limited access to legal permits. In counties where enforcement activities and regulatory structures matured, unlicensed cultivation receded notably. Ethnographic evidence also suggested that localized enforcement in historically strong cultivation zones contributed to this reduction, even in counties where permits could not be obtained or permitting barriers were high.

Between 2022 and 2024, spatial modeling indicated relative stabilization in cultivation levels at lower volumes (approximately equivalent to 2018 levels). Ethnographic data depicted a markedly transformed unlicensed sector: in some regions, participants reported that unlicensed cultivation had nearly disappeared, while in others (particularly remote or economically marginal areas) it persisted at reduced scale. Counties that had earlier adopted or stabilized their permitting programs tended to show sustained reductions, while jurisdictions maintaining prohibitions or imposing restrictive licensing saw modest rebounds. Across study sites, interviewees in 2024 depicted a sector that had contracted substantially, with unlicensed operations continuing primarily among cultivators who lacked alternatives or were adapting to new economic and policy realities.

Finding #2: Cultivation moved from the hills to the flatlands and back again.

Between 2018 and 2020, spatial modeling indicated that cannabis cultivation expanded in flatter, less remote areas with higher building densities, more roads, and more distance from public lands. Ethnographic data suggested that this movement reflected both *pull* and *push* factors. Pull factors included increasing social acceptability of cultivation in populated valleys, the perception that flatter lands would be easier to permit, and the opportunity to "blend in" with licensed or transitional operations. Push factors included intensified environmental enforcement in steep terrain, complex permitting terms in hillside zones, and fears of legal exposure tied to environmentally sensitive "tripwires." Across multiple counties, cultivators relocated from rugged, legacy sites toward more accessible, arable, and infrastructure-proximate lands, often anticipating permits that never arrived. Others took advantage of early leniency or proximity to licensed and hemp operations to operate in plain sight.

During 2020 to 2022, spatial modeling showed that contraction was strongest in these same flatter areas, while hillier and remote regions experienced more modest declines. Ethnographic data indicated that the maturing of county enforcement and inspection programs, combined with new zoning restrictions, such as Lake County's Farmland Protection Zone Ordinance, Trinity County's opt-out zones, or Riverside's zoning exclusions and code enforcement efforts, discouraged unlicensed cultivation in visible or easily accessed places. Civil complaint mechanisms and code enforcement activities further prompted cultivators to seek

more discreet locations, balancing concealment with proximity to infrastructure. Simultaneously, falling wholesale prices incentivized relocation to lower-cost or marginal parcels where profitability could be sustained. Ethnographic accounts emphasized that remoteness was not synonymous with isolation: cultivators sought spaces that offered both discretion and logistical practicality, rather than the extreme remoteness characteristic of pre-legalization eras.

By 2022 to 2024, spatial modeling and ethnographic evidence jointly depicted a cultivation stabilization and persistence in remote areas, accompanied by selective re-expansion in flatter zones. Spatial modeling confirmed that remoteness became positively associated with unlicensed cultivation during this period, reflecting the struggle of producers with limited alternatives in economically marginal locations. Ethnographic data showed that many who remained in remote areas did so because of low land costs, limited mobility, or cultural and social ties to place, with some modestly expanding cultivation area to offset falling prices. However, economic considerations increasingly dominated siting choices: as land values rose in accessible valleys and proximity to markets became critical, some cultivators, especially in Southern California counties, moved closer to consumer and logistics hubs. Licensed market data demonstrated that Southern California, particularly along the corridor from Monterey through Santa Barbara to Los Angeles, became the epicenter of market activity. Ethnographic accounts suggested that unlicensed cultivation mirrored this geography, co-locating in regions that benefited from the infrastructure, supply chains, and market velocity of the legal sector.

Finding #3: Over time, those who persisted in unlicensed cultivation were increasingly in tenuous socio-economic situations and attached to place for cultural-historical reasons.

Between 2018 and 2020, CannaVision and licensing data indicated widespread participation in the unlicensed market across counties. Ethnographic data suggested that participants during this period represented a broad cross-section of cultivators, from smallholders in hilly legacy regions to suburban and exurban producers experimenting with small-scale grows. Established and new growers thrived in the unlicensed market.

From 2020 to 2022, participation in the unlicensed sector declined sharply and its demography began to shift. Ethnographic data showed that many middle-income and mobile growers exited the market entirely. Those remaining were increasingly individuals with constrained economic or geographic mobility, such as people who owned or occupied marginal parcels and lacked feasible livelihood alternatives. In places like Nevada, Trinity, and Siskiyou, participants linked cultivation persistence to barriers associated with age, poverty, race, or rural isolation. Older residents, often on fixed incomes or with limited capacity to relocate, were especially likely to continue growing. In Nevada County, for instance, older age correlated with continued or expanded cultivation through 2024, supported by ethnographic reports that such growers were land-rich but cash-poor, unable to sell property, and invested in their properties. In

some cases, predatory land arrangements emerged, with distressed or uninformed cultivators leasing plots from absentee LLCs, only to face repeated enforcement raids.

By 2022 to 2024, quantitative and ethnographic evidence portrayed the unlicensed sector as increasingly defined by marginalization and immobility. Ethnographic data revealed that those still cultivating were overwhelmingly situated in economically depressed rural enclaves, particularly in the dense, infrastructure-poor subdivisions of Siskiyou, Trinity, and Nevada counties. These small parcels, often created before California's 1974 *Subdivision Map Act*, had become strongholds of persistence due to their affordability, established social networks, and collective self-reliance. Residents in communities such as Shasta Vista, Hayfork, and Trinity Pines, The Ridge described enduring cultivation not purely as an economic pursuit but as an outcome of cultural identity, mutual aid, and attachment to place. Such "stickiness of place" was reinforced by shared histories of interdependence, distrust of regulatory authorities, and adaptive cooperation in the face of enforcement risk. As economic returns dwindled, the unlicensed landscape bifurcated: a small number of larger, adaptive, multi-site cultivators coexisted with a growing base of subsistence-level or semi-personal growers maintaining cannabis as a survival livelihood. Together, the data depict a residual unlicensed sector rooted less in opportunism than in social persistence, economic exclusion, and deeply embedded rural community ties.

Finding #4: Unlicensed cultivators moved away from public lands into private land.

Ethnographic data consistently recorded a movement of cultivators away from public lands, where consequences for cultivation were more significant than private land (i.e. felonies vs. misdemeanors). Additionally, with cannabis legal, stigma and official complaints on private lands appeared to decline, especially in areas with significant cannabis cultivation. The ability to invest in private lands, rather than cultivate on public ones, attracted some growers. Finally, with the intensification of environmental policing and multi-agency attentions on public land, growers sought to avoid this land altogether. By 2024, officials in Nevada, Trinity, and Siskiyou reported near-zero observed grows on public land. The relative affordability and accessibility of land (particularly private subdivision parcels) in remote northern counties enabled cultivators to continue operations with lower risk of felony charges. In Lake, Trinity and elsewhere, extensive wildfire damage and post-fire aerial surveillance drastically reduced the viability of forested public land sites. Meanwhile in Riverside, some growers allegedly forged partnerships with tribes to cultivate as they were pushed off of public and private lands alike. Ethnographic evidence shows that shifts out of public lands were not simply reactive to enforcement but reflected deeper calculations around risk, enforcement, norms, and jurisdictional differences.

Though spatial modeling did not include data from public lands, it did track areas that bordered public land. From 2018-20, cultivation generally moved away from those public-

private areas with a minor reversal in 2020-22, due to factors that include less visibility, cheaper land, maturing private-land enforcement, and a growing need for concealment. In the final period (2022-'24) cultivation moved minimally back toward public-private border land.

Finding #5: Cultivation Transitioned from Outdoor to Mixed-Light Production.

Over the 2018–2024 study period, spatial modeling indicated a transition from outdoor to mixed-light (greenhouse) production, with the shift accelerating after 2020. Ethnographic data suggested that the motivations for this shift varied considerably by region and over time. Between 2018 and 2020, cultivators pursued mixed-light facilities to access higher prices for visually superior flower and to avoid aerial identification and enforcement actions, especially in areas that banned outdoor cultivation. From 2020 to 2022, these factors persisted. Two new factors emerged as drivers: (1) environmental disruption, particularly wildfire smoke, pushed cultivators toward mixed light and (2) market price drops incentivized mixed light cultivation, which made possible more harvests, higher-value crops. By 2022-24, outdoor cultivation (including unlicensed product) was valued low as biomass input for a growing manufacturing sector.

Finding #6: Unlicensed cultivation was sensitive to major fire years.

Spatial modeling in 2018-20 indicates that cultivation was negatively associated with remoteness, but only in high fire hazard areas. (In the absence of high fire hazard, cultivation increased. Though 2018 was at the time the worst fire season on record, 2020 broke the record and was extremely and broadly disastrous (2021 was similar, but slightly less severe). For 2020-22, both fire hazard and remoteness were significant negative predictors of unlicensed cultivation. As 2022 and 2023 were more moderate fire seasons, data from 2022-2024 indicates no significant effect of fire hazard on unlicensed cultivation. From 2022-24 remoteness once again became a reliable predictor of increasing unlicensed cultivation.

Ethnographic data suggested that fire impacts did not uniformly drive abandonment. Some cultivators, especially in higher-income groups, relocated or paused production, whereas others (particularly marginalized or immigrant growers) adapted by altering practices, shifting crop cycles, or relaunching operations in place. Fire exposure appeared to disrupt production in the short term but rarely eliminated unlicensed activity entirely, instead prompting adaptive responses that reshaped how and where cultivation persisted.

Finding #7: Indoor cultivation exhibited increasing prevalence, particularly in 2020-21.

Energy records show significantly more indoor cultivation in Central Valley (North and South) and Sierra regions than in coastal regions, with 2020-21 showing more relative growth

than 2021-23. Based on the results of the random forest model, the estimated prevalence of unlicensed indoor cannabis cultivation in the South Central Valley region was approximately double the estimated prevalence of the next highest region. Under an assumption that 1 out of 100 utility accounts grow cannabis in California, that prevalence was an estimated 3 out of 100 in the South Central Valley. Even under an assumption that only 1 out of 400 utility accounts grow cannabis statewide, the estimated prevalence in the South Central valley was approximately 4 out 400. It is therefore reasonable to assume that at least 1% of utility accounts in this region may be growing unlicensed indoor cannabis- the power load of which would likely well exceed 1% of the electrical grid in this region, given the higher energy demand of cannabis relative to other power users.

Finding #8: Unlicensed indoor cultivation has shown more consistent growth than unlicensed outdoor cultivation.

Unlike outdoor cultivation which saw a rapid increase, followed by a rapid retraction, results from the random forest model suggested that unlicensed indoor cultivation increased in 2020-21, stabilized in 2021-22, and grew in most areas from 2022-23, except in the Northern Central Valley region, which contracted. Furthermore, the two regions with the highest estimated prevalence of unlicensed indoor cultivation over the study period also showed the largest increases in the most recent year of available data. Finally, the largest increases across study regions occurred between 2020 and 2022, precisely the time period when unlicensed outdoor cultivation saw its dramatic retraction.

6.3 OBJECTIVE 2: IDENTIFYING FACTORS INFLUENCING THE OBSERVED EXTENT OF UNLICENSED CULTIVATION

Finding #1: Presence of licensed cultivation was most consistently correlated with declines in unlicensed cultivation.

Across all three study periods (2018–20, 2020–22, and 2022–24), spatial modeling showed that the presence of licensed cannabis cultivation sites was associated with reduced unlicensed activity. From 2018-20, while unlicensed cultivation grew overall, it grew most slowly near licensed operations. This was a period when unlicensed growers were generally moving out of hills to less remote areas, thus explaining some movements of unlicensed toward more licensable areas. Further, regulatory systems were not well established in this period and many skeptical growers hovered at the edge of permitting. Prior work (Bodwitch et al 2021) shows that cultivators did not feel pressured by other cultivators at the time to obtain a license or stay unlicensed, thus indicating less differentiation among licensed and unlicensed growers.

From 2020-22, the deterrent effect of licensed cultivation became more pronounced. Spatial modeling outputs showed sharp declines in unlicensed growing near licensed sites. However, the presence of a permitting program was not enough to deter cannabis – unlicensed cultivation decreased somewhat more in ban counties in this period. Therefore, in this period it is not permitting, per se, but the widespread dispersion and presence of farms across a jurisdiction that affects unlicensed cultivation. Ethnographic findings indicated that increased inspections and regulatory enforcement contributed to this trend – inspections of a licensed farm brought officials to farms where they could often see or otherwise detect nearby unlicensed cultivation. Thus, during inspections a "knock on" effect against unlicensed sites was more likely around permitted farms. Additionally, communities around licensed farms became more informed about cannabis laws, fostering some local intolerance of unlicensed cultivation, especially as prices declined. Simultaneously, social norms among cultivators began shifting toward compliance as licensed operators invested more heavily in legal frameworks and infrastructure.

By 2022–24, licensing had become the strongest predictor of reduced unlicensed cultivation. Unlike the prior period, the presence of a permitting program (not just a permitted farm) was correlated with steeper declines in cultivation. Stated differently, jurisdictions with bans or stalled licensing programs saw ongoing or displaced unlicensed production (see below). Ethnographic data emphasized that the industry was becoming increasingly bifurcated: licensed cultivators, typically capital-intensive and rooted in place, contrasted with unlicensed operators who were more mobile and sought increasingly marginal, less regulated terrain.

These patterns collectively suggest that permitting *and dispersing* cannabis cultivation was an effective long-term deterrent to unlicensed activity. Because only "permit counties" have permitted farms, it stands to reason that permitting programs are also associated with declining unlicensed cultivation, but in this study sequence we only saw this effect in the last period, potentially indicating that the capacities of permit programs need to mature before a general effect on unlicensed production takes effect. Ethnographic and policy analysis shows that permit programs have more capacities and agencies at hand to address unlicensed cultivation than ban counties, where law enforcement (alone or in lead position) enforces in more narrow ways (Getz et al 2024).

Finding #2: Bans were not a consistent or powerful indicator of growth or decline in unlicensed cannabis cultivation.

Across time periods, spatial modeling revealed that cultivation bans had no reliable effect on unlicensed cannabis activity. In the first period (2018-20), bans had no significant effect on unlicensed cultivation. Both banned and permitted counties exhibited a mix of increases and decreases. Factors such as geography, enforcement intensity, and local cultivation histories were more influential than ban/permit status alone. Ethnographic data supported this interpretation,

showing that unlicensed activity was shaped by community tolerance, enforcement practices, and economic rationales rather than by the mere existence of a formal ban.

From 2020-22, spatial modeling indicated that unlicensed cultivation declined overall but the contraction was slightly more pronounced in ban counties overall. (The results, however, were lopsided: 9 of 10 counties with the least decrease or slight gains all had bans.) In the 2022–24 period, however, this trend reversed: unlicensed activity expanded in banned jurisdictions but declined in permit counties overall. Seven of the ten counties with the highest growth in cultivation density had bans, and two others, Riverside and El Dorado, operated under de facto bans due to stalled permitting programs. Ethnographic findings suggested that as permitting and enforcement systems matured in regulated counties, these areas gained the institutional capacity to manage both licensed and unlicensed cultivation through coordinated civil enforcement, education, and abatement tools. Ban counties, in contrast, generally lacked these mechanisms and relied on resource-intensive, short-lived law enforcement actions.

By the final period, the divergence between banned and permitted counties reflected a larger structural shift. Counties that had developed integrated regulatory programs were better able to control unlicensed cultivation, while those dependent on prohibition or intermittent enforcement saw unlicensed activity persist or rebound. Humboldt County, which implemented early and continuous permitting and enforcement, was the only county to demonstrate absolute declines in unlicensed cultivation in every period, while Siskiyou and Riverside, which leaned heavily on policing approaches, experienced diminishing returns. (Notably, in 2022-24 the six counties with the most decrease in cultivation were all legacy counties with robust permitting programs. Humboldt was the only county that continuously declined relative to 2018 numbers.) Ethnographic evidence further indicated that bans often displaced cultivators into more remote areas and encouraged more coordinated and covert operations. Overall, these results support the conclusion that comprehensive permitting frameworks, rather than outright bans, serve as the more effective long-term deterrent to unlicensed cannabis cultivation.

Finding #3: The perceived likelihood of strong enforcement was an initial deterrent, but became less important over time.

Spatial modeling showed that jurisdictions with strong reputations for law enforcement experienced initial reductions in unlicensed cannabis cultivation during the first study period (2018–20). Using total plant eradication as a proxy for enforcement intensity, areas with high historical enforcement ranks demonstrated measurable declines in unlicensed cultivation. However, this effect weakened in the second period (2020–22) and reversed in 2022–24, when stronger enforcement reputations were correlated with greater relative growth in unlicensed activity. These findings indicate that while a reputation for aggressive enforcement was initially a deterrent, its influence declined as cultivators adapted to the enforcement landscape.

Ethnographic data supported this observation. In the early years, cultivators actively avoided counties or localities with visible, punitive enforcement. Over time, however, the deterrent value of enforcement diminished as growers learned to adapt through relocation, technological adjustments, and changes in cultivation methods. Some moved operations into greenhouses, smaller parcels, or more remote areas, while others consolidated into more organized and discreet networks.

By 2022–24, enforcement-based strategies had entered a cycle of diminishing returns: they remained costly, displaced growers into more environmentally fragile or inaccessible zones where cultivation could occur, and often reinforced inequities by targeting more vulnerable populations, causing headaches for and imposing costs on counties. Some counties continued robust enforcement but other counties with limited resources and attention decelerated enforcement. Short-term crackdowns, like those in Siskiyou and Riverside, often created adaptive responses (like moving sites) rather than long-term deterrence, especially when cultural, locational and economic logics were at play. The evidence suggests that a reputation for aggressive enforcement loses efficacy over time.

Finding #4: Civil policy and civil enforcement efforts became key drivers of declines in unlicensed cultivation over time.

Spatial modeling and ethnographic data jointly indicate that civil enforcement strategies such as code enforcement, fines, landowner liability rules, and environmental regulations, grew increasingly effective over the study period in curbing unlicensed cultivation. Following the boom of 2018-2022, the decline of 2020-22 was more pronounced in areas with denser stream networks, potentially reflecting enforcement priorities. Though cultivation had co-located with hemp in 2018-20, tightening hemp programs reversed that trend in 2020-22, leading to a negative correlation between hemp and cannabis. Hemp and water regulations may have had appreciable effects on reducing cultivation statewide.

By the 2022–24 period, civil enforcement had matured into a general and consistently applied policy framework across several counties. Modeling results showed that landowner liability, the existence of permit programs, and higher fine levels correlated with reductions in unlicensed cultivation. Ethnographic data supported this correlation, noting that counties such as Nevada and Trinity relied on discretion, education, and abatement processes to reduce unlicensed activity, while more punitive jurisdictions such as Riverside experienced renewed increases. This suggests that, over time, consistent, predictable, targeted and transparent civil enforcement systems may be more effective deterrents than law enforcement–led approaches. Across counties, cultivators learned to adapt their practices to conform to civil codes, often adjusting farm locations and designs to avoid enforcement triggers such as proximity to streams or visible environmental degradation. As enforcement predictability and public awareness of environmental standards increased, cultivators became more compliant, and overall unlicensed

cultivation declined. This is in contrast to adaptations to law enforcement, which are often perceived by growers as arbitrary and unpredictable and thus induce any manner of (mal)adaptations to avoid detection.

Civil enforcement, like law enforcement, encounters limits over time. From 2022–24, slight increases in unlicensed cultivation near permitted hemp farms and in stream-dense regions indicated potential declining returns to civil enforcement or difficulties in sustaining enforcement over time. Civil and law enforcement may matter less than other pressures, like those of economic viability and cultural belonging. Economic conditions likely pushed some growers back into marginal lands where environmental enforcement was difficult. While civil enforcement provides clearer rules and a broader range of regulatory tools, its long-term effectiveness depends on consistent funding, clear communication of standards, and the legitimacy of its aims (i.e. serving a discernible, consistent public good). No or limited pathways to licensure may also affect the legitimacy and efficacy of civil regulation. The evidence overall points to the long-term advantages of mature civil enforcement systems.

Finding #5: Issues in permitting programs prevented many cultivators from becoming licensed.

Ethnographic data indicated that delays, suspensions, and overly restrictive permitting requirements were among the most significant causes of continued unlicensed cultivation across the study period. In accord with previous findings (Bodwitch et al 2021), it was access – not willingness to comply – that typified non-licensure, though many cultivators cited negative attitudes toward regulatory systems they see as benefiting larger, capitalized firms.

Lawsuits and administrative delays prevented participation in permit programs. Growers who sought to transition into the legal market were unable to do so because programs were halted, redesigned, or burdened with unclear requirements. In Trinity, a lawsuit and a county-imposed permit cap effectively froze licensing activity. In Mendocino, shifting regulatory standards and the repeated suspension of provisional permits created uncertainty and discouraged participation. Nevada was delayed due to CEQA concerns (though the program operated efficiently once launched in 2019). Though Riverside launched a program in 2019, it was years before the first cultivation license was issued. Across this initial period, unlicensed cultivation boomed because cultivators lacked a viable path to licensure.

Permitting counties struggled to reconcile compliance expectations with the realities of transitioning a large legacy industry into regulated frameworks. Ethnographic accounts from this period described Riverside County's permitting system as overly burdensome, characterized by high financial barriers, strict zoning, and long review timelines that excluded most small or legacy cultivators. Many were instead drawn to nearby municipalities offering more attainable

local permits. Mendocino and Trinity offer similar cautions, particularly after environmental and residential groups raised compliance requirements that excluded many farmers and imposed significant costs on those seeking licensure. In contrast, Nevada County's permitting system was intentionally structured to support small-scale farms and was aided by strong communication between cultivators and local government.

Jurisdictions that maintained transparent and stable frameworks, like Nevada and Humboldt, preserved modest but functioning legal cultivation sectors. Others, such as Trinity, Mendocino, Lake and Riverside, had low program participation as programs stalled, became prohibitively complex, or failed to support permittees amidst economic decline. Ethnographic data suggested that the presence of trade associations was a key factor in facilitating program success. Where such organizations were active, cultivators benefited from advocacy, technical assistance, and clearer communication with regulators (e.g. Trinity, Nevada), although they have not been able to consistently overcome organized opposition from environmental, residential, agricultural, or other land user groups (e.g. Riverside, Lake, Trinity). In contrast, counties such as Siskiyou, which maintained bans on commercial cultivation and severely limited personal cultivation, left cultivators with no realistic legal pathway. In sum, the evidence indicates that failures in local permitting systems, rather than a lack of willingness to comply, sustained unlicensed cultivation across much of the study region.

Finding #6: Cultivation bans and other enforcement policies were linked with "whack-a-mole" dynamics around unlicensed cultivation.

Spatial modeling shows that "whack-a-mole" patterns – in which displaced growers re-establish operations elsewhere rather than exiting the market altogether – are strongest in ban counties and in jurisdictions with historically high levels of law enforcement activity. Ethnographic data supported this finding. Ban enforcement efforts in Siskiyou targeted unlicensed sites aggressively, but the primary outcome was relocation rather than cessation. Cultivators frequently moved to new parcels with lower oversight, often in areas with cheaper land or weaker enforcement capacity. Enforcement officials and cultivators alike described an ongoing cycle of removal and reestablishment that was costly for both sides. In some cases, growers returned to the same sites after abatement or eradication, suggesting that enforcement created temporary disruptions rather than long-term deterrence. This dynamic was most evident in rural zones with active social networks and accessible parcels. In contrast, counties with stable permitting programs and active civil enforcement frameworks (e.g. Nevada) exhibited more spatially stable cultivation, even if unlicensed activity persisted.

There was also more whack-a-mole patterning when landowners were liable for tenant cultivation activities, suggesting that landowners were more likely to evict and require movement by cultivators. This policy environment led to shorter-term tenancies and more transient cultivation activity. These policies may have encouraged land ownership by cultivators,

as in Riverside, where some growers reportedly conducted “re-grows” on the same sites after fines or raids, particularly in more isolated zones.

Ethnographic data indicated that local social structures played an important role in shaping these patterns. In Trinity and Siskiyou, tight-knit cultivation communities and permissive or pro-cannabis Property Owners Associations allowed movement within informal networks, sustaining unlicensed cultivation despite repeated interventions. Conversely, anti-cannabis associations and declining economic viability in certain areas reduced both the frequency and persistence of site relocation, as in Riverside and ag-res zones of Nevada. This suggests that local norms, shaped by social structures, can influence how much ability to move between places there is.

Finding #7: Market forces and price decline were major factors in driving unlicensed cultivation decisions.

Declining cannabis prices since 2021 were a central influence on cultivation siting decisions across all case counties. From 2018 to 2020, all cultivators reported relatively stable market conditions, and site choices were shaped primarily by regulatory and enforcement factors. Despite (or because of) a brief spike in prices in 2020 due to Covid, prices began to fall sharply in 2021. Growers increasingly prioritized economic survival over licensure or long-term planning. They sought cheaper land, reduced labor costs, and assumed more of the work themselves to sustain minimal profitability. Many reported difficulties selling products or covering costs. Some left the unlicensed market altogether. Others downsized to small personal gardens for self-provisioning or supplemental income, particularly in counties that permitted limited outdoor or mixed-light personal cultivation with low compliance costs.

Growers adapted to the economic crisis by relocating to lower-cost areas and cutting operational expenses. This often meant moving into more remote or less regulated zones where land was inexpensive and enforcement capacity limited. In counties like Riverside and Nevada, interviewees noted visible expansion of cultivation into marginal lands, including the eastern desert areas of Riverside and remote uplands in central Nevada County. Siskiyou also experienced dispersed small-scale activity in low-value parcels (a trend earlier noted in San Bernardino; Getz et al 2024). Across cases, site mobility appeared increasingly tied to affordability and cost reduction rather than enforcement avoidance alone (see Getz et al 2024 on Napa and the pricing out of unlicensed cultivation).

By 2022 to 2024, the consequences of sustained price decline were visible across the unlicensed landscape. Ethnographic data suggested that cultivators continued to shrink or abandon operations depending on their access to capital and alternative livelihoods. Lower-income growers and those with limited land-use options often continued cultivating despite the risk of fines, as cessation would jeopardize their basic financial stability. Others shifted from

outdoor to mixed-light cultivation to improve yields and reduce detection risk, even though this required higher upfront investment. The financial impacts of enforcement, including fines and abatement fees, intensified pressure on cultivators, but only up to a point. For those already on the economic margins, enforcement penalties were less deterrent than existential threats. The data also showed a demographic shift in this period, with older cultivators and retirees comprising a larger share of those remaining active in cultivation, as younger participants increasingly exited the market. Overall, the findings suggest that the price collapse, more than enforcement or environmental regulation, became the defining force guiding whether, where and how unlicensed cultivators continued.

These shifts had negative economic implications for rural economies that had previously been supported by unlicensed cultivation. The most visible effect was the closure of stores that depended on cultivation money, though these were symptomatic of the general evacuation of younger growers, the increasing economic tenuousness of older residents, and the disintegration of cultural-economic fabrics that sustained cultivation-dense areas. Some sought other livelihoods, where possible, though formal sector jobs are rare in many cultivation-dense areas, leading to out-migration, significant turnover in properties, and disruption of the social systems that cannabis had stabilized.

6.4 OBJECTIVE 3: COMPARING LICENSED AND UNLICENSED PRODUCTION AND ESTIMATE LEAKAGE OF LICENSED PRODUCT INTO UNLICENSED MARKET

To assess the relationship between licensed and unlicensed cultivation, we compared the volume of licensed cultivation in key counties over time and compared it to the trends in unlicensed cultivation. We were not able to estimate the leakage of licensed products into the unlicensed market due to licensed data source limitations. Detecting leakage requires accurate data on (1) on-farm accounting for all plants grown and material moved off of the farm; and (2) the movement of product through the supply chain as individual products and not grouped into manifests or re-assigned ID numbers through the process. Licensed harvest data had numerous gaps and reporting errors, and the supply chain tracking did not allow for the analysis of how individual products moved from cultivation to manufacturing to retail, making any estimate of diversion there impossible. Further, in California's track-and-trace system, products are combined into new batches and assigned new ID numbers when they move from one place to another. These shipments are tied to manifests. While we can see where manifests originate and end, we cannot see which products are in each manifest and cannot trace those product ID's back to their place of cultivation or production (see more in the limitations section).

Finding #1: Growth of licensed cultivation was more consistent than unlicensed cultivation over the course of the study period.

Harvest data indicated that licensed production rose every year. Yet, CannaVision data demonstrated a different pattern among unlicensed cultivation. Although there was a sharp rise in unlicensed cultivation between 2018 and 2020, the 2020-2022 time period showed a drastic reduction in mapped unlicensed cultivation that matched the magnitude of the 2018-2020 increase. Between 2022 and 2024 cultivation, on average, stabilized and neither demonstrated dramatic expansion or contraction. Reduction in unlicensed outdoor and mixed light cultivation was likely somewhat offset by small increases in unlicensed indoor production, as suggested by our limited analysis.

Finding #2: As licensed cultivation increased in counties like Santa Barbara, activity decreased in rural, legacy production counties, like Mendocino.

There are several possible regulatory and industry related reasons for this trend. First, Santa Barbara allowed for larger scale cultivation, attracting larger companies with greater capital and the ability to grow at scale, increasing their margins. Counties like Mendocino and other legacy counties, however, often capped cultivation and required more extensive permitting and CEQA processes due to environmentally sensitive lands (unlike Santa Barbara, which did not have the same land features; see Dillis et al 2021). As an illustration of this, the harvested weight in Mendocino steadily decreased every year after the 2021 harvest peak, while in Santa Barbara harvest sizes continued to increase annually.

Second, distance to market disadvantaged licensed and unlicensed cultivation alike. Most transfers of licensed goods occur near population centers. It is more cost effective to move flower shorter distances for processing, manufacturing and retail. While Humboldt County was one of the top 10 counties for manifests of origin, neither Mendocino nor any other rural Northern California county was in the top 10 for manifests of destination. Los Angeles County dominated manifests of origin and destination, demonstrating the relationship between population centers and cost effectiveness for a highly regulated industry.

6.5 OBJECTIVE 4: ASSESSING POTENTIAL FOR ENVIRONMENTAL IMPACTS OF UNLICENSED PRODUCTION IN BAN AND PERMIT COUNTIES

Finding #1: Environmental sensitivity eventually became associated with reductions in unlicensed cultivation, particularly in permit counties.

Between 2018 and 2020, cannabis cultivation expanded across nearly all counties, with no clear connection to environmental sensitivity. From 2020 to 2022, cultivation generally

declined, and there was a weak, non-significant tendency for larger decreases in counties with higher environmental sensitivity. This pattern was more noticeable in counties with permits, although the sample size was too small to reach statistical significance, and there was no such pattern in counties under bans. Finally, from 2022-24, a clear pattern emerged: counties with higher environmental sensitivity experienced absolute declines in cultivation, while less sensitive counties saw absolute increases. This trend was again more pronounced in permit counties than in ban counties. This indicates that permit counties were more effective than ban counties in driving cannabis away from environmentally sensitive areas. This was likely due to numerous reasons including the involvement of environmental protection agencies, more resources and tools dedicated to environmental protection, and targeted prioritization of decreasing environmental harms rather than generalized policing of cultivation.

6.6 KEY TAKEAWAYS

1) **Despite an initial boom, total unlicensed cultivation contracted to 2018 levels.** After initial expansion from 2018-20, unlicensed cultivation decreased. By 2024, total acreage was equal to 2018 levels with some variation across geographies and policy approaches. *See Obj 1, Finding 1.*

2) **Unlicensed cultivation is diverging from licensed cultivation.** This is occurring along geographic and socioeconomic lines. Unlicensed cultivation persists in more remote areas, away from permitted farms. Frequently, those persisting to cultivate without licenses have few or no other formal livelihood options, are bound to place for cultural or economic reasons, and are economically and socially marginalized. Local policies – bans, permits, enforcement regimes – and socioeconomic conditions has created a wide array of developmental patterns across California. *See Obj 1, Finding 2-4, 6; Obj 3, Finding 1-3.*

3) **A permitted farm is the most effective deterrent for unlicensed cultivation.** The presence of a licensed farm best predicts declines in unlicensed cultivation. Correlatively, more licensed farms can diminish unlicensed cultivation. This occurs for several reasons including increased presence of inspectors and officials near licensed farms, more open landscapes near licensed farms, and community norms that develop over time. Notably, it is not the presence of a permitting program in general that is consistently and powerfully correlated to unlicensed cultivation (though it did have an appreciable effect from 2022-24). It is the localized effects of permitted farms, suggesting an importance to *dispersion* of numerous licensed farms across an area. *See Obj 2, Finding 1.*

4) **Permit programs are important in addressing environmental impacts of unlicensed cultivation.** Where permitting programs are present, negative environmental impacts decline. Bans were associated with more cultivation on sensitive lands, including "whack-a-mole" dynamics of churning cultivation sites. Permit programs often have a larger suite of agencies and capacities to address unlicensed cultivation. Permit programs can also increase awareness – even among unlicensed cultivators – of the impacts of cultivation and mitigation techniques. Even if cultivators are not licensed they can still absorb local norms and a "culture of compliance" fostered by permitting programs. *See Obj 2, Findings 1-2, 4, 6; Obj 4, Finding 1.*

5) **Bans were not a consistent indicator of growth or decline of unlicensed cultivation.** However, *how* ban policies are implemented (i.e. enforcement, related policy) and other factors (e.g. land affordability, cultural belonging) may matter more than the presence of a ban. Bans *do* successfully render cultivators unlicensed by fiat. This affects vulnerable, immobile, lower-income populations more to the degree relocation or alternative livelihoods are not an option. *See Obj 2, Finding 2, 4, 6.*

6) **Eradication-oriented enforcement loses efficacy over time.** While enforcement reputation initially deterred unlicensed cultivation, over time it lost deterrent efficacy. Those intending to exit cultivation because of enforcement did so in the first few years but those with higher risk tolerance or fewer alternative options, stayed. By 2022-24, enforcement reputation was actually correlated with an *increase* in unlicensed cultivation. This suggests that, by itself, enforcement is less effective over time in addressing unlicensed cultivation, particularly to the degree it forfeits other civil enforcement approaches, like code enforcement, water and hemp inspections, etc. The only consistent effect of punitive, eradication-focused enforcement, particularly in ban counties, is that it causes cultivators to move to other places within jurisdiction. *See Obj 2, Finding 3, 6; Obj 4, Finding 1.*

7) **Civil regulatory policies that foster norms can effectively discourage unlicensed activity over time.** Regulatory policies take time to disperse through populations. The increasing correlation of civil approaches (e.g. permit programs, landlord liability, fine regimes) to declining unlicensed cultivation suggests civil policies need time and consistency to spread through communities and create the kind of adaptations desired. Enforcement is important, but education *prior* to enforcement is key for fostering social adjustment to new policies. *See Obj 2, Finding 4-6.*

8) **Decisions around unlicensed cultivation are driven by economic concerns.** Livelihood prospects drove decisions by cultivators to continue or abandon unlicensed cultivation. As economic conditions (i.e. wholesale price of cannabis) worsened, unlicensed cultivators with other livelihood options stopped growing. Those who

persisted cultivating, however, often lacked other livelihood possibilities. In both cases, economics were key factors. Economics also affected *how* (e.g. outdoor or mixed light) and *where* cannabis was grown (e.g. remote, cheaper land). *See Obj 1, Finding 3; Obj 2, Finding 7.*

POLICY RECOMMENDATIONS

The following policy-related recommendations derive from the above research, as deliberated by the team of co-authoring researchers.

1) **Maximize quantity of licensed, owner-occupied farms throughout the state.** As licensed farms were the most significant factor in declines of unlicensed cultivation, we recommend maximizing licensed cultivator participation and dispersion throughout the state. These farms should be owner-occupied to ensure that local norms and a "culture of compliance" can be communicated and maintained through local networks (as opposed to absentee owner-operators). To avoid overproduction and farm failure, farms should be small. Correlated policies include: reducing or eliminating barriers to cultivation licensure; expanding areas where cannabis can be locally permitted; programs to retain and support existing licensed farmers; clawbacks of large and stacked licenses, which reduce farm numbers and are more likely to be absentee owned. Expansion of retail opportunities (e.g. more dispersed retail, longer hours, direct-to-consumer sales, cannabis events,) is also important to ensure markets can sustain new producers (See Polson et al 2022 & 2023 for specific recommendations.)

2) **Create statewide small-farm carve-outs or ministerial pathways for localities to permit farms.** In order to reduce unlicensed cultivation, increase farm counts, and reap the social, economic, and environmental benefits of licensure, new pathways to licensure are needed. Since many localities do not have the bandwidth or resources to create permitting programs, alternative pathways could be created. A statewide exception for small farms (e.g. up to 2500 or 5000 square feet), with lowered barriers to entry (Polson et al 2022) even in ban areas, could encourage small farm dispersion throughout the state. Allowance of a ministerial local permit and state license (Biber et al 2023) could also create pathways for localities to benefit from small farm production. State assistance to ban counties could be conditioned on such pathways and supported by the creation of a Best Practices template from the DCC on what regulatory and implementation strategies have been most effective.

3) **Ensure personal cultivation is affordable and feasible throughout the state.** Maximizing allowance for personal gardens allows an exit from unlicensed production in

ways that enable continued enjoyment of cultivation and foster norms around cannabis. Eliminate local barriers to personal cultivation, especially restrictions on outdoor or mixed light cultivation that would otherwise be acceptable for other gardens. Conduct a state audit of personal cultivation allowances, costs, and restrictions to ensure that the intent of Proposition 64 to allow personal cultivation is not being abridged.

4) **Address economic and social drivers of unlicensed activity in enforcement responses.** Our research suggests that eradication-focused law enforcement has declining efficacy over time and that multi-agency responses that incorporate civil, non-punitive measures can reduce unlicensed cultivation by addressing the economic and social drivers of unlicensed cultivation. Economic consequences (e.g. fines) may be effective at discouraging unlicensed cultivation but if other livelihood and land use opportunities do not exist, economic consequences can simply compound harms on already-vulnerable populations. Providing education on how to avoid violations and services to increase resilience and social integration are more suitable alternatives than adversarial enforcement.

5) **Tie enforcement funding to accurate data assessments of extent and development of unlicensed cultivation.** Claims about unlicensed/illegal activity, including their environmental impacts, are commonly used to acquire limited public resources. However, these claims often use blunt, outdated, or inaccurate measurements. Enforcement agencies should utilize up-to-date methods and data sources, like those modeled here, to substantiate the need for enforcement and demonstrate the efficacy of prior enforcement strategies. This should include resource requests by counties with ban policies (including requests to the Board of State and Community Corrections, as authorized under AB141), which not only fail to stop unlicensed cultivation but are associated with more significant environmental impacts.

6) **Support policy responsiveness to the economic and social predicaments of unlicensed cultivators.** Ethnographic research consistently conveyed the importance of economic considerations among unlicensed cultivators. Land prices, wholesale cannabis prices, and market access mediate whether and how cultivators persist. Economic vulnerability is often rooted in social marginalization (e.g. age, location, race/ethnicity, immigration status). Many persist because other economic options do not exist, indicating a need to (a) innovate approaches to economic development in remote, low-income, non-white, and legacy cultivator communities and (b) include persistent cultivators and communities in economic development planning and programming.

7) **Eliminate exceptional penalties regarding cannabis agriculture and integrate cannabis into existing agricultural processes.** In recent years, regulators have adopted cannabis policies that apply uniquely stringent penalties to cannabis agriculture (e.g.

SB753). This is often done without adequate substantiation that environmental impacts of cannabis are more dire than any other agricultural form or that heightened consequences would effectively discourage these impacts. Environmental impacts should be accurately assessed and addressed through processes that already exist for other forms of commercial agriculture – including through outreach and education.

8) **Improve California's Track-and-Trace Program (CTTP) to minimize human error and enhance traceability.** Assessing supply chain flows is hindered by inaccurate data and an inability to track a harvest forward through the supply chain. Human errors could be minimized by implementing a non-punitive, non-onerous audit system or by streamlining farm reporting to off-farm transfers and reducing/eliminating plant tags. Supply chain analysis could be enhanced by adjusting the batching processes to ensure that harvests can be traced from the point of origin to point of sale, which would enable a more clear understanding of how the supply chain operates.

9) **Foster a Culture of Compliance.** Effective regulation and discouragement of unlicensed cultivation requires the fostering of social-regulatory norms. To foster a "culture of compliance" that grounds regulation in communities, efforts have to be made to positively integrate cultivation into communities. Destigmatizing cannabis, integrating it into existing systems (see above), and upholding positive examples of cultivation helps to build communal norms that, among other things, discourage unlicensed cultivation.