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Agriculture and Natural Resources

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Special issue: Cannabis

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COVER: A close-up of a cannabis flower on an outdoor farm. *Photo by Danaan Andrew Pacleb, ShutterStock.*

Special Issue: Cannabis

In 1953, amid reports that cannabis was growing around San Mateo County, the local sheriff's office and the UC Agricultural Extension Service in Half Moon Bay issued a booklet entitled *Identify and Report Marihuana*. The booklet envisioned "total eradication" of cannabis. The authors couldn't have imagined that, in 2017, the San Mateo County Board of Supervisors would pass an ordinance allowing greenhouse cultivation of cannabis in the county's unincorporated areas.

A lot can happen in 60-plus years — such as voter approval of Proposition 64, the 2016 ballot measure that altered California law to allow the recreational use of cannabis by adults.

The measure's passage presented policymakers with the challenge of regulating, licensing and taxing a large, complex and fast-changing recreational cannabis industry — a challenge made more acute because scientific research on many aspects of cannabis in California had never been conducted at scale. UC is now working to fill that research gap. At least nine UC research centers, most of them new, now focus entirely or in part on cannabis (page 106). A sense of momentum has begun to suffuse cannabis research.

That said, federal restrictions still inhibit many aspects of research (see page 104 for more detail). Cannabis research is also inhibited by funding constraints. The $10 million in annual research funding that Proposition 64 allocated to California universities has not begun to flow, and the Bureau of Cannabis Control — the entity responsible for disbursing the money — reports that it is still establishing guidelines for doing so.

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Despite these obstacles, UC cannabis research in the legalization era is well underway, as attested by this special issue of *California Agriculture*. The research articles presented here fall into three broad categories — research into cannabis production, into the economics of the cannabis industry in California and into the social and community impacts of cannabis.

The three articles focused on cannabis production include the results of the first known survey of California cannabis growers' production practices, by Wilson et al. (page 119). In the article "Characteristics of farms applying for cannabis cultivation permits" (page 128), Schwab et al. combine data on cannabis farms with information about applications for cultivation permits, establishing that, of farms within the dataset, those seeking permits tended to be larger and to have expanded faster than other farms. And on page 146, Dillis et al. analyze data submitted to the regional water quality control board to characterize the water sources used by cannabis cultivators in the Emerald Triangle region (Humboldt, Mendocino and Trinity counties).

Articles focused on the economics of the cannabis industry include a study by Goldstein et al. (page 136) analyzing online retail prices for cannabis flower and cannabis-oil cartridges as changes in regulation and taxation have taken effect in recent years. Valdes-Donoso et al. (page 154) analyze data from sources including California's cannabis testing laboratories to estimate the cost per pound of testing under the state's regulatory framework.

Four articles explore the social and community impacts of cannabis production. On page 161, Valachovic et al. report the results of a survey of timberland and rangeland owners in Humboldt County, who shared their experiences with the rapid expansion of cannabis production in their region and its attendant social, economic and environmental challenges. LaChance (page 169) interviewed noncannabis farmers, ranchers and others across Humboldt, Mendocino and Sonoma counties, eliciting their views on issues such as increased land prices amid cannabis legalization. For the article "Growers say cannabis legalization excludes small growers, supports illicit markets, undermines local economies" (page 177), Bodwitch et al. surveyed cannabis growers to gain insight into their experiences with the state's system for regulation of commercial cultivation. Finally, on page 185, Polson and Petersen-Rockney employed ethnographic methods to study cultivation regulations in Siskiyou County and their effects on the county's Hmong-American community.

The special issue was conceived by Van Butsic and Ted Grantham — UC Cooperative Extension (UCCE) specialists based at UC Berkeley — and Yana Valachovic — a UCCE forest advisor and director for Humboldt and Del Norte counties. Butsic, Grantham and Valachovic developed the issue in collaboration with Daniel Sumner, a UC Davis professor of agricultural economics and director of the UC ANR Agricultural Issues Center, and with the staff of *California Agriculture*.

— Editors

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INTRODUCTION

California cannabis regulation: An overview

In 2016, Proposition 64 decriminalized the possession and use of cannabis by anyone in California aged 21 or over. But the 2015 Medical Marijuana Regulation and Safety Act had begun the process of regulating cannabis in the state.

by Robin S. Goldstein and Daniel A. Sumner

More than two decades ago, on November 5, 1996, California voters passed the ballot initiative known as the Compassionate Use Act (Proposition 215). The Compassionate Use Act removed criminal penalties for the possession, use and sale of cannabis for medicinal purposes, thus making California the first U.S. state to decriminalize cannabis since the substance had first been classified by the federal government, in 1970, as a Schedule I narcotic.

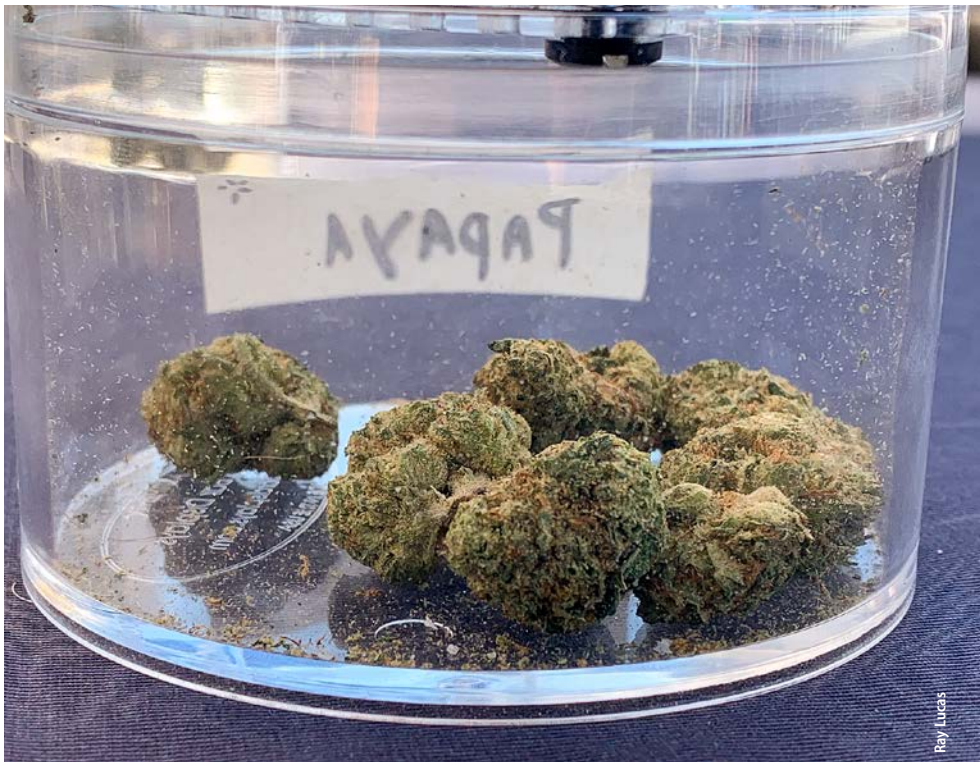
By 2019, 36 U.S. states had enacted legislation to remove criminal penalties for the possession and use of medicinal cannabis (the "medicinal decriminalization" of cannabis). In general, medicinal decriminalization means that cannabis can only be sold to customers who obtain a medical doctor's recommendation to use cannabis as a treatment for a state-specified medical condition. In some of the states that have decriminalized medicinal cannabis, only a few specific medical conditions are approved for cannabis treatments; in other states, such as California, there has been little practical restriction on medicinal recommendations.

As of 2019, 10 U.S. states (all of which have decriminalized the medical use of cannabis) have also decriminalized "recreational" or "adult-use" cannabis. The decriminalization of adult-use cannabis in these states means, at a minimum, that a doctor's recommendation is not necessary in order for a state resident or out-of-state visitor to legally possess and use cannabis.

Adult-use legalization

In everyday usage, "legalization" has a variety of connotations. The word might refer to the legal possession of cannabis, the legal purchase and sale of cannabis or the reporting of cannabis sales to state-level authorities and those authorities' taxation of cannabis sales. In the United States, common usage of the word "legalization" does *not* imply that cannabis is legal under federal law. Since the passage of the U.S. Controlled Substances Act of 1970, cannabis has been a Schedule I narcotic. The federal government has approved no medicinal use of tetrahydrocannabinol (THC), the psychoactive component of cannabis. The sale of cannabis remains a felony under federal law.

In California, Proposition 64 — a 2016 ballot initiative known as the Adult Use of Marijuana Act (AUMA) — decriminalized the possession and use of cannabis by any person in California aged 21 or over.



As of 2019, 10 U.S. states have decriminalized "recreational" or "adult-use" cannabis.

Proposition 64 left in place medical cannabis decriminalization for consumers between 18 and 21 (or below 18, with a parent or guardian's permission) — and opened a "legal" cannabis market both to state residents without medical recommendations and to visitors from out of state, who under medicinal cannabis law had previously been excluded from buying cannabis through the decriminalized system.

Although Proposition 64 broke down some legal barriers on cannabis sales (especially the ban on selling to non–state residents), it is probably true that, even before the proposition passed, most California residents who wanted to buy cannabis without breaking state laws regarding cannabis possession were able to obtain medical cannabis recommendations with relative ease. By early 2016, for instance, it was possible for a California resident over the age of 18 to receive an official, state-endorsed medicinal cannabis recommendation by simply submitting an online medical form claiming headaches and paying less than $50. As of the early fall of 2016, the process of obtaining a medicinal cannabis recommendation for the first time, and then

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using it to order cannabis from a delivery service, could be completed in less than half an hour from start to finish.

Taxation and regulation

Even before Proposition 64, the 2015 Medical Marijuana Regulation and Safety Act (MMRSA) — which was later extended as the Medicinal and Adult-Use Cannabis Regulation and Safety Act (MAUCRSA) — had begun the process of regulating cannabis in California. The law assigns licensing and regulation to three agencies: The Department of Food and Agriculture is responsible for cultivation, the Department of Public Health for manufacturing and the Bureau of Cannabis Control for distribution, testing and retailing (with the bureau, under the Department of Consumer Affairs, designated as the lead agency). Regulations pursuant to the law were initially issued through a series of emergency and temporary rules. Final regulations came into effect in January of this year (though many licensees continued to operate under temporary licenses). The final regulations, which apply statewide, establish guidelines under which local jurisdictions can (but are not required to) set their own additional taxes and regulations on cannabis businesses.

The cost of retail cannabis in the legal regulated market is about 50% higher than it would be without taxes and regulations.

The regulatory agencies collect license fees from cannabis businesses under their purview. At each stage, the fees range from a few hundred dollars for very small operations up to $100,000 or more for large-scale cultivators, manufacturers, distributors, testing laboratories and retailers. License fees generate the revenue needed to fund the regulatory apparatus and are generally in the range of 1% to 2% of the gross value of output.

Based on specifications in Proposition 64, the state imposes: (1) taxes on sales at the cultivation stage, including a cultivation tax of $9.25 per ounce ($148 per pound), on cannabis flower (or dried-flower equivalent) produced and transferred and (2) an excise tax of 15% on the value of retail cannabis, calculated using a formula that multiplies the actual wholesale price by an assumed retail-to-wholesale price ratio of 1.6. Retail sales of cannabis are also subject to the California state sales tax of 7.25% and county and city supplemental sales taxes that range from zero to 2.75%. In addition, local governments may apply additional cultivation taxes or assessments, as well as cannabis-specific excise taxes, for which the most common tax rate is about 10%.

Regulations based on specifications in the legislation require that cannabis be tested for potency and product consistency, as well as for pesticides and other contaminants. Regulations specify detailed tests for a wide range of compounds, with low accepted thresholds and tight specifications that are costly to meet. The state's "track-and-trace" system requires cannabis businesses to register the flow of cannabis products through the supply chain to prevent movement of product between licensees and the illegal cannabis supply chain, which continues to operate parallel to the legal industry.

Other important regulations require licensing and background checks, as well as compliance with requirements regarding packaging, labeling, handling, transportation, waste disposal, security, data reporting and hours of operation. It is also important to emphasize that, for many cannabis businesses that had previously operated outside normal legal and regulatory channels, the broad set of environmental, employment and social regulations that covers other farms, manufacturers, wholesalers and retailers was new and unfamiliar. Competitors from the illegal segment of unlicensed businesses, who are not subject to any of these restrictions, continue to grow, process and sell cannabis in a parallel market that still includes many consumers in California.

State-level regulations — from requirements for video security to expensive required testing — also add costs to retail cannabis sold in the legal regulated market. The natural result is that the cost of retail cannabis in the legal regulated market (including compounded taxes and regulatory costs) is about 50% higher than it would be without the taxes and regulations. Wholesale prices have declined because decriminalization has brought new capital, management procedures and technology to the cannabis industry; likewise, the risks inherent in illegal operations are reduced for compliant operators. Nonetheless, (regulated) retail prices through the first half of 2019 have been higher than the (decriminalized but unregulated) retail prices of 2017, and well above the 2019 prices of cannabis products available in the unlicensed and unregulated market. CA

For further information:

- The first stop for official regulatory and tax information is the California Cannabis Portal at https://cannabis.ca.gov/.
- For the required regulatory impact analysis provided by the Bureau of Cannabis Control, see www.dof.ca.gov/Forecasting/Economics/Major_Regulations/Major_Regulations_Table/documents/DCA_Cannabis_SRIA_2018.pdf.

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A concise cannabis guide: History, laws and regulations

1937 The Marijuana Tax Act is signed into federal law. The Act, though it does not explicitly outlaw cannabis, establishes tight restrictions that effectively prohibit its sale and use.

1970 The Controlled Substances Act, a federal law, establishes schedules that categorize drugs according to their perceived medical utility and potential for abuse. Cannabis, along with heroin and LSD, is assigned to the highly restrictive Schedule I. As a result, even scientists face great difficulty in obtaining cannabis for research purposes.

1996 California voters approve the Compassionate Use Act, legalizing medical cannabis in the state. For the next 19 years, California's medical cannabis industry operates essentially unregulated.

2015 The California Legislature passes and Gov. Brown signs the Medical Marijuana Regulation and Safety Act (later renamed the "Medical Cannabis Regulation and Safety Act"). The law establishes a three-agency regulatory structure for cannabis activities.

2016 California voters approve Proposition 64, the Adult Use of Marijuana Act, which legalizes on the state level the cultivation, possession, sale and use of recreational cannabis.

2017 The Legislature passes the Medicinal and Adult-Use Cannabis Regulation and Safety Act, integrating Proposition 64 and the Medical Cannabis Regulation and Safety Act, thus establishing a combined regulatory system for medical and adult-use cannabis in California.

California's cannabis regulators

Agency	Bureau of Cannabis Control	Manufactured Cannabis Safety Branch	CalCannabis Cultivation Licensing
Parent organization	Department of Consumer Affairs	Department of Public Health	Department of Food and Agriculture
Primary activities	Licenses and regulates cannabis retailers, distributors, microbusinesses, testing laboratories and temporary events; is designated as state's lead cannabis agency	Regulates manufacturing of cannabis products such as extracts and edibles, ensuring that products are properly packaged and labeled and are free of contaminants	Licenses and regulates cannabis cultivators; implements the state's track-and-trace system, which follows the movement of cannabis from seed to sale

What cannabis activities are allowed — and where?

While state law provides for the cultivation and manufacture of cannabis and its sale in retail stores, cities and counties may pass ordinances banning these activities. Localities without explicit bans on cannabis activities also may effectively ban them through, for example, zoning ordinances (certain activities, such as delivery of cannabis from a different jurisdiction, may not be banned). The table below gives examples of what is allowed in a few cities and counties.

Location	Commercial cultivation	Manufacturing	Adult-use retail stores
State of California	Allowed	Allowed	Allowed
Selected cities			
Anaheim	Prohibited	Prohibited	Prohibited
Portola	Prohibited	Prohibited	Prohibited
Selected counties			
Kern County	Prohibited	Prohibited	Prohibited
Orange County	Prohibited	Prohibited	Prohibited
Santa Barbara County	Allowed	Allowed	Allowed
Tehama County	Prohibited	Prohibited	Prohibited
A city/county split*			
Oakland	Allowed	Allowed	Allowed
Alameda County	Allowed	Prohibited	Allowed

* Where city and county ordinances differ, the city's ordinance applies within its boundaries.

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Restrictions and opportunities for UC cannabis research

Cannabis is legal in California but illegal in the United States. The plant's ambiguous status cuts off many avenues of cannabis research — but leaves other approaches wide open.

When California voters approved Proposition 64 in 2016, legalizing recreational cannabis for adults, they fundamentally altered the state's cannabis landscape. They also, albeit unintentionally, furnished UC researchers with intriguing new avenues of potential inquiry — many of which are blocked by federal law and pursuant UC policy. For example, researchers interested in the cannabis-derived sprays and beverages readily available at California's retail cannabis establishments cannot obtain those products for research purposes by any permissible means. Licensed cannabis businesses dot the state today, but cannabis research still operates within the same strict constraints that have hindered it since legalization was a futile sentiment on a bumper sticker.

Because state law is subordinate to federal law, Proposition 64 is subordinate to the 1970 Controlled Substances Act. Associated with that act is a "scheduling" apparatus, overseen by the Drug Enforcement Administration (DEA), that identifies cannabis as ripe for abuse and devoid of medical merit. Thus, along with heroin and other Schedule I substances, the psychoactive variety of cannabis cannot under federal law be cultivated, processed, sold, consumed — or, for the most part, researched. (However, change is afoot for research on industrial hemp, the non-psychoactive variety of cannabis — more on this below.)

The University of California, as a law-abiding institution, complies with the Controlled Substances Act and its nearly total cannabis prohibition. As an institution that receives federal funding, UC complies with the Drug-Free Workplace Act and the Safe and Drug-Free Schools and Communities Act — which require universities, if they wish to receive federal funding, to implement policies prohibiting on-campus activities such as possession or use of controlled substances. UC personnel, including staff, faculty and UC Cooperative Extension (UCCE) specialists and advisors, are therefore prohibited, in their professional capacities, from direct contact with the cannabis plant or its extracts, and also from certain types of indirect contact. They cannot, for example, visit cannabis cultivation sites or advise cannabis growers on topics such as yield increases. Researchers can't even use cannabis or cannabis-derived products in medical studies — unless they fulfill a rather daunting set of federal (and state) requirements.

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Though researchers who wish to study the cannabis plant face strict federal constraints, opportunities to conduct cannabis research are not scarce around the UC system.

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Those requirements for medical studies include obtaining a Schedule I license from the DEA; submitting research protocols for Food and Drug Administration (FDA) approval; submitting to the FDA an investigational new drug application (if human subjects are involved in the research); and, as a non-federal matter, gaining the approval of a state entity, the Research Advisory Panel of California (housed within the Office of the Attorney General). If all goes well, researchers can then obtain cannabis or cannabis-derived substances from a DEA-licensed cultivator, a DEA-registered bulk manufacturer or, with a DEA import license, a foreign exporter. The only DEA-licensed cannabis cultivator is the University of Mississippi, which grows the plant under a contract funded by the National Institute on Drug Abuse (an entity within the Department of Health and Human Services). Bulk manufacturers of cannabis products such as tetrahydrocannabinol (THC) — the psychoactive component in cannabis — include, for example, the Massachusetts-based life science company MilliporeSigma (until recently, Sigma-Aldrich). Providers of imported cannabis products — such as Tilray, a Canadian firm — must be based in jurisdictions where such products are legal.

No matter which path researchers choose, the process isn't fast or easy. "You need a patient, dedicated team willing to jump through extra hoops at the institutional, state and federal levels," says Jeffrey Chen, Executive Director of UCLA's Cannabis Research Initiative. Even so, Chen reports, federal restrictions on types and sources of cannabis products can prevent researchers from conducting cannabis studies at all. And again, only medical researchers are eligible to obtain cannabis for research. Those who wish to perform agronomic studies, for example, are simply out of luck.

For all that, opportunities to research cannabis are not scarce around the UC system. Observational studies of cannabis users are permissible, though the cannabis in question cannot be provided by the university and must be consumed off campus. Researchers interested in the legal or economic dimensions of cannabis, or in cannabis policy, will discover few obstacles in the Controlled Substances Act. Several UC researchers are vigorously investigating the environmental consequences of cannabis cultivation — and in fact Proposition 64 has effectively expanded the scope for such research. According to Ted Grantham, a UCCE specialist at UC Berkeley and co-director of the UCB Cannabis Research Center, researchers can now interact with cannabis growers — to learn, for example, about their cultivation practices — in a way that grower reluctance previously precluded. Today, Grantham reports, "a subset of growers is very interested in daylighting the cannabis industry to establish its legitimacy as an agricultural crop rather than an illicit substance."

In years to come, UC investigators will likely perform extensive research on industrial hemp. This form of cannabis, which contains extremely small amounts of THC, is useless for producing a "high" — but very useful for making fabrics, insulation, paper and more. Until recently, however, federal law did not distinguish between low-THC hemp and high-THC cannabis — nor between THC and cannabidiol (CBD), a non-psychoactive cannabis compound purported to relieve medical conditions ranging from arthritis to anxiety.

The legal landscape for hemp and CBD began to change on the federal level in 2014, when that year's Farm Bill allowed universities to cultivate industrial hemp for research purposes (though UC established no such program). In June of last year, the FDA approved a CBD-based medicine for treatment of epilepsy-related seizures. With last December's passage of the 2018 Farm Bill, industrial hemp became a legal crop — pending establishment of a regulatory framework to govern it. Hemp-derived CBD now appears on course for complete de-scheduling by the DEA, and the FDA is wrestling with how to regulate the CBD-based consumer products already hitting the market in many states. Amid this liberalization of federal law on hemp and CBD, it becomes easy to envision UC academics and UCCE personnel performing agronomic studies with hemp — and providing California hemp growers with the same sort of research-based knowledge that has long been available to cultivators of almonds, grapes and lettuce. CA

— Lucien Crowder

UC researchers are vigorously investigating the environmental consequences of cannabis cultivation.

Cannabis and hemp — what's the difference?

- Cannabis and industrial hemp are precisely the same plant — *Cannabis sativa* — but they differ in their concentration of the psychoactive compound tetrahydrocannabinol (THC).
- Under the stipulations of the 2018 Farm Bill, the THC content of industrial hemp may not exceed 0.3% (on a dry-weight basis). *Cannabis sativa* whose THC content exceeds that level is regarded as marijuana by the federal government. (The state of California prefers the scientific term "cannabis" to the racially charged term "marijuana.")
- Psychoactive cannabis is mainly used to produce a "high" — though many California consumers use cannabis for medicinal purposes as well. Hemp is used for fiber and in diverse industrial applications, and also as a source of cannabidiol (CBD, a non-psychoactive compound purported to confer numerous health benefits).
- In the past, hemp was bred mainly for fiber and cannabis was bred to produce large buds that were rich in THC. The appearance of hemp and cannabis plants therefore usually differed. Today, because hemp is often bred to produce CBD — concentrated, like THC, in the buds of *Cannabis sativa* — industrial hemp and psychoactive cannabis often differ little in appearance.

The rapid evolution of UC cannabis research

At campuses across the UC system, cannabis researchers are grappling with questions that have accompanied legalization.

In 2016, when voters approved Proposition 64, they set the stage for radical change across California's cannabis landscape. Licensed, regulated cannabis stores would soon throw open their doors. A flood of novel cannabis-derived products would make their way to market. The state's vast cannabis industry would begin to emerge from illegality, though unlicensed operations would surely persist.

UC researchers immediately understood that cannabis legalization would present California with pressing new questions, along numerous dimensions, that could only be answered through rigorous, broad-ranging research. How would legalized cannabis cultivation affect the state's water, wildlife and forests? How might impaired driving, or interconnections between cannabis and tobacco, influence public health? How would tax and regulatory policy affect the rate at which cannabis cultivators abandoned the illegal market? These questions and many more are now the subject of research around the UC system, and multiple campuses are establishing centers dedicated to cannabis research. This article surveys UC's emerging architecture for cannabis research in the legalization era — and presents a sampling of notable research projects, both completed and ongoing.

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UC Berkeley

The Cannabis Research Center (CRC) at UC Berkeley is an interdisciplinary program that, bringing together social, physical and natural scientists, evaluates the environmental impacts of cannabis cultivation; investigates the policy-related and regulatory dimensions of cultivation; and directly engages cannabis farmers and cannabis-growing communities. The center, according to Ted Grantham — one of three CRC co-directors and a UC Cooperative Extension (UCCE) assistant specialist affiliated with UC Berkeley's Department of Environmental Science, Policy, and Management — is "focused on cannabis as an agricultural crop, grown in particular places by particular communities with unique characteristics." For Grantham and the center's co-founders, establishing the program was "a chance to develop policy-relevant research at the time of legalization and a time of rapidly shifting cultivation practices."

The center's co-directors, in addition to Grantham, are Van Butsic — a UCCE assistant specialist affiliated with UC Berkeley's Department of Environmental Science, Policy, and Management — and Eric Biber, a UC Berkeley professor of law. Other CRC researchers are associated with entities such as the

Multiple UC campuses are establishing centers in which researchers will study the effects of legalized cannabis cultivation on water, wildlife, forests and public health.

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UC Berkeley Department of Integrative Biology, the UC Berkeley Geography Department, the UC Merced Environmental Engineering program and The Nature Conservancy. The center itself is affiliated with the UC Berkeley Social Science Matrix. The CRC formally launched with a public event in January.

The center's ongoing research includes a multifaceted project to assess specific aspects of Northern California's cannabis farms, including the number and size of noncompliant cultivation sites; the environmental effects of noncompliant sites (on stream habitats, for example); and the challenges to regulatory compliance that cannabis cultivators encounter. According to a grant proposal associated with the research, the project is motivated by an urgent need to understand the environmental threats posed by noncompliant farms and the reasons that some farms successfully navigate state regulations while others fail.

The researchers are combining high-resolution satellite images with local and state permitting data to identify permitted and nonpermitted cultivation sites. In parallel, the researchers are combining permit specifications with water use models to estimate the effects on stream flows of nonpermitted versus permitted cultivation. Additionally, they are determining which factors associated with cannabis cultivation are most closely linked to compliance — whether parcels are large or small, old or new — and, through written grower surveys and in-person interviews, they are seeking to understand what stands in the way of cultivator compliance. Ultimately, the work will yield a policy report outlining ways in which state and local governments can decrease the harm of noncompliant cannabis cultivation while increasing rates of compliance. The research is supported by a grant from the Campbell Foundation, provided through the Resource Legacy Fund.

In another example of CRC research focused on cannabis and the environment, last year Butsic, Jennifer Carah (a CRC-affiliated senior scientist at The Nature Conservancy) and additional co-authors published the results of their work on "agricultural frontiers" (Butsic et al. 2018). These are places where, due to increased profit potential for agricultural activity, land is newly cultivated — frequently resulting in environmental impacts such as forest fragmentation and threats to sensitive species. Such transformations, the authors write, occur when economic circumstances are altered by some new mechanism — such as, in the case of cannabis, a new legal status. The researchers, documenting the emergence of such a frontier, studied cannabis cultivation sites in Humboldt and Mendocino counties from 2012 to 2016. Using satellite imagery to develop a database of cultivation sites, the researchers correlated site characteristics such as remoteness and erosion potential with the spread of agricultural frontiers.

They report that, over the study period, cannabis cultivation sites in the study area nearly doubled in number, with total acreage under cultivation likewise nearly doubling, and that a significant portion of the new cultivation occurred in areas such as sensitive watersheds. They found, for example, that nearly 90% of the areas newly developed for cannabis cultivation had been covered in natural vegetation as late as 2006. The researchers argue that agricultural frontiers can develop "almost anywhere institutions fail to prevent" them — and note that, for 18 years after medicinal cannabis use became legal in California with the 1996 Compassionate Use Act, the state devoted no funds to regulating cannabis cultivation and production.

In this issue of *California Agriculture*, Grantham and four co-authors from the North Coast Regional Water Quality Control Board present the results of their research into cannabis cultivators' patterns of water use in several Northern California counties. For the research that resulted in "Watering the Emerald Triangle: Irrigation sources used by cannabis cultivators in Northern California" (see page 146), Grantham and his colleagues analyzed reports submitted to the board by cannabis cultivators. The researchers determined how many cultivators sourced their water from wells, surface water diversions, spring diversions and other sources; how water sourcing behavior changed over the course of a year; and how water use patterns varied according to whether growers operated within the state's legal cannabis market. The researchers determined that cannabis growers rely on well water to a greater degree than is generally supposed — and that their reliance on well water may increase as more growers join the legal market because of well water's less restrictive permitting requirements.

One UC Berkeley project is motivated by an urgent need to understand the environmental threats posed by noncompliant farms and the reasons that some farms successfully navigate state regulations while others fail.

In separate research, Michael Polson — a postdoctoral researcher in UC Berkeley's Department of Environmental Science, Policy, and Management — has investigated the environmental dimensions of cannabis from an anthropological perspective. In a paper published earlier this year, Polson shows how cannabis has been identified as an environmental problem that requires public intervention (Polson 2019). On the basis of participant observation and more than 70 interviews with subjects across the cannabis spectrum — from park rangers to environmentalists to "criminalized people" — Polson demonstrates how cannabis production has been defined as pollution — "dovetail[ing] with [cannabis] prohibition's history of marking people and substances as socially polluting." Polson argues, as he highlights the legacy of cannabis prohibition in environmental debates, that policymaking is at its most innovative when it includes a broad range of cultivators and when stigmas are explicitly addressed.

UC Davis

Research into the environmental aspects of cannabis is also underway at UC Davis, where Mourad Gabriel is a research associate member in UCD's School of Veterinary Medicine. In 2018, Gabriel and co-authors, including Robert Poppenga — a professor of molecular biosciences at the California Animal Health and Food Safety Lab at UC Davis — published the results of their research on the effects of rodenticides on owls in northwestern California forests (Gabriel et al. 2018). The researchers, working on privately owned timberland in Humboldt and Del Norte counties, investigated the prevalence of anticoagulant rodenticides in areas characterized by illegal cannabis cultivation. Anticoagulant rodenticides, used by some cannabis cultivators to control pests, are known to affect nontarget species in urban areas and recently have been shown to affect carnivores in California's remote forest areas as well.

Integral Ecology Research Center

In a reclamation project conducted this May at 16 illegal cannabis cultivation sites in the Shasta-Trinity National Forest, a team of governmental and nongovernmental entities removed 6,000 pounds of trash, which included rodenticides and more than 5 miles of irrigation lines. UC researcher Mourad Gabriel estimates that removal of the irrigation lines restored more than 500,000 gallons of water — daily — into affected watersheds.

Gabriel and his co-authors undertook to determine whether the northern spotted owl, a threatened species, is exposed to anticoagulant rodenticides in the study area — and also to determine if barred owls, a common species, can be used as a surrogate to determine exposure levels in northern spotted owls. The researchers analyzed liver samples from 84 barred owls and 10 northern spotted owls. (The barred owls were removed by other researchers for an unrelated project, with appropriate permits; the carcasses of northern spotted owls were discovered opportunistically.) Within the study area, 70% of northern spotted owls and 40% of barred owls tested positive for anticoagulant rodenticides. The researchers hypothesize that cannabis cultivation in the area is the main source point for the presence of dangerous rodenticides. They also determined that barred owls are a suitable surrogate for determining rodenticide levels in the threatened northern spotted owl.

Gabriel, in his capacities as a UC researcher and as executive director of the Integral Ecology Research Center, a nonprofit organization based in Humboldt County, is currently carrying out reclamation projects at illegal cannabis cultivation sites in California and Oregon. In a project conducted this May in the Shasta-Trinity National Forest, a team representing 11 governmental and nongovernmental entities worked at 16 cultivation sites within eight large cultivation complexes, removing 6,000 pounds of trash, which included rodenticides and more than 5 miles of irrigation lines. Mourad estimates that removal of the irrigation lines restored more than 500,000 gallons of water — daily — into affected watersheds. Agencies including the California Department of Fish and Wildlife and the Law Enforcement and Investigations arm of the U.S. Forest Service have provided grant funding for 170 such projects, 112 of which have already been completed.

In an entirely different vein, UC Davis–based cannabis research has been conducted since 2016 at the UC Agricultural Issues Center (AIC), a UC Agriculture and Natural Resources statewide program operating since 1985. The center's broad mission is to provide research-based information on the economic dimensions of emerging issues in agriculture. Cannabis, then, is right in the center's wheelhouse.

Dan Sumner, the center's director, reports that AIC began pursuing cannabis-related work after the 2015 passage of a set of laws known collectively as the Medical Marijuana Regulation and Safety Act. This legislation laid the groundwork for state regulation of medicinal cannabis and ultimately of the recreational cannabis industry. The lead agency in regulating commercial cannabis licenses for distributors and retailers, among other business types, is the Bureau of Cannabis Control (BCC) — for which, between 2016 and 2018, the AIC prepared a Standardized Regulatory Impact Analysis (UC Agricultural Issues Center 2018). In the process, the AIC advised the BCC on the economic dimensions of various regulatory scenarios — and the bureau used the center's analysis to inform the final cannabis regulations that it issued on Jan. 16 of this year.

According to Sumner, a principal insight that the AIC furnished to the BCC was that, since illegal cannabis continues to be attractive to retail buyers because it is cheaper than cannabis from regulated (and taxed) retailers, "much of the cannabis sold in California [after legalization] would remain in the illegal segment." Moreover, regulations that generate benefits for consumers at lower costs will help sustain the legal marketplace.

In this issue of *California Agriculture*, three AIC researchers — Pablo Valdes-Donoso, a postdoctoral scholar; Robin S. Goldstein, principal economic counselor; and Sumner — present their research on California's rather stringent system for testing cannabis that enters the legal market (see page 154). All cannabis sold legally in the state is tested for more than 100 contaminants. Of those contaminants, 66 are pesticides — and tolerance for 21 of those pesticides is set at zero.

In many cases, allowable levels of cannabis contaminants are lower than those established for food sold in the state.

The researchers, drawing on data provided by testing laboratories and manufacturers of testing equipment, estimated how much it costs to test a pound of cannabis under California's regulatory regime, as well as the cost of collecting samples. They concluded that the need to destroy batches of cannabis that fail testing accounts for a large share of testing costs. The researchers argue that, though the availability of certifiably safe and legal cannabis products may prompt some customers to join the regulated market, other customers will remain in the cheaper illegal market. They speculate that, over time, increased availability of data about cannabis testing and sales will allow for greater certainty about the effect of the testing regime on cannabis prices and demand for legal cannabis.

Meanwhile, UC Davis is establishing a dedicated center for research into psychoactive cannabis and industrial hemp — the Cannabis Research Initiative. According to Cindy Kiel, executive associate vice chancellor for research administration at UC Davis, the initiative will draw on the comprehensive strengths of UC Davis faculty in areas ranging from agricultural and environmental impacts to legal, economic and policy outcomes to human and animal health. In particular, the initiative will benefit from UC Davis's strong emphasis on agricultural issues such as soils, water, genomics and plant science and from faculty interest in two-way interactions such as those between cannabis and the environment. Funding is envisioned to flow from the UC Davis budget, from research funds established in Proposition 64 and from outside sources such as industry partners. Funding could also flow from the federal government via the National Institutes of Health. The initiative will be headed by co-directors (not yet chosen) representing the agricultural and medical sides of cannabis research.

In May, UC Davis faculty members including Chemistry Professor Mark Mascal, along with colleagues from the University of Reading in the United Kingdom, published an article (Mascal et al. 2019) demonstrating that a synthetic analogue of cannabidiol (CBD, a nonpsychoactive component of cannabis) is as effective as CBD in controlling seizures in rats — and that it provides several benefits in comparison to CBD. The synthetic analogue is cheaper than herbal CBD, cannot be converted into psychoactive tetrahydrocannabinol (THC) and is not restricted by the Drug Enforcement Administration's "scheduling" apparatus. Meanwhile, the UC Davis–affiliated Western Center for Agricultural Health and Safety is studying issues such as workplace safety for cannabis workers, who face risks that include unhealthy pesticide exposure. For students, UC Davis has offered cannabis courses including the graduate-level *Cannabis sativa*: The Plant and Its Impact on People — and, for undergraduates, Physiology of Cannabis.

UC Merced

A brand-new entrant into UC cannabis research is the UC Nicotine and Cannabis Policy Center at UC Merced (NCPC), established just last year to study tobacco- and cannabis-related issues in public health and public policy, especially in the San Joaquin Valley. The center, partnering with local public health departments and organizations such as the American Heart Association, aims to produce tobacco and cannabis research that places special emphasis on the San Joaquin Valley's diverse population of teens and young adults and informs policy decisions that affect the region.

The center's flagship research initiative is a long-term, survey-based effort to understand issues surrounding cannabis, tobacco and e-cigarettes. The project is led by Bonnie Halpern-Felsher, a professor of pediatrics at Stanford University (and formerly a faculty member at UC San Francisco) and Mariaelena Gonzalez, assistant professor in public health at UC Merced. According to NCPC Director and UC Merced Associate Professor Anna Song, the researchers intend to provide data to counties that will allow them to make informed decisions about policy. Song notes that the counties in the study area are very different from, say, the Bay Area or Southern California, so state-level data isn't adequate for formulation of local tobacco and cannabis policy.

Song reports that the center's work will fill gaps in knowledge about cannabis intake behavior; epidemiological data is spotty, she says, because many people won't admit to engaging in behavior that has historically been illegal and continues to be federally illegal. The researchers are also keen to understand the interconnections between tobacco and cannabis — emerging data indicates that perceptions of tobacco risk are related to perceptions of cannabis, and the relationship between the two may affect individuals' future tobacco use. "These are the things we are trying to disentangle," Song says. (The center is conducting a parallel research project that focuses on American Indians in the same study area.)

The center was founded with a $3.8 million grant from the Tobacco-Related Disease Research Program, a state initiative administered by the UC Office of the President, which dispenses funds derived from the Tobacco Tax Increase Initiative, a proposition approved by California voters in 2016.


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UC San Diego

Cannabis institutes at three UC campuses in Southern California — UC San Diego, UC Irvine and UC Los Angeles — conduct research on the health effects and medical uses of cannabis and its derivatives. But they differ greatly in their approach. The program at UC San Diego focuses closely on medical cannabis research and public safety issues. The UC Irvine program brings together medicine and law. The UCLA program has set itself the ambitious interdisciplinary task of exploring how cannabis affects society along the medical, legal, economic and social dimensions.

The UC Center for Medicinal Cannabis Research (CMCR) at UC San Diego, the oldest of the three institutes, was established when California Senate Bill 847 (the Marijuana Research Act of 1999) enabled UC to establish a program to "enhance understanding of the efficacy and adverse effects of marijuana as a pharmacological agent." Today, the center's cannabis research covers a broad range of clinical conditions such as neuropathic pain, autism, bipolar disorder and early psychosis — as well as public safety issues surrounding the use of cannabis and cannabinoids.

Researchers at the UC Center for Medicinal Cannabis Research at UC San Diego are studying the effect of different dosages of THC on driving. Participants complete a full day of testing in a driving simulator after consuming THC in specified doses.

A notable current CMCR study, authorized by the 2015 Medical Marijuana Regulation and Safety Act, seeks to better understand the effect on driving of THC. CMCR Director Igor Grant describes the study as "one of the first in the United States that looks in great detail into different dosages of THC and their effect on driving." Each research day begins with study participants — already experienced with cannabis — entering driving simulators to undergo driving assessments. Participants then consume THC in specified doses and continue over the course of the day to undergo driving assessments. Meanwhile, their bodily fluids are drawn over the course of several hours. The study seeks to determine how multiple dosing strengths of cannabis affect driving and for what duration driving impairment continues after cannabis use. The research also seeks to determine if saliva or breath tests can substitute for blood samples in determining cannabis intoxication and if sobriety tests administered with iPads can supplement standard field sobriety tests. The study is led by Thomas Marcotte, a professor of psychiatry at the UCSD School of Medicine.

Another notable CMCR study, tentatively set to begin at the end of the summer, concerns autism. The research, which includes both a clinical trial and a basic science component, investigates the effect of CBD on severe autism spectrum disorder, a condition that affects one in every 68 U.S. children. In the clinical trial — overseen by Doris Trauner, a professor of neurosciences and pediatrics at UCSD — researchers will administer oral doses of CBD or a placebo to 30 children who have been diagnosed with moderate to severe autism. CBD interacts with the endocannabinoid system, a network in the human body that regulates various physiological and cognitive processes. Researchers will attempt to determine whether CBD is safe for the study population to use, whether it addresses their symptoms, whether it alters neurotransmitters or improves brain connectivity, and if so, how.

In the basic science component of the study, researchers will use cells from the skin and blood of participants and, in Grant's words, "re-engineer these cells to be neurons — to create little brain organoids, if you will." This feat of re-engineering will allow researchers to observe how the cells function and, if CBD has benefited the subjects of the clinical trial, to investigate the associated mechanism of action. The study will be conducted with funding from the Wholistic Research and Education Foundation.

Grant notes that Proposition 64 allocates $2 million annually to the CMCR. The center intends to use the funding partly to support its core facility and partly to fund small-scale pilot studies that might be conducted at the center itself, at other UC campuses or at campuses of other universities in California.

UC Irvine

A much newer entrant into medical cannabis research is UC Irvine's Center for the Study of Cannabis (CSC). As an interdisciplinary venture involving UC Irvine's School of Medicine and School of Law, the center includes basic medical science, clinical science and jurisprudence in its purview. Daniele Piomelli, director of the center — as well as a professor of anatomy and neurobiology at the UC Irvine School of Medicine — calls cannabis "a quintessential multidisciplinary problem." Because much existing cannabis law was

written when medical knowledge about cannabis was scarce, he says, new knowledge to underpin new legislation is urgently needed.

Piomelli further argues that because cannabis encompasses, for example, commercial and agricultural dimensions, researchers across disciplines must engage with each other (and with policymakers) to find realistic solutions to cannabis-related problems. "If medicine and science and law don't talk to one another," he says, "we'll never have sensible legislation." In that spirit, the center has two directors — Piomelli representing the medical side of the interdisciplinary undertaking and Robert Solomon, a clinical professor of law at UC Irvine School of Law, representing the legal side. About 30 faculty members across law and medicine are involved in the center's work.

The centerpiece of the CSC's work so far is an ongoing preclinical study called Impact of Cannabinoids Across the Lifespan. Piomelli, who directs the study while a team of UC Irvine principal investigators conducts the bulk of the research, characterizes it as a broad research project with many components, from which a stream of independent discoveries and publications is expected over the next 3 or 4 years. Piomelli reports that the study's main purpose is to study THC's effect on adolescents — and particularly on the adolescent brain. The human brain routinely produces neurotransmitters known as endocannabinoids — molecules, similar to cannabis derivatives, that are important in learning, memory and experiencing emotion. The key questions that the study addresses are these: Does exposure to THC, in a persistent way, change the brain's endocannabinoid system? If so, what changes at the cellular and molecular level explain the alterations? Does exposure to THC during adolescence carry lasting implications for learning and emotion? The study has received a $9 million Center of Excellence Grant from the National Institute on Drug Abuse.

UC Los Angeles

Another new entrant into cannabis research is the UCLA Cannabis Research Initiative, founded in 2017 with a broad remit — "to understand how cannabis affects bodies, brains and society." The initiative, encompassing an interdisciplinary team of 40 faculty members from 15 university departments, aims to function as an education, research and service organization that leads public discussions of cannabis, policy and health.

The initiative got its start in the months before Proposition 64 was approved by voters. According to Jeffrey Chen, the initiative's director, leadership at the Semel Institute for Neuroscience and Human Behavior (which partially funds the initiative) anticipated that legalization would soon create the world's largest market for recreational cannabis — and that California and particularly Los Angeles would "play an outsize role in establishing normative behaviors" around cannabis. Los Angeles, in Chen's view, has become the world's cannabis capital overnight. He and his colleagues hypothesize that, given the city's status as a major tourist destination and an exporter of culture, "what happens in Los Angeles is very likely to be transmitted around the world."

So far, Chen says, the initiative's research remains mainly oriented toward health-related issues. One study — soon to start, and led by Kate Wolitzky-Taylor, an assistant clinical professor in UCLA's Department of Psychiatry and Biobehavioral Sciences — seeks to develop and evaluate a behavioral treatment for young adults who exhibit cannabis use disorder and who use cannabis to cope with anxiety, depression and the like. Cannabis, according to the researchers, is the most commonly used drug among young adults, and it can be harmful when its use qualifies as a "maladaptive way" of contending with negative experiences.

Wolitzky-Taylor reports that the research project is a randomized clinical trial focusing on participants' reactions to the anxiety and depression that might lead them to use cannabis. The treatment, she says, will draw on strategies such as "mindfulness, cognitive reappraisal skills, problem solving and … gradual exposure to distressing but objectively safe stimuli." The treatment was developed in an iterative manner — an early version has already been tested with a small group of patients and further refinements may be made after the clinical trial is complete. The research is funded by a 3-year, $450,000 grant (in direct costs) from the National Institute on Drug Abuse. Individuals with cannabis use disorder, if they are 18 to 25 years old, are encouraged to email the project's coordinator, Nick Pistolesi (npistolesi@mednet.ucla.edu), regarding participation in the study.

A second example of the initiative's work is decidedly nonmedical. Brett Hollenbeck, an assistant professor of marketing at the UCLA Anderson School of Management, analyzed — along with Kosuke Uetake of Yale University — a large dataset of cannabis transactions in the state of Washington to learn about firm and consumer behavior in legal cannabis markets (Hollenbeck and Uetake 2018). Their goal was to provide policymakers, including in California, information useful for optimal development of cannabis taxation and regulation — optimal in the sense of maximizing tax revenues, safeguarding public health and discouraging a black market for cannabis.

Washington created a legal framework for growing and selling cannabis in 2012. Legal sales began there in 2014. Since then, every cannabis transaction in the state has been recorded in an administrative dataset. The researchers used the data to model consumer demand for cannabis products and measure price elasticity. Their

analysis, covering the period from November 2014 to September 2017, indicates that Washington's strict cap on cannabis retailers — some 550 are allowed in the entire state — has permitted retailers to command high prices and behave like local monopolies.

The researchers report that when prices for regulated cannabis rise in Washington, consumers often switch to cheaper cannabis alternatives available from regulated retailers, rather than seeking out black-market cannabis. Indeed, the researchers argue that Washington's 37% sales tax rate for cannabis, though it appears high, does not drive down tax revenue, and in fact the state could generate higher revenue by raising the tax rate to 40% or higher. Further, the researchers calculate that Washington could substantially increase its revenue if it acted as the state's sole cannabis retailer, as it did for alcohol sales until 2012, and could do so without causing an increase in cannabis prices.

UC Riverside

UC Riverside, though it has established no dedicated cannabis program, will soon host cannabis research for the first time. Nicholas DiPatrizio — a UC Riverside assistant professor in the School of Medicine's Division of Biomedical Sciences who is newly equipped with a DEA Schedule I license — is set to begin research investigating the effects of long-term cannabis use on metabolic diseases, including type 2 diabetes. DiPatrizio's lab, using technologies such as tandem mass spectrometry, will study how cannabis use affects glucose homeostasis (the stable equilibrium of glucose) in wild-type mice — and will also investigate whether long-term cannabis use is sometimes associated with positive health outcomes such as increases in high-density lipoproteins (often called good cholesterol).

DiPatrizio's research has received more than $700,000 in funding from the Tobacco-Related Disease Research Program, the same entity that provides funding for the UC Nicotine and Cannabis Policy Center at UC Merced. DiPatrizio reports that, though his research will not specifically investigate cannabis-to-bacco interactions, it is eligible for the program's funding because type 2 diabetes is a tobacco-related disease.

UC San Francisco

Returning now to Northern California, a team of UC San Francisco researchers led by Gregory Marcus — a professor of medicine at the UC San Francisco School of Medicine — recently published an article based on their research into the influence of cannabis legalization on health care utilization (Delling et al. 2019). The researchers, analyzing a medical-coding database that contained information on 16 million hospitalizations between 2010 and 2014, sought to determine if and how Colorado's 2012 cannabis legalization had changed health care utilization in the state (with data about Oklahoma and New York providing points of comparison).

The data revealed that, after legalization, motor vehicle accidents increased by 10% in Colorado, while rates of alcohol abuse and overdoses resulting in injury or death increased by 5%. (Marcus explains that the database's codes for overdose indicated that a patient had suffered an injury related to use of some drug — not that patients had overdosed on cannabis per se.) Diagnoses of chronic pain, however, decreased, and the overall result was that utilization of health care services remained level. In Marcus's view, his team's research demonstrates that the repercussions of public policy tend to be complex and nuanced. In particular, even if new legislation results in certain harmful health effects, it can prove beneficial to society in other ways. No one has yet attempted an analogous study in California — adult-use legalization is still very new in the state, and the availability of datasets tends to lag real-world events by several years. Marcus and his team, however, would be eager to take on the job.

— *Lucien Crowder*

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CalCannabis: Regulating a previously unregulated industry

An interview with Richard Parrott, Director of the California Department of Food and Agriculture's CalCannabis Cultivation Licensing Division

Richard Parrott

Richard Parrott directs CalCannabis, the state agency that licenses commercial cannabis farmers and oversees the California Cannabis Track-and-Trace system, which tracks all commercial cannabis and cannabis products — from cultivation to sale. He has served in state government for more than three decades, primarily at the State Board of Equalization — where he administered 30 tax and fee programs, including a program focused on alcoholic beverage taxes.

Could you please briefly explain what CalCannabis does?

Yes. CalCannabis Cultivation Licensing is a division within the California Department of Food and Agriculture. We license all cannabis cultivation for the state of California. We are also the agency responsible for leading the implementation of the statewide cannabis track-and-trace system.

We have two branches within our division. Our licensing branch is responsible for issuing and renewing licenses for all the cultivators in California. Our compliance and enforcement branch contains the team that implements track-and-trace and also our field staff — special investigators who go to licensed sites and perform inspections to make sure farmers are complying with all state rules. They are limited peace officers — they have powers of arrest and the ability to obtain search warrants, but they are not armed. At CalCannabis we work very closely with our partner agencies out in the field, such as the California Department of Fish and Wildlife, the State Water Resources Control Board, the Bureau of Cannabis Control and state law enforcement.

Since CalCannabis focuses mainly on cultivation, how does it work institutionally for you to track and trace cannabis all the way to the point of retail sale?

Although we're the agency responsible for leading the implementation of the track-and-trace system, there are three state agencies that license cannabis businesses in California: the California Department of Food and Agriculture for cultivation; the California Department of Public Health for manufacturers of products such as edibles; and the Bureau of Cannabis Control for testing labs, retailers, distributors, temporary cannabis events and microbusinesses (a microbusiness licensee is allowed to engage in at least three smaller-scale commercial cannabis activities at once, such as cultivation, manufacturing, distribution and/or retail). We've worked very closely with our partner agencies on the implementation of track-and-trace. We have been meeting with teams from those agencies since 2016 to make sure all of the agencies' requirements are captured within the track-and-trace system. Every licensee is required to use the track-and-trace system. Cultivators affix identification tags to their plants and, as they harvest those plants and package flower, the packages will have identification tags. As products go to manufacturers who perform extraction processes, the extracted product will go into containers that have tags. Essentially the concept of the track-and-trace system is that all products are tagged from cultivation until they work their way through to retail. Every time the product changes hands, every time it moves from one licensee to another, or changes its composition, everything is tracked and accounted for.

But how is enforcement of track-and-trace handled? Who in particular makes sure that people all through the system comply with the tagging and reporting requirements?

We work with the Bureau of Cannabis Control and the California Department of Public Health to ensure everyone is trained and knows what's in the system. When the three agencies go out and do inspections — for example, when we at CalCannabis inspect a cultivation site — we look at the system and it tells us how many plants that cultivator has tagged, and we'll verify that. Each agency has its own compliance and enforcement team. Everyone uses track-and-trace as a component of their inspections. It's basically a tool for us to determine compliance. It's not the only thing we use, but it's definitely a tool that helps us gauge whether a licensee is doing things correctly.

Now, medicinal and adult-use cannabis are legal in California, but still illegal under federal law. What challenges do you encounter in overseeing the cultivation of a crop with an ambiguous legal status?

Certainly there are challenges. Prior to this position, I worked for 30 years for the California Department

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of Tax and Fee Administration, and oversaw a lot of tax and fee programs where there was a coordinated state and federal system. For example, I worked for the Board of Equalization on their alcoholic beverage tax program. There was a very coordinated sync-up between state and federal regulations for alcohol and for reporting tax collection at the federal level and the state level — and you could always look to federal guidelines or regulations. We're not able to do that here. It's just not as smooth. I could give you a couple of examples — one of them is banking. Cultivators pay license fees to us, but those who can't engage in banking [because of federal restrictions] have to pay their fees in cash. We have arrangements so they can make cash payments in Sacramento or Eureka. We have a contract with the Bureau of Cannabis Control so our applicants can make an appointment with the Bureau in Sacramento and pay cash. Or, if they're in a northern county, we have an office in Eureka.

Another example is pesticides. Pesticide labels have to be approved at the federal level. [Because cannabis is illegal at the federal level], no pesticides are approved for use on cannabis. The Bureau of Cannabis Control has regulations on the amount of a [particular] pesticide that would trigger a [cannabis] product to fail testing, and we work very closely with the California Department of Pesticide Regulation, and with county agricultural commissioners, on which pesticides can be used. But if you had a coordinated federal system, it would be very clear which pesticides could be used. You would have the federal Environmental Protection Agency saying, "These are okay. These are legal for use."

Growers sometimes complain that the burdens of achieving compliance with cannabis regulations are very high. Then again, I've heard the argument that cannabis regulations are actually less onerous than forestry regulations. What's your response to the growers' viewpoint, as well as to this alternative viewpoint?

There are always different viewpoints. And although cannabis cultivation has been happening for a very long time in California, state and local regulation is new for the industry. The existing industry has been used to doing things a certain way. And then you go from zero regulation to all kinds of regulation, almost overnight. So there are understandably a lot of growing pains, as there will be with any new program. I always stress that we see this as a partnership with the industry. We did a lot of stakeholder outreach across the state as we developed the regulations. Certain procedures were mandated by statute, and we created others through our regulatory process. We carefully considered all public input and, where we could make changes along the way, we have. And we're going to continue to engage with the industry.

We also have two new programs on the horizon. One is a comparable-to-organic program for cannabis, called OCal, and we are creating a process for cultivators to establish appellations for cannabis, called the CalCannabis Appellations Project. Those programs are mandated by law and must be in place by January 1, 2021.

Why "comparable-to-organic" instead of just "organic"?

Interesting you say that. I can point you back to the [previous] question on the conflict [between federal and state cannabis law]. Under the U.S. Department of Agriculture (USDA) is the National Organic Program. The state laws that were passed for legalization of both medicinal and adult-use cannabis say that the state will create an organic program for cannabis that's comparable to the National Organic Program — and the reason we call it "comparable" instead of "organic" is because the term "organic" is basically owned by the USDA and the National Organic Program. So, while we will follow the same path that's being used [at the federal level], meaning the same guidelines, we just can't call it "organic" until or unless there is a sync-up between federal and state laws.

I'm told by some enthusiasts of sun-grown cannabis that it's allowed in relatively few California localities — but indoor cultivation, on the other hand, requires a lot of electricity, which sun-grown cannabis growers will tell you conflicts with the state's climate goals. Does CalCannabis have a position on this one way or another? And if you favor sun-grown cannabis, what can you do to encourage it, if anything?

As a regulatory agency, we don't take a position on or favor any particular part of the industry. Our goal is to have regulations that we apply consistently across the licensee base. We prepared an environmental impact report as we were creating the regulations for our program, and our regulations incorporate greenhouse-gas emission reduction standards that go into effect in 2022. Also, you may not know that we offer 17 types of commercial cannabis cultivation licenses. They are categorized primarily by size and the type of growing process — indoor, outdoor or mixed light.

A serious obstacle to getting full compliance among growers in California is that so much California cannabis goes out of state to places where it's illegal — illegal at the federal level in every state, and illegal on the state level in most states. That's a hard problem. How do you begin to address it?

Good question. Difficult issue. Ideally, it would be accomplished at the federal level. And until then, we're working hard every day to bring people into the regulated market. We're issuing licenses every day and we're processing applications every day. And when we're aware of people who aren't getting into the [regulated] market and are creating an unfair marketplace, we work as diligently as we can with our partner agencies to address those issues. It's not going to happen overnight. [As we continue issuing licenses,] we are ramping up and filling all our field enforcement positions so we will have staff located statewide to conduct inspections at licensed sites and work with our partner agencies on addressing [unlicensed cultivation]. We also work to ensure that, if a site is licensed, [other agencies] are aware of that. We're here to protect the people who are licensed, and part of that protection is addressing those who aren't licensed, because that creates an unfair marketplace. And by licensing and regulating commercial cannabis farmers in California, we're also ensuring public safety and environmental protection. CA

For more information about CalCannabis Cultivation Licensing, a division of the California Department of Food and Agriculture, visit calcannabis.cdfa.ca.gov.

Science and law enforcement teaming up to help "critters"

An interview with Scott Bauer, Senior Environmental Scientist, California Department of Fish and Wildlife

Scott Bauer

California's legal cannabis market is regulated by a suite of state agencies that follow the plant on its journey from cultivation site to manufacturing facility to ultimate point of sale. But a special role is played by three Watershed Enforcement Teams — which, operating within the California Department of Fish and Wildlife (CDFW), work in cannabis-growing regions to protect native plant and wildlife species from practices such as illegal stream diversions, habitat destruction and illegal use of pesticides. Scott Bauer, a senior environmental scientist with the CDFW, works on one of these teams.

How would you describe a typical day's work as a member of a Watershed Enforcement Team?

The Watershed Enforcement Team focuses on cannabis-related violations of the Fish and Game Code — for example, people illegally diverting water from streams or lakes, or causing dirt to enter the stream. We focus on both compliant and noncompliant cannabis sites, but mainly black-market cultivation sites. We have three teams across the state, and our goal is to protect the environment.

Each team is composed of scientists and wildlife officers. Our scientists spend a lot of time looking at watersheds with cannabis cultivation and deciding how we should focus our efforts — how to get a game plan ready for subsequent enforcement. We look at watersheds that have a lot of sensitive natural resources, such as salmon and steelhead, or Northern spotted owls. We have experience in a big variety of biological and physical sciences. Depending on the site we're going to, we [might] need a geologist or an aquatic toxicologist or what have you. My team operates in Humboldt, Del Norte and Trinity counties — basically, the Emerald Triangle — and I have a herpetologist, a hydrologist, a wildlife management person and a natural resource management person.

A lot of us have been involved in this issue for years and have been to hundreds of sites. We know what to look for, where the violations will occur and what the impacts are. We've all been trained in environmental impact assessment. We use those backgrounds to help develop strong cases, to figure out how to remediate sites and do restoration of sites. When it comes to actual enforcement, we document violations and write reports, which hopefully causes people to get into compliance. Or, if it's a black-market site, we write environmental documents to help support the court case when needed. We [scientists] document the environmental crimes. The law enforcement [people] do the cases.

Would you say the environmental problems associated with unlicensed cannabis cultivation, such as illegal water diversions and irresponsible use of pesticides, are getting better or worse in the Proposition 64 era?

Well, it's a good question. There are thousands of people applying for licenses around the state, and that's a great thing. People are coming into compliance. [Compared to] when we started this enforcement team 4 or 5 years ago, it's a different world. The majority of the people [at that time] were not in the system, not actively pursuing a legitimate site.

It's so fluid right now. We still have black-market sites, and they're still abundant, and we've been to a few sites in the past year where we [found] a banned pesticide, carbofuran, which we hadn't seen before on private-land cultivation sites. We still go out and find really egregious sites. I think our team alone did 150 enforcement actions last year, so there's plenty of work

California Department of Fish and Wildlife

Fuel and trash next to a stream at a noncompliant cannabis cultivation site.

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A Western screech owl trapped in netting at a noncompliant cannabis cultivation site.

to do. It seems like the sites that we visit on enforcement actions still have violations — that's not changing. But I would say it's getting better, because more people are entering the system and getting permits. The trend is definitely better.

Growers becoming compliant is one force, but another possible force is more people growing cannabis — the "green rush" phenomenon. In your view, which is going faster? Are people coming into compliance faster than the overall rate of cannabis cultivation is growing?

I think that's a fair assumption — though we haven't done a deep analysis of that, and maybe the total acreage is still increasing across the state because we have other counties, besides the Emerald Triangle, entering the system. There are counties like Santa Barbara, with a huge, thriving cultivation scene that has added to the [overall] amount [of cultivation]. But in Humboldt County, we're seeing people leaving the system. They're done with cultivation. They've sent in their notices to the county to withdraw their applications. So what's the balance right now between Santa Barbara, with a bunch of new greenhouses, and Humboldt County, where people are leaving? It's safe to say that supply exceeds demand. That extra supply leaves the state through the black market. But I don't think, in general, there is a giant increase in cultivation across the state.

My impression, and it's nothing but an impression, is that law enforcement shows up at relatively few illegal cultivation sites. Who decides which sites get busted? How big a role does evidence of environmental harm play in those decisions?

What drives actions with all of our teams is a focus on natural resource impacts. That's our mission — to protect public trust resources for the state of California and its citizens — so we focus on where those impacts are. It's different in different places. In Humboldt, Trinity and Mendocino, we've got salmon and steelhead populations that we are trying to recover and protect. Protecting those species has been a big focus. But if you go down south, in the San Joaquin, it's a little different. You've got endangered critters like kangaroo rat and Mohave ground squirrels that are affected by cultivation in the desert. The focus in the south may be these endangered terrestrial animals whereas, up north, it's more aquatic — though we still look at issues around Northern spotted owl and the [Pacific] fisher. We're trying to focus our enforcement efforts on important areas that will conserve sensitive species, and every year we're more efficient. People tend to think we don't get to much. But, partnering with local law enforcement and others, we've been pretty effective. I think we've been doing a good job of protecting our sensitive plants and animals and fish.

What do you think is most likely to mitigate the environmental harms that are associated with illegal cannabis cultivation — more enforcement, bringing more growers into the legal market or something else I'm not thinking of?

I think it's a combination of all that. Getting people permitted, and abiding by the rules that are meant to protect our water quality and our native wildlife, is super important. But if you don't have an enforcement component, people tend to not follow the rules. You have to have both. I think we're achieving a good balance of that. We're permitting hundreds of sites and we're also doing enforcement. There's a balance there and I don't think either is more important than the other.

Are you optimistic that over the medium term — the next 5 or 10 years — that this issue of environmentally harmful cannabis cultivation sites can be brought well under control?

Absolutely. I really am. I'm hopeful that, in 5 years, it will be a much better situation. CA

CONVERSATION

"Like every other industry" — An on-the-ground perspective on Proposition 64

An interview with Amanda Reiman, Vice President of Community Relations, Flow Kana

Amanda Reiman

Amanda Reiman is vice president of Community Relations at Flow Kana, a cannabis distribution company that operates in California's "Emerald Triangle" (Humboldt, Mendocino and Trinity counties). Additionally, Reiman sits on the boards of the California Cannabis Tourism Association and The Initiative (an incubator for women-owned cannabis businesses). Reiman was until recently secretary of the International Cannabis Farmers Association, and has previously been director of Research and Patient Services at Berkeley Patients Group and manager of marijuana Law and Policy for the Drug Policy Alliance.

How would you assess the landscape for cannabis growers in California — in terms of legislation, regulations, taxation and so on — compared to what might have been hoped when Proposition 64 passed?

Proposition 64 was really focused on the criminal justice aspects of cannabis prohibition — on [addressing] the negative impact of criminalization, primarily on people of color. It also focused on what happens to consumer safety and protection in the absence of regulation. It didn't really prescribe regulation for the commercial sale of cannabis. The Legislature had already come up with a framework for regulating medical cannabis prior to Proposition 64 passing, and we didn't have any reason to think that [the Legislature's framework] would change drastically just because the criminal code had changed. We were right.

California regulates cannabis with a strong hand and high taxes. You have to interface with a lot of agencies to be compliant. Those agencies are often overburdened and understaffed. Cannabis farmers and the cannabis industry in general have to navigate the same pitfalls that we see [elsewhere] in the California regulatory landscape. But when you add in [the cannabis industry's] lack of access to banking, and [its] inability to transfer product across state lines — it makes it even more difficult for folks involved in this industry.

When you look at the legal, regulatory and tax regime in California, what single change would you identify as most important for bringing cannabis growers into the legal market?

I would probably say rethinking our tax structure. In the current regulatory environment, taxes are assessed at a flat rate for each pound of cannabis flower and trim that's sold to a distributor. What we'd really like to see is cannabis [taxed the way] they currently tax alcohol, based on production level. If you are an alcohol producer, you get quite a substantial tax break up until a certain amount that you produce. That way, smaller players pay less taxes and their work is actually subsidized by the folks that are making a lot more product and are able to keep costs down. I think that the state is a little reluctant to look at the tax structure, primarily because — and rightfully so — they have something to prove in terms of tax revenue. To start messing with the tax structure now, before they feel they've really proven that they can make the revenue — they're very reluctant to [do] that. But moving forward, the smaller producers will always need that extra support.

Could you identify one aspect of bringing cannabis cultivators into the legal structure that hasn't gone as well so far as might have been hoped?

An overarching issue is the tendency of localities to move toward indoor cultivation. We only have about 17 localities in the state — counties or cities — that allow sungrown cultivation [cultivation without

Only a limited number of California localities allow cannabis cultivation without supplemental light.

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Proposition 64 has profoundly altered the cannabis industry in the Emerald Triangle — Humboldt, Mendocino and Trinity counties — and across the state.

supplemental light]. We're not doing enough to educate localities and regulators about the energy impacts of high-intensity lighting, or [the drawbacks] of setting up systems where the only way you can cultivate cannabis commercially is through very energy-intensive methods — which go very much against California's goals [for reducing] carbon emissions. I think the California Department of Food and Agriculture could talk more about sustainable cultivation — about implementing [incentive programs similar to those developed for] other industries — so that, from the get-go, we're establishing sustainable systems, rather than going back 10 or 15 years later to do a greening of the cannabis industry.

Would you say compliant growers, and those on their way to becoming compliant, generally support stepped-up enforcement against outlaw growers — the ones who dewater streams and use noxious pesticides and that sort of thing?

If I had to rank the type of cultivator that licensed cultivators are okay seeing law enforcement go after, number one would be people that are doing environmental degradation on public land. Folks in the forest or the national park who are harming the environment — I would say that almost no one would ever disagree [with enforcement against them]. The attitude changes when we talk about people on private land. Because even though nobody wants folks to be diverting from streams, there is a sense that "It's their land," and maybe they're *trying* to do better. That's part of the culture up here [in the Emerald Triangle]. A lot of folks came up here to buy big pieces of land [partly because] they wanted privacy, and to be themselves on their land. No one wants to see environmental degradation, but when it comes to private land, they may say "Is there a way you can go in and try to help [noncompliant growers] before law enforcement comes in? Can you go and give them a warning?"

In terms of people on private land who are not harming the environment, there is a strong belief that law enforcement should not be involved. Maybe these individuals want to become compliant but can't afford to become compliant. So instead of law enforcement prioritizing them, we should instead offer support and say, "What can we do to support you in transitioning to the regulated market?" It's not an all-or-nothing thing. There are definitely people cultivating without a license who are way more egregious than others.

I've heard people in the cannabis industry say that they just want to be treated like any other industry. Do you think that's a realistic hope in California over, say, the next decade or so?

Over the next decade, I do. I think that there are probably two main components that have to happen before we can start thinking about cannabis like other industries — one, of course, being banking. We cannot be treated like any other industry when we cannot bank. Until banking is allowed and we can get small business loans, we will not be like any other industry. The second thing is being able to ship across state lines. You can't ship wine to every state, but you can ship it to most states, and the ability of states like California and Oregon, or California and Washington, to enter into an agreement so cannabis can flow across the borders — that's another way that we will be able to be treated like every other industry. Until then, you have to cap production [at the level] your state can consume. Do we say, "Florida, you can only grow so many oranges because [your oranges] all have to stay in Florida?" That doesn't make sense. I'm hoping that both [banking and interstate shipments] will happen in the next 10 years. I think banking will happen *this* year — the SAFE Banking Act [a cannabis banking bill] was introduced in Congress this year with over 100 sponsors from both sides of the aisle.

If you bring people into the banking system, there isn't so much suspicious cash floating around unaccounted for — right?

Absolutely. That's why we don't we don't understand why we haven't gotten it already. If they really want to keep tabs on us, banking is the best way to do it. It also makes business safer and more stable for everyone involved. CA

RESEARCH ARTICLE

First known survey of cannabis production practices in California

Most growers in this survey produced their crop outdoors or in greenhouses, relied primarily on groundwater, used biologically based inputs for pest management and employed seasonal workers paid at fixed piece rates.

by Houston Wilson, Hekia Bodwitch, Jennifer Carah, Kent Daane, Christy Getz, Theodore E. Grantham and Van Butsic

Abstract

Legalization of cannabis production has daylighted a unique and highly valuable crop in California agriculture. State and regulatory agencies must now address the ecological, social and agricultural effects of cannabis production, but little is known about how growers produce this crop. Using an online survey, we gathered information from growers in July 2018 on their production practices. According to responses from about 100 growers, most cannabis was produced outdoors or in greenhouses, relied primarily on groundwater and used biologically based inputs for pest management. Many farms employed seasonal workers paid at fixed piece rates. Regulatory compliance varied according to farm size. Beginning to document growing practices will help scientists formulate key environmental, social and agronomic questions and develop relevant research and extension programs to promote best management practices and minimize negative environmental impacts of production.

Legalization of cannabis production in 2017 has generated demands for state regulatory, research and extension agencies, including UC, to address the ecological, social and agricultural aspects of this crop, which has an estimated retail value of over $10 billion (UC AIC 2017). Despite its enormous value and importance to California's agricultural economy, remarkably little is known about how the crop is cultivated.

While general information exists on cannabis cultivation, such as plant density, growing conditions, and nutrient, pest and disease management (Rosenthal 2010), only a few studies have attempted to measure or characterize some more specific aspects of cannabis production, such as yield per plant and regional changes in total production area (Bouchard 2009; Butsic and Brenner 2016; Potter et al. 2013, 2015; Toonen et al. 2006). These data represent only a very small fraction of domestic or global activity and are likely skewed since they were largely derived not from field studies but indirectly from police seizure data (e.g., Toonen et al. 2006) or aerial imagery (e.g., Butsic and Brenner 2016). In California, where approximately 66% of U.S. marijuana is grown (NDIC 2009), knowledge of the specific practices across the wide range of conditions under which it is produced is almost nonexistent.

Currently, 30 U.S. states have legalized cannabis production, sales and/or use, but strict regulations remain in place at the federal level, where it is classified as a Schedule I controlled substance. As a land-grant institution, UC receives federal support; were UC to engage in work that directly supports or enhances marijuana production or profitability, it would be in

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Most of the cannabis growers who responded to a 2018 survey conducted by UC researchers reported growing their crop outdoors or in greenhouses, such as the hoop house shown here.

Hekia Bodwitch

violation of federal law and risk losing federal support. As a result, UC research on California cannabis production has been limited and focused on the geography of production and its environmental impacts (Butsic and Brenner 2016; Carah et al. 2015; Levy 2014). These studies have documented the negative effects of production on waterways, natural habitats and wildlife. While such effects are not unique to cannabis agriculture per se, they do present a significant threat to environmental quality and sensitive species in the watersheds where cannabis is grown (Butsic et al. 2018). Science-based best management practices to mitigate or avoid impacts (which exist for most other crops) have not been developed for cannabis. Because information on cannabis production practices is so limited, it is currently not possible to identify key points of intervention to address the potential negative impacts of production.

As a first step toward understanding cannabis production practices, we developed a statewide survey on cultivation techniques, pest and disease management, water use, labor and regulatory compliance. The objective was to provide a starting point from which UC scientists could build research and extension programs that promote best management practices — which are allowable as long as their intended purpose is not to improve yields, quality or profitability. Survey results also establish a baseline for documenting changes in cultivation practices over time as legal cannabis production evolves in California.

Cannabis production survey

To characterize key aspects of cannabis production in California, we developed an anonymous online survey using Qualtrics survey software (Qualtrics, Provo, UT). A web-based survey that masked participants' identity was determined to be the most suitable approach given that in-person interviews were limited by legal restrictions on UC researchers visiting cannabis farms, and mail or telephone surveys were constrained by the lack of any readily available mailing address or telephone contact information for most cannabis growers, who are understandably discrete with this information. An online survey was also the most cost-effective means of reaching a large number of cannabis growers.

Survey questions focused on operational features (i.e., farm size and cultivation strategies, including outdoor, indoor and greenhouse cultivation), pest and water management, labor, farm revenue and grower demographics. Two draft surveys were reviewed by a subset of cannabis growers to improve the relevance of the questions and terminology. A consistent critique was that the survey was too long and asked for too much detail, taking up to 2 hours to complete, and that such a large time commitment would significantly reduce the response. We therefore made the survey more concise by eliminating or rephrasing many detailed questions across various aspects of cannabis production.

The final survey included 37 questions: 12 open-ended and 25 structured (http://ucanr.edu/sites/cannabis/). Structured questions presented either a list of answer choices or a text box to fill in with a number. Each list of answer choices included an "Other" option with a box for growers to enter text. Open-ended questions had a text entry box with no character limit.

Condensing the survey to capture more respondents resulted in less detailed data, but the overall nature of the survey remained the same — a survey to broadly characterize multiple aspects of cannabis production in California. Data from the survey has supported and contextualized research by other scientists on specific aspects of cannabis production, such as water use (Dillis et al. 2019, this issue), permitting (Bodwitch et al. 2019 and Schwab et al. 2019, this issue), law enforcement (Polson et al. 2019, this issue), testing requirements (Valdes-Donoso et al. 2019, this issue), crop prices (Goldstein et al., unpublished data) and perceptions of cannabis cultivation in the broader community (LaChance 2019 and Valachovic et al. 2019, this issue).

Recruitment of survey participants leveraged networks of California cannabis growers who had organized themselves for various economic and political purposes (see table 1). These were a combination of county, regional and large statewide organizations, with many growers affiliating with multiple groups. We identified the organizations through online searches and social media and sent recruitment emails to their membership list-serves. The emails contained an

TABLE 1. California cannabis grower organizations contacted to recruit survey participants

Region	Organization
Statewide	California Cannabis Industry Association
	California Growers Association
	Flow Kana
	International Cannabis Farmers Association
Central Coast	Coastal Growers Association
North Coast	Emerald Grown Co-op
	Humboldt's Finest
	Humboldt Sun Growers Guild
	Lake County Cannabis Growers Alliance
	Sonoma County Growers Alliance
	True Humboldt
Sierra Foothills	Inland Cannabis Farmers Association
	Nevada County Cannabis Alliance
	Plumas County Growers Coalition
Southern California	Cultivators Alliance

explanation of the survey goals, a link to the survey website and a message from the grower organization that endorsed the survey and encouraged members to participate.

The emails were sent in July 2018 to approximately 17,500 email addresses, although not all members of these organizations necessarily cultivated cannabis, and the organizations noted that their mailing lists somewhat overlapped the lists of other groups that we contacted. For these reasons, the survey population was certainly less than 17,500 individual cannabis growers, but because we were not able to view mailing lists nor contact growers directly, and because there are no comprehensive surveys of the number of cannabis farms in California, we could not calculate a response rate or evaluate the representativeness of the sample. Respondents were given until Aug. 15, 2018, to complete the survey. All survey participants remained anonymous, and response data did not include any specific participant identifiers.

Survey responses

In total, 101 surveys were either partially or fully completed. Responses to open-ended questions were coded before summary. Since incomplete surveys were included in this summary, the number of responses varied between questions. Each response was considered a unique grower and farm operation. As noted, survey response rate was difficult to quantify, and participants were self-selecting, which introduces bias. The survey data should be taken only as a starting point to guide more detailed evaluations of specific practices in the future, not as a basis for developing recommendations for production practices or policies.

Farm location, size, prior land use

Survey respondents (n = 58) operated farms primarily in Humboldt (24%), Mendocino (20%) and Nevada (11%) counties, but survey responses also came from Trinity (6%), Santa Cruz (4%), Sonoma (4%), San Luis Obispo (2%), Sacramento (2%), Butte (1%), Calaveras (1%), Fresno (1%), Los Angeles (1%), San Diego (1%), San Mateo (1%) and Siskiyou (1%) counties and Josephine County, Oregon (1%).

In line with California regulatory guidelines, small farms were defined as those of 10,000 sq ft or less, medium farms 10,001 to 22,000 sq ft and large farms 22,001 sq ft or more. Accordingly, 74% of farms were small, 16% were medium and 8% were large (n = 61). For those growers who reported on their land use in 2013 (n = 58), most (78%) farmed on land that was previously used entirely or in part for cannabis production (47% cannabis only; 31% mixed cannabis and other uses). The other 22% indicated that the land was used in 2013 for agricultural crops, ranching, open space or "other" land uses.

Cultivation techniques

For this survey, we differentiated between outdoor (open air, sunlight), greenhouse (partial or full sunlight) and indoor farming (artificial light). The most common ways to farm were all outdoors (41%), combined outdoor and greenhouse (25%) and greenhouse only (10%). This was followed by various combinations of greenhouse and indoor (5%), greenhouse and other (5%), outdoor and other (5%), outdoor and indoor (3%), all indoor (3%) and other (3%) (n = 63).

When measured by total plants, farms with combined outdoor and greenhouse facilities were responsible for 41% of crop production, followed by outdoor and other (38%), greenhouse only (7%), outdoor only (5%), greenhouse and other (4%), outdoor and indoor (3%), greenhouse and indoor (2%) and other (1%). A majority of survey respondents grew their cannabis crop in raised beds (59%), native soil (49%) and/or grow bags (41%), followed by hydroponic systems (10%) and plastic pots (5%) (n = 55).

The average number of plants grown in outdoor farms was 166 (range 1 to 1,000, n = 47), in greenhouses, 582 (range 2 to 6,000, n = 26) and indoors, 383 (range 22 to 2,000, n = 7). When adjusted for total cropping area, this equates to 0.05 plant per sq ft for outdoor cultivation (range < 0.01 to 0.39 plant per sq ft, n = 41), 0.13 plant per sq ft for greenhouse cultivation (range 0.01 to 0.50 plant per sq ft, n = 25) and 0.64 plant per sq ft for indoor cultivation (range 0.06 to 2 plants per sq ft, n = 7).

Growing season, harvests, yields

The average growing season for outdoor growers was 190 days (range 122 to 334 days, n = 18) and for greenhouse growers 158 days (range 107 to 245 days, n = 8). Only one indoor grower provided information on growing season, indicating that the operation was farming 365 days a year.

Among outdoor growers, 93% produced a single annual cannabis crop, with the others reporting two or three harvests per year (n = 46). Among greenhouse growers (n = 27), only 48% reported a single annual harvest; the others reported two (33%), three (7%) and up to four to nine harvests per year (12%). Indoor growers almost always reported multiple annual harvests: 14% reported two harvests, 57% reported four harvests and 29% reported six harvests per year (n = 7).

Average yield was 1.08 lb per plant (range 0.02 to 10 lb per plant, n = 46), but yields varied by growing conditions: outdoor crops averaged 2.51 lb per plant (range 0.02 to 10 lb per plant, n = 46), greenhouse crops, 0.60 lb per plant (range 0.15 to 1.23 lb per plant, n = 26) and indoor plants, 0.20 lb per plant (range 0.06 to 0.40 lb per plant, n = 7). Adjusted for cropping area and plant density, average yields were 0.10 lb per sq ft for outdoor cultivation (range < 0.01 to 1 lb per sq ft, n = 40), 0.04 lb per sq ft for greenhouse cultivation (range < 0.01 to 0.12

lb per sq ft, n = 25) and 0.16 lb per sq ft for indoor cultivation (range 0.01 to 0.80 lb per sq ft, n = 7).

While outdoor production had the highest yield per plant harvested, indoor production generated higher overall yields per square foot harvested due to a shorter growing cycle and higher planting density, which allowed for multiple harvests from a greater number of plants.

Crop prices, revenues

In fall 2017, the average cannabis sales price was $853 per lb for flowers (range $200 to $1,900 per lb, n = 37) and $78 per lb for trim (range $20 to $200 per lb, n = 18). While most growers received $500 to $1,100 per lb (fig. 1), small growers received more variable sales prices (fig. 2), from $200 to $1,900/lb ($n$ = 34), which is likely the result of more diverse market relationships in this sector.

Income from cannabis varied: 34% of growers obtained 80% to 100% of their annual gross income from cannabis, while 33% reported no income from cannabis at all and the remaining 33% fell somewhere in the middle (n = 36). Of those growers who obtained 80% to 100% of their annual gross income from cannabis, 58% operated small farms, 17% medium farms and 25% large farms. Those who reported no income from cannabis all operated small farms.

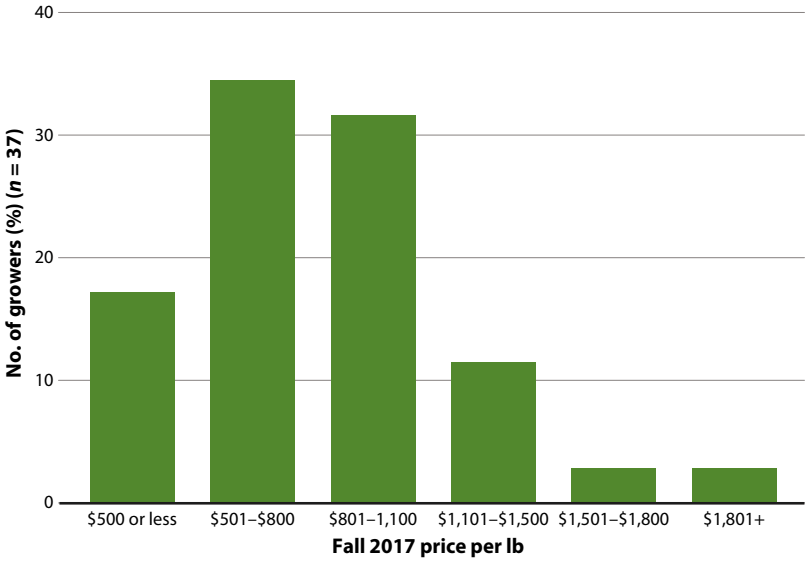


FIG. 1. Growers reported fall 2017 cannabis prices ranging from less than $500 per lb to over $1,801 per lb.

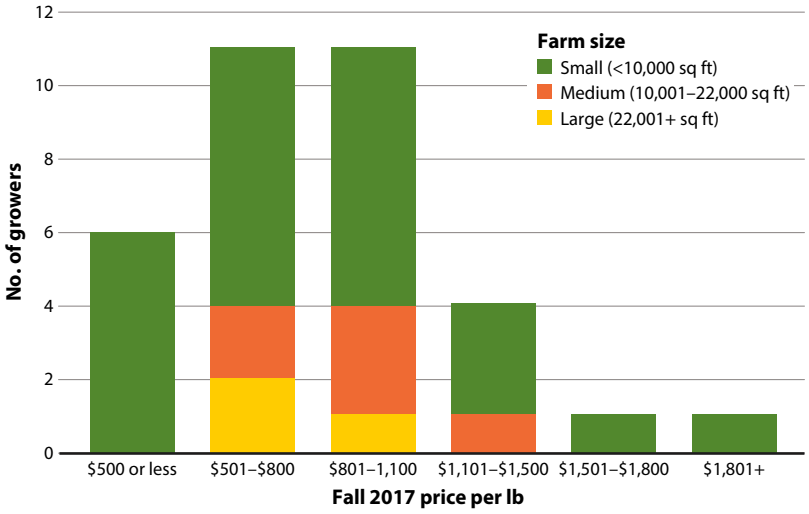


FIG. 2. Small growers experienced most cannabis price variability.

Grower demographics

Respondents' (n = 32) ages ranged from 34 to 72. The mean age was 54, and the median age was 59. Of those reporting (n = 35), 69% identified as male, 29% identified as female and 3% as other. Most growers reporting held a bachelor's degree or equivalent (59%), 11% a master's degree, 40% attended some college and 1% attended some school (n = 35). A majority reported household incomes of $50,000 to $99,999 (52%), followed by $20,000 to $49,999 (24%), $100,000 to $199,999 (10%), over $200,000 (10%) and less than $19,999 (4%) ($n$ = 29). Those who reported marital status (n = 35) mostly indicated that they were married or living with a partner (68%); 34% reported being single.

Survey respondents reported farming cannabis on average for 15 years (range 1 to 50 years, n = 84). The breakdown was as follows: 0 to 4 years (24%), 5 to 9 years (15%), 10 to 19 years (32%), 20 to 29 years (15%) and > 30 years (14%). Most growers operated only one farm (73%), 16% had two farms, 4% had three farms, 6% had four farms and 1% had five farms (n = 77).

Water sources, storage, use

Most growers reported groundwater as their primary water source for irrigation (n = 28) (fig. 3A), with some growers reporting use of multiple water sources. Those using groundwater extracted 87% of annual volume between June and October. Of those storing water, most stored exclusively well or spring water, though some stored municipal water or rainwater (n = 16) (fig. 3B). Extraction to storage was greatest in summer but was relatively well distributed throughout the year.

Many growers reported that adding storage was either cost prohibitive or limited by regulatory constraints. Half the respondents indicated that additional storage was not needed, 40% indicated that the high costs of building storage were limiting, and 5% reported there was insufficient water available and 5% that they were unable to obtain permits to store (n = 40).

Most growers reported using variable amounts of water across the growing season. Outdoor growers applied, on average, 5.5 gal per day per plant (0.22 gal per sq ft per day) in August and 5.1 gal per day per plant (0.17 gal per sq ft per day) in September. Greenhouse

growers applied an average of 2.5 gal per day per plant (0.18 gal per sq ft per day) in August and 2.8 gal per day per plant (0.22 gal per sq ft per day) in September (fig. 4A and 4B). When standardized by area, application rates were very similar between cultivation types (fig. 4B).

In our survey, growers reported using low maximum pumping rates (n = 15): 53% indicated rates ranging 1 to 50 gal per minute, 7% did not know their pumping rate and the remaining 40%, who used groundwater or municipal water sources, indicated that this question did not apply to them.

Nutrition, fertility

Growers reported (n = 55) using more than 30 different soil amendments and foliar nutrient sprays (fig. 5). The most commonly reported was organic fertilizer (35%), followed by various animal manures (33%) and meals (33%), compost tea (27%) and worm castings (24%).

Pests and diseases

Growers experienced a wide range of crop damage (n = 63). The most frequently reported was 1% to 5% crop damage (37%), followed by 10% to 25% (21%) or no crop damage (20%), and finally 5% to 10% crop damage (16%). The remaining 6% of growers reported damage levels greater than 25%.

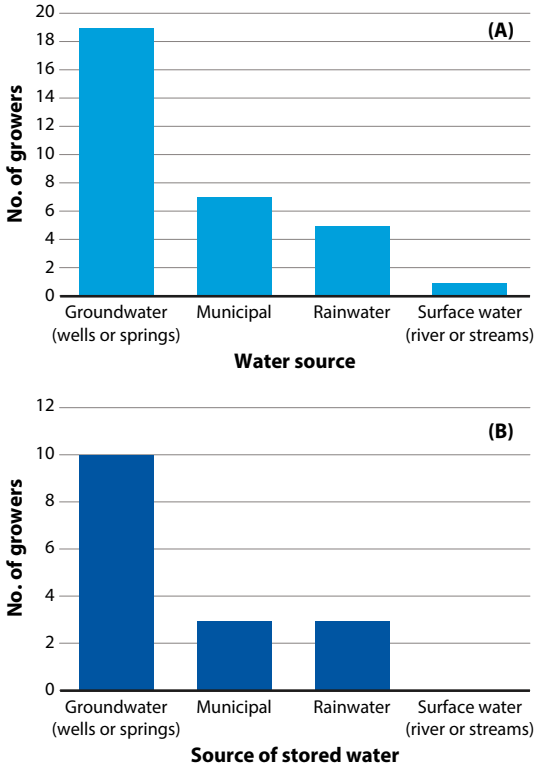


FIG. 3. Most growers reported using groundwater for cannabis cultivation (A). Half the survey respondents indicated that they did not need to store water. Those who did store water, sourced it mostly from wells or springs (B).

Growers experienced a wide range of crop damage (n = 65). The most frequently reported was 1% to 5% crop damage (37%), followed by 10% to 25% (21%) or no crop damage (20%).

Growers reported 14 different arthropods, 13 diseases and nine vertebrates that had negative impacts on cannabis production (fig. 6) (n = 60). The most frequent arthropod pest was mites (70%), followed by thrips (25%), aphids (17%) and unknown larvae (15%). The most common vertebrate pests were gophers, mice and rats (8%), followed by deer (5%) and wild boars (2%). Powdery mildew was by far the most commonly

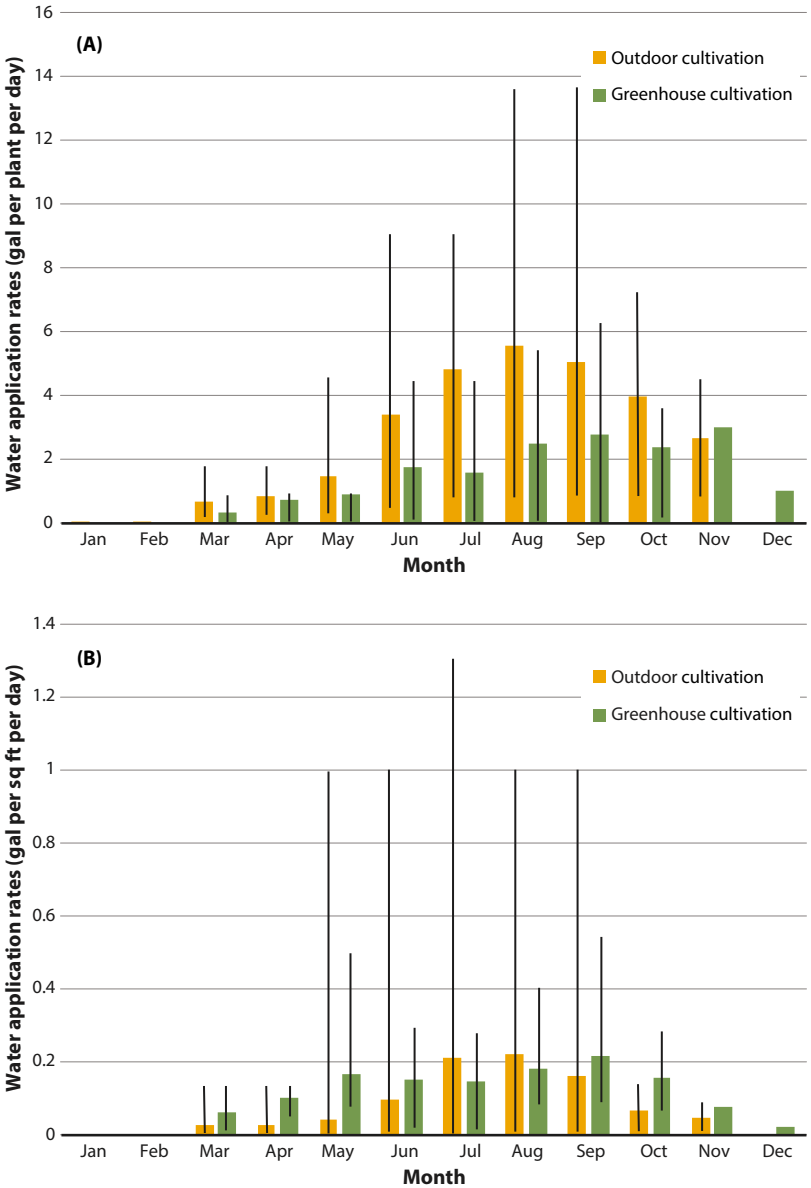


FIG. 4. Average water application rates for outdoor and greenhouse cannabis cultivation by month, in gallons per plant per day (A) and gallons per square foot of cultivated area per day (B). When standardized by area (B), application rates were similar in outdoor and greenhouse cultivation. Black lines indicate the range of values reported.

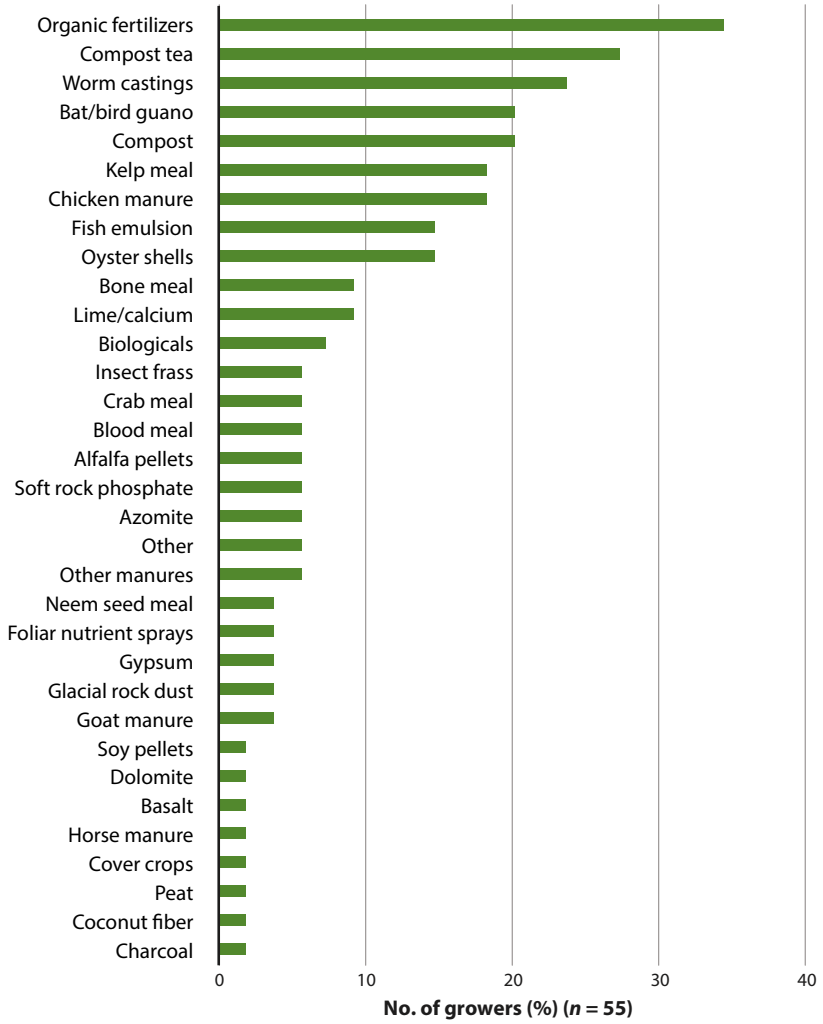
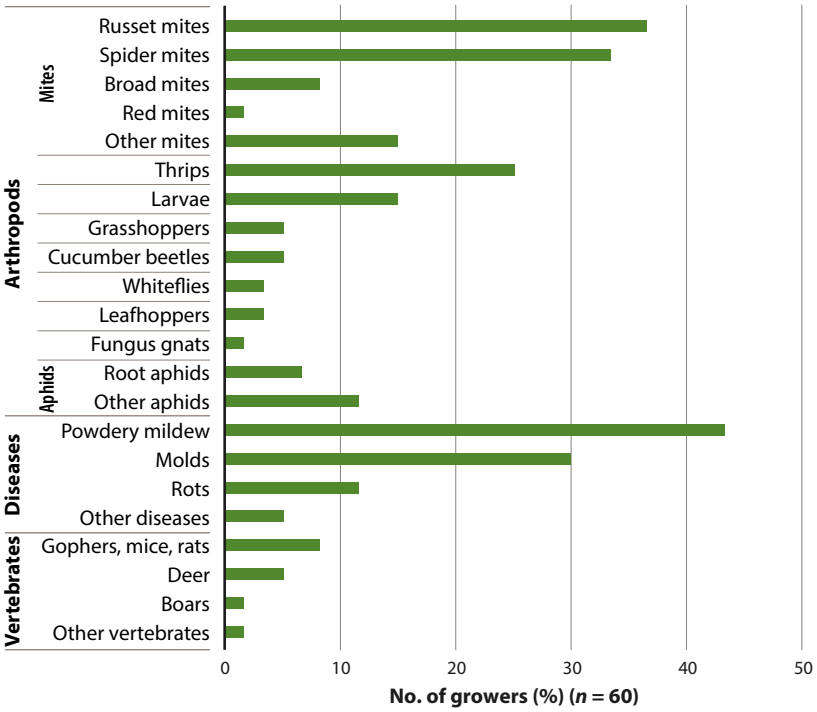


FIG. 5. Cannabis growers reported using many different types of soil amendments and foliar nutrient sprays.



Spider mite webbing on cannabis. Mites were the most frequently reported arthropod pest in the authors' survey.

reported disease (43%), followed by other fungal diseases such as molds (30%; bud mold, grey mold, *Botrytis* spp.) and rots (12%; root rot, stem rot, bud rot, *Fusarium* spp.).

While these findings are in line with cannabis pests and diseases reported by others (McPartland et al. 2000; Rosenthal 2012), survey data are self-reported data and grower identification of pests and diseases may not be entirely accurate. For instance, the complex of mites reported included russet mites, spider mites, broad mites and red mites. Growers were likely referring to hemp russet mite (Eriophyidae: *Aculops cannibicola*), two-spotted spider mite (Tetranychidae: *Tetranychus urticae*), broad mite (Tarsonemidae: *Polyphagotarsonemus latus*) and Carmine spider mite (Tetranychidae: *Tetranychus cinnabarinus*), respectively, but this remains unclear because there are many species of mite commonly referred to as russet mite, spider mite and red mite (ESA 2019). This similarly applies to aphids, thrips, larvae, mildew, rots and molds. Accurate species identification of these pests and diseases will remain uncertain until they can be more systematically collected and identified by UC academics or other scientists.

The most common approach to pest and disease control (n = 59) was to apply some type of solution or chemical to the crop (72%), followed by augmentation of natural enemies (33%) and various cultural practices (32%) (fig. 7).

FIG. 6. Cannabis growers reported a wide range of pests and diseases. Mites, thrips, aphids and powdery mildew and molds were the most frequently reported.

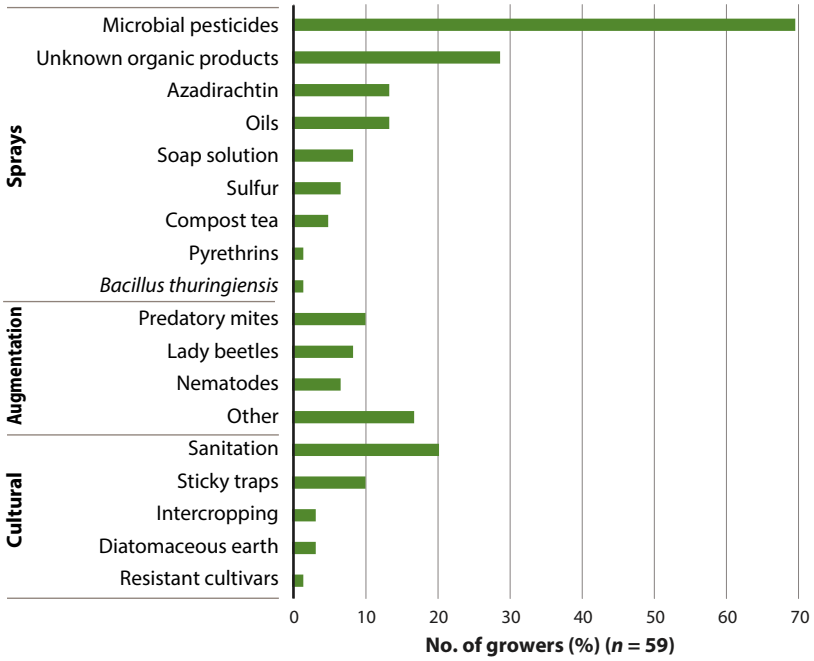


FIG. 7. Cannabis growers reported using various sprays, natural enemy augmentation and cultural practices for pest and disease management.

A majority of sprays (69%) were products that were biologically derived or approved for use in organic production. Products specifically used for control of arthropod pests included azadirachtin (13%), soap solution (8%), pyrethrins (2%) and *Bacillus thuringiensis* (2%). Many respondents indicated that certain products were effective against both pests and diseases, for instance microbial pesticides (69%), oils (14%) and compost tea (5%). Sulfur (7%) was the most commonly applied product specifically used for disease control. In addition, 29% of respondents claimed to use certified organic products for pest and disease management but did not name any product specifically. Finally, 2% of respondents reported that they did not spray for pests and diseases at all.

Augmentation of natural enemies involved the introduction of predatory mites (10%), lady beetles (9%), predatory nematodes (7%) and other unnamed beneficial insects (17%). Cultural practices included removal of infested plant material (i.e., sanitation) (20%), insect trapping (10%), intercropping (3%), use of diatomaceous earth (3%) and selection of resistant cultivars (2%).

Labor, regulatory compliance

Growers who reported hiring labor (n = 22) employed from one to 160 workers. Most common were seasonal workers (< 7 months) paid piece rate per pound of cannabis trimmed (81%). The reported per-pound trimmed piece rate in 2017 varied from $50 to $200, with an average of about $150. This range is lower than 2016 industry rates of $120 to $250 per pound trimmed (ERA Economics 2017).

Growers (59%) also reported hiring seasonal hourly workers, with starting pay at $15 to $20 per hour. Other less common types of labor included permanent (> 7 months) hourly workers (37%, n = 8), permanent salaried workers (44%, n = 9), seasonal salaried workers (22%, n = 9) and permanent workers paid with a percentage of total crop, in the form of cash or product (50%, n = 10). No growers reported paying workers via profit sharing.

As of August 2018, a majority of growers reported that they had not applied for a state license to grow cannabis. From those reporting (n = 36), 47% had applied for a license and 53% had not. Nonparticipation in the licensing process was highest among small growers (fig. 8).

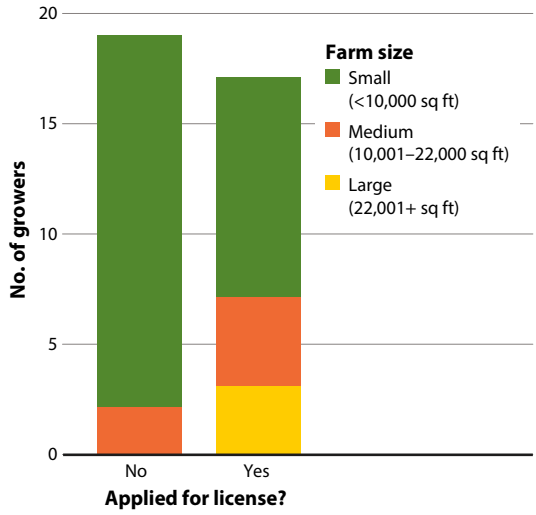


FIG. 8. Nonparticipation in the licensing process was highest among small growers.

Need for more data

Our survey, although of limited sample size, is the first known survey of California cannabis growers and provided insights into common forms of cultivation, pest and disease management, water use and labor practices. Since completing this survey, we have discussed and/or presented the survey results with representatives from multiple cannabis grower organizations, and they confirmed that the data were generally in line with production trends. Evident in the survey results, however, was the need for more data on grower cultivation practices before best management practices or natural resource stewardship goals can be developed.

All growers monitored crop health, and many reported using a preventative management strategy, but we have no information on treatment thresholds used or the efficacy of particular sprays on cannabis crops. Likewise, the details of species-level pest and disease identification, natural enemy augmentation and sanitation efforts remain unclear.

Growers did not report using synthetic pesticides, which contrasts with findings from previous studies that documented a wide range of synthetic pesticide residues on cannabis (Cuypers et al. 2017; Schneider et al. 2014; Voelker and Holmes 2015). Product selection for cannabis is very limited due to a mixed regulatory environment that currently does not allow for the registration of any insecticide or fungicide for use specifically on cannabis (Stone 2014; Subritzky et al. 2017), although growers are allowed to use products that are exempt from residue tolerance requirements, exempt from registration requirements (e.g., food-grade essential oils) or registered for a use that is broad enough to include cannabis (e.g., "other horticultural crops"). As such, it may be that in the absence of legally available chemical controls growers were choosing allowable, biologically derived products (e.g., microbial pesticides, compost teas) or alternative strategies such as natural enemy augmentation and sanitation. Our survey population was perhaps biased toward nonchemical pest management — the organizations we contacted for participant recruitment included some that were formed to share and promote sustainability practices. Or, it may be that respondents were reluctant to report using synthetic chemicals or products not licensed for cannabis plants.

The only other published data on water application rates for cannabis cultivation in California we are aware of is from Bauer et al. (2015), who used estimates for Humboldt County of 6 gallons per day (gpd) per plant for outdoor cultivation over the growing season (June–October). Grower reported estimates of cannabis water use in this survey were similar to this rate (5.5 gpd/plant) in the peak growing season (August), but was otherwise lower. Due to the small sample size, we cannot say that groundwater is the primary water source for most cannabis growers in California or that few use surface water diversions. However, Dillis et al. (2019) found similar results on groundwater being a major water source for cannabis growers, at least in northwest California. If the irrigation practices reported in our survey represent patterns in California cannabis cultivation, best management practices would be helpful in limiting impacts to freshwater organisms and ecosystems. For example, where groundwater pumping has timely and proximate impacts to surface waters, limiting dry season groundwater extraction by storing groundwater or surface water in the wet season may be beneficial (Grantham et al. 2014), though this will likely require increases in storage capacity. The recently adopted Cannabis Cultivation Policy (SWRCB 2017) requires a mandatory dry season forbearance period for surface water diversions, though not for groundwater pumping. Our survey results indicate that the practical (especially financial) constraints on adding storage may be a significant barrier for compliance with mandatory forbearance periods for many growers.

More in-depth research with growers and workers is needed to explore the characteristics of the cannabis labor force and the trajectory of the cannabis labor market, especially in light of legalization. Several growers commented on experiencing labor shortages, a notable finding given that recent market analyses of the cannabis industry suggest that labor compliance costs are the most significant of all of the direct regulatory costs for growers (ERA Economics 2017).

Higher rates of licensing compliance among medium and large farms is not surprising given the likelihood that they are better able to pay permitting costs. Yet, that the majority of respondents indicated they had not applied for a license to grow cannabis, with over half noting some income from cannabis sales, indicates potentially significant effects if these growers remain excluded from the legalization process. More research is needed to understand the socioeconomic impacts of legalization, which likely extend beyond those accounted for in the state's economic impact analysis, which primarily focuses on economic contributions that a legalized market will bring to the state (ERA Economics 2017). Bodwitch et al. (2019) report that surveyed growers characterized legalization as a process that has excluded small farmers, altered local economies and given rise to illicit markets.

The environmental impacts of cannabis production have received attention because of expansion into remote areas near sensitive natural habitats. The negative impacts are likely not because cannabis production is inherently detrimental to the environment, but rather due to siting decisions and cultivation practices. In the absence of regulation and best management practices based on research, it is no surprise that there have been instances of negative impacts on the environment. At the same time, many growers appear to have adopted an environmentally proactive approach to production and created networks to share and promote best management practices.

Organizations that we approached to recruit survey participants had a fairly large base membership (1,000 to > 10,000 members), which is on a par with other major commodity groups, like the Almond Board of California (~ 6,800 members) and California Association of Winegrape Growers (~ 5,200 members). Membership included cannabis growers, distributors and processors as well as interested members of the public, and some people were members of more than one organization, suggesting a large, engaged community. Most of the organizations we contacted enthusiastically agreed to help us recruit growers for our survey, and we received excellent feedback on our initial survey questions. Growers who completed the survey were also clearly knowledgeable about cannabis cultivation.

Some potential future research topics include the development of pest and disease monitoring programs; quantifying economic treatment thresholds; evaluating the efficacy of different biological, cultural and chemical controls; developing strategies to improve water use and irrigation efficiency; understanding grower motivations for regulatory compliance; understanding the impacts of regulation; and characterizing the competition between labor in cannabis and other agricultural crops — to name just a few. As cannabis research and extension programs are developed, it will be critical to ensure that future surveys capture a representative sample of cannabis growers operating inside and outside the legal market, to identify additional areas for research and develop best practices for the various cultivation settings in which California cannabis is grown. CA

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RESEARCH ARTICLE

Characteristics of farms applying for cannabis cultivation permits

In Humboldt County, larger and faster-growing cannabis farms apply for permits at higher rates than do smaller or slower-growing farms.

by Benjamin Schwab, Ariani Wartenberg and Van Butsic

Abstract

Cannabis producers in California can now participate in a regulated supply chain — but little is known, despite considerable speculation, about which types of producers are likely to seek legal status. Growers' decisions about joining the legal market are central to questions about how formalization will transform cannabis production in California, and in particular whether small farms, which were encouraged under Proposition 64, can remain part of the industry. We combine data on the location and characteristics of cannabis farms in 2012 and 2016 with applications for cultivation permits from 2018 to investigate farm characteristics associated with cannabis formalization in Humboldt County. We find strong evidence that the farms most likely to start the permit process are larger, existed in 2012 prior to the start of the "green rush" and expanded at greater rates between 2012 and 2016. The evidence is consistent with concerns that formalization of the cannabis industry may lead to industry consolidation, as has been the trend in California's agricultural and timber industries more broadly.

Agriculture in the United States has undergone massive consolidation over the past 50 years and the same is true in California. Several economic and market factors have contributed to farm consolidation, but new regulations on agriculture have also played a role (Dunn 2003; Howard 2015). Compliance costs associated with increased regulatory burdens can decrease producer profits and limit market entry (Thilmany and Barrett 1997). Small producers may be particularly harmed by the need to achieve compliance, as economies of scale provide larger producers an advantage (Dean et al. 2000). Small firms may lack sufficient capital to change production methods to comply with regulations, or even to manage the burdens associated with reporting. (See McCullough et al. 2017 for a more comprehensive discussion of regulatory costs to California farmers.)

The cannabis industry has historically resisted widespread farm consolidation, perhaps due to its

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In Humboldt County, a permitted cannabis grow is integrated with a small-scale commercial vegetable farm operation. Results from a recent study suggest that cannabis farms with more plants are more likely to apply for cultivation permits than farms that grow fewer plants.

Ted Grantham

status as an unregulated, and illicit or semi-licit, activity. While the amount of cannabis produced in California is substantial (Macewan et al. 2017), evidence from 2016 suggests that most outdoor cannabis was then produced on farms smaller than one acre (Butsic et al. 2018). When Proposition 64 legalized nonmedicinal cannabis in 2016, its size provisions explicitly acknowledged the state's desire to see cannabis farms remain small (California NORML 2016b). Initial regulations limited each permit to an area no greater than one acre and limited each entity (person or corporation) to only one permit. Federal laws against cannabis have also encouraged small farms: Farmers with more than 99 plants potentially face federal minimum sentences of five years in prison (California NORML 2016a).

Local permitting may also favor smaller producers. Each jurisdiction in California can create its own permitting system, and possessing a local permit is a condition for obtaining a state permit. Most local jurisdictions place limitations on field sizes, and these limitations can encourage small-scale farming. While local permits may provide an avenue for local governments to protect small farmers (for example, by restricting field size), they also add another layer of regulation, potentially increasing entry costs.

Beginning with California's first attempt to implement a comprehensive regulatory system for the cultivation and distribution of legal cannabis, through the 2015 passage of the Medical Marijuana Regulation and Safety Act, stakeholders have expressed concerns that the permitting process privileges large farms over small. MacEwan et al. (2017) calculate that, due to the nature of regulatory costs, the type of small cannabis farmer prevalent in Northern California is the "least likely to participate in the regulated market." (MacEwan et al. estimate that total regulatory costs for typical outdoors producers range between $207 and $248 per pound.) Yet to date, empirical evidence on cannabis producers' engagement with the formal market under the new regulatory framework has been lacking. In particular, there is a large evidence gap about the types of farms that participate in the regulated market and those that do not. The gap exists partly because of a lack of public data about growers who have not applied for permits. We remedy that gap by combining information about farmers who have started the permit application process with a unique dataset of cannabis farms in Humboldt County in 2012 and 2016. We then ask:

1. Were there size differences between farms that started the permit application process and those that did not?
2. Were farms that expanded between 2012 and 2016 more likely to apply for permits than those that did not?
3. Were farms created between 2012 and 2016, during the peak of the "green rush," more likely to apply for permits than farms already producing cannabis in 2012?
4. Were there other significant differences in farm and parcel characteristics between farms that applied for permits and those that did not?

Linking farms with permit applications

Humboldt County is one of the largest cannabis-producing regions in California and perhaps the world. Cannabis farming began there in the early 1960s, with rapid expansion following in the 1970s, and cannabis has been among the most valuable crops in the county at least since a proposition legalizing medical cannabis was approved by voters in 1996 (Budwig and Bank 2013). Recent studies suggest that at least 5,000 cannabis farms operate in Humboldt County (Butsic et al. 2018). (By way of comparison, the 2017 federal agricultural census [USDA-NASS 2019] identified 849 noncannabis farms in the county, not including timber operations.) In the lead-up to the enactment of regulated cultivation of cannabis — which began for the medicinal market in 2016 and for the adult-use market in 2018 — the region experienced a cannabis boom, with the number of plants under cultivation increasing by 150% between 2012 and 2016 (Butsic et al. 2018). This time of massive cannabis expansion is often referred to locally as the "green rush."

In the lead-up to the enactment of regulated cultivation of cannabis . . . Humboldt County experienced a cannabis boom, with the number of plants under cultivation increasing by 150% between 2012 and 2016.

To track both permitted and unpermitted cannabis growers, we used data created by Butsic et al. (2018). In their study, Butsic et al. hand-digitized cannabis farms (both greenhouse and outdoor grows) using very high-resolution satellite imagery. Cannabis production was measured in both 2012 and in 2016. Outdoor plants were counted and the number of plants inside greenhouses was estimated based on greenhouse size. Of the 1,724 farms in the dataset, 942 started producing cannabis between 2012 and 2016 ("new farms") and 782 produced at least some positive amount in both 2012 and 2016 ("existing farms").

For permit data, we used publicly available data from the Humboldt County Planning Department, compiled from applications for commercial cannabis cultivation permits (Humboldt County Planning and Building Department 2018). We were able to combine the farm location data with the permit data based on the unique parcel identification that existed in both datasets. In total, applications were received for cultivation on 1,945 unique parcels. Of these, 533 were located within our study area (322 from existing farms and 211 from new farms). We also include data (see online technical appendix) describing farm/parcel characteristics.

Locational variables such as distance to public roads and cities are used to proxy for transportation cost, while distances to endangered and threatened fish species (chinook salmon and steelhead) habitat proxy for the environmental sensitivity of a site. Distance to ocean provides a summary measure of the coastal environment of the farm. Biophysical characteristics such as slope and presence of prime agricultural soils are used to describe the growing conditions of a site, while zoning designations are used to identify areas where growing cannabis is allowed (Butsic et al. 2018). We also determined if a timber harvest plan had been associated with a parcel at any point since 1997.

Methods to compare farms by permit application decision

The overall aim of our empirical analysis is to describe the type of cannabis farms likely to apply for a permit. To do this we use a twofold approach. First, we compare farms that applied for a permit and farms that did not in terms of the means of their farm and parcel characteristics. We use a simple two-tailed test to determine if the univariate mean differences between these groups are statistically significant. We focus on differences in farm size (i.e., number of plants), farm-size expansion during the "green rush" period (2012–2016) and tenure of the farm.

In a second step we estimate models of application decisions using multivariate regressions, which allow us to isolate the impact of each characteristic while controlling for variation in others (Wooldridge 2010). We implement two such models. Our main specification (equation 1) is a probit model in which the binary dependent variable ($Apply_i$) is equal to 1 if a permit application was submitted for parcel i. (An alternative logit specification produced nearly identical results.) The size of the farm is included with a quadratic specification and the other parcel and farm characteristics (the vector X) enter the model linearly as independent variables. We use the probit model to estimate the marginal contribution of each of these variables to the likelihood that a parcel applies for a permit.

$$Apply_i = \beta_0 + \beta_1 Size_i + \beta_2 Size_i^2 + X_i\beta + \varepsilon_i \quad (1)$$

We also estimate a linear probability model of the binary application decision that includes watershed fixed effects (equation 2). The watershed fixed-effects model includes a dummy variable for each of the 59 watersheds (σ_j) in the sample, so coefficient estimates are identified by within-watershed variation. Because some predictors of application are likely correlated within geographic regions, estimating the model in this manner allows us to purge higher-level effects common at the watershed level from the parcel-level estimates (Wooldridge 2010). We use the same vector of covariates for the fixed-effects model as for the probit model.

$$Apply_{ij} = \beta_0 + \beta_1 Size_{ij} + \beta_2 Size_{ij}^2 + X_{ij}\beta + \sigma_j + \varepsilon_{ij} \quad (2)$$

We include the quadratic term on farm size to increase the goodness of fit in our model and allow a more flexible relationship between farm size and permit application. The other covariates included in our regression are useful predictors of permit application, as they explain site-specific characteristics as well as proxy for potential land-use opportunities. They have been found to be significant predictors of farm location (Butsic et al. 2017) or farm abandonment (Butsic et al. 2018). Importantly, these other covariates are primarily time-invariant or predetermined at the time growers decide whether to apply for permits. Specifically, we include variables of environmental sensitivity (distance to steelhead and chinook salmon habitat) as proxies for potential challenges in obtaining approval from the Regional Water Quality Control Board. We include zoning information to help describe the other potential uses of the parcel if it were not being used for cannabis. Finally, we include a variable indicating if the area had ever had a timber harvest plan since 1997. We include

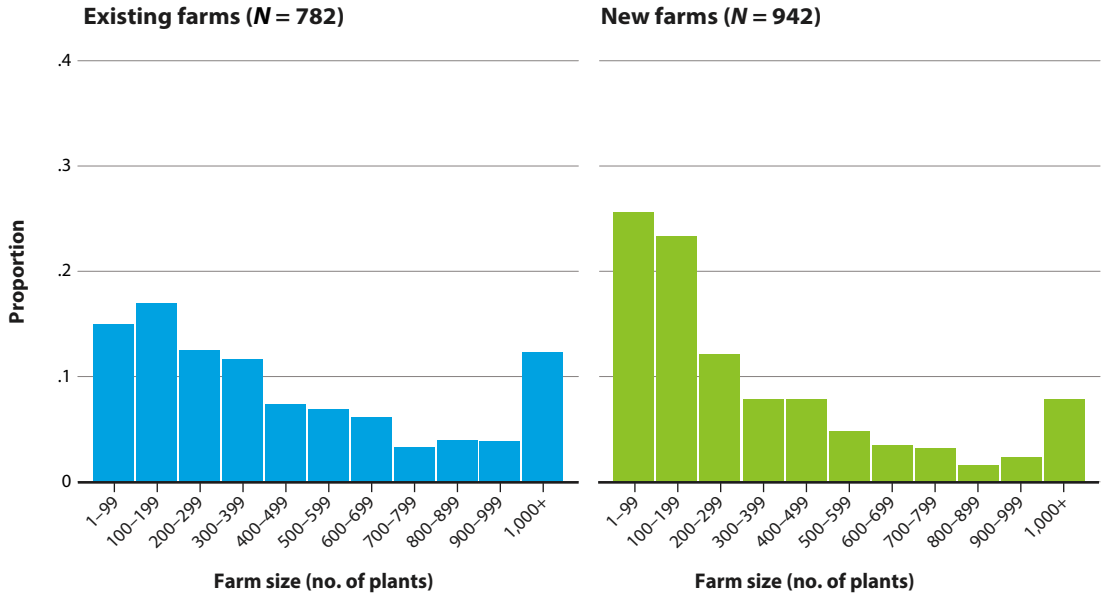

FIG. 1. Distribution of sample by farm size in 2016 for new and existing farms, shown as a histogram of cannabis farm size by farm category, where size is determined by the number of cannabis plants on the property in 2016. Existing farms are defined as properties with a strictly positive (>0) number of cannabis plants in 2012, while new farms are defined as properties that produced zero cannabis plants in 2012.

this variable to see if past land use (i.e., timber harvest) influences the likelihood of permit application.

Clear patterns in farms' decisions about applying for permits

The average farm size in 2016 was 432 plants, with a median of 263 plants, a minimum of 14 and a maximum of 12,901 (fig. 1). Over 90% of farms produced fewer than 1,000 plants and fewer than 2% produced more than 2,000. Examining permit application rates by farm size reveals a distinct size gradient (fig. 2), as application rates increase substantially over farm-size categories. This pattern holds for both existing and new farms, but the rise is much sharper for the latter. Approximately 10% of small new farms (i.e., new farms with fewer than 250 plants) apply for a permit, but rates jump to 61% and 50%, respectively, for the largest farm size groupings.

We found a significant difference in size ($p < .01$) between farms that applied for a cannabis permit in 2016 (mean size of 633 plants) relative to those that did not apply (mean size of 345 plants) (table 1). The trend according to which larger farms applied for permits

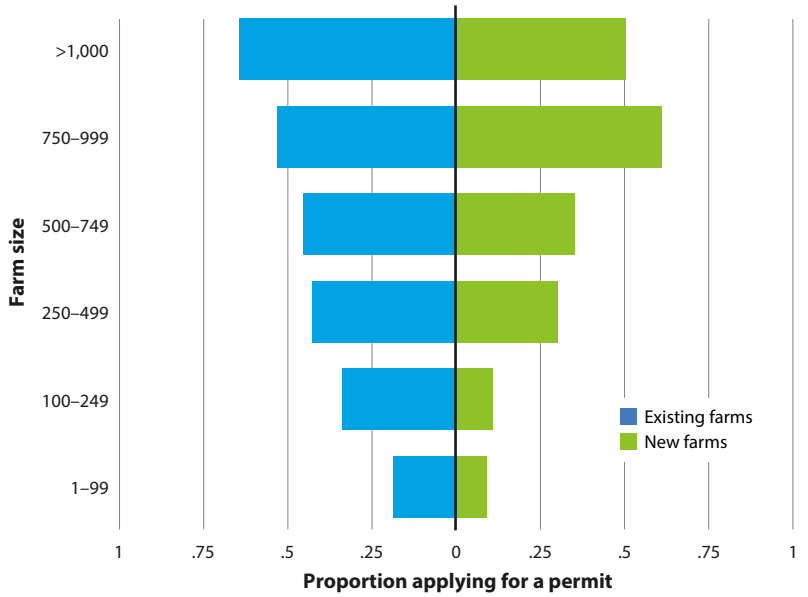

FIG. 2. Probability of applying for a permit by farm size for new and existing farms. For both existing (blue) and new (green) farms, bars represent unadjusted proportion of each farm-size group that applied for a permit. Existing farms are defined as properties with a strictly positive (>0) number of cannabis plants in 2012, while new farms are defined as properties that produced zero cannabis plants in 2012.

TABLE 1. Mean differences between farms that did and did not apply for permits from 2017 to 2018

Variable	Applied	Did not apply	Difference in means
	(N = 533)	*(N = 1,191)*	*t-test*
New farm (= 1 if no plants in 2012, 0 otherwise)	0.40 [0.02]	0.61 [0.01]	−0.22*
Total number of cannabis plants in 2016	625.31 [22.45]	345.60 [16.50]	279.71*
Total number of cannabis plants in 2012	246.28 [14.51]	100.42 [5.84]	145.86*
Change in total plants 2012 to 2016)†	212.20 [21.36]	130.50 [13.18]	81.70*
Number of greenhouse cannabis plants in 2016	577.21 [22.55]	323.31 [16.15]	253.89*
Number of greenhouse cannabis plants in 2012	213.22 [13.74]	84.02 [5.26]	129.20*
Change in greenhouse plants (2012 to 2016)†	216.71 [21.98]	135.97 [12.86]	80.74*
Number of outdoor cannabis plants in 2016	48.10 [3.17]	22.29 [1.63]	25.81*
Number of outdoor cannabis plants in 2012	33.06 [3.04]	16.40 [1.58]	16.66*
Change in outdoor plants (2012 to 2016)†	−4.51 [4.04]	−5.47 [3.65]	.96
Northness (Y coordinate in tens of mi)	114.19 [1.69]	120.83 [1.22]	−6.64*
Distance to city or town (00s of mi)	0.97 [0.02]	0.86 [0.01]	0.12*
Distance to an ocean (00s of mi)	0.16 [0.00]	0.11 [0.00]	0.05*
Distance to stream (mi)	0.19 [0.01]	0.28 [0.01]	−0.09*
Distance to steelhead habitat (mi)	0.03 [0.00]	0.03 [0.00]	−0.01
Distance to chinook salmon habitat (mi)	0.02 [0.00]	0.02 [0.00]	−0.00
Distance to road (mi)	0.13 [0.00]	0.18 [0.00]	−0.06*
Slope over 30% on property	0.20 [0.01]	0.17 [0.01]	0.03‡
Property size (acres)	60.29 [2.38]	56.76 [3.00]	3.53
Timber plan since 1997	0.21 [0.02]	0.19 [0.01]	0.02
Agricultural zone	0.23 [0.02]	0.29 [0.01]	−0.05‡
TPZ or forest recreational zone	0.45 [0.02]	0.21 [0.01]	0.24*
Parcel has been transacted since 2015	0.21 [0.02]	0.07 [0.01]	0.14*
Prime ag soil	0.08 [0.01]	0.20 [0.01]	−0.13*

Each row is a separate univariate comparison. Brackets indicate standard errors.
* Statistically significant at 1% level.
† Existing sample only ($N = 322$; $N = 460$).
‡ Statistically significant at 5% level.

TABLE 2. Regression analysis of factors that explain farm decisions to apply for a permit

Sample	All farms			New farms	Existing farms	
Independent variables	(1) Basic model	(2) Full model	(3) Watershed fixed effects	(4) Full model (new farms)	(5) Full model (existing farms)	(6) Farm-growth model
New farm	−0.134 (0.020)*	−0.073 (0.020)*	−0.058 (0.031)‡			
Total # of plants in 2016 (00s of plants)	0.039 (0.003)*	0.024 (0.003)*	0.023 (0.004)*	0.020 (0.004)*	0.024 (0.005)*	
Total # of plants in 2012 (00s of plants)						0.031 (0.008)*
Total plants change (00s of plants)						0.015 (0.005)*
Northness (tens of mi)		−0.001 (0.000)†	−0.004 (0.001)*	−0.001 (0.000)	−0.001 (0.001)	−0.001 (0.001)
Distance to a city (00s of mi)		−0.052 (0.032)	−0.015 (0.117)	0.001 (0.038)	−0.102 (0.065)	−0.088 (0.066)
Distance to an ocean (00s of mi)		0.746 (0.151)*	1.460 (0.508)*	0.824 (0.203)*	0.715 (0.237)*	0.660 (0.240)*
Distance to stream (mi)		−0.052 (0.030)‡	−0.030 (0.041)	−0.019 (0.031)	−0.113 (0.056)†	−0.113 (0.057)†
Distance to steelhead habitat (mi)		−0.187 (0.130)	−0.156 (0.119)	−0.123 (0.136)	−0.292 (0.261)	−0.294 (0.259)
Distance to chinook salmon habitat (mi)		0.241 (0.154)	0.145 (0.145)	0.221 (0.158)	0.226 (0.315)	0.232 (0.314)
Distance to road (mi)		−0.238 (0.094)†	0.019 (0.118)	−0.102 (0.112)	−0.314 (0.160)†	−0.304 (0.159)‡
Slope over 30% on property		0.009 (0.042)	0.022 (0.045)	−0.047 (0.051)	0.071 (0.073)	0.051 (0.073)
Property size (00s of acres)		0.115 (0.027)*	0.037 (0.037)	0.157 (0.041)*	0.095 (0.045)†	0.091 (0.045)†
Timber plan since 1997		−0.039 (0.026)	−0.008 (0.039)	−0.020 (0.032)	−0.064 (0.042)	−0.061 (0.042)
Agricultural zone		0.005 (0.027)	0.037 (0.030)	−0.012 (0.034)	0.009 (0.045)	0.008 (0.045)
TPZ or forest recreational zone		0.057 (0.025)†	0.053 (0.030)‡	0.084 (0.032)*	0.029 (0.041)	0.024 (0.041)
Parcel transacted since 2015		0.158 (0.028)*	0.188 (0.029)*	0.163 (0.032)*	0.143 (0.048)*	0.147 (0.048)*
Prime ag soil		−0.059 (0.038)	−0.036 (0.064)	0.026 (0.043)	−0.172 (0.077)†	−0.174 (0.077)†
N	1,724	1,722	1,709	941	779	779
Watershed fixed effects	No	No	Yes	No	No	No

* Statistically significant at 1% level.

† Statistically significant at 5% level.

‡ Statistically significant at 10% level.

Table 2 contains results from six separate regressions. Each regression models the impact of farm characteristics (i.e., independent variables) on the farm's likelihood of applying for a cannabis permit. The sample is indicated in the column header: columns 1–3 include all farms in the data; column 4 includes only farms that began producing cannabis after 2012 (i.e., "new farms") and columns 5 and 6 include only farms that produced in both 2012 and 2016 (i.e., "existing farms"). The dependent variable in all regressions is a dummy equal to 1 if the farm applied for a permit, and zero otherwise. Positive values of the coefficient estimates indicate that greater values of the independent variable are associated with a higher likelihood of applying. For all regressions except column 3, average marginal effects of the probit model are shown; the probit model incorporates the quadratic term for total plants and property size. Column 3 estimates are derived from a linear probability model that includes a dummy variable for each of the 53 watersheds in the sample, and coefficients represent percentage point changes (divided by 100) estimated based on the within-watershed relationship between permit application and the independent variables. Standard errors appear in parentheses below means, and are clustered by watershed for column 3.

at higher rates held true regardless of production type (greenhouse or outdoor). The size differences are proportionally similar for both greenhouse and outdoor plants, so we do not find evidence that the relationship between farm size and permit application is solely driven by production method.

Our regression models (table 2) confirm that this result is robust to controlling for other covariates. In all our regression specifications, the coefficient on the total number of plants (in hundreds) in 2016 is positive and statistically significant at the 1% level. The effect size of the number of plants indicates that, controlling for parcel characteristics, an increase of 100 plants increases the probability of applying for a permit by 2.4% (column 2), with the slope of the relationship declining for extremely large farms (fig. 3). The overall marginal effect is similar for existing and new farms, (table 2, columns 4 and 5), though the declining marginal effect for very large farms is driven by new farms (fig. 3), and is robust to the inclusion of watershed fixed effects (table 2, column 3). The pattern also holds for size in 2012. Restricting the sample to existing farms, an increase of 100 plants in 2012 increases the probability of application by 3.1%.

Growth rate

We first categorize growth of existing farms according to the proportionate change in plants produced between 2012 and 2016. The "declining production" group consists of farms that shrank by more than 5% (accounting for 11% of the existing-farm sample); "minimal change" farms experienced between −5% and 5% growth (39% of the sample); "moderate growth" farms grew between 5% and 50% (14%) and "high growth" farms grew by more than 50% (37%). Within the sample of existing farms, there is a clear gradient of application rates with respect to growth between 2012 and 2016 (fig. 4). The farms least likely to apply are those that declined in size, followed by those with minimal growth. Application rates for existing farms that grew moderately jump to over 40%, with high-growth farms the most likely to apply. Note that across all expansion rates for existing farms, application rates are significantly higher than the average rate for new farms.

Statistical tests confirm this trend. Existing farms that applied for permits displayed a mean expansion of 212 plants between 2012 and 2016, while the mean expansion for farms that did not apply was 130 plants (table 1). This difference of 82 plants is significant at the 1% level. Our regression results also find expansion associated with permit application (table 2). In column 6, an increase of 100 plants among existing growers (i.e., total plants change) is associated with a 1.5% higher probability of applying for a permit, with the result positive and statistically significant at the 1% level.

Old farms and new farms

Older farms are 25% larger, on average, than new farms. Both predominantly produce cannabis in greenhouses, where multiple crops can be produced each year. This increases potential revenue, though the share of greenhouse production is slightly higher among new

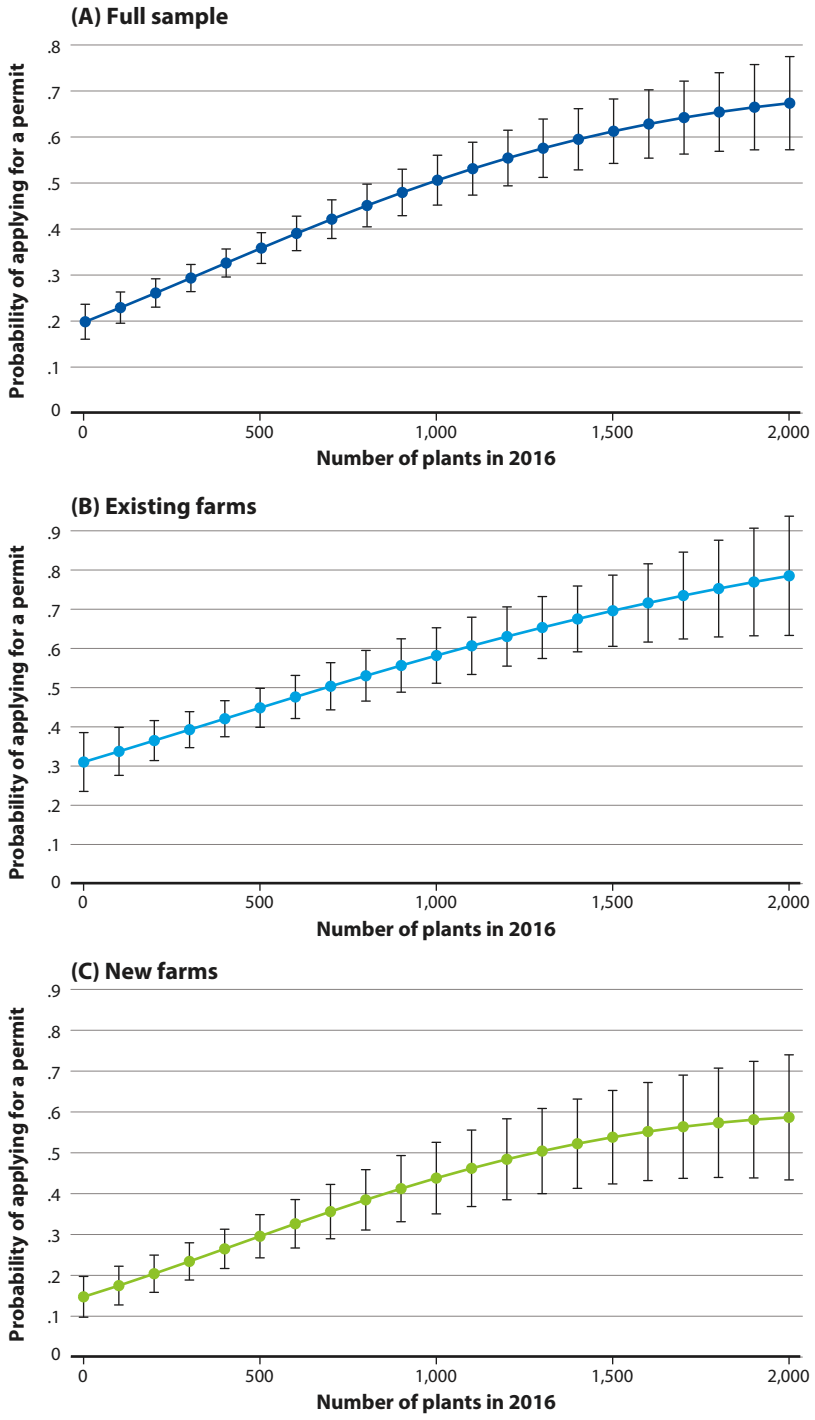

FIG. 3. Predicted probability of permit application by farm size. Predicted probabilities derived from marginal effects estimated from equation (1). Panel A corresponds to column (2) of table 2. Panel B corresponds to column (5). Panel C corresponds to column (4).

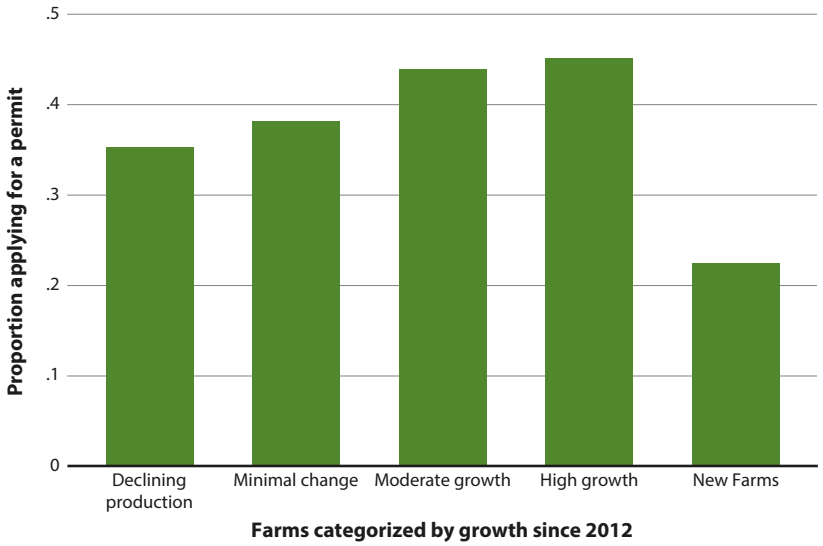

FIG. 4. Probability of applying for a permit by farm growth between 2012 and 2016. The height of each bar corresponds to the proportion from each group that apply for a permit. The leftmost four bars are subgroups of existing farms (i.e., produced cannabis in both 2012 and 2016), while the rightmost bar consists of all farms with positive 2016 cannabis production but no 2012 production ("new farms"). The "declining production" group consists of farms that shrank by more than 5% (11% of the existing farm sample); "minimal change" farms had between −5% and 5% growth (39%); "moderate growth" farms grew by between 5% and 50% (14%) and "high growth" farms grew by more than 50% (37%).

farms than existing farms (95% compared to 88%). However, new farms are far less likely to apply for permits than existing farms. The univariate comparison shows that, on average, a new farm was 22% less likely to apply for a permit than a farm that already existed in 2012. Our regression results indicate that this relationship is robust to controlling for associated covariates, including farm size. The coefficient on new farms is statistically significant and negative in all regression specifications. Controlling for other factors, new farms are approximately 7.3% less likely than existing farms to apply for a permit, with the magnitude of the effect slightly reduced when relying only on within-watershed variation (table 2, columns 2 and 3). Small new farms are very unlikely to apply for a permit, even in comparison with existing farms of similar size (fig. 2).

Continued expansion of regulated cannabis in California may disproportionately favor the establishment of large farms, despite measures seemingly designed to prevent this outcome.

Other factors in permit status

Regression results indicate that farms which have *not* applied for permits tend to be located further north, closer to both cities and the coast and further away from roads (table 2). They are also more likely to be located on prime agricultural soils, which is a listed requirement for obtaining a permit. However, there seems to be no effect associated with flat terrain or agricultural zones, which are also requirements for permits. These results suggest that siting criteria in the permit ordinance do not appear to be positive independent drivers of application decisions.

In contrast, farms that *did apply* for permits tend to be located closer to streams and chinook salmon habitat, even as permit eligibility requires the use of non-diversionary water sources (table 2). Applying farms are also more likely to be located in forest recreation or timber production zones (TPZs) and to have been transacted at least once since 2015. They also tend be located on larger parcels. However, from comparing the results in columns (2) and (3), it is clear that a number of regression outcomes between permit applications and parcel characteristics (excluding those related to farm size, timing of production, land sales and coastal location) are not robust to the inclusion of watershed fixed effects. This suggests the existence of underlying geographic drivers which might influence these relationships.

Small farms face an uncertain future

Cannabis has been profitably produced in California, primarily on small farms, for decades (Polson 2013; Short Gianotti et al. 2017). As cannabis becomes increasingly legal, production practices have become more standardized, and many small farms fear that the increased regulatory costs associated with formalization will force them to either shut down or remain on the black market (Wagner et al. 2018).

Here, we use empirical data on farm location and permit status to investigate differences between cannabis farms that applied for permits to produce in the legal market and those that did not. We find strong evidence that farms with more plants are more likely to apply for permits than farms that grow fewer plants. This is consistent with the argument that increased formalization disfavors small-scale farms (Guthman 2004, 2014). A potential implication of this trend is that continued cannabis expansion in California may disproportionately favor the establishment of large farms, despite measures seemingly designed to prevent this outcome. Small cannabis farms may face challenges similar to those faced by small farms producing other crops (Tourte and Faber 2011) — and if small farms are valued, additional policy solutions are required.

While our results point toward a robust positive relationship between size and permit application (e.g., table 1), we cannot definitively attribute the cause to either the fixed cost of initial application or ongoing costs associated with regulatory compliance. Small farms, for example, may be less able to engage with the legal supply chain or obtain favorable pricing in the legal market, or they may systematically differ from larger farms in risk tolerance. Thus, because we are unable to directly control for these factors in the

regression analysis, it is unclear which of these potentially omitted variables might be driving the size-application relationship. That ambiguity suggests a topic for future study.

We also find that existing farms that expanded during the "green rush" years were more likely to apply for permits. This finding could arise via multiple pathways. Perhaps farms that expanded during this time were those endowed with, or able to accumulate, sufficient capital to enter the regulated market. Alternatively, some farms may have invested more heavily specifically in anticipation of formalization and legal marketing opportunities. We also found that farms that were established after 2012 were less likely to apply for permits, all else equal. Whether these newer farms will continue to operate illegally or abandon their operations remains unknown. Nevertheless, it suggests potential divergence in formalization strategies between newer entrants and older producers. Whether that divergence is driven by systematic differences in operators' human capital and experience levels, in financial capital or in other unobserved factors like risk tolerance or "taste"-based considerations (i.e., attitudes toward cannabis production) remains a subject for further research.

Indeed, while formalization is clearly favored by larger farms, we do find evidence that smaller farms traditionally associated with Northern California cannabis production have not been completely shut out of the legal market. Though permit application rates for the smallest farms are substantially lower than those for large farms, the small farms that do apply tend to be farms with longer production histories.

Our work documents permit applications at a dynamic moment in formalization, and we suggest that the trends we have seen to this point may change going forward. Many farms that applied for permits may not complete the application or gain approval, or may fail to receive necessary permits from state offices. Likewise, new cannabis investments continue in the county and some farms that initially resisted formalization may now decide to join the market. New cooperative businesses that specifically focus on supporting small farms are emerging, and these organizations are assisting small farmers in the permitting process. The final chapter of formalization is yet to be written. CA

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RESEARCH ARTICLE

Retail cannabis prices in California through legalization, regulation and taxation

A study investigates price patterns at California cannabis retailers during a period of major regulatory changes.

by Robin S. Goldstein, Daniel A. Sumner and Allie Fafard

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Abstract

Traditional sources of retail price information, such as scanner data and government price surveys, are not available for cannabis. To help fill this gap, between October 2016 and July 2018 the UC Agricultural Issues Center collected online retail price ranges for dried cannabis flower and cannabis-oil cartridges at retailers around California. During this 21-month time period, the legal landscape of the California cannabis market underwent three broad regulatory changes: adult-use decriminalization, licensing and regulation and mandatory testing. This article provides unique primary data on legal cannabis prices in California before and after each of these three changes. Our data are imperfect but do provide a glimpse of the patterns of California cannabis prices at different times. For dried cannabis flower, we observe relatively stable retail prices over the 21-month period at both the top and bottom ends of the price range. For cannabis-oil cartridges, we observe relatively stable prices at the bottom end but increasing prices at the top end between November 2017 and July 2018.

Observing patterns in retail prices is fundamental for understanding the economics of any agricultural consumer product. The study of cannabis retail prices, like the study of other economic aspects of the cannabis industry, is fraught with difficulty, in part because cannabis remains a Schedule I narcotic under U.S. federal law. Consumer price indexes, tax records, commercial retail scanner data, industry association reports and other sources of data typically available for agricultural products such as wine, almonds and cut flowers are unavailable for cannabis. Cannabis retailers have limited access to banking services; most cannabis retail transactions are conducted in cash; and cannabis businesses are understandably reluctant to share their financial data. There is a need for better information about all aspects of the cannabis industry, including prices and price patterns.

In this article, we aim to contribute to the scant literature on cannabis retail prices by describing the basic patterns of price ranges at retailers in California over a 21-month time span during which the industry underwent a series of significant regulatory changes. Several times between October 2016 and July 2018, researchers at the UC Agricultural Issues Center (AIC) gathered cannabis retail prices published on Weedmaps, a leading online cannabis retail platform. We report average

P. Saranya, ShutterStock

maximum and minimum prices for three common types of cannabis packages: one-eighth ounce of dried cannabis flower, 1 ounce of dried cannabis flower and 500-milligram cannabis-oil cartridges.

In our first 11 months of data collection (October 2016 to August 2017), we collected prices from retailers in seven representative counties around California. Next, in November 2017, we collected prices from all retailers in California that listed prices on Weedmaps, while continuing to track prices in the representative counties. After mandatory licensing began in January 2018, we collected three more rounds of prices from all retailers that listed prices on Weedmaps and that had received temporary licenses to operate legally from the Bureau of Cannabis Control, a state regulatory agency.

Despite differences in coverage among our rounds of data collection, the data seem to represent a wide swath of cannabis retail prices for retailers that posted prices openly and were part of the legal medicinal or adult-use cannabis segments during a period of unusual change for the cannabis industry.

Regulatory background

Under California law, medicinal cannabis patients have been able to legally purchase a variety of cannabis products since the Compassionate Use Act of 1996. However, state regulation of the industry was minimal for the two decades following the passage of the Act. The legislative process (starting in 2015) that finally introduced regulation and taxation to the California cannabis market is summarized in Goldstein and Sumner (2019) and covered in greater depth in Sumner et al. (2018) and UC Agricultural Issues Center (2018). Here we will review only the major regulatory changes that occurred between 2016 and 2018, when we were collecting price data.

Change 1: The Adult Use of Marijuana Act

Proposition 64, a voter initiative, decriminalized adult-use cannabis in November 2016, the month following our first round of price data collection. The proposition — the Adult Use of Marijuana Act (AUMA) — eliminated criminal penalties for possession, by adults 21 and over, of up to 1 ounce of cannabis flower and/or six cannabis plants. Changes to criminal penalties took effect almost immediately, but state regulatory agencies were given until January 1, 2018 to write regulations for licensing, safety and taxation for all legal (adult-use and medicinal) cannabis.

This left a period of about 13 months, from November 2016 to December 2017, during which California's 20-year-old medicinal cannabis industry was able to continue operating largely as it had before AUMA: permitted but unregulated on the state level, partially and inconsistently regulated at the county and/or municipal levels and mostly untaxed on any level. During this 13-month period, medicinal retailers continued selling cannabis to state residents with up-to-date recommendations from physicians. However, some medicinal cannabis businesses faced unusual local challenges in 2017 as some cities and counties that were opposed to the establishment of an adult-use cannabis industry restricted or banned all cannabis operations from their jurisdictions (UC Agricultural Issues Center 2018).

Change 2: Mandatory licensing, taxation, packaging, labeling and security regulations

On January 1, 2018, all cannabis businesses that had not applied for temporary licenses from state agencies became illegal from the point of view of the state. The Bureau of Cannabis Control, the California Department of Food and Agriculture, the California Department of Public Health and other state agencies propagated regulations that implemented most parts of a regulatory structure that merged AUMA with previous medicinal cannabis legislation (jointly codified as the Medicinal and Adult-Use Cannabis Regulation and Safety Act, or MAUCRSA [2017]).

As of January 1, 2018, licensed distributors were required to pay a 15% state excise tax on all medicinal and adult-use cannabis sold at retail, and licensed growers were expected to pay a cultivation tax of $9.25 per ounce ($148 per pound) for any cannabis that entered legal market channels in 2018. In some counties and cities, additional local taxes were imposed. All licensees were also required to follow costly new regulations governing security, age verification, handling, labeling, child-proof packaging, inventory storage and "seed-to-sale" tracking — but not yet mandatory testing, one of the costliest elements of the new regulations (Valdes-Donoso et al. 2019).

Change 3: Mandatory testing

On July 1, 2018, the Bureau of Cannabis Control began enforcing regulations for pesticide and contaminant testing. After this date, cannabis could not be sold legally in California unless it had passed a stringent battery of laboratory tests, which added about 5% to the cost of supplying cannabis to the legal retail market (Valdes-Donoso et al. 2019). Because not all retailers update their prices immediately with every change in wholesale costs, we expect that testing effects were not fully reflected in our July 2018 data. In addition, some testing requirements were not implemented until January 1, 2019 (Valdes-Donoso et al. 2019).

Medicinal vs. adult-use cannabis

A final regulatory point worth noting is that since the launch of adult-use sales in January 2018, the California cannabis retail environment has drawn little distinction between medicinal and adult-use cannabis, and we do not distinguish between the two in our reporting of retail prices. There are some differences between the medicinal and adult-use systems: Retailers need separate medicinal cannabis permits to sell medicinal cannabis; the minimum age for purchasing

TABLE 1. AIC cannabis price data: Demographics of 7-county sample, Oct 2016

	Non-Latino white	Latino	Asian	Black	Population	Income per capita	Poverty
Butte	72.1%	16.4%	4.8%	1.8%	229,294	$25,077	19.5%
Fresno	29.5%	53.2%	11.0%	5.8%	989,255	$21,057	25.5%
Kern	34.0%	53.4%	5.4%	6.2%	839,119	$21,094	22.4%
Los Angeles	26.2%	48.6%	15.3%	9.0%	10,163,507	$29,301	16.3%
Sacramento	44.8%	23.3%	16.6%	10.9%	1,530,615	$28,292	16.3%
San Diego	45.5%	33.9%	12.5%	5.5%	3,337,685	$32,482	12.4%
Santa Clara	31.6%	25.6%	37.5%	2.8%	1,938,153	$46,034	9.3%
Full 7-county sample	32.7%	41.7%	16.4%	7.5%	19,027,628	$30,641	15.7%
All counties in Calif.	37.2%	38.0%	13.0%	6.0%	39,536,653	$31,458	14.3%

Source: U.S. Census Bureau 2019.

medicinal cannabis is 18 instead of 21; the maximum quantity that may be purchased is 8 ounces instead of 1 ounce; and purchases are exempt from sales tax if the customer has a medicinal recommendation and a county-issued medicinal ID card. However, the cannabis supply for adult-use and medicinal sales is interchangeable. Medicinal and adult-use cannabis are subject to the same testing, labeling and packaging standards. Cultivators and manufacturers have no reason to distinguish between the two product types. In general, the only substantial cost faced by a medicinal cannabis retailer who enters the adult-use market is an additional license fee.

Meanwhile, the potential market for medicinal retailers is severely limited because consumers of medicinal cannabis, if they wish their purchases to be exempt from sales tax, must obtain county identification cards for medicinal cannabis in addition to medical recommendations — at a combined cost of up to $100 per year. With adult-use cannabis now widely available, many consumers (other than 18-to-20-year-olds) who participated in the medicinal market in 2017 chose not to renew their medicinal recommendations in 2018. From an economic perspective, the 2018 California cannabis market is thus more usefully viewed as a single market than as separate adult-use and medicinal markets.

Data collection

The leading source of publicly available data on U.S. cannabis retail prices is Weedmaps, an internet platform that enables retailers in California and other states to publish and update their price lists, locations and other practical information on a standardized consumer-facing website and app. Weedmaps has operated since 2008. Researchers have used it to study the California cannabis industry since well before the autumn of 2016, when AIC researchers first gathered information from the site. For instance, Freisthler and Gruenewald (2014) used Weedmaps listings to study the industrial organization of cannabis retailers in California.

Weedmaps listings do not collectively represent the full California retail landscape. We found no reliable estimates of the percentage of California retailers listed on Weedmaps. But because retailers may add or remove listings from Weedmaps for business or marketing reasons other than opening or closing, Weedmaps provides incomplete and constantly changing coverage of California's retail cannabis market. Bierut et al. (2017), another study that uses Weedmaps data, finds that Weedmaps includes about 60% of retailers in Colorado and 40% of retailers in Washington, but does not analyze California retailers on Weedmaps. This uncertainty should be kept in mind when interpreting our data.

We began gathering price data from Weedmaps in October 2016. We recorded prices by product type and also collected information on retail sales locations and whether retailers were storefront or delivery-only operations. We collected only the minimum and maximum listed price (i.e., the price range) for three of the most common cannabis products. Many retailers listed a price schedule with just two levels for each product type: entry-level and "top-shelf" prices. Some retailers maintained three to four price levels, but during the first year of data collection, we rarely encountered more than five levels (see UC Agricultural Issues Center 2018, section 4.3). With or without intermediate prices, we had no access to information about quantities sold and could not construct quantity-weighted average prices. Moreover, cannabis strains and forms of packaging were often specific to individual retailers, and measures of specific brand or product characteristics were not consistently available on Weedmaps.

Considering that not all retailers list prices on Weedmaps, and that some retailers who at some point listed prices on Weedmaps might have removed their listings while continuing to conduct business, we supplemented our data set with prices from Leafly, a competing cannabis portal whose functionality and

business model are similar to those of Weedmaps. In particular, we turned to Leafly when Weedmaps price information was not available for retailers whose prices we were already tracking — or, in later rounds of data collection, from retailers that had obtained licenses from the Bureau of Cannabis Control to operate in the regulated 2018 environment. Coverage provided by Weedmaps and Leafly is partly overlapping: Some retailers list prices on both portals whereas others list prices only with one service or the other (or neither). To test for bias that might result from the inclusion of Leafly prices as part of our data set, we compared Weedmaps and Leafly average minimum and average maximum prices in a subsample of non-overlapping retailers, controlling for package size, and we found no statistically significant differences between Weedmaps and Leafly average minimum and average maximum prices.

Product types

We collected up to six prices from each retailer, representing minimum and maximum prices for the following three product types:

1. One-eighth ounce of dried cannabis flower (the most common of all product types, known informally as "an eighth"), typically packaged in a plastic bag or glass jar
2. One ounce of dried cannabis flower, typically packaged in a plastic bag
3. 500 milligrams of cannabis oil, packaged either as a disposable cartridge to be used with a reusable portable electric cannabis vaporizer ("vape pen") or as a self-contained disposable vape pen

All retailers listed prices for one-eighth ounce of packaged flower. (The number of "retailers" is equivalent to the sample size for the average minimum and maximum prices we report for one-eighth ounce of packaged flower.) Not all retailers listed prices for 1 ounce of packaged flower or 500-milligram oil cartridges. In later rounds of data collection, the share of retailers listing prices for 1 ounce of flower was smaller and the share of retailers listing prices for 500 milligrams of oil was larger. For instance, in October 2016, 90% of the 542 retailers listed prices for 1 ounce of flower and 57% listed prices for 500 milligrams of oil. In August 2017, 91% of retailers still listed prices for 1 ounce of flower and 82% listed prices for 500 milligrams of oil. By July 2018, only 49% listed prices for 1 ounce of flower and 89% listed prices for 500 milligrams of oil.

The decrease in prevalence of 1-ounce packages might be associated with the introduction of regulations in January 2018 requiring that all cannabis be pre-packaged and pre-labeled, such that after January 2018, retailers might incur extra inventory risk by pre-packaging cannabis in 1-ounce packages. The increase in prevalence of 500-milligram oil packages, on the other hand, might be best explained by the opening and expansion of the adult-use market. Vape pens, which are comparatively easy to use and do not require additional paraphernalia or prior experience with cannabis (for example, rolling a joint or packing cannabis into a pipe), may have greater appeal to "cannabis novices" than dried flower. In the interest of space, we do not list individual sample sizes for each price average in each round of data collection.

Data collection: October 2016 to August 2017

During the first two weeks of October 2016, we collected prices, retailer locations and other information from each of 542 cannabis retailers on Weedmaps in seven counties around California. We chose these counties to serve collectively as a reasonable approximation of the statewide market. We call this initial group of 542 retailers the "seven-county sample." The seven counties cover a wide range of geographic and economic conditions in California. According to the U.S. Census Bureau (USCB 2019), their basic demographics as of 2016 were in the aggregate similar to the demographics of California as a whole. The seven counties are shown in table 1.

Summary statistics provided in table 1 support the notion that the demographic and economic characteristics of the sample are similar to those of California as a whole. Within the sample, the collective population is 42% Latino, 33% non-Latino white, 16% Asian and 8% black (compared to 38%, 37%, 13% and 6% for all of California) and the per capita income is about $30,600 (compared to $31,500 for all of California). Collectively, as of 2016, the seven counties included approximately half of the state's population.

In January 2017, March 2017 and August 2017, we collected three new rounds of prices from the seven-county sample. In each of these three rounds, we collected prices from all of the retailers in the original October 2016 group that still listed price data on Weedmaps or Leafly. In order to continue tracking as many of the original 542 retailers as possible, we attempted to follow businesses that moved to new locations or that temporarily closed and then re-opened. We coded retailers by county, city and phone number. When a retailer's listing disappeared, we searched for other listings under the same name or phone number. When we found the same retailer or a branch of the same retail chain elsewhere in the same county, we kept the retailer in the data set. If a retailer disappeared and then reappeared (within the county) in a later round of data collection, we kept it in the data set. If a retailer removed its online price list, or moved its only location(s) outside the original seven counties, we removed it from the data set for that data collection round (but kept it in the data set for any rounds during which the retailer was active).

Between January 2017 and August 2017, we observed significant attrition from the initial group of 542 retailers in the October 2016 seven-county sample. By August 2017, 389 (72%) of the original 542 retailers

remained in the data set. As shown in tables 2 and 3, average prices for these retailers changed little during this 11-month period. We call this "attrition" because the data collection method was consistent over this time period. In our 2018 rounds of data collection, we impose the additional condition that retailers must be licensed, thus changing the data collection method (see table 2). Thus, for 2018 data collection rounds, the percentage of retailers dropping out of the data set from the original October 2016 sample of 542 retailers should not be thought of as "attrition."

Some retailers may have removed their online price lists from both Weedmaps and Leafly but continued to operate. Attrition from the initial 542 retailers thus should not be interpreted solely as a measure of how many cannabis retailers left the legal cannabis segment.

Data collection: November 2017

In November 2017, while continuing to track the original group of retailers that had been listing prices on Weedmaps since October 2016, we also collected data from all other retailers listing prices on Weedmaps in all counties of California. These included the 169 retailers that by that time remained from the original panel; 700 additional retailers that had newly listed retail prices in the seven original counties after October 2016 (for a total of 869 retailers in the seven original counties); and 1,652 retailers in other counties, for a total of 2,521 retailers across California.

Data collection: February to July 2018

In January 2018, mandatory licensing laws went into effect, thus rendering illegal under state law any cannabis retailer without a temporary license from the Bureau of Cannabis Control. (We call cannabis sold at licensed retailers "legally marketed" cannabis.) We verified licensing status by cross-referencing all Weedmaps and Leafly listings in California with the publicly available lists of temporary licenses granted by the Bureau of Cannabis Control. If both a Weedmaps and a Leafly listing were found, we used the Weedmaps data and dropped the Leafly data.

In computing averages for our last three data collection rounds (February, May and July of 2018), we

TABLE 2. Retail price ranges for legally marketed cannabis, Oct 2016–Jul 2018

Data collection round	Retailers	Dried flower, avg. prices				Oil cartridge, avg. prices	
		1/8 oz min	1/8 oz max	1 oz min	1 oz max	0.5 g min	0.5 g max
1. Oct 2016*	542	$28.12	$54.39	$181.52	$340.53	$30.51	$41.07
November 8, 2016: Proposition 64 passes; adult-use cannabis decriminalized							
2. Jan 2017*	475	$27.36	$53.82	$175.76	$338.99	$30.66	$41.43
3. Mar 2017*	433	$27.39	$53.68	$174.03	$330.29	$29.96	$41.97
4. Aug 2017*	389	$27.85	$51.15	$172.88	$319.34	$29.25	$40.95
5. Nov 2017							
7 sample counties†	869	$31.57	$51.61	$175.96	$311.49	$28.78	$44.36
All counties‡	2,521	$31.11	$51.50	$180.06	$306.33	$30.62	$40.76
January 1, 2018: Regulation and taxation begin; unlicensed retailers become illegal							
6. Feb 2018							
7 sample counties, licensed§	50	$27.75	$60.49	$184.12	$372.60	$32.33	$49.88
All counties, licensed¶	176	$27.44	$56.72	$184.15	$344.59	$30.33	$49.01
7. May 2018							
7 sample counties, licensed§	126	$25.77	$57.05	$168.74	$343.50	$29.68	$51.94
All counties, licensed¶	289	$25.83	$53.83	$169.90	$319.44	$31.01	$49.09
July 1, 2018: Mandatory cannabis testing enforcement begins							
8. Jul 2018							
7 sample counties, licensed§	120	$30.90	$55.05	$187.51	$321.83	$32.24	$57.52
All counties, licensed¶	270	$31.01	$54.46	$191.73	$311.42	$31.80	$54.07

* Prices listed by retailers among the original October 2016 sample of 542 retailers in 7 representative counties who remained active in each data collection round.

† Prices listed by all retailers active in each data collection round in the original 7 representative counties.

‡ Prices listed by all retailers active in each data collection round in all of California.

§ Prices listed by all retailers active in each data collection round in the original 7 representative counties that had obtained temporary licenses from the Bureau of Cannabis Control to operate legally at the time of the data collection round.

¶ Prices listed by all retailers active in each data collection round in all of California that had obtained temporary licenses from the Bureau of Cannabis Control to operate legally at the time of the data collection round.

calculated "legally marketed" minimum and maximum price averages at California cannabis retailers that listed prices on Weedmaps and that had obtained temporary licenses to sell cannabis in compliance with state regulations at the time of each data collection round. For comparative purposes, we also collected a sample of about 90 unlicensed retailers in 20 counties from Weedmaps or Leafly, distributed similarly to the licensed retailers. We chose these retailers from within a set of 20 representative counties, approximately in proportion to the relative populations of those counties. We selected retailers for this "20-county unlicensed sample" arbitrarily (and blindly with respect to their prices) from the first page of search results on Weedmaps for retailers in each of the 20 counties, but we did not use mathematical randomization to select the counties or the listings we chose within counties.

Limitations of price data

These data may not be fully representative of legal cannabis price ranges for several reasons. First, as discussed above, not all legal retailers use Weedmaps or Leafly, and prices may not be representative of all prices.

The price data we collected also may not fully represent the range of products in the market, which may have varied in different rounds of data collection. As is suggested by the changing prevalence of 1-ounce flower packages and 500-milligram oil cartridge packages, product assortments may have changed within each of these categories. This problem plagues price data in many different industries, but changes in product assortments and price listings may have been especially rapid in the emerging cannabis market.

The differences in price ranges we report here should not be interpreted as measures of price dispersion, because we are not observing maximum and minimum prices for exactly the same products at different retailers and thus are not comparing "apples to apples," as is traditionally required to measure price dispersion. However, concrete differences in product attributes — such as potency (as commonly measured by tetrahydrocannabinol, or THC, content) or grow type (indoor, outdoor or greenhouse) for minimum-priced or maximum-priced cannabis — may also vary between retailers, and may correlate with price differences (Orens et al. 2015; Sifaneck et al. 2007), even if price differences between agricultural products do not necessarily correlate with sensory characteristics (Goldstein et al. 2008). For instance, the minimum price for one-eighth ounce of flower at a particular retailer might represent a price for outdoor-grown cannabis with a THC concentration of 15%, whereas the minimum price for one-eighth ounce of flower at another retailer might represent a price for indoor-grown cannabis with a THC concentration of 20%.

By analogy, if one were to collect minimum and maximum prices for all wine at retailers around California, the minimum-maximum range could not be used to measure price dispersion in a traditional sense; in order to measure dispersion, one would have to compare, for instance, the price of the same Kendall-Jackson Chardonnay at different stores. For our research, comparing prices for identical products across retailers would not have been feasible, given the Weedmaps format and our data collection methods. Our approach here, in reporting cannabis price ranges, is to make no assumptions about quality and assume that minimum and maximum prices are simply prices for different types of products.

It would be interesting, in future work, to explore dispersion by collecting and comparing data on standard product types across retailers. Beyond requiring product standardization, an analysis of cannabis price dispersion with respect to geographic areas would also likely require a larger data set than ours. Hollenbeck and Uetake (2018) comment that regulatory barriers to entry can facilitate the exercise of monopolistic behavior by retailers. Dispersion measures, as proxies for competition, might help illuminate regulatory impacts. As more tax and sales data are released by government agencies, it might soon become possible for researchers to collect data sets of sufficient size and precision for dispersion to be measured.

Results

Table 2 shows average minimum and maximum prices over the course of the 21-month data collection period for the three product types that we studied, along with the number of observations in each period.

In the last four rounds of data collection (November 2017 to July 2018), we generally observe only relatively slight differences in both average prices and upward or downward movements among the three retailer groups (retailers from the original sample, all retailers in the seven counties and all retailers in California). Both statewide and within the seven-county sample, average minimum and maximum prices for one-eighth ounce of flower and for 1 ounce of flower differed by 2.5% or less, but averages differed by up to 8.8% for 500-milligram cartridges.

In table 3, we report prices over the 21-month period for the non-attrited sample of the original retail store locations whose prices we collected in October 2016. These retailers may not be representative of overall state averages, particularly after the substantial attrition from the original group of retailers that we observed beginning in November 2017. However, this set of observations avoids potentially confounding factors introduced by the changing sample composition over time.

Table 3 shows substantial attrition from the original seven-county sample of 542 retailers that listed prices on Weedmaps in October 2016. By July 2018, 21 months after the first round of price collection, only 74 non-attrited retailers (14%) from the original sample remained active on Weedmaps or Leafly. Local police

crackdowns and municipal bans in some counties surely contributed to this 86% attrition rate, which should not be interpreted as representative of statewide attrition from Weedmaps or evidence of the general rate of business closures. What is more interesting, perhaps, is the basic observation that only 270 licensed cannabis retailers were listed on Weedmaps in all of California in July 2018, whereas in November 2017, near the end of the unregulated market, about 2,500 California cannabis businesses operated without the need for a license. This observation suggests, at least, that many medicinal cannabis retailers that had been operating legally in 2017 had not yet obtained licenses and entered the new legal market as of mid-2018.

Figures 1, 2 and 3 show average minimum and maximum prices for one-eighth ounce of flower, 1 ounce of flower and 500-milligram oil cartridges for each round of data collection, both for legally marketed cannabis and (in 2018) for the 20-county unlicensed sample.

In the 2016 and 2017 price data, before mandatory licensing, regulation and taxation, we observe relative stability in California cannabis price ranges for all three product types. In 2018, after licensing, regulation and taxation, we observe three patterns. First, we observe falling prices for all products between February and May 2018, which may be related to retailers' need to liquidate untested inventory that would become illegal as of July 2018. Second, we observe generally rising prices between May and July 2018, which may be related to the introduction of mandatory testing rules. However, because of the limitations and uncertain representativeness of the Weedmaps sample, as well as changes to our sampling methods in different rounds, we do not have a basis for inferring a causal relationship between testing rules or other regulatory events and our minimum and maximum price averages.

Third, we observe rising maximum prices for 500-milligram oil cartridges over our last four data collection rounds. At all retailers statewide that listed prices on Weedmaps or Leafly, we observed a 33% increase in maximum prices from November 2017 to July 2018. Table 2 shows that the latter pattern (rising maximum prices for cartridges) can be observed, with some

TABLE 3. Cannabis price ranges at non-attrited retailers remaining from original Oct 2016 sample of 542 retailers, Oct 2016–Jul 2018

		Dried flower, avg. prices				Oil cartridge, avg. prices	
Data collection round	Retailers*	1/8 oz min	1/8 oz max	1 oz min	1 oz max	0.5 g min	0.5 g max
1. Oct 2016†	542	$28.12	$54.39	$181.52	$340.53	$30.51	$41.07
Nov 8, 2016: Proposition 64 passes; adult-use cannabis decriminalized							
2. Jan 2017†	475	$27.36	$53.82	$175.76	$338.99	$30.66	$41.43
3. Mar 2017†	433	$27.39	$53.68	$174.03	$330.29	$29.96	$41.97
4. Aug 2017†	389	$27.85	$51.15	$172.88	$319.34	$29.25	$40.95
5. Nov 2017†	169	$28.88	$52.61	$171.02	$327.05	$30.54	$42.47
Jan 1, 2018: Regulation and taxation begin; unlicensed retailers become illegal							
6. Feb 2018							
Licensed‡	59	$28.10	$61.27	$191.58	$386.10	$32.79	$50.36
Unlicensed§	24	$27.59	$51.78	$150.72	$315.35	$28.08	$40.08
All†	86	$27.68	$54.25	$163.02	$334.79	$29.56	$43.34
7. May 2018							
Licensed‡	64	$25.22	$56.81	$163.56	$343.69	$29.45	$51.92
Unlicensed§	14	$22.36	$50.29	$155.64	$305.29	$27.95	$38.06
All†	78	$24.71	$55.64	$161.97	$336.01	$29.22	$49.77
Jul 1, 2018: Mandatory cannabis testing enforcement begins							
8. Jul 2018							
Licensed‡	61	$30.95	$54.61	$187.80	$335.05	$32.54	$51.15
Unlicensed§	13	$22.56	$48.78	$172.29	$288.68	$27.76	$45.61
All†	74	$29.48	$53.58	$183.92	$323.46	$31.68	$50.16

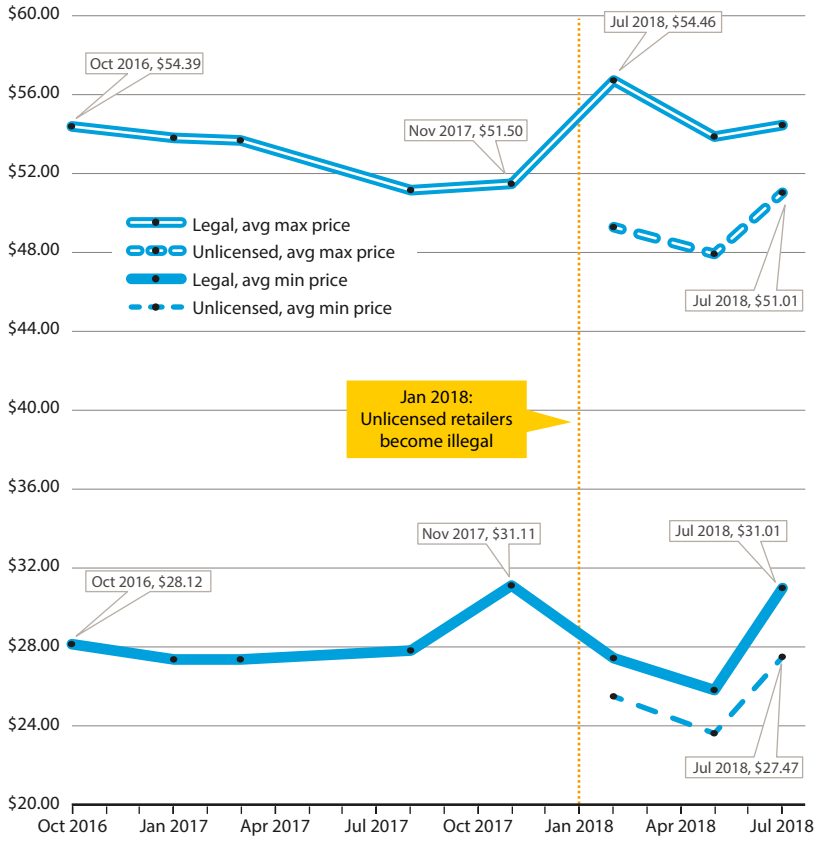
* Number of retailers among the original October 2016 sample of 542 retailers in 7 representative counties who remained active in their original locations in each round of data collection.

† Prices listed by retailers among the original October 2016 sample of 542 retailers in 7 representative counties who remained active in each data collection round.

‡ Prices listed by all retailers from the original October 2016 sample of 542 retailers in 7 representative counties who remained active in each data collection round and had obtained temporary licenses from the Bureau of Cannabis Control to operate legally at the time of the data collection round.

§ Prices listed by all retailers from the original October 2016 sample of 542 retailers in 7 representative counties who remained active in each data collection round and had not obtained temporary licenses from the Bureau of Cannabis Control to operate legally at the time of the data collection round. These unlicensed prices from the original non-attrited sample of retailers should not be confused with the unlicensed prices from the separate 20-county sample of retailers whose prices are reported and compared with prices in the licensed statewide sample of retailers shown in table 4.

FIG. 1. Retail price ranges for 1/8 oz cannabis flower: Average minimum and maximum retail prices listed on WeedMaps for California, Oct 2016–Jul 2018. October 2016 to August 2017 averages are for retailers remaining from the original October 2016 sample of 542 retailers in seven counties (Butte, Fresno, Kern, Los Angeles, Sacramento, San Diego and Santa Clara), with 28% attrition by August 2017. November 2017 averages are for all counties in California. January through July 2018 "legally marketed" averages are for all counties in California, but include only retailers that obtained temporary licenses to operate legally from the Bureau of Cannabis Control. January through July 2018 "unlicensed" averages are for a representative sample of unlicensed retailers in 20 counties around California (Alameda, Contra Costa, Los Angeles, Marin, Mendocino, Orange, Riverside, Sacramento, Santa Clara, San Bernardino, San Diego, San Francisco, San Luis Obispo, Santa Cruz, Shasta, Solano, Sonoma, Stanislaus, Tulare and Yolo). The 20-county unlicensed sample was collected by arbitrarily selecting several retailers that came up in the first page of Weedmaps search results from each of these counties, in approximate proportion to their relative populations.

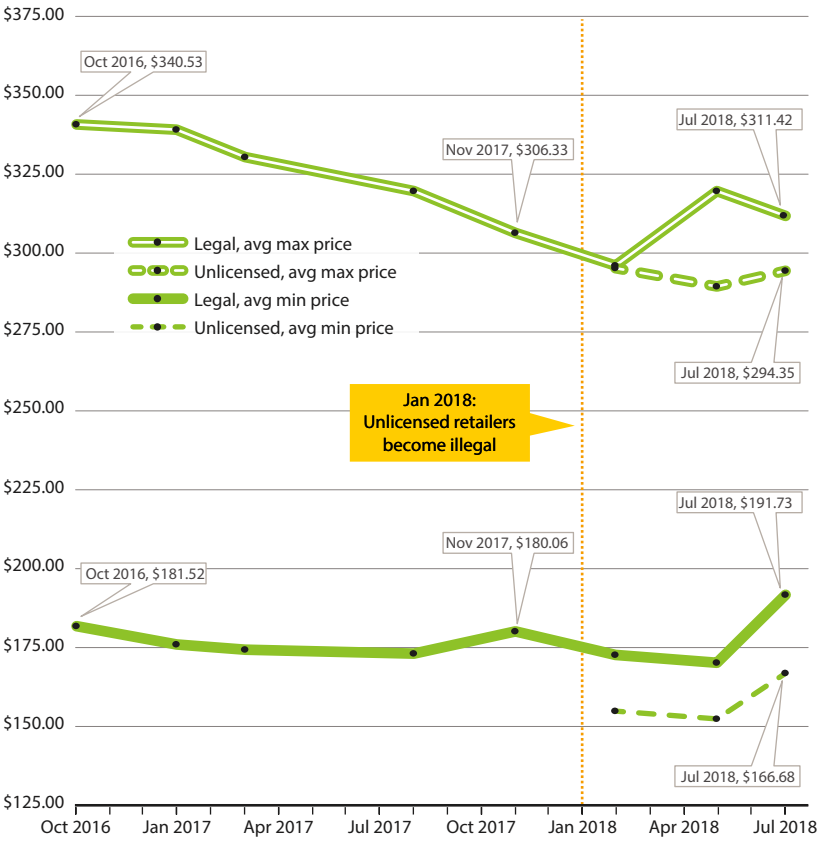


variation, in prices both in the original seven counties and in all of California.

We do not know to what extent the maximum price increases for cartridges might be attributed to the introduction of new, higher-end products with differentiated sensory or functional attributes as the market has evolved; to differentiated packaging attributes; to price increases generated by increased high-end demand; to supply-side factors; or to other market effects.

In general, the price patterns we observe demonstrate little evidence of seasonality, even though wholesale cannabis prices are known to vary seasonally because of the annual outdoor harvest and consequent increase in outdoor cannabis supply in the fall and winter months (UC Agricultural Issues Center 2018).

FIG. 2. Retail price ranges for 1 oz cannabis flower: Average minimum and maximum retail prices listed on WeedMaps for California, Oct 2016–Jul 2018. October 2016 to August 2017 averages are for retailers remaining from the original October 2016 sample of 542 retailers in seven counties (Butte, Fresno, Kern, Los Angeles, Sacramento, San Diego and Santa Clara), with 28% attrition by August 2017. November 2017 averages are for all counties in California. January through July 2018 "legally marketed" averages are for all counties in California, but include only retailers that obtained temporary licenses to operate legally from the Bureau of Cannabis Control. January through July 2018 "unlicensed" averages are for a representative sample of unlicensed retailers in 20 counties around California (Alameda, Contra Costa, Los Angeles, Marin, Mendocino, Orange, Riverside, Sacramento, Santa Clara, San Bernardino, San Diego, San Francisco, San Luis Obispo, Santa Cruz, Shasta, Solano, Sonoma, Stanislaus, Tulare and Yolo). The 20-county unlicensed sample was collected by arbitrarily selecting several retailers that came up in the first page of Weedmaps search results from each of these counties, in approximate proportion to their relative populations.



This relative lack of seasonal price variation could be the result of good inventory control by retailers, or of the fact that a significant portion of legal cannabis is indoor-grown or greenhouse-grown and is thus less subject to seasonal price variation than illegal cannabis. Wholesale cannabis prices are beyond the scope of this article; see UC Agricultural Issues Center (2018) for a discussion of wholesale price patterns over this time period.

Prices at licensed and unlicensed retailers

In table 4, we report results from a comparison between licensed retailers and unlicensed retailers from the three data collection rounds during the post-regulation phase in 2018.

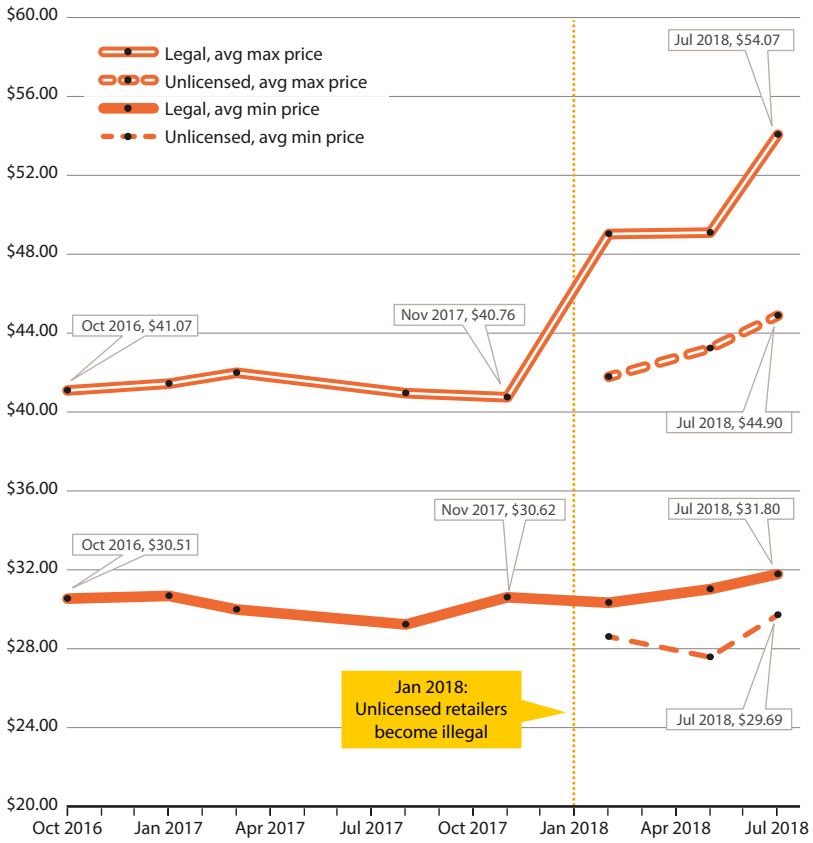


FIG. 3. Retail price ranges for 500-mg cannabis oil cartridge: Average minimum and maximum retail prices listed on WeedMaps for California, October 2016–July 2018. October 2016 to August 2017 averages are for retailers remaining from the original October 2016 sample of 542 retailers in seven counties (Butte, Fresno, Kern, Los Angeles, Sacramento, San Diego and Santa Clara), with 28% attrition by August 2017. November 2017 averages are for all counties in California. January through July 2018 "legally marketed" averages are for all counties in California, but include only retailers that obtained temporary licenses to operate legally from the Bureau of Cannabis Control. January through July 2018 "unlicensed" averages are for a representative sample of unlicensed retailers in 20 counties around California (Alameda, Contra Costa, Los Angeles, Marin, Mendocino, Orange, Riverside, Sacramento, Santa Clara, San Bernardino, San Diego, San Francisco, San Luis Obispo, Santa Cruz, Shasta, Solano, Sonoma, Stanislaus, Tulare and Yolo). The 20-county unlicensed sample was collected by arbitrarily selecting several retailers that came up in the first page of Weedmaps search results from each of these counties, in approximate proportion to their relative populations.

TABLE 4. Legally marketed vs. unlicensed retail cannabis price differences, California, Feb 2018–Jul 2018

Data collection round	Retailers	Dried flower, avg. prices				Oil cartridge, avg. prices	
		1/8 oz min	1/8 oz max	1 oz min	1 oz max	0.5 g min	0.5 g max
Feb 2018							
Licensed*	176	$27.44	$56.72	$184.15	$344.59	$30.33	$49.01
Unlicensed†	88	$25.51	$49.25	$154.76	$295.11	$28.58	$41.78
License premium‡		7.6%	15.2%	19.0%	16.8%	6.1%	17.3%
May 2018							
Licensed*	289	$25.83	$53.83	$169.90	$319.44	$31.01	$49.09
Unlicensed†	93	$23.61	$47.90	$152.22	$289.11	$27.60	$43.19
License premium‡		9.4%	12.4%	11.6%	10.5%	8.5%	13.0%
Jul 2018							
Licensed*	270	$31.01	$54.46	$191.73	$311.42	$31.80	$54.07
Unlicensed†	89	$27.47	$51.01	$166.68	$294.35	$29.69	$44.90
License premium‡		12.9%	6.8%	15.0%	5.8%	7.1%	13.7%

* Prices listed by retailers active in each data collection round that had obtained temporary licenses from the Bureau of Cannabis Control to operate legally at the time of the data collection round.

† Prices from a representative sample of unlicensed retailers in 20 counties around California (Alameda, Contra Costa, Los Angeles, Marin, Mendocino, Orange, Riverside, Sacramento, Santa Clara, San Bernardino, San Diego, San Francisco, San Luis Obispo, Santa Cruz, Shasta, Solano, Sonoma, Stanislaus, Tulare and Yolo). The 20-county unlicensed sample was collected by arbitrarily selecting several retailers that appeared in the first page of Weedmaps search results from each of these counties, in approximate proportion to their relative populations. We collected the 20-county unlicensed sample separately for the purposes of this comparison, and only in the three 2018 data collection rounds. The 20-county unlicensed sample aims to be representative of the whole state, and is unrelated to the original October 2016 sample with attrition or the seven-county sample shown in tables 2 and 3. Differences between licensed and unlicensed prices in the original October 2016 sample, with attrition, are also shown in table 3; however, because of unequal attrition in the seven original counties, licensed-unlicensed differences in table 3 are more likely to be biased. We thus calculate percentage license premiums only in table 4.

‡ Calculated as (licensed – unlicensed)/unlicensed.

We were not surprised to find that prices at unlicensed retailers, which presumably do not bear all the costs of regulation and perhaps taxation, are generally lower than prices at licensed retailers.

Storefront prices and delivery-only prices

In table 5, for data collection rounds 1 to 4, we report the percentage difference in delivery-only prices compared with storefront prices.

From the results reported in table 5, we observe that delivery-only services, compared with storefronts, charge higher prices for cannabis. Price differences are most pronounced for low-end products, perhaps reflecting the higher operating costs per transaction of delivery-only services. We do not carry this analysis through to the regulated 2018 market because not enough delivery-only services had been licensed to make meaningful observations of average prices.

TABLE 5. Delivery-only vs. storefront price range differences, Oct 2016 to Aug 2017*

	Oct 2016	Jan 2017	Mar 2017	Aug 2017
Delivery only *n* =	236	215	192	179
Storefront *n* =	306	260	241	210
1/8 oz min	+7.5%†	+12.3%	+11.6%	+7.2%
1/8 oz max	−1.5%	−1.0%	−1.1%	+4.4%
1 oz min	+7.4%	+8.0%	+5.2%	+8.3%
1 oz max	−0.6%	+2.1%	+2.2%	+3.5%
500 mg min	−4.4%	+0.002%	+1.7%	+4.4%
500 mg max	+0.4%	+2.4%	+0.5%	+3.0%

* Percentage difference between storefront and delivery-only maximum and minimum prices from non-attrited retailers remaining from original October 2016 sample of 542 California cannabis retailers.

† Percentages calculated as ((delivery-only price – storefront price) / delivery-only price) – 1.

Discussion

We collected eight rounds of price data from the legal California retail cannabis market during a 21-month period of regulatory transition, as cannabis was being decriminalized, legalized and regulated in stages. Given the differences between the data sets we collected and the unknowns about Weedmaps that we have discussed above, readers should be especially cautious in interpreting the movements we observe as "trends." We instead describe them as "patterns." In general, one surprising result from our price data sets over time may be the relative *lack* of overall price movements in California cannabis prices, with the exception of rising maximum prices for cannabis oil cartridges in 2018.

The data we report in this paper provides one source of unique information on the retail prices of cannabis flower and oil during the state's period of transition to a regulated market environment. We hope that our data may useful to economists and other researchers who need to make basic assumptions about characteristics of the cannabis market. We did not collect price data for numerous products now available on the legal cannabis market in California, including edibles, waxes and topicals. The market has also changed in important ways since mid-2018. Many other basic reports on price data beyond ours are still needed to understand the economics of California's rapidly changing cannabis market. CA

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142,277

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RESEARCH ARTICLE

Watering the Emerald Triangle: Irrigation sources used by cannabis cultivators in Northern California

Reported subsurface water use among North Coast cannabis cultivators is widespread and may become increasingly common.

by Christopher Dillis, Theodore E. Grantham, Connor McIntee, Bryan McFadin and Kason Grady

Abstract

Water use by cannabis cultivators represents an emerging threat to surface flows in Northern California's sensitive watersheds. To date, however, no data has been available to formally assess where cannabis sites source their water. This study analyzed data from annual reports, covering the year 2017, submitted by 901 cannabis cultivators enrolled in the Cannabis Waste Discharge Regulatory Program administered by the North Coast Regional Water Quality Control Board. The analysis identified cannabis cultivators' most common sources for water extraction, monthly patterns for each water source and differences between sites compliant and not compliant with the cannabis program. The most commonly reported source of water was wells (58% of sites), with most extraction from wells occurring during the growing season (April through October). Surface water diversions (22% of sites) and spring diversions (16% of sites) were the most common sources after wells, with extractions from these sources distributed much more evenly across the year. Although nearly one-third of noncompliant sites (33%) used wells, this source was more than twice as frequently reported among compliant sites (68%), indicating that wells may become increasingly common as more sites become part of the regulated cannabis industry.

Assessing the environmental impacts of the cannabis industry in Northern California has been notoriously difficult (Carah et al. 2015; Short Gianotti et al. 2017). The federally illegal status of cannabis has prevented researchers from obtaining funding and authorization to study cultivation practices (Arnold 2013; Kilmer et al. 2010). Fear of federal enforcement has also driven the industry into one of the most sparsely populated and rugged regions of the state (Bauer et al. 2015; Butsic and Brenner 2016; Corva 2014; Leeper 1990; Thompson et al. 2014), further limiting opportunities for research. The result has been a shortage of data on cultivation practices and their environmental risks (Short Gianotti et al. 2017).

An improved understanding of cannabis cultivators' water use practices is a particularly pressing need. Given the propensity of cannabis growers to establish farms in small, upper watersheds, where streams that support salmonids and other sensitive species are vulnerable to dewatering (Bauer et al. 2015), significant concerns have been raised over the potential impacts of diverting surface water for cannabis cultivation. The

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At this cannabis farm in Trinity County, photographed during the early growing season, infrastructure for mixed-light cultivation is visible in the background. Full-sun outdoor cultivation, with associated drip irrigation, is visible in the foreground.

North Coast Water Quality Control Board

environmental impacts of stream diversions are likely to be greatest during the dry summer months (Deitch et al. 2008, 2016), which coincide with the peak of the growing season for cannabis. Further, because cannabis cultivation operations often exhibit spatial clustering (Butsic et al. 2017), some areas with higher densities of cultivation sites may contain multiple, small diversions that collectively exert significant effects on streams (Grantham et al. 2010; Merenlender et al. 2008).

An important assumption underlying these concerns, however, is that cultivators rely primarily on surface water diversions for irrigation during the growing season. Assessments of water use impacts on the environment may be inaccurate if cultivators in fact use water from other sources. For instance, withdrawals from wells may affect surface flows immediately, after a lag or not at all, depending on the well's location and its degree of hydrologic connectivity with surface water sources (Konikow and Leake 2014). Documenting the degree to which cannabis cultivators extract their water from aboveground and belowground sources is therefore a high priority.

In 2015, the North Coast Regional Water Quality Control Board (hereafter, "water quality control board"), one of nine regional boards of the State Water Resources Control Board, developed a Cannabis Waste Discharge Regulatory Program (hereafter, "cannabis program") to address cannabis cultivation's impacts on water, including streamflow depletion and water quality degradation. A key feature of the cannabis program is an annual reporting system that requires enrollees to report the water source(s) they use and the amount of water they use each month of the year. Enrollees are further required to document their compliance status with several standard conditions of operation established by the cannabis program. These include a Water Storage and Use Condition, which requires cultivators to develop off-stream storage facilities (if necessary) to minimize surface water diversions during low flow periods, among other water conservation measures. Reports that demonstrate noncompliance with the Water Storage and Use Standard Condition indicate that enrollees have not yet implemented operational changes necessary for achieving regulatory compliance. In this research, we analyzed data gathered from annual reports covering 2017 to gain a greater understanding of how water is extracted from the environment for cannabis cultivation. We addressed three main questions:

1. From what sources do cannabis cultivators most commonly report extracting water for cannabis cultivation in the North Coast region — and do patterns of extraction differ across the region?
2. How does reliance on each water source differ from one month to another?
3. Do sites that report compliance with the Water Storage and Use Standard Condition, and sites that report noncompliance, rely on different water sources?

The data used to answer these questions was self-reported. Individuals providing data were not required to use standardized, controlled collection procedures or calibrated instrumentation. Authors of this research took steps to increase the dataset's integrity, but the data should be used and interpreted with a recognition that uncertainty and various potential biases are involved.

Data collection

The data used in this study was collected from cannabis sites enrolled for regulatory coverage under the cannabis program. The program was adopted in August 2015, with the majority of enrollees entering the program in late 2016 and early 2017. The data presented in this article was collected from annual reports submitted in 2018 (n = 1,702), which reflected site conditions during the 2017 cultivation year. The data therefore represents, for the majority of enrollees in the cannabis program, the first full season of cultivation regulated by the water quality control board. Because the data was self-reported, we screened reports for quality and restricted the dataset to reports prepared by professional consultants. Most such reports were prepared by approved third-party programs that partnered with the board to provide efficient administration of, and verification of conformity with, the cannabis program. Additional criteria for excluding reports included claims of applying water from storage without any corresponding input to storage, substantial water input from rain during dry summer months and failure to list a proper water source. Reports containing outliers of monthly water extraction amounts were also identified and excluded due to the likelihood of erroneous reporting or the difficulty of estimating water use at very large operations. Extreme outliers were defined as those values outside 1.5 times the bounds of the interquartile range (25th percentile through 75th

Wellhead at a permitted cannabis cultivation site.

Withdrawals from wells may affect surface flows immediately, after a lag or not at all.

Cannabis growers often establish farms in small, upper watersheds, where streams that support sensitive species such as coho, pictured, are vulnerable to dewatering.

percentile range of all values). Farms were not required to use water meters, and those without meters often estimated usage based on how frequently they filled and emptied small, temporary storage tanks (250 to 2,500 gallons) otherwise used for gravity feed systems or nutrient mixing. The final dataset included 901 reports.

Parcels of land where cannabis was cultivated — including multiple contiguous parcels under single ownership — constituted a site, and this is the scale on which reporting was conducted. The spatial extent of the cannabis program included all of California's North Coast region (fig. 1); however, only a subset of the counties in this region allow cannabis cultivation and therefore reports were only received from the following counties: Humboldt (n = 465), Trinity (n = 269), Mendocino (n = 156) and Sonoma (n = 11). Because Sonoma County contributed relatively little data, we combined Sonoma County's enrollments with those from Mendocino County when making county-level comparisons.

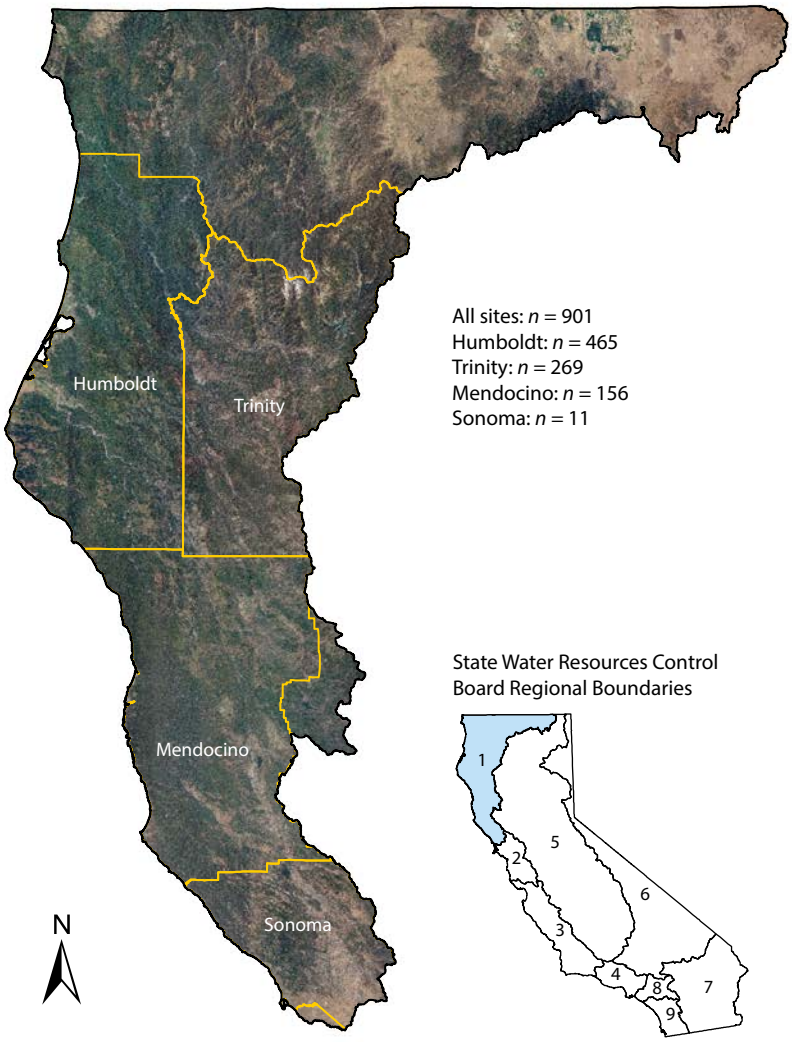


FIG. 1. Map of study area. Humboldt, Trinity and Mendocino counties together comprise the "Emerald Triangle," entirely contained within the North Coast region of California. Additional reports were collected from sites in Sonoma County but, due to the small size of that sample, the reports were combined with Mendocino County's for analysis.

The data used for this analysis included the source and amount of water that cultivators added to storage each month as well as the source and amount of water applied to plants each month. We did not analyze absolute water extraction rates. Rather, we used the amount of water extracted each month — whether water was added to storage or applied to plants directly from the source — to analyze seasonal variation in each water source's share of total water extraction. Water sources included: surface (surface water diversion), spring (spring diversion), rain (rainwater catchment), well (subsurface water), delivery (water truck) and municipal (municipal tap) (fig. 2). The two external sources — delivery and municipal — were consolidated into a single category (off-site). Because staff from the water quality control board were not able to corroborate the accuracy of reported data, enrollees may have classified water sources erroneously. A well placed in proximity to a stream, for example, might properly qualify as a diversion of surface water; so might rainwater catchment ponds or spring diversions that are hydrologically connected to a watercourse. We attempted to minimize these potential errors by restricting the dataset to reports prepared by professional consultants.

As mentioned, enrollees were required to assess several standard conditions in their site reports, including water storage and use requirements. To encourage cultivators to join the regulated industry, and because many cultivation sites existed prior to adoption of the cannabis program, existing sites were not required to comply with standard conditions as a prerequisite for enrollment. Rather, cultivators unable to comply with the standards when they enrolled were required to indicate their lack of compliance and develop a plan for achieving compliance. Such sites were not held in violation of regulations, thus removing a potential motivation to falsely report site conditions. More than one-quarter (28%, n = 249) of enrollees in the dataset (n = 901) reported noncompliance with the Water Storage and Use Standard Condition.

Analysis of water sources

To address question 1 — from which sources cannabis cultivators most frequently extract water across the North Coast region, and if extraction patterns differ across the region — we calculated the percentage of sites that reported use of each water source (surface, spring, well, rain, off-site). We also calculated, for sites using each source, the percentage of sites that also used at least one other source category. Directly applying water to plants and also placing water in storage did not constitute use of multiple extraction sources if the water was drawn from the same source category. Additionally, sites that used multiple inputs from the same category — for example, multiple wells — were not considered users of multiple sources, as this classification was reserved for extraction from multiple categories of sources. We performed all elements of

our analysis for the entire dataset and for each county individually.

To address question 2 — how reliance on each water source differed from one month to another — we divided each site's monthly water extraction total by its annual extraction total to calculate the relative percentage of water extracted in each month, and performed similar calculations for each source category. The median amount of water extracted and interquartile range were calculated for each month — both for overall extractions and for each source category individually.

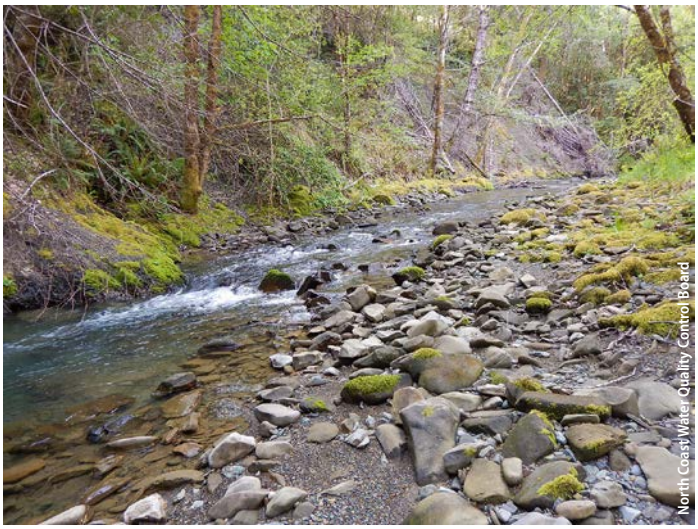
To address question 3 — whether sites reporting compliance with the Water Storage and Use Standard Condition relied on different water sources than those reporting noncompliance — we compared water source extraction patterns for sites of both types. Specifically, we calculated for each compliance status the percentage of sites that extracted water from each source category and made comparisons accordingly; and did likewise for monthly extraction patterns, following procedures similar to those described in regard to question 2. The purpose of this comparison was strictly qualitative, and no inferential statistics were performed to determine statistically significant differences. Instead, this element of our analysis was performed for exploratory purposes, with the intention of identifying broad trends that warrant future attention.

Water sources varied across counties

The most commonly reported water source was wells (fig. 3). Over half the sites (58.2%) reported at least some reliance on wells for their irrigation water.

FIG. 2. Examples of water sources (municipal and delivery sources not pictured).

Subsurface water well. Well casing with associated power box and piping, used to convey water to storage or used for direct application.



Surface water diversion. Example of a typical stream used for surface water diversion. Streams may vary from perennial watercourses to seasonal drainages.

Spring diversion. Spring box installed to consolidate flow, which is then directed through PVC piping.

Rainwater catchment. Storage tanks with filtered tops are one of many means for collecting rainwater.

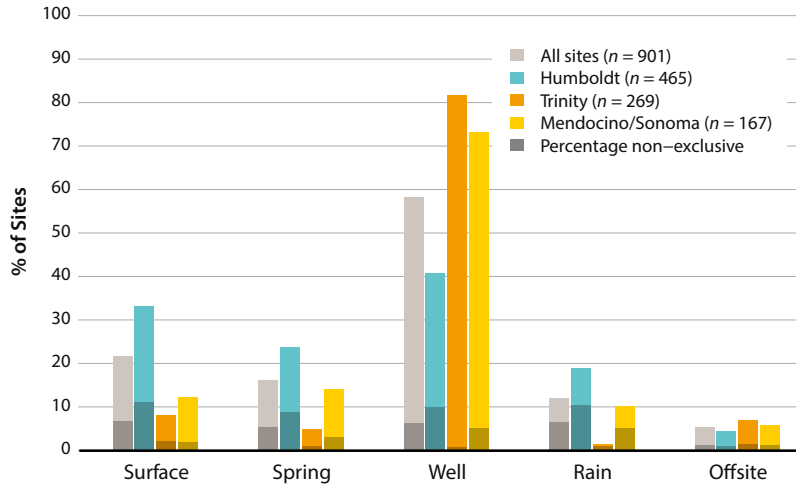
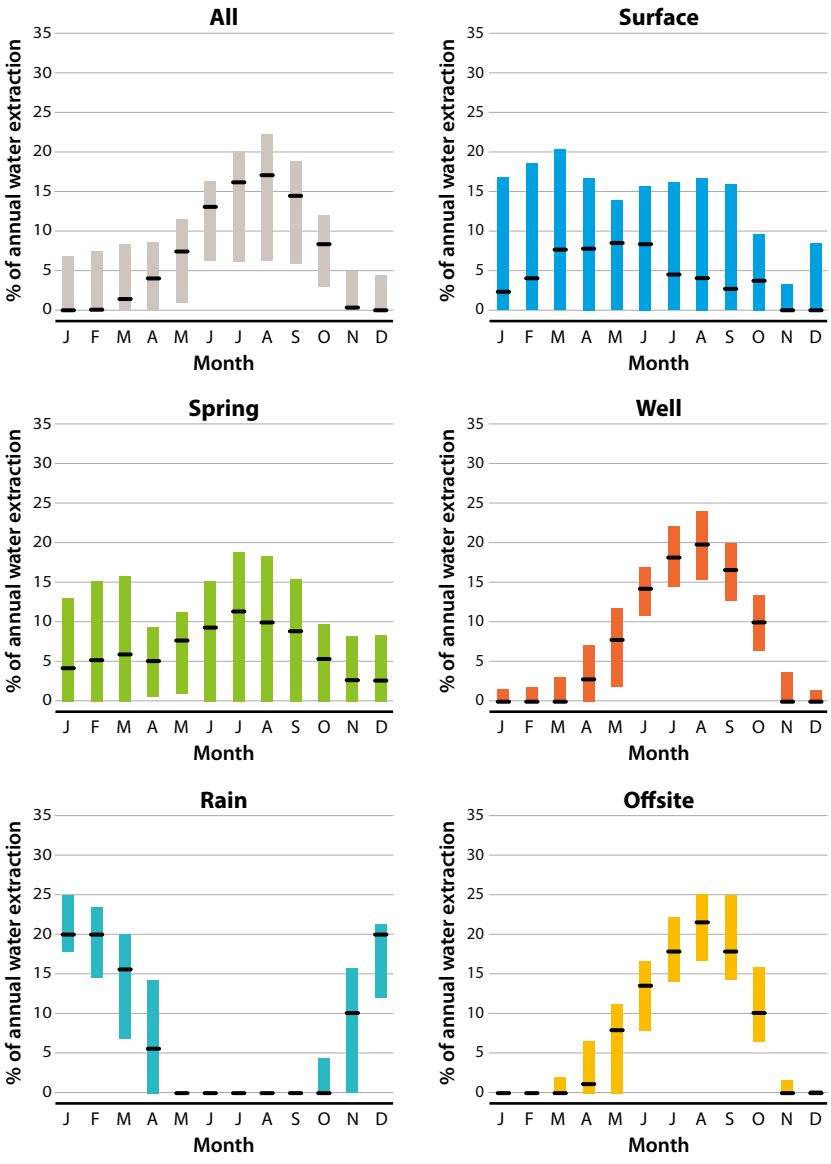


FIG. 3. Percentage of sites extracting water from each source, overall and in each county analyzed. Shaded portions of bars depict the percentage of sites using each respective source that also used additional sources (i.e., the percentage exhibiting nonexclusive use). The shaded portion depicting percentage corresponds to the length of each bar individually, rather than the x-axis.



Surface water (21.6%) and springs (16.2%) were the next–most common sources. Rainwater catchment and off-site water were the least commonly used water sources (12.0% and 5.4%, respectively). Sites using wells and off-site sources were the least likely to use additional sources (10.7% and 22.4%, respectively). In contrast, sites using rain catchment systems most frequently reported using an additional source category (55.6%), followed by sites reporting use of spring diversions (33.6%) and surface diversions (31.3%). To determine if the observed high frequency of well use was due to bias associated with examining only reports prepared by consultants, we reincorporated sites without consultants and reran the analysis on this dataset (n = 1,342). Reported well use was slightly more common among sites not using consultants (60.0%) than among sites using consultants (58.2%).

Counties displayed notable variation in the frequency with which cannabis cultivators used particular water sources (fig. 3). Compared to all sites in the dataset, sites in Humboldt County relied more on surface water (33.1%) and spring diversions (23.9%), with fewer relying on wells (40.9%). The pattern was reversed in Trinity County, with a high percentage of sites there reporting well use (81.7%) and relatively few using surface (8.2%) and spring (4.8%) diversions. A large number of sites (n = 154) in Trinity County were located in a single watershed known for a high concentration of similar cultivation practices, so we recalculated the percentages with these sites excluded. The resulting totals for Trinity County were closer to the overall results: wells (59.4%), surface (20%), spring (11.2%), rain (2.6%) and off-site (14.7%). Mendocino and Sonoma counties (together) reported a similar pattern of extraction sources per site: wells (73.1%), surface (12.1%), spring (14.1%), rain (10.3%) and off-site (5.8%). Patterns of using multiple sources varied among counties. Sites in Humboldt County using well water extraction much more commonly used additional sources of water (24.2%) than did similar sites in Trinity (1.0%) and Mendocino/Sonoma (7.1%) counties. Use of additional sources was also more common among Humboldt County sites extracting surface water (33.8%) and spring water (36.9%) than among sites using surface and spring water in Trinity County (27.3% and 23.1%, respectively) and Mendocino/Sonoma counties (15.8% and 22.7%, respectively).

Wells were a prominent water source for cannabis cultivators during the summer months (fig. 4). Extraction from wells generally peaked in August and declined in off-season months. The pattern was reversed for rainwater use, with most extraction occurring in off-season months. Spring water use was generally even across the year, with slightly higher use

FIG. 4. Relative monthly water extraction. Boxes depict the interquartile range, with black lines at median values for each month. Monthly values reflect the sum of water placed in storage and directly applied to plants.

during the growing season. Surface diversions occurred throughout the year, but declined late in the growing season, likely reflecting declining availability of surface water. The pattern exhibited in off-site water use closely matched that of well water; the former, however, was a less substantial source of water in general.

There appeared to be differences in the extraction sources reported by compliant and noncompliant sites (fig. 5). Although nearly one-third of noncompliant sites (32.5%) used well extraction, this source was more than twice as frequently reported among compliant sites (67.9%). In contrast, noncompliant sites reported surface diversion (39.4%) and spring diversion (36.1%) more commonly than did compliant sites (14.9% and 8.6%, respectively). Rain and off-site sources were the least commonly used for both compliant sites (12.1% and 6.3%, respectively) and noncompliant sites (11.6% and 3.2%, respectively). Use of additional alternative sources was lower for compliant sites with wells (7.0%) than for noncompliant sites with wells (32.5%). The seasonal extraction patterns of compliant and noncompliant sites were generally similar (fig. 6), following the overall pattern discussed above.

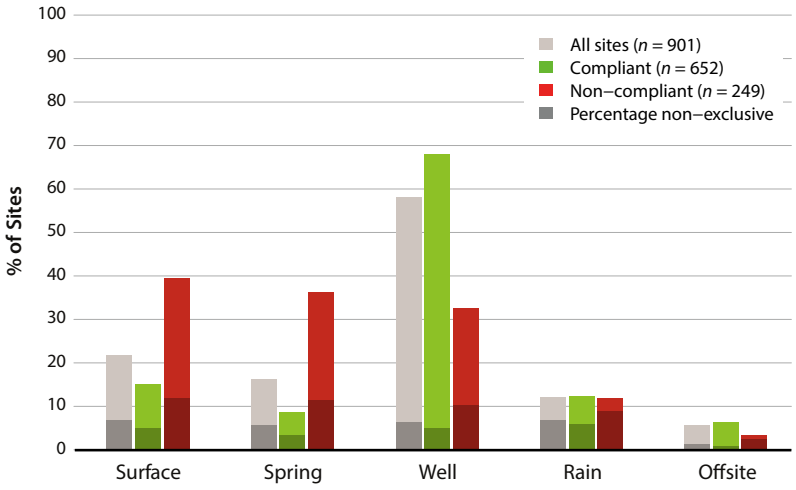


FIG. 5. Percentage of sites extracting water from each source, organized according to reported compliance status. Shaded portions of bars depict the percentage of sites using each respective source that also used additional sources (i.e., the percentage exhibiting nonexclusive use). The shaded portion depicting percentage corresponds to the length of each bar individually, rather than the x-axis.

Effects on streamflow

We found that well water is the most commonly reported source of extracted water for cannabis cultivation in the North Coast region of California. Furthermore, among the source categories, wells are least frequently supplemented with alternative sources. Spring and surface water diversions together are also important water sources, with seasonal patterns of use that are distinct from well water extraction. Reported timing of well water extraction closely tracks the water demand patterns of plants, indicating that cultivators are applying well water directly to plants, rather than storing it. In contrast, the timing of extractions of spring water and surface water remains relatively consistent throughout the year, suggesting that water from these sources may be diverted to storage in the winter, reducing the need for extraction in the summer months. These seasonal extraction patterns and the relative predominance of each source may inform assessments of cannabis cultivation's impacts on water availability.

The use of well water for cannabis cultivation, in comparison to other water sources, presents both potential threats and benefits for instream flow. In upper reaches of small watersheds, streams are dependent throughout the summer months on subsurface water flows from the landscape into the stream. Well water extraction may reduce cold water inputs — limiting streamflow or, in extreme conditions, dewatering stream channels (Barlow and Leake 2012). The extent to which use of subsurface water affects streamflow and water temperature depends on the degree to which well water sources are hydrologically connected to streams. When wells are shallower and closer to streams, and when soil conductivity is greater, subsurface water pumping is more likely to directly capture streamflow. However, if wells are less hydrologically connected to streams, the effects of extraction will be attenuated, resulting in smaller-magnitude and temporally lagged streamflow depletions. With sufficient groundwater recharge in wet months, well water extractions may affect streamflow less than surface water diversions, which were previously assumed to be cannabis cultivators' predominant means of obtaining water in the region (Bauer et al. 2015). Further analysis is necessary to understand the potential impacts of well use on streamflow depletion. Such an analysis would incorporate information on well locations and depths and would consider the underlying geology and soil properties at cultivation sites (Konikow and Leake 2014). Meanwhile, the prevalence and distribution of wells relative to other water sources are influenced by broader geospatial characteristics such as topography and precipitation patterns. Understanding these issues will also be important for assessing the threats and benefits associated with subsurface water extraction.

Variation between counties in well extraction patterns demonstrates that, although subsurface water may be the most common source of water in North Coast cannabis cultivation, the availability of alternative (that is, seasonal) sources may play an important role. Humboldt County watersheds included in this study consistently receive more average annual precipitation (mean = 73.7 inches) than do those in Trinity (53.2 inches), Mendocino (55.1 inches) and Sonoma (46.5 inches) counties (PRISM Climate Group 2018). This difference translates into more available surface and spring water in Humboldt County over the course of the growing season. The observation that fewer sites in Humboldt County report well use, compared to other counties in the study, suggests that if surface or spring water is available, cultivators are likely to use it. Conversely, the potential necessity of groundwater use in counties that receive less rainfall holds particular importance in consideration of emerging areas of

industry growth throughout California. Further analysis is needed to understand how likely cultivators are to rely on wells if other sources of water are available to them. The winter preceding the 2017 growing season was the wettest on record. It is important to understand how cultivators may source their water during years in which summer water availability is not as abundant.

These findings suggest that cultivators may utilize wells both as insurance against surface water scarcity in the summer drought months and as a means of achieving regulatory compliance. The observation that nearly one-third of noncompliant sites reported well extraction indicates that use of subsurface water may be a common means to avoid water scarcity in the late growing season. While Northern California receives considerable seasonal rainfall, there is also significant spatial variability in rainfall totals and in corresponding summer flow persistence of small streams (Zimmerman et al. 2017). Considering the ephemeral nature of surface water in many areas (Arismendi et al. 2013; Deitch and Dolman 2017), the increasing frequency of drought due to climate change (Diffenbaugh et al. 2015) and cannabis cultivation's consistent demand for irrigation water as crops near harvest (Cervantes 2006), cultivators are strongly motivated to secure reliable water sources for the entirety of the growing season. Therefore, it is likely that water extraction from wells is a common practice for cultivators, beyond those seeking participation in the regulated industry (Wilson et al. 2019). Although cannabis regulations place no explicit restrictions on where water is sourced, those currently within or seeking to

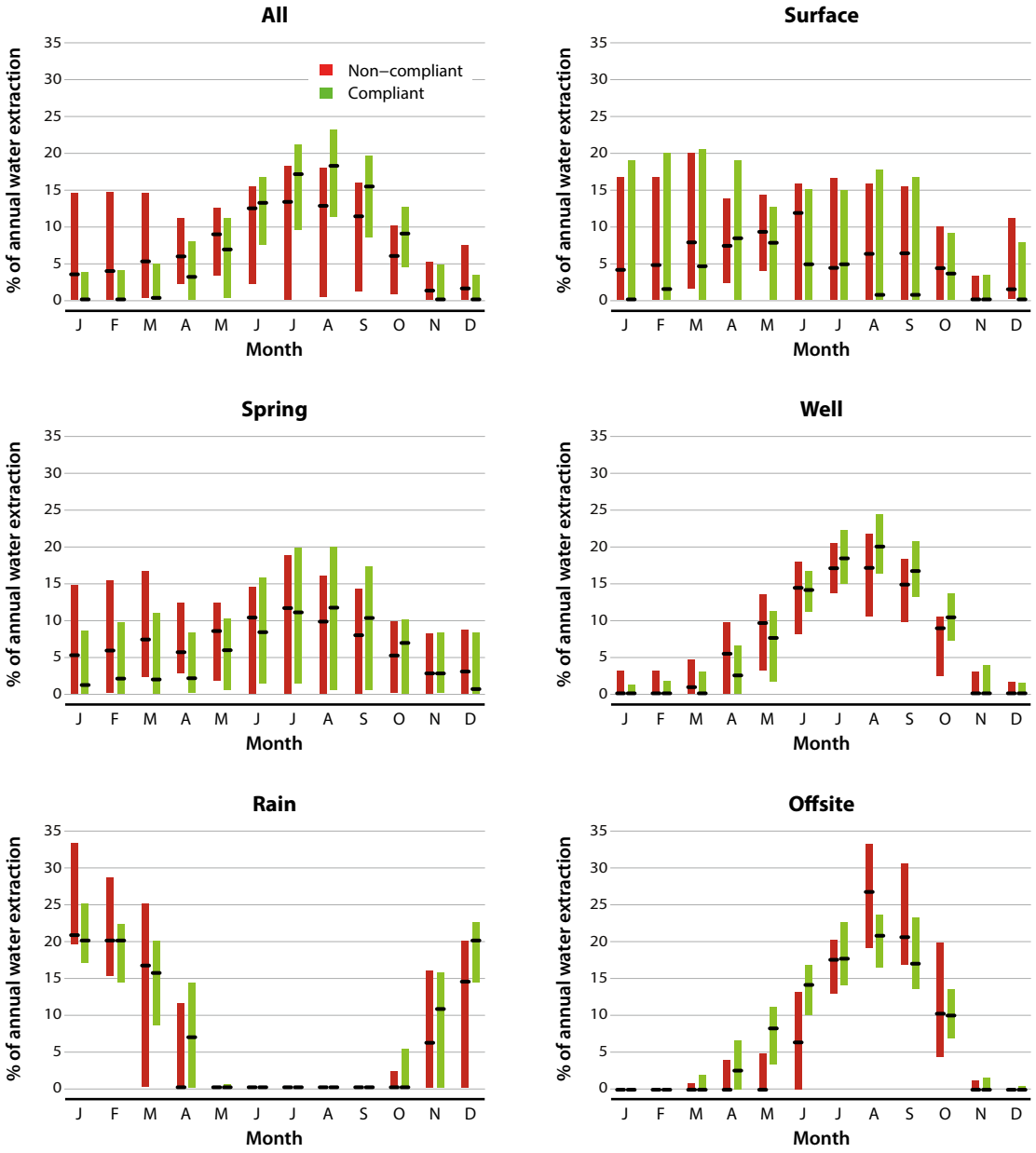


FIG. 6. Comparison of relative monthly water extraction for compliant and noncompliant sites. Boxes depict the interquartile range, with black lines at median values for each month. Monthly values reflect the sum of water placed in storage and directly applied to plants.

join the regulated cannabis industry will be subject to a restriction on diversions of spring and surface water during the growing season (April through October). This requirement (formally referred to as a "forbearance period") is already in place for permits issued by the California Department of Fish and Wildlife and will also be enforced by the State Water Resources Control Board beginning in 2019. The data provided in this study indicates that, in order to meet the forbearance period requirement, cultivators may be more inclined to drill a well to achieve compliance than to develop water storage for spring and surface water. Determining cultivators' capability to store the water they need for the growing season may shed further light on the likelihood that growers will seek subsurface water. If compliance necessitates drilling a well, it will be important to account for the impacts of this potential shift in cultivation practices.

Successful protection of freshwater resources in Northern California will require a more complete accounting of where cannabis cultivators source their water and the amount and timing of water extracted (Megdal et al. 2015). Study of cannabis as an agricultural crop has been notoriously inadequate, but data provided by the water quality control board's cannabis program offers critical new insights into the water use practices of cultivators entering the regulated industry. In this initial analysis, we found that subsurface water may be much more commonly used in cannabis cultivation than previously supposed. Further analyses of cannabis cultivation's water extraction demand, as well as of geospatial variation in water demand, may help elaborate the ramifications of this finding. Ultimately, a better understanding of cannabis cultivation's water demand will be useful for placing the cannabis industry in the greater context of all water allocation needs in the North Coast and throughout California. CA

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RESEARCH ARTICLE

Costs of mandatory cannabis testing in California

California's safety standards for cannabis — compared to standards in other states and to standards for food products in California — are tight.

by Pablo Valdes-Donoso, Daniel A. Sumner and Robin S. Goldstein

Abstract

Every batch of cannabis sold legally in California must be tested for more than 100 contaminants. These contaminants include 66 pesticides, for 21 of which the state's tolerance is zero. For many other substances, tolerance levels are much lower than those allowed for food products in California. This article reviews the state's testing regulations in context, including maximum allowable tolerance levels — and uses primary data collected from California's major cannabis testing laboratories and several cannabis testing equipment manufacturers, as well as a variety of expert opinions, to estimate the cost per pound of testing under the state's framework. We also estimate the cost of collecting samples, which depends on the distance between cannabis distributors and laboratories. We find that, if a batch fails mandatory tests, the value of cannabis that must be destroyed accounts for a large share of total testing costs — more than the cost of the tests that laboratories perform. Findings from this article will help readers understand the effects of California's testing regime on the price of legal cannabis in the state — and understand how testing may add value to products that have passed a series of tests that aim to validate their safety.

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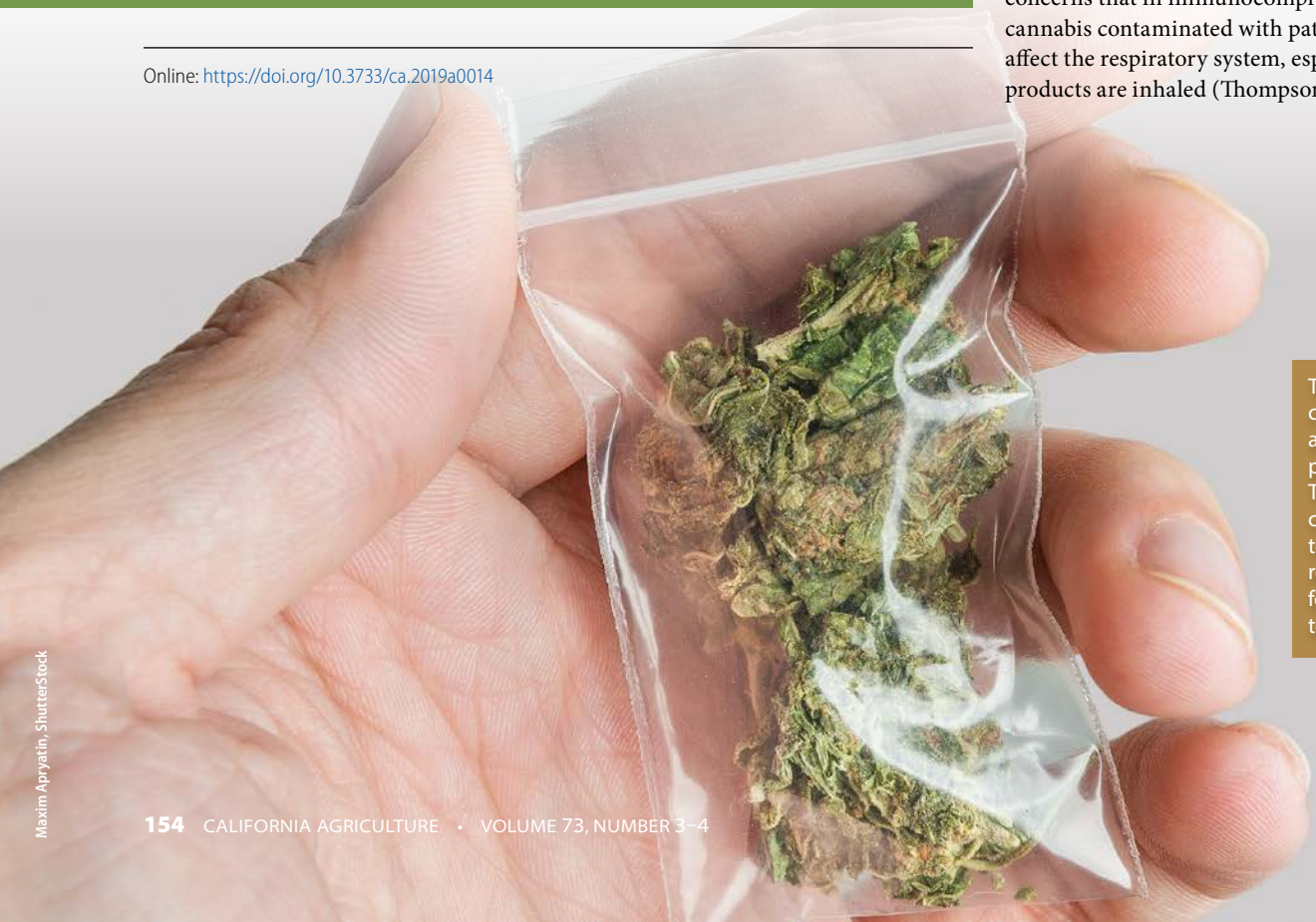
Since California's Compassionate Use Act of 1996, cannabis has been legally available — under state but not federal law — to those with medical permission. Until 2018, however, no statewide regulations governed the production, manufacturing and sale of cannabis. Prior to development and enforcement of statewide regulations, there were no testing requirements for chemicals used during cannabis cultivation and processing, including pesticides, fertilizers or solvents (Lindsey 2012; Stone 2014). Residues were common in the legal cannabis supply — a 2017 investigation found that 93% of 44 samples collected from 15 cannabis retailers in California contained pesticide residues (Grover and Glasser 2017). Some studies of data from the unregulated period suggest a relationship between cannabis consumption and exposure to heavy metals (Moir et al. 2008; Singani and Ahmadi 2012), while others demonstrate that potentially harmful microorganisms may colonize cannabis flowers (McLaren et al. 2008; McPartland 2002; McPartland and McKernan 2017; Ruchlemer et al. 2014). A 2017 study raised concerns that in immunocompromised patients, use of cannabis contaminated with pathogens may directly affect the respiratory system, especially when cannabis products are inhaled (Thompson et al. 2017).



Testing cannabis for contaminants such as chemicals and pathogens is expensive. The lost value of cannabis that fails tests to enter the legal retail market accounts for a large share of testing costs.

Maxim Apryatin, ShutterStock

The currently prevailing statutes governing cannabis testing are contained in Senate Bill 94, the Medicinal and Adult-Use Cannabis Regulation and Safety Act (MAUCRSA) of 2017 — which brought together all of California's previous cannabis legislation, including Proposition 64, the Adult Use of Marijuana Act of 2016 (AUMA). Since MAUCRSA, state agencies have propagated regulations for both medical use and adult use (that is, use for nonmedical purposes). MAUCRSA amends various sections of the California Business and Professions Code, Health and Safety Code, Food and Agricultural Code, Revenue and Taxation Code and Water Code, and introduces a new statewide structure for the governance of the cannabis industry — as well as a system by which the state may collect licensing and enforcement fees and penalties from cannabis businesses. A significant portion of MAUCRSA is comprised of testing rules that aim to certify cannabis safety (Bureau of Cannabis Control 2018a).

These rules, however, may increase the production cost and therefore the retail price of tested cannabis, thereby reducing demand for legal cannabis in California. Thus it is important to understand the costs of cannabis testing relative to the value of generating a safer product. This article evaluates the challenges of safety testing regulations for cannabis in California.

We first review maximum allowable tolerance levels — that is, the amount of contaminants permitted in a sample — under the state's cannabis testing regulations and compare them with tolerance levels for other food and agricultural products in produced in California. We then briefly compare testing regimes and rejection rates in other states where medical and recreational use is permitted. Finally, we use primary data from California's major cannabis testing laboratories and from several cannabis testing equipment manufacturers, as well as a variety of expert opinions, to estimate the cost per pound of testing under the state's framework for the cannabis business (taking into account the geographical configuration of the industry). We conclude by discussing implications of this research and potential regulatory changes.

Tests for contaminants and potency

Since July 1, 2018, all cannabis products have been required to pass several tests before they can be sold legally in California. The specific test for each batch of cannabis depends on product type. Types include (a) dried flowers (sometimes in "pre-rolled," consumer-ready form), (b) edibles (for example cookies, gummy bears and beverages), (c) vape-pen cartridges containing cannabis oil and (d) a wide variety of other processed cannabis goods, including tinctures, topicals (such as lotions, lip balms and creams) and cannabis in crystallized, wax or solid hashish form.

In order to enter the market legally, all these products must be tested for cannabinoids and a large variety of contaminants. Table 1 shows the substances measured in each test (for example, cannabinoids or pesticides), provides a description of each test and specifies

TABLE 1. Summary of mandatory testing per batch type and criteria used to pass tests

Test conducted for	Test description	Batches tested (products)	Criteria required to pass
Cannabinoids	Measures concentration of THC, THCA, CBD, CBDA, CBG and CBN	All	Concentration of any cannabinoid must be within +/- 10% of the labeled value
Foreign material	Determines presence of foreign material (hair, insects, feces, packaging contaminants and manufacturing waste)	All	≤ ¼ of sample area covered by sand, soil, cinders, dirt, mold or any imbedded foreign material. ≤ 1 insect fragment, rodent hair or fragment of mammalian excreta per 3 g
Pesticides	Confirms absence of 21 and limited presence of 45 pesticide residues	All	Levels of specific contaminants below action levels (see table 3)
Heavy metals	Confirms limited presence of 4 heavy metals	All	Levels of specific contaminants below action levels (see table 3)
Mycotoxins	Screens for Aflatoxin B1, B2, G1 and G2, and Ochratoxin A	All	Aflatoxin B1, B2, G1 and G2, and Ochratoxin A < 20 parts per million
Microbial impurities	Screens for Shiga toxin —*Escherichia coli*, *Salmonell*a spp. and pathogenic *Aspergillus* species	All*	Shiga toxin and *Salmonella* spp., and *Aspergillus* species (*A. fumigatus*, *flavus*, *niger* and *terreus*) undetected in 1g
Moisture content and water activity	Measures moisture content and water activity (A_w) according to type of product	Flowers, processed solid and semi-solid products	A_w < 0.65 for dried flowers or < 0.85 for solid and semi-solid edible products; lab must report moisture content
Solvents and processing chemicals	Confirms absence of 6 and limited presence of 14 solvent and processing chemical residues	Manufactured cannabis products or pre-rolled cannabis	Levels of specific contaminants below action levels (see table 2)
Terpenoids	Determines if sample conforms to the labeled content of terpenoids	All labeled products	Concentration of terpenoids must be within +/- 10% of the labeled value

Source: Bureau of Cannabis Control 2018a.

* Screening of *Aspergillus* species only in inhalable cannabis or inhalable cannabis products.

TABLE 2. Tolerance levels for residual solvent and processing chemicals in cannabis products in California

Solvent and processing chemicals	Tolerance levels (microgram per gram)
1,2-dichloroethane, benzene, chloroform, ethylene oxide, methylene chloride, trichloroethylene*	1
Acetone	5,000
Acetonitrile	410
Butane, ethanol, ethyl acetate, ethyl ether, heptane	5,000
Hexane	290
Isopropyl alcohol	5,000
Methanol	3,000
Pentane, propane	5,000
Toluene	890
Total xylenes (ortho-, meta-, para-)	2,170

Source: Bureau of Cannabis Control 2018a.

* This group of residual solvents is categorized as I, while the remaining residual solvents are categorized as II.

the products to which the test applies and the criteria for passing the test. Most tests, such as those for potency, presence of foreign materials, pesticides, heavy metals, mycotoxins, microbial impurities and terpenoids, apply to all batches. Moisture tests, however, apply only to flowers and solid or semi-solid products — while tests for solvents or processing chemicals apply only to processed or "manufactured" products. That is, the specifics of each test depend on which cannabis product is tested.

Independent, licensed testing laboratories are responsible for receiving samples for testing from licensed distributors. The laboratories then conduct a full set of analyses, following the criteria established by MAUCRSA and specified by regulations. Laboratories must deliver to distributors a certificate of analysis indicating the results (pass or fail) of each analytical test. A batch must pass all required tests before it can be released to retailers.

Table 2 shows a list of residual solvents and processing chemicals, with the maximum permitted tolerance (action) levels for legal cannabis. Tests evaluate two groups of solvents and processing chemicals (categories I and II), with a very low tolerance established (1.0 microgram per gram) for those in category I.

Table 3 shows tolerance levels for pesticide residues and heavy metals. The maximum permitted tolerance levels for pesticide residues are particularly tight when compared with tolerance levels for other agricultural products in California. For many pesticides, the maximum residual level is zero, meaning that very stringent tests are required and that no trace of the chemical may be found. Among pesticides with allowable limits above zero, the tolerance levels for inhalable products are particularly low. In some cases, tolerance levels for

TABLE 3. Tolerance levels for pesticide residues and heavy metals in cannabis and cannabis products in California

Pesticide	Tolerance Level (µg/g)	
	Inhalable	Other
Aldicarb, carbofuran, chlordane, chlorfenapyr, chlorpyrifos, coumaphos, daminozide, dichlorvos (DDVP), dimethoate, ethoprop(hos), etofenprox, fenoxycarb, fipronil, imazalil, methiocarb, methyl parathion, mevinphos, paclobutrazol, propoxur, spiroxamine, thiacloprid*	0	0
Acephate, acetamiprid, bifenazate	0.1	5
Abamectin	0.1	0.3
Acequinocyl	0.1	4
Azoxystrobin	0.1	40
Bifenthrin	3	0.5
Boscalid	0.1	10
Captan	0.7	5
Carbaryl	0.5	0.5
Chlorantraniliprole	10	40
Clofentezine	0.1	0.5
Cyfluthrin	2	1
Cypermethrin	1	1
Diazinon	0.1	0.2
Dimethomorph	2	20
Etoxazole	0.1	1.5
Fenhexamid	0.1	10
Fenpyroximate, flonicamid, hexythiazox	0.1	2
Fludioxonil	0.1	30
Imidacloprid	5	3
Kresoxim-methyl	0.1	1
Malathion	0.5	5
Metalaxyl	2	15
Methomyl	1	0.1
Myclobutanil	0.1	9
Naled	0.1	0.5
Oxamyl	0.5	0.2
Pentachloronitrobenzene	0.1	0.2
Permethrin	0.5	20
Phosmet	0.1	0.2
Piperonylbutoxide	3	8
Prallethrin	0.1	0.4
Propiconazole	0.1	20
Pyrethrins	0.5	1
Pyridaben, spinetoram, spinosad	0.1	3
Spiromesifen	0.1	12
Spirotetramat	0.1	13
Tebuconazole	0.1	2
Thiamethoxam	5	4.5
Trifloxystrobin	0.1	30
Heavy metals		
Cadmium	0.2	0.5
Lead	0.5	0.5
Arsenic	0.2	1.5
Mercury	0.1	3

Source: Bureau of Cannabis Control 2018a.

* Pesticides for which zero residue is allowed are categorized as I, while those for which a limited amount is allowed are categorized as II.

inhalable products are one-four-hundredth the levels for other products.

To help interpret the cannabis tolerances, it is helpful to consider them in the context of food safety testing. The top row of table 4 shows, based on more than 7,000 samples, the percentage of California food products in which, from 2015 to 2017, any pesticide residues were detected (California Department of Pesticide Regulation 2018). These percentages were above 60%. The second row of table 4 shows that, despite the high share of food products in which some pesticide residue was detectable, only 1.51% of samples in 2016 contained pesticide residue above tolerance levels set by the U.S. Environmental Protection Agency (EPA) — and only 0.45% exceeded those levels in 2017. The bottom panels of table 4 show that, of the 7,000 samples tested, more than 12% of 2017 samples would have been above California's product tolerance limits for inhalable cannabis. More than 3% of the 2017 samples would have exceeded even the less stringent tolerance levels established for other (non-inhalable) cannabis products. As shown in table 4, similar results apply to the samples for the other two years.

Costs of cannabis testing

In California's licensed, legal cannabis channel, all products must be held by a licensed distributor while they are tested in an independent, licensed laboratory. Licensed testing laboratories do not publish their prices and the costs of testing services are not generally available. Testing prices depend on the number of samples to be tested, the type of product tested and the specifics of the contract between the distributor and the laboratory, among other factors.

We collected detailed data to construct in-depth estimates of the capital, fixed and variable costs required to run a licensed testing laboratory in California. This information included the costs of equipment, facilities, maintenance, supplies, technical and non-technical labor, taxes and other inputs. We gathered data from established cannabis testing companies (those that have been in business for several years), new cannabis testing companies, laboratories that test other agricultural products, and other industry sources, including advisors of the cannabis industry and cannabis retailers.

We collected prices for testing equipment, supplies, chemical reagents and other cannabis testing inputs by contacting the sales representatives of large equipment supply companies (Aligent Technologies Inc., Schimadzu Scientific Instruments Inc., and VWR). We considered the costs of sampling and transportation to and from test facilities, adjusting those costs estimates according to the geographical configuration of testing laboratories and distributors across the state.

Finally, we used data from the California Department of Pesticide Regulation (see table 4) and some assumptions based on experience in other states to estimate the share of cannabis that fails testing and therefore the lost inventory due to failed tests. To make these cost calculations we accounted for inventory that first fails testing, but then is remediated. In addition, to understand the opportunity cost of cannabis used in the tests or lost in the process, we use data from wholesale prices and a survey of retail cannabis prices conducted by the University of California Agricultural Issues Center (Goldstein et al., unpublished data).

Based on this information, we developed a cost per unit of cannabis tested for representative labs of three different sizes to approximate the distribution of costs in the industry. For simplicity, we assumed that testing labs of different sizes use the same inputs, but in different proportions, to provide testing services. We assume economies of scale with higher share of capital costs per unit of output for the smaller labs. We used information reported by the Bureau of Cannabis Control in the first half of 2018 to compile a list of cannabis licensed testing laboratories and distributors in California (Bureau of Cannabis Control 2018b).

TABLE 4. Percentage of California food product samples indicating any detection of pesticide residues, above EPA tolerance levels, and percentage above tolerance levels for cannabis products (2015–2017)

Food product	2015	2016	2017
With any detection of pesticide residues*	60.35%	60.06%	61.46%
With pesticide residues above EPA tolerance levels*	0.32%	1.51%	0.45%
Food that would have exceeded cannabis tolerance levels			
Using criteria for inhalable cannabis products	12.86%	13.44%	12.79%
Using criteria for other cannabis products	4.07%	3.62%	3.90%

* Sources: California Department of Pesticide Regulation 2018, and Bureau of Cannabis Control 2018a.

We used information on the geographic location of testing labs relative to cannabis production and consumption to assess the cost of transporting samples from distributors to testing labs. In March 2019, there were 49 active testing licensees and 1,213 licensed distributors. Both testing licensees and distributors are located in many areas across the state, but they are concentrated in traditional cannabis production areas in the North Coast region of California and in large population centers.

Table 5 shows capacities, annualized capital costs, and other annual expenses for three size categories of testing labs: small, medium and large. The size categories are based on the number of samples analyzed annually (2,200, 6,190 and 23,160, respectively) and were chosen to represent typical firms, based on our discussions with the industry. We assume about 25% of labs are small, 25% are large and the remaining half are in the medium category. By regulation, these labs test only cannabis. The annualized cost of specific testing equipment and other general laboratory equipment is a significant share of total annual costs. The cost of equipment and installation is about $1.5 million for

a small lab, about $2.4 million for a medium lab and about $3.8 for a large lab. These costs are expressed as annual flows in table 5. To account for the annual cost of investment in equipment we use a discount rate of 7.5% per year that reflects the combined effects of depreciation and interest over a 10-year horizon, using the standard equivalent annual cost formula, typically used in budgeting studies:

Annual Cost = $(0.075)K/(1 - (1.075)^{-10})$ where K is the invested capital for each of the three testing labor sizes. These annualized costs of the invested capital for each size of testing lab operations are shown in the top row of table 5.

Our survey and discussions with laboratories provide the rest of the estimated costs. Equipment maintenance costs, rent, utilities and labor also are large cost categories. Each of these costs is less than proportional to the number of samples tested and thus contributes to economies of scale. This cost of consumable supplies is calculated on a per sample basis and thus is proportional to the number of samples tested. Finally, the return to risk and profit is estimated as 15% of the sum of the foregoing expenditures. Our estimated total annual costs are about $1.6 million for small labs, $3.3 million for medium labs and $7.0 million for large labs.

The scale advantage of larger testing labs is reflected in the testing cost per sample: $324 for large labs, compared with $562 for medium labs and $750 for small labs. These cost differences arise from economies in scale in the use of laboratory space, equipment and labor. Each large testing lab processes about 10 times the number of samples as a small lab but has annualized operating costs only about five times those of a typical small testing lab. That means that small-scale labs tend to specialize in servicing more remote cultivators or manufacturers that have products handled by smaller and more remote distributors located at a cost-prohibitive distance from large labs.

We used data on the annual testing capacities of small, medium and large labs and our assumption about the number labs of each size to calculate the share of testing done by labs of each size category. We expect that small labs will test about 6% of all legal cannabis in the state by volume, medium-sized labs will test about 33% of legal cannabis, and large labs will test 61% of legal cannabis. Using these shares, the weighted average cost per sample tested is about $428.

Let us now turn from the cost per batch tested to the cost per pound of cannabis marketed. The per pound costs of laboratory testing depends on the number of pounds tested in each test. Therefore, we must consider batch size. Regulations have set a maximum batch size of 50 pounds of cannabis flowers (or 150,000 units for processed cannabis products). We expect that the batch size will differ within this constraint depending on the product type and origin and size of the cultivator and manufacturer and explore implications of batch size differences. Using the weighted average cost per sample of $428, the testing cost for a small batch of 5 pounds is $85.60, while for the largest-allowed batch size of 50 pounds, the cost is just $8.56 per pound.

Next, we turn to several costs not included in the cost of testing a sample in the lab (these costs are included in table 6). First and most straight forward is the cost of compliance with security measured including video surveillance and archival, disposal and quarantine, and other compliance costs that we estimated were equivalent to $4.88 per pound for small labs, $4.06 per pound for large labs and $3.25 per pound for large labs for a weighted average of $3.62 per pound.

The cost of testing requirements on a retail cost basis is best expressed as the full cost per unit of cannabis that reaches the market. Expressing the full cost in this way raises two additional costs.

The first is simple: the value of the cannabis used up in the testing procedure. Based on MAUCRSA, the sample size must be at least 0.35% of the total batch of cannabis tested. We use an average wholesale value of $1,360 per pound of cannabis flower equivalent at the testing stage, which represents a recent weighted average price across outdoor grown, greenhouse grown and indoor grown cannabis and products (Sumner et al. 2018). Thus, for each pound of cannabis tested, flower worth $4.76 is used up.

The second issue, costs associated with a failure to pass the test, is more complex. These costs include the cost of the testing process as well as the (much greater)

TABLE 5. Itemized costs and costs per sample by laboratory scale of operation

Item	Small	Medium	Large
Mean no. of effective samples analyzed year	2,200*	6,190†	23,160‡
Annual operating costs		*($ thousands)*	
Capital investment, interest plus depreciation§	$215.23	$348.30	$556.05
Equipment maintenance and acquisition and maintenance of ISO/IEC-17025	$232.47	$371.76	$593.92
Rent and basic utilities costs	$168.46	$200.22	$226.61
Sales, general and administrative costs	$70.58	$92.05	$118.42
License fees	$20.00	$45.00	$90.00
Labor	$422.63	$1,158.43	$1,976.75
Consumable costs	$239.77	$674.92	$2,525.77
Return to risk and profit (15%)	$205.38	$433.61	$913.15
Total for the laboratory	$1,574.52	$3,324.27	$7,000.67
	Costs per sample tested		
Average cost per sample of cannabis within lab testing	$716	$537	$302
Cost of collection, transport and handling	$34	$25	$22
Average cost per sample of testing	$750	$562	$324

Source: Author survey and calculations.

* Assumes that a firm operates 250 days per year, 8 hours per day, and that machinery runs 55% of the hours per year. Also, assumes that 80% of the attempted tests are successfully completed.

† Assumes that a firm operates 260 days per year, 8 hours per day, and that machinery runs 70% of the hours per year. Also, assumes that 85% of the attempted tests are successfully completed.

‡ Assumes that a firm operates 290 days per year, 14 hours per day, and that machinery runs 80% of the hours per year. Also, assumes that 95% of the attempted tests are successfully completed.

§ Annual payment flow uses a 7.5% discount rate and a 10-year investment horizon.

cost of the cannabis that must be destroyed when it is considered unacceptable to be marketed by virtue of a failed test.

Stringent maximums for pesticides, microbials and other contamination mean that there will be a significant chance that a sample is rejected. In some cases, the owner will attempt to remediate or process that batch, intending to eliminate the cause of the non-passing the test. A batch can be remediated up to two times. If a batch fails its testing after its second remediation, regulations mandate that that batch must be destroyed in a verifiable way. This is a major cost of the testing regime required by California legislation and regulation.

To estimate the cost of such rejections, we used a range of potential rejection rates, drawing from information that was available on contamination of cannabis in other states. However, the experience of other states is of limited value and must be adjusted based on information from industry sources.

Washington state mandates tests on potency, moisture, foreign matter, microbiological and mycotoxin screening, residual solvent and heavy metals, but, unlike in California, testing on pesticide residues is not mandatory (Washington Administrative Code 2018). Washington state enforcement is based on spot checks. Based on Washington state data, we found that in 2017, the second year after the testing began, 8% of the total samples submitted failed one or more tests.

Colorado state mandates tests on residual solvents, microbial, mycotoxins, heavy metals, pesticides and potency. The Colorado Marijuana Enforcement Division reported that during the first six months of 2018, 8.9% of total samples of adult-use cannabis failed testing (Colorado Department of Revenue 2018). Testing on pesticide residues only became mandatory in August of 2018 in Colorado, so systematic data on test results were not available. However, the Department of Agriculture in Colorado informed us that 60% of spot-checks based on complaints or concerns between 2015 and 2017 found pesticide residues (Michael Rigirozzi, Colorado Department of Agriculture, personal communication).

Given the cost of cannabis that must be destroyed in case of failed tests, cultivators and manufacturers may pre-test to decrease the chances of failing official tests. For our cost analysis, we assume that 25% of cannabis is pre-tested before being submitted for the formal and binding tests. To express costs in terms of the pounds of cannabis legally marketed, and account for pre-testing and pounds lost because of testing, we need to express the ratio of pounds tested to pounds that pass testing. The following equation expresses that ratio tested to passed:

$$\text{Ratio of tested to passed} = [1+ \text{pretest\%} + (\text{fail\%}) \times (\text{retest\%})] / [1 - (\text{fail\%} - (\text{fail\%}) \times (\text{retest\%}) \times (\text{fail\% of retests})]$$

Into this equation we put assumptions for the pre-test, fail and retest rates based on our best assessments after interviewing testing labs and analyzing data from other states. We set the pretest share at 25%, the retest share of failed samples at 50% and the failure rate of re-tested samples at 50%. We explore costs associated with three initial failure rates — 7%, 12.5% and 25% — to reflect the range of information we gathered. With these inputs to the equation, the ratio of tested cannabis to passed cannabis is 1.365 if the initial failure rate is 7%, 1.448 if the initial failure rate is 12.5% and 1.692 if the initial failure rate is 25%. These factors must be multiplied by all the costs per pound tested to calculate the cost per pound of cannabis actually marketed.

Table 6 reports, in three components, the costs per pound of cannabis marketed: (1) the cost of laboratory testing, (2) the value of lost inventory (opportunity cost of cannabis rejected) and (3) the relatively small cost of remediating failed batches. For small batch sizes, laboratory testing costs are an important testing cost, especially when the rejection rate is low. For a 50-pound batch size, laboratory costs are a small share of overall costs, especially as rejection rates rise. In the medium case of a 25-pound batch and a 12.5% rejection rate, which might be fairly typical, lab costs are $30 per pound and the cost of cannabis lost in the testing process is $148, so laboratory testing represents only one-sixth the total cost of complying with laws and regulations regarding mandatory testing. In this case, the total cost of testing, including the loss of the potential value of marketable cannabis, is $179 per pound, or about 13% of the wholesale value of cannabis assumed in this research.

Legal versus illegal

The costs of establishing and operating a cannabis testing facility that meets California's mandates are largely accounted for by investment in precise equipment, the cost of highly skilled labor and costs of materials.

TABLE 6. Itemized costs of testing under different rejection-rate and batch-size assumptions

Rejection rate*	Batch size	Laboratory cost*	Cannabis lost	Remediation cost	Total
	(Pounds)	*($/pound)*	*($/pound)*	*($/pound)*	*($/pound)*
7.0%	5	$121	$83	$1	$204
7.0%	25	$28	$82	$1	$111
7.0%	50	$17	$82	$1	$99
12.5%	5	$129	$148	$1	$278
12.5%	25	$30	$148	$1	$179
12.5%	50	$18	$148	$1	$167
25.0%	5	$151	$322	$3	$476
25.0%	25	$35	$322	$3	$360
25.0%	50	$21	$322	$3	$346

Source: Author survey and calculations. Note: totals may not reflect sums of rows due to rounding.

* For laboratory costs, in addition to those listed in table 5, laboratories have compliance costs for surveillance, disposal and other activities that are applied per pound tested. These costs are $4.88 for small labs, $4.06 for medium-size labs and $3.25 for large labs. The weighted average of these costs is included in the laboratory costs per pound.

Testing is expensive, but the lost value of cannabis that fails tests to enter the legal retail market is an even bigger issue. It is difficult to predict rejection rates with great confidence; the data we present, however, is consistent with reports of pesticide detection in California food crops and information available from other states. Evidence suggests that major drivers of both direct laboratory costs and lost cannabis costs are low or zero tolerance levels set for pesticides (see tables 2 and 3) and the difficulty of dealing with microbial contamination. We have shown that if these low tolerance levels were applied to other California food crops, a significant proportion would have failed tests in recent years (see table 4). Thus California's safety standards for cannabis are tight compared to other states' standards and to standards for other products within California. We note that there may be safety reasons that cannabis is subject to such tight tolerance levels, but they are not in the literature and are beyond the scope of this article.

California's system for testing cannabis has been under pressure since the implementation of the state's testing regime in July 2018 because of difficulties in supplying the market with product that has passed the tests and has been labeled correctly. Some producers, after receiving inconsistent test results for contaminant residues from different laboratories, have voluntarily recalled product (Schroyer 2018a; Schroyer 2018b). However, California has not yet reported detailed data on official test rejection rates.

Costs of testing will be reflected in the price of marketed legal cannabis. Thus it is crucial to understand the value that testing creates for consumers compared to the costs. Competition between legal cannabis and untested illegal cannabis is a major issue in cannabis policy. Rules that help ensure safe and high-quality products for consumers of legal cannabis can encourage some consumers to shift from the illegal supply chain to the legal, licensed supply chain. Before the passage of AUMA in 2016, the low prevalence of testing in California's essentially unregulated market for medicinal cannabis indicated that many consumers entertained a limited willingness to pay for higher safety standards. This suggests that at least some consumers may remain today in the illegal, low-priced market, even though certified, tested products are available in the licensed supply chain.

Taxes and regulations will make legal cannabis more expensive than illegal cannabis. However, safety testing is the basis of product differentiation for legal cannabis sold through licensed retailers. In some agricultural product industries, growers have urged product safety and consistency standards, as well as more stringent testing standards, to increase demand (Gray et al. 2005). As the regulated cannabis market develops, we expect that increased access to data will help clarify the impact on demand of mandatory testing rules. CA

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RESEARCH ARTICLE

Perceptions of cannabis among Humboldt County timberland and ranchland owners

A Humboldt County survey investigates traditional agriculturalists' views on cannabis cultivation.

by Yana Valachovic, Lenya Quinn-Davidson, Jeffery Stackhouse and Van Butsic

Humboldt County has been an epicenter of cannabis cultivation for decades, and an element of social division has characterized the region: the "back-to-the-landers" versus the born-and-raised locals, the "hippies" versus the "rednecks," and the pot growers versus the loggers and ranchers (Leeper 1990). However, as cannabis cultivation has been decriminalized in California, the social dynamics around cannabis have become more complex. Over the last 20 years, new growers from different parts of California, the United States and even outside the United States have moved to Humboldt County and surrounding areas to grow cannabis — a so-called green rush of growers hoping to strike it rich (Corva 2014). Growers have come from a host of countries beyond the United States, including Bulgaria, Russia, Mexico and nations in Southeast Asia (William Honsal, Humboldt County sheriff, personal communication; unreferenced). Some work independently while others work together in operations that may qualify as more organized. For many Humboldt County residents — "mom-and-pop" cannabis growers and more traditional agricultural producers alike — the near-exponential growth of the industry has been a shock, and it has unleashed numerous social, economic and environmental concerns.

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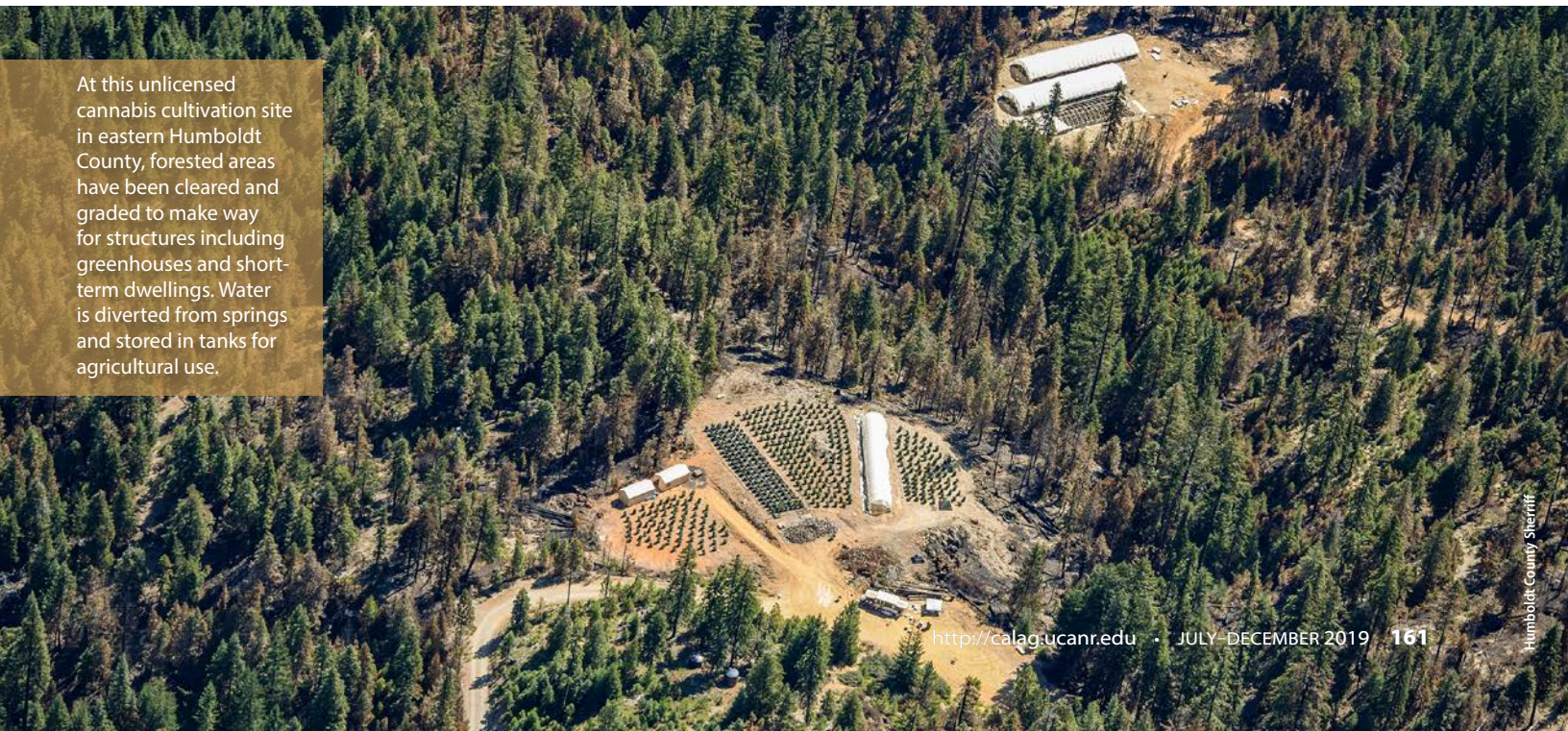
Abstract

Cannabis is often grown on agricultural and forest lands in California, but little is known about the adjustments that traditional agriculture and timber producers are making to their livelihoods as cannabis becomes legal under state law. Our goal in this research was to better understand how larger landowners, whose families have often produced timber and cattle for generations, are experiencing increased cannabis production in their areas — and also to better understand these landowners' perceptions of the impacts of cannabis, whether positive or negative, on their communities. To accomplish this, we surveyed landowners who owned at least 500 acres in Humboldt County, an area that — more than 40 years ago — became one of the first California counties to begin experiencing expansive cannabis cultivation. Of the 211 landowners we invited to complete a survey, 71 responded, providing insights into their experiences with and perceptions of cannabis production. Many survey respondents reported illegal cultivation on their properties, problems with shared roads and other direct negative effects of cannabis production. Most landowners also reported that cannabis production has increased the cost of labor, though they acknowledge that it has increased the value of their property as well. Survey respondents, however, have not changed their views of cannabis with legalization. The findings of this study illustrate some of the challenges involved in developing land use ordinances and other policies that can support multiple industries whose interests may be in competition.



At this unlicensed cannabis cultivation site in eastern Humboldt County, forested areas have been cleared and graded to make way for structures including greenhouses and short-term dwellings. Water is diverted from springs and stored in tanks for agricultural use.

Humboldt County Sheriff

California voters, when they legalized cannabis for adult recreational use in 2018, created conditions for competition among agricultural interests and changes in rural social dynamics.

This situation is not unique to Humboldt — cannabis cultivation has increased rapidly throughout rural California (Butsic et al. 2018). California voters, when they legalized cannabis for adult recreational use in 2018, created conditions for competition among agricultural interests and changes in rural social dynamics. Indeed, because new cannabis farming is often conducted near traditional ranching and timber-producing lands (Butsic and Brenner 2016), the potential for conflict — or collaboration — between traditional land uses and cannabis production has grown. But little research documents the effects of cannabis production on traditional agricultural producers, and therefore we know little about such producers' adaptation to change. Understanding this dynamic is important for local governments as they develop land use policies to govern when, where and how much cannabis production is permissible (AIC 2017). Cannabis production's effects on neighbors is an important point for local government officials to consider as they develop and adopt new policies to encourage the transition of black-market cannabis operations into compliant operations. The effects of cannabis production on neighbors is also important to consider while formulating policies to mitigate unintended consequences — such as unwanted odors and nighttime lights — which can exacerbate land use and social conflicts. For example, should cannabis be allowed on lands zoned for timber production or prime agriculture? Should cannabis production be allowed in cities and in unincorporated towns? What areas are compatible or incompatible with cannabis?

Top, materials from a trespass grow that were left on a neighbor's property. *Bottom*, an example of water theft, in which growers on private land trespass onto a neighbor's property to find water, which can be in limited supply in this region.

Increased cannabis production can directly or indirectly affect traditional agriculture and timber producers. Over the last decade, cannabis cultivation has expanded rapidly in rural communities, with many cannabis farmers having moved only recently to the areas where they grow (Polson 2015). These new arrivals are sometimes described as green rush growers. Conflicts can arise if new growers, who are often unaware of community norms, don't manage workers appropriately, control dogs, close gates, help maintain shared roads (private dirt roads that facilitate access to multiple parcels, with landowners providing their own maintenance and upkeep) — or if, in other ways, they complicate operations for traditional agricultural producers. Likewise, even cannabis producers who have been in business for many years — including some whose families have grown cannabis for two generations — may hold different views of rural life than do traditional agriculture and timber producers (Polson 2017). In addition, while cannabis is now legal in California, many cannabis farmers still grow outside the regulated system, and some traditional agricultural producers may retain the sense that illegal activity is negatively affecting their community. In recent years, the environmental impacts of cannabis cultivation have been a matter of increasing focus in California, and traditional agricultural producers and other community members have voiced concerns about water diversions (Bauer et al. 2015), pollution from chemical fertilizers (Carah et al. 2015), the impacts of pesticides on wildlife (Gabriel et al. 2015), light pollution (Stansberry 2016a) and forest fragmentation (Wang et al. 2017). Concerns have also arisen regarding negative impacts on local

livestock producers (Ramirez 2016; Sims 2016; Walker 2017) and challenges for public land managers attempting to control trespass growing operations (Rose et al. 2016).

At the same time, cannabis cultivation can contribute to community well-being in a variety of ways. It can bring economic gains to rural areas (Polson 2013) where the timber, livestock and fisheries industries have experienced declines. For example, cannabis cultivation can provide new business opportunities to traditional agricultural producers in the form of heavy equipment work, firewood sales, trucking, forest management or construction services. In addition, cannabis production may help buffer population declines such as those experienced in many of California's rural areas over the last 20 years; in particular, rural schools may benefit from the enrollment of cannabis growers' children. More broadly, cannabis farmers can bring new energy to rural communities through engagement at schools, volunteer fire departments and other points of gathering.

Traditional growers' perceptions of cannabis farmers can vary based on several factors, including the scale at which cannabis farmers operate. Scales of operation have expanded greatly over the last 20 years. Some cannabis farmers produce a few plants for personal use, others augment their incomes by growing moderate amounts of cannabis and still others grow on an industrial scale, with multiple operations on numerous parcels. All scales of operation include both regulatory-compliant growers and black-market growers. One might expect traditional agricultural producers to regard these different varieties of cannabis growers differently. But large landowners are themselves not homogenous — for example, some are absentees. In this research we hypothesized that absentee landowners would have different experiences and perceptions of the cannabis industry than do traditional producers who live on their land.

Humboldt County and many communities around California are currently setting ordinances to manage legal cannabis production. But as they do so, little is known about the potential interaction of cannabis with traditional agriculture and timber producers and whether these industries are compatible. Information about the effects of cannabis production on traditional agricultural producers may be helpful to policy makers because traditional producers are often important contributors to rural economies and stewards of public-trust resources such as wildlife and clean water. We conducted this research with the goal of determining how larger landowners — who, in Humboldt County, are generally timber or beef producers — experience and perceive cannabis production. We surveyed by mail all landowners in Humboldt County who own at least 500 acres (n = 211). We asked a series of questions about landowner experiences with the cannabis industry and how the industry directly affected landowners' economic well-being, community, property and personal safety. We also asked how, in their view, the cannabis industry influences the community and the environment. We asked landowners to provide their views on grower demographics and on changes in their communities over time. In addition, we compared the experiences and perceptions of absentee and non-absentee landowners.

Study area

Humboldt County has long been among the leading cannabis-producing regions in the United States (Corva 2014). Located on the North Coast of California, Humboldt County is characterized by steep terrain and a Mediterranean climate; a climatic gradient runs from the cooler and wetter coastline to the drier and warmer inlands (State of California 2015). Humboldt County's agricultural and timber industries are significant in scale, with agricultural production amounting to $326 million in 2016 (including $99 million in livestock) and timber production amounting to $70 million in the same year (Humboldt County 2016) — although the timber numbers are down from a decade ago. These agricultural production numbers do not include cannabis production revenues, but recent estimates put cannabis production in the larger Humboldt, Trinity and Mendocino region, known as the "Emerald Triangle," at $5 billion annually (Macewan et al. 2017).

These satellite images illustrate the expansion of cannabis grows in Humboldt County. The top is from 2012 and the bottom from 2014; both are of the same location near Garberville.

Humboldt County is home to numerous species of concern — including threatened and endangered salmonids, spotted owls, marbled murrelets, fishers and so on — that are protected under the U.S. Endangered Species Act (Mooney and Zavaleta 2016). Cannabis cultivation occurs within these species' habitat areas, including in locations near and adjacent to old-growth redwood and Douglas fir forests.

Survey methodology

The intent of the survey was to understand how cannabis production in Humboldt County was affecting traditional agricultural producers, and therefore we focused only on landowners with enough property (at

least 500 acres) to derive a large percentage of their income from agriculture and timber activities. We identified landowners with at least 500 acres by combining land use and tax roll data. In total, 211 landowners fit this description.

Landowners were mailed a paper survey, along with a stamped, pre-addressed envelope in which to return it, in January 2018. After 3 weeks, follow-up postcards were sent to landowners who had not returned their surveys. In total, 71 landowners responded to the survey (a response rate of 34%). Of these, two landowners reported owning less than 500 acres and one landowner did not confirm meeting this minimum standard; we did not include these three surveys in our analysis. All survey responses were anonymous.

Survey organization

Surveys were organized into three sections. One portion of the survey asked landowners about their direct experiences with the cannabis industry, asking them to agree or disagree with 22 statements that corresponded to four themes: (1) how the cannabis industry has affected the economics of their operations (five statements); (2) how cannabis has impacted their local community (five statements); (3) how cannabis has affected their properties (eight statements) and (4) how cannabis has affected their safety (four statements). The surveys asked landowners to respond to each statement using a five-point Likert scale, with responses ranging from strong disagreement (one point) to strong agreement (five points). Respondents could also respond "NA" to statements that did not apply to them. Additionally, respondents were given space at the end of each subsection to provide comments or examples.

In another section of the survey, we tested respondents' perceptions of cannabis by asking them how they felt about certain cannabis-related issues and whether cannabis cultivation has had positive or negative impacts on their communities, specifying that their responses should not necessarily be based on their personal experiences. We provided 36 statements that corresponded to four themes: (1) community (13 statements); (2) the environment (seven statements); (3) changes over time in property values, community safety, community demographics and so on (nine statements) and (4) grower demographics (seven statements). Respondents were asked to agree or disagree with the statements using a 5-point Likert scale and were able to provide comments after each subsection.

The third section of the survey solicited background information about each respondent. Respondents were asked whether they earned income from timber, ranching or dairying, how long their families had owned the land they worked and whether they were absentees. In addition, we asked landowners if they had been approached about selling their land for cannabis cultivation (and if so, when) and if they had next-generation succession plans for the family ranch or timber business. We also asked if landowners knew of nearby cannabis growing.

Analysis

All data from the survey was entered into spreadsheets by hand and then imported into Stata statistical software. For each statement, we created histograms of the Likert-scale responses (1–5) to understand the experiences and perceptions of respondents. We used a two-sample t-test to compare differences in responses between absentee and non-absentee landowners.

Landowner background

As indicated previously, all respondents included in our survey owned at least 500 acres of land. Twenty-two percent owned between 500 and 1,000 acres, 51% owned between 1,000 and 5,000 acres and 28% owned more than 5,000 acres. Of the 69 landowners whose responses were included in our results, 63 respondents managed timberland and 56 respondents managed ranchland, meaning that most respondents managed both land types; only one respondent was involved in dairy farming. Forty-six percent of respondents lived on their properties full time, while 20% lived on their properties part time. Thirty-three percent of respondents were absentee landowners. In general, the land represented in the survey had been in respondents' families for a long time — more than 50 years in 81% of the cases, 25 to 50 years in another 10% of the cases, less than 25 years in 6% and less than 5 years in only 3% of the cases. Fifty percent of respondents reported that their primary income was from traditional forms of agriculture or timber production; no respondents reported cannabis as their primary income source.

Landowner experiences

Economics

Seventy-one percent of landowners reported that they did not grow cannabis on their property while 18% reported that they did. These percentages, however, are derived only from the 34 of 69 respondents who agreed or disagreed with the statement that they had used their property to grow cannabis. The remaining respondents — half the total — chose not to indicate whether they had grown cannabis, potentially indicating landowners' reluctance to associate themselves with the cannabis industry. About 40% of respondents had indirectly profited from cannabis through off-farm work such as heavy equipment work, trucking and so on (fig. 1). Fifty-seven percent of all respondents agreed or strongly agreed with the statement that "the cannabis industry has negatively affected my livestock operations," while 27% disagreed with this statement. Over 60% of respondents agreed that cannabis had increased the cost of labor. Comments that respondents offered on the cost of labor included "Property values

are inflated by the cannabis industry, hence costing us more for leases and ownership."

Community effects

Seventy-five percent of respondents agreed or strongly agreed with the statement that "shared roads have been degraded by cannabis growers" (fig. 2) and 65% agreed that noise pollution has increased due to cannabis growing. Fifty-five percent of respondents agreed that growers increase light pollution and 71% reported having experienced illegal garbage dumping by cannabis growers on or near their property. Forty percent of landowners disagreed or strongly disagreed with the statement that "I know growers who have values that align with my own" (fig. 1). At the same time, 34% of respondents agreed or strongly agreed with that statement (fig.1). One respondent added that "[M]onetary impact is obvious. Cultural and moral impacts are terrible."

Property

Fifty-six percent of respondents agreed or strongly agreed that water sources have been impacted by cannabis growers, while 25% disagreed with this statement. Fifty-six percent also agreed that water had been stolen from their property. Seventy-two percent of respondents had experienced trespassing, while 20% had not. Forty percent of respondents reported that their fencing or infrastructure had been destroyed by cannabis growers, though a similar percentage had not. Fifty percent of landowners reported that neighboring growers had failed to assist with fence maintenance, and 75% of landowners reported having discovered trespass grows on their property (fig. 2). One respondent added that "[Growers'] dogs killed our cattle. My brother confronted a grower in fatigues carrying an assault rifle on our property. [Our] fences have been wrecked, roads damaged, and stream water theft." Another respondent wrote that "Yes, this is true in the past, but with the pot market collapsing I don't think this will be a problem in the future".

Safety

Roughly 55% of landowners reported having been threatened by cannabis growers' dogs while 24% did not. Forty-six percent of landowners reported that their safety had been threatened by growers. Equal proportions of landowners reported, and did not report, having felt unsafe due to interactions with growers on public lands. Finally, 50% of landowners agreed that growers had committed crimes against them or their property.

Landowner perceptions

Community effects

Perceptions of cannabis growers were relatively unified among survey respondents. A majority of respondents (78%) did not perceive growers as having values similar to their own (fig. 3). The majority of landowners (77%) felt that growers had changed how it feels to live in their community (fig. 3), and 77% of landowners expressed concern about the changes that growers are bringing to their community. More than 80% of respondents were concerned about growers taking over working lands

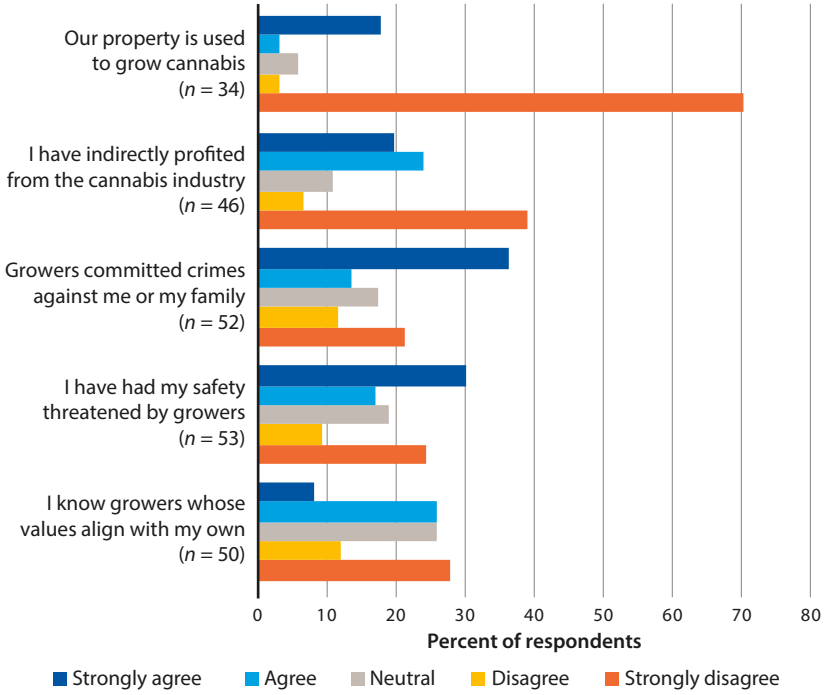


FIG. 1. Survey respondents reported their direct experiences with cannabis. Not all respondents were comfortable sharing personal information — of 69 respondents who returned surveys, only 46 indicated whether they had indirectly profited from the cannabis industry and only 34 responded to a question about growing cannabis on their properties.

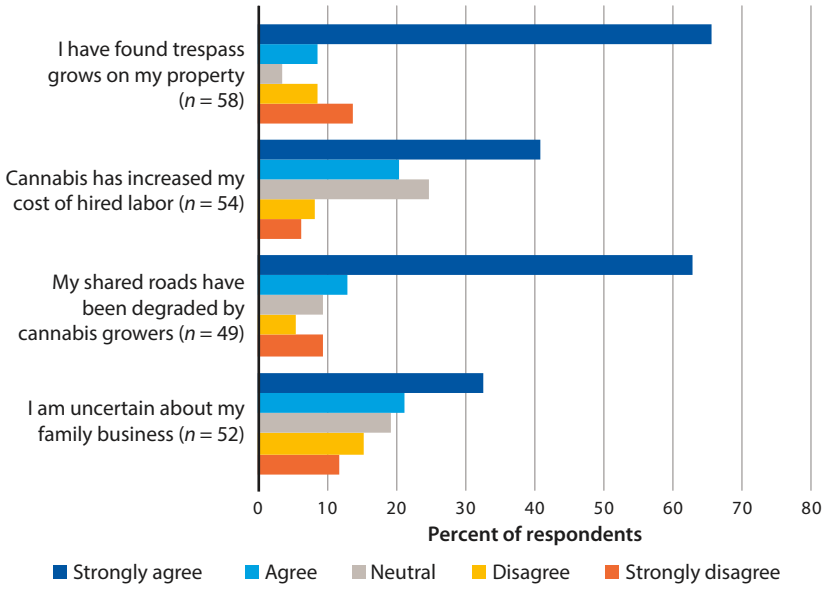


FIG. 2. Survey respondents have experienced direct negative impacts related to neighboring cannabis production and express concern for the future of their family businesses.

in their communities, and the same percentage were concerned that growers reduce the influence in the community of timber managers and ranchers. One respondent wrote that "The bottom line is that our family would accept the negative economic impact of eliminating 'pot' in return for the elimination of all the negative impacts of the grower culture." More than 90% of respondents agreed that growers from urban locations do not understand rural land management. Most landowners (60%) disagreed that growers are reinvigorating their rural communities or that growers are the only thing keeping their communities going (60%). Eighty-three percent of respondents disagreed with the statement that growers do a good job of policing themselves. Most landowners (64%) have not changed their views on cannabis with medical or recreational legalization (fig. 3).

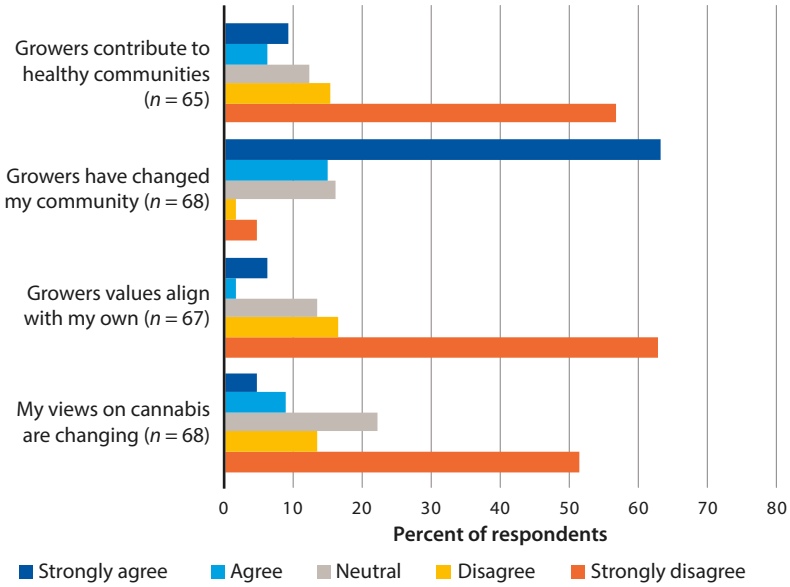


FIG. 3. Survey respondents' reported perceptions indicate that their views of cannabis have not changed and suggest a generally negative view of cannabis growers' contributions to the local community.

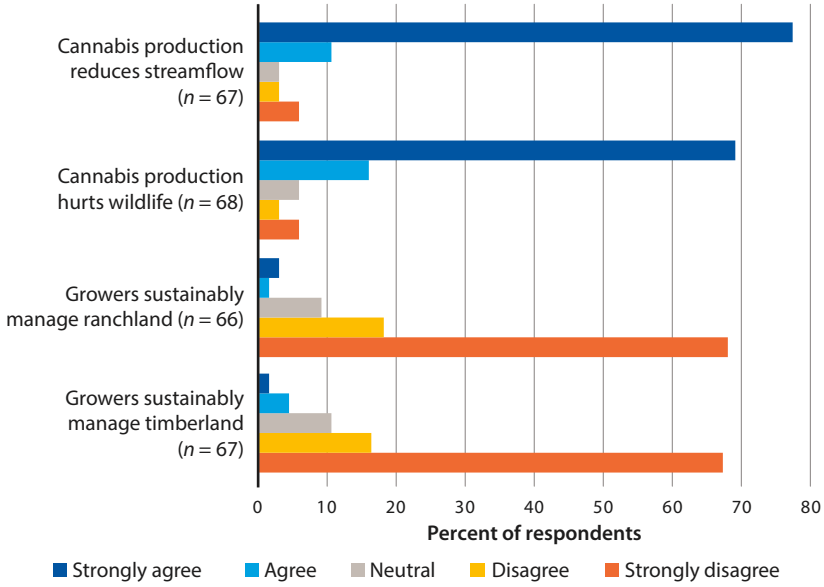


FIG. 4. Survey respondents reported their generally negative perceptions of cannabis growers' environmental stewardship and identified environmental impacts of cannabis growing.

Environment

The clear majority of respondents (84%) did not think cannabis growers manage timberlands sustainably (fig. 4) and a similar percentage (86%) felt the same about ranchlands. Eighty-five percent of respondents regarded cannabis growing as negatively affecting wildlife and 87% regarded it as negatively affecting stream flow (fig. 4). Eighty-four percent thought cannabis growing leads to soil erosion and 70% thought it increases fire hazard. Seventy-eight percent believed that cannabis production in ranchlands and timberlands leads to habitat fragmentation and the same percentage suggested that the economic value of cannabis incentivizes the subdivision of large parcels.

Changes over time

Fifty percent of landowners felt that their property value had increased due to cannabis production while 40% were neutral on that question. Eighty-three percent of respondents thought that Humboldt County was a safer place before cannabis and 76% of respondents perceived new cannabis growers as less responsible than cannabis growers who have been in the county for years. About half of respondents (51%) believed that increased cannabis legalization will be good for Humboldt County. Fifty-seven percent of respondents were not yet willing to accept that cannabis is a leading industry and that people should support it. Fifty-four percent of respondents believed that Humboldt County would be better off in the future without cannabis.

Grower demographics

Most landowners (80%) included in the survey reported having observed changes in grower demographics in the last decade. Most (57%) felt that the number of small cannabis growers is decreasing. Sixty-one percent felt that the number connected to organized crime is increasing and perceived that there is an increasing number of green rush growers (83%) in their communities. Most respondents (76%) were concerned about organized crime, while only 48% were concerned with green rush growers and 18% with small growers.

Comparison of resident and absentee owners

Overall, resident and absentee owners expressed similar views on most issues. Of the survey's 59 statements on experiences and perceptions, statistically significant differences between the two groups appeared for only eight statements. Absentee owners were more likely to report that their surface water resources had been

impacted by growers; that their fences or infrastructure had been destroyed by growers; that their safety had been threatened by growers and that they had been threatened by growers on public land. Absentee owners were also more likely to be concerned that growers were taking over public land. They were less likely to agree that growers manage timberland sustainably and that cannabis production decreases their property values.

Environmental, social and economic challenges

With this study, we aimed to better understand the experiences and perceptions of traditional agricultural producers — the families who, in most cases for several generations, have made a living off their land, all the while watching changes occur in the social, economic and environmental dynamics that surround cannabis.

This survey's documentation of social tensions may not come as a surprise to those who have lived in Humboldt County (note that three of the authors live in the county and thus have a personal vantage point on the issues). Even after many decades of cannabis cultivation, traditional agricultural producers have not warmed to the people or practices involved in the cannabis industry. Indeed, changes in the social fabric of the cannabis industry have only perpetuated and intensified existing tensions.

As this survey shows, concerns about "small growers" are minimal now — those growers have become part of the community, and one-third of respondents agreed that they know growers whose values align with their own. What was novel 40 years ago is now a cultural norm. Today's concerns center instead on the challenges of current cannabis culture: environmental degradation and the threat of major social and economic change. Respondents mostly agreed that growers today are less reasonable than those who have been in the county for many years. As one respondent wrote, "Growers are a cancer on Humboldt County." This distrust highlights the challenges that, in rural areas, can often hinder community-building and mutual assistance mechanisms, which are often needed in isolated communities (Morzillo et al. 2015).

The economic influence of cannabis can be seen throughout the county. As the survey shows, approximately 40% of respondents have been impacted indirectly by the cannabis industry, and some respondents have directly profited through cannabis production themselves. Interestingly, just over half the respondents chose not to say whether they grow cannabis, hinting at the possibility that, even for traditional agricultural producers, cannabis has presented an opportunity to supplement income and cover the costs of landownership. However, the broader economic growth attributed to the cannabis industry is not always viewed favorably, and a majority of respondents agreed that Humboldt County would be better off in the future without cannabis. Some respondents claimed that the industry has increased the cost of labor and that, in many cases, it can be difficult to find laborers at all because the work force has been absorbed by higher-paying cannabis operations. Likewise, many respondents agreed that land values have increased because of cannabis. But for landowners whose property has been passed down through generations, and who have little intention of selling, increased land values translate into increased taxes and difficulty in expanding operations, both of which can be limiting for families who are often land-rich but cash-poor. One respondent wrote, "Yes, the price of land has gone up… but this is a negative. It increases the inheritance tax burden, and it has become so expensive that my own adult children cannot afford to live here." In Humboldt County's unique economic climate, it's difficult for most landowners to decide whether the opportunities the cannabis industry provides are worth the toll that they believe the industry takes on their culture and community — it's not a simple story. As one respondent noted, "If I had taken this survey 40 years ago, my response would have been very different. With Humboldt County's poor economy, everyone is relying on the cannabis industry in one way or another." Our survey provides an important baseline from which such changing attitudes can be measured.

Our results should be seen in the context of larger trends involving population and agricultural land in Humboldt County. At the time we were preparing our survey, property records indicated that slightly more than 200 landowners in the county owned at least 500 acres; these individuals made up our survey population. Past research, however, has documented that cannabis was likely grown on over 5,000 distinct parcels (of smaller sizes) in Humboldt County in 2016 (Butsic et al. 2018). Our survey respondents, because of their large holdings, may be unusually exposed to cannabis growers physically because their larger properties may have more contact with cannabis growers. At the same time, these respondents might be better able to survive economically in a Humboldt County without cannabis. It is unclear if the experiences and perspectives of many Humboldt County smaller landowners would be similar to those of these large landowners.

For many in Humboldt County, the impacts of cannabis production on property and the environment are a central concern. Respondents mentioned problems involving shared roads and fences, illegal garbage dumping and contamination, deforestation, fire hazards, feral dogs and impacts on wildlife and domestic livestock. One respondent wrote that "Growers leave a mess, steal water, tear up roads, let guard dogs damage neighbors' property, including livestock, poison wildlife, increase soil erosion and threaten people." In many ways, it seems that land ethics are at the center of the concerns that traditional agricultural producers harbor about the new wave of cannabis growers.

Though respondents remarked on cannabis growing's direct impacts on the environment, they also largely agreed that the cannabis industry is causing fewer young people to enter traditional farming careers — and that growers are taking over working lands. It is unknown if the rates at which successive generations stay in the family business are lower in Humboldt County than in rural communities less influenced by cannabis. For families who have managed and lived off these lands for decades — most of them for more than 50 years — these shifting stewardship ethics threaten their immediate environment as well as their very identity.

Conclusion

The cannabis industry is undergoing drastic changes throughout California and elsewhere in the United States. In many places, the cannabis industry is novel, and social and environmental ethics are developing in concert with the growth of the industry. Humboldt County, in contrast, has been on the leading edge of cannabis cultivation for decades. County residents have watched the industry grow and change substantially over the years, with varying impacts on the culture and economy of the region (Stansberry 2016b). The mixed blessings of cannabis are not lost on most who live in Humboldt County: Over the last several decades, cannabis has breathed life into many of the smaller communities that had suffered losses in timber

and other industries, and this boon has been palpable in the more populated parts of the county, too. However, the pace of change in the cannabis industry has been very quick, and the pressures that the industry exerts on communities are intense. Few have felt these pressures more than the county's traditional agricultural producers, whose communities, livelihoods and landscapes have been most affected.

It is not clear how recent and future changes to cannabis law will change social and economic conditions in Humboldt County, but this survey helps describe the competing interests at stake in the evolution of Humboldt County's agricultural identity. For the longtime Humboldt landowners included in our survey, the consistent pressure exerted by the cannabis industry over the last 40 years has forced them to define — and sometimes redefine — their values and alliances. This survey shows that, as the cannabis industry has expanded, traditional agricultural producers have felt an increased pull toward the ethics of stewardship, community and family identity. However, the stark lines that once separated cannabis growers from farmers and ranchers are not so clear now, and there is a shared curiosity and concern in the county about the next wave of change in cannabis cultivation: How will small versus large operations capitalize on legalization? How will compliant growers and black-market growers compete in this new era? How will the values that have long defined Humboldt County's agricultural lands — community, a locally based economy, working lands and working families — maintain a place among so much change? And how will public policy makers mediate the challenges? This study helps document how the last 40 years of cannabis production have largely been incompatible with ranch and timber operations. Public land use policy can help mediate land use conflicts and zoning, but it will not be able to mediate all social behaviors and industry needs. The survival of rural economies is dependent on balancing support for new economic opportunities with supporting the needs of multigenerational industries. Success will be measured by the persistence, environmental health and economic prosperity of rural communities. CA

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RESEARCH ARTICLE

“We can’t just be a county that supports inebriants”: Voices of the noncannabis agricultural community

Interviews with noncannabis producers in Northern California revealed a variety of concerns about legal cannabis production, from access to land and crop shifts to outsider investments.

by James C. LaChance

Traveling over the ridges and through the fertile valleys of Humboldt, Mendocino and Sonoma counties, one encounters a variety of farms, ranches, wineries and farm stands — and now a proliferation of cannabis industry billboards. Touting cannabis appellations and the ease of acquiring cannabis goods and services, their message is loud and clear: legal recreational cannabis has arrived. As the cannabis sector has come fully into public view, so too has its interaction with noncannabis agriculture.

In Humboldt, Mendocino and Sonoma counties, as in other California counties, cannabis regulations over the expansion of recreational cultivation are still being refined. The uncertainty about how they will impact local economies, environments and communities is also affecting the noncannabis agricultural community. The changes farmers and ranchers will undoubtedly face are situated within broader questions about farmland transitions in the United States.

Finance, land access, crop shifts

Across the United States, farmland is increasingly subject to financial investment and speculation. Research suggests that financial investment in the food system

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Abstract

Legalized recreational cannabis poses uncertainty and challenges for the noncannabis agricultural and ranching community in Northern California, including what it might mean in terms of the price of farmland and ranchland and the effects on the regional culture of diverse crop production. In-depth interviews in Humboldt, Mendocino and Sonoma counties with noncannabis farmers, ranchers and key individuals closely tied to the community revealed insight and an overarching concern about the future for noncannabis producers in those counties. The research was conducted in the summer and fall of 2017, when the state and counties were ramping up development and implementation of recreational cannabis cultivation policies. Interviewees expressed concern about land prices, potential crop shifts, and outside investment in the cannabis sector, and recognized the parallels and emerging alliances between wine and cannabis producers. They also identified opportunities for diversifying their production and for improving the environmental impacts of cannabis production.

Clockwise from left, billboards announcing the new legal status of recreational cannabis use have sprung up in Northern California; a soil amendment advertisement outside a farm supply store targets cannabis growers; a fertilizer aisle at a Northern California farm supply store caters to cannabis growers.

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has already had considerable impacts on food production in some regions, including investments in farmland, food processing, agricultural inputs and more (Burch and Lawrence 2009). Questions of scale and implications of ownership have long been a focus of agricultural research, as these factors clearly shape farming communities and can lead to negative socioeconomic and community outcomes (Goldschmidt 1978; Lobao and Stofferahn 2008).

In some rural areas of the United States, outside financial investors have caused land values to rise and increased farmer tenancy while decreasing farmer ownership. U.S. Department of Agriculture (USDA) statistical data confirm this trend in California; many counties have seen an increasing amount of both rented land and nonoperator landlords — common indicators of financial investment in farmland (Nickerson et al. 2012). Other research has reported on these trends, particularly how financial actors — from hedge funds to university endowments — have acquired farmland across the United States (Fairbairn 2014; Kesmodel and Newman 2015).

The expansion of recreational cannabis production in Northern California intersects with this trend. Articles have highlighted entrepreneurs developing industrial-scale cannabis farms in the Central Coast (Fuller 2017), rapid consolidation of cannabis markets across North America (Kelloway 2018) and large corporate alcohol interests — Constellation, Molson Coors and others — investing billions of dollars in the cannabis industry (Maloney 2018; Miller 2018).

Outside investments in land can amplify the challenges food producers face. Already in much of California there is a history of significant land use change and crop regime shifts (Walker 2004). Particularly in Northern California, food producers have experienced the effects — for example, Sonoma County apple growers have been impacted by the arrival of grapes and a related increase in farmland prices. More broadly, conventional growers in California have been impacted by organic production increasing the price of farmland (Guthman 2014). But grapes and organics are not directly analogous to cannabis. Until recently, cannabis had never legally been grown for recreational use on California land zoned for agriculture; it was instead part of the counterculture (Meisel 2017).

Environmental concerns, new revenues

The uncertainty being experienced in the noncannabis agricultural community also extends to environmental concerns. Reports have been published about rodenticide poisoning and excessive irrigation use in cannabis (Bauer et al. 2015; Gabriel et al. 2012); furthermore, recent research described how despite the overall small footprint of cannabis production on the landscape, it can have significant negative impacts, including to landscape fragmentation and important ecosystem processes (Wang et al. 2017).

The shift to legal production of recreational cannabis brings with it a chance to create environmental standards for the industry. Regulations might begin to curtail negative environmental impacts as producers transition into the legal framework. Furthermore, now that production has been legalized, some noncannabis growers might choose to diversify their agricultural operations to bring an influx of new revenue. A recent article asked whether Ukiah, in Mendocino County, could become the "Napa of pot" (Swindell 2018).

Collecting the perspectives of the noncannabis sector

As cannabis development continues and counties negotiate policy and regulatory decisions, it is vital that evidence of impacts and opportunities be collected and that community members, including noncannabis farmers and ranchers, maintain a voice in the negotiations. My research project was undertaken to better understand and articulate the farming and ranching communities' perspectives and needs post-Proposition 64 in Northern California. It was born out of conversations with UC Cooperative Extension (UCCE) specialists who noticed an increased frequency with which the noncannabis farming and ranching communities discussed interactions with the cannabis sector surrounding the passing of Proposition 64.

Of specific interest was how these interactions were being talked about at food policy council meetings in Northern California. At the outset, it was clear that these conversations covered a spectrum of opinions ranging from apprehension to optimism. It was also clear that while the division between the cannabis and noncannabis communities was not always completely transparent — in some cases, noncannabis farmers may at times have grown cannabis on the side — this framing was useful for beginning to understand key themes related to what could be a divisive topic.

The project took place in the summer and fall of 2017, and it was completed before Jan. 1, 2018, when legal recreational cannabis cultivation began. Research was approved by the UC Berkeley Committee for Protection of Human Subjects Institutional Review Board, Protocol ID 2017-05-9973. Humboldt, Mendocino and Sonoma counties were selected because they approximate a gradient of food production versus cannabis development, include a diversity of food and fiber production, and adopted different regulatory frameworks for recreational cannabis. Livestock is the largest agricultural enterprise by gross production value in Humboldt County, and wine grapes are the main enterprise in Mendocino and Sonoma counties (table 1).

TABLE 1. Crop value data in Humboldt, Mendocino and Sonoma counties, 2016 (the most recent year data is available from all three counties): the top three crops by gross production value, the number of million-dollar crops in the county and the total gross value of the agricultural commodities from each county. Sources: County of Humboldt 2017; County of Mendocino 2018; Sonoma County ND.

Humboldt County	
Top 3 crops	
Livestock products	$99,695,000
Livestock	$90,488,000
Timber production	$70,395,000
No. of million-dollar crops	7
Total gross for all county crops	**$326,076,000**

Mendocino County	
Top 3 crops	
Wine grapes	$120,251,300
Timber	$76,696,600
Pears	$14,894,400
No. of million-dollar crops	7
Total gross for all county crops	**$242,533,700**

Sonoma County	
Top 3 crops	
Wine grapes	$586,517,700
Milk	$146,475,400
Misc. poultry	$40,823,200
No. of million-dollar crops	14
Total gross for all county crops	**$898,125,200**

Average farm size in Humboldt and Mendocino counties is similar, around 630 acres; in Sonoma County, there are many more farms and the average size is 165 acres (fig. 1). In terms of acreage, all three counties have most land farmed as pasture (fig. 2).

Information about land use and top-ranked non-cannabis crops (by value) produced in each of the three counties is provided in figures 1 and 2 and table 1. These figures and tables are from 2016 county-level crop reports that track agricultural commodities, which do not include cannabis. At the time of this research similar data on legal recreational cannabis was not available, and collecting information such as historical production trends and the identity of cannabis growers was not the focus of this research. To date, USDA census of agriculture data does not exist, as cannabis remains federally illegal.

I conducted preliminary interviews with UCCE and related agricultural professionals to develop research questions before interviewing 24 key informants across the three counties. The interviewees were selected to include a wide range of people familiar with cannabis and agricultural trends in the region but especially those who were closely connected to the policymaking and regulatory process: they included state and county officials involved in agriculture, cannabis regulation, planning, building and zoning; realtors; food policy council members; members of prominent farming and

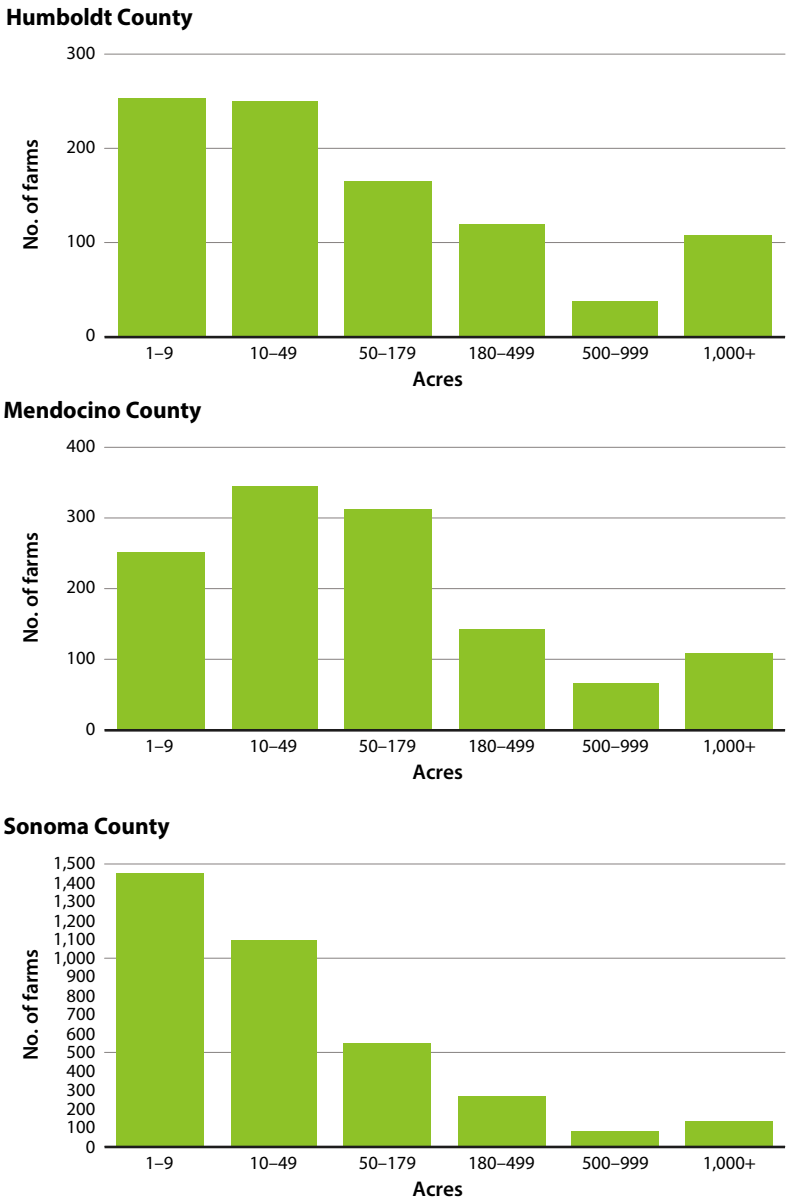

FIG. 1. Number of farms by size in each county, 2012. Humboldt County: 930 farms, average size 638 acres; Mendocino County: 1,220 farms, average size 631 acres; Sonoma County: 3,579 farms, average size 165 acres. Source: USDA NASS 2012.

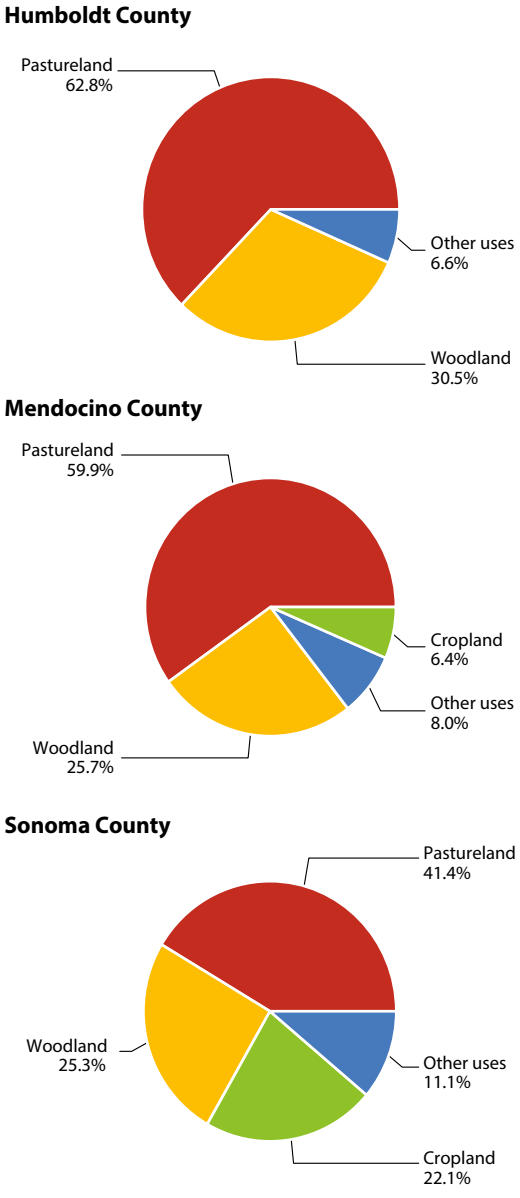

FIG. 2. Land use in each county, 2012. Source: USDA NASS 2012.

TABLE 2. Guiding questions for interviews

Introduction
Can you tell me a bit about how long you've lived or worked in Sonoma/Mendocino/Humboldt County and about your connection to the agricultural and ranching community?
Character of the county's agriculture and ranching community
Have you heard of any positive or negative interactions between noncannabis agriculture and cannabis?
What are your thoughts on how the legalization of cannabis might impact food production in the county?
Do you think that recreational cannabis might impact noncannabis agriculture's ability to access any particular resources, such as land, water, or labor?
How do you think the legalization of recreational cannabis might impact the operation of farms and ranches in the future?
What do you think will be the biggest impact for the operation of Sonoma/Mendocino/Humboldt's noncannabis farms and ranches from the legalization of recreational cannabis?
What are your opinions about the legalization of cannabis as it relates to farming?
Access to land
In the time that you have lived there, has who owns the land changed in Sonoma/Mendocino/Humboldt? a. What do you think is responsible for the biggest change in ownership? b. Where does most of the buying and selling of land happen?
Have you noticed any changes to the price of land recently? a. Why do you think that is? b. Do you have a sense of who is buying the land?
I've heard that in some counties agricultural land is being purchased for cannabis production. Have you heard of anything like that happening in your county?
Have you heard from farmers about how it has been securing land to rent or own lately? a. Have you heard of a change in how much is owned vs. rented? b. Do most producers have landlords in Sonoma/Mendocino/Humboldt?
Do you know who is generally growing or intends to grow recreational cannabis?
Do you know who is making these investments in cannabis? a. Or who, in terms of farmland companies, is managing or purchasing land in the county? b. Any specific examples?

TABLE 3. A range of interviewee perspectives describing perceived and potential impacts of increased cannabis industry development

Negative	Neutral	Positive
Land price volatility	Shifts in culture of each county's agriculture and ranching communities	Diversification of crops
General uncertainty of impacts to community	Changing crop regimes and "new frontiers"	Opportunity for cannabis to indirectly subsidize food agriculture
Potential spillover of new regulations into noncannabis sector	Land use changes	Opportunity for environmental improvement
Negative crop and neighbor interactions (e.g., smell, wine taint, livestock damage, crime, etc.)	Zoning changes	Opportunity for economic development
Challenges to land access, particularly for new and beginning farmers and those who lease land	General shift in culture of broader community	Increased opportunities for farmers and ranchers to lease land to cannabis producers
Attraction of mega-businesses (e.g., "Philip Morris," "Walmart of weed") that do not align with more common cottage industry production		Tax revenues for county and state
Labor impacts (increased competition for labor)		Improved public safety

ranching organizations and agriculture and ranching–related nonprofit organizations; and other key agricultural community members.

Interviews were open ended, semistructured and generally lasted 1 to 2 hours. I asked questions about access to land and other resources, trends in investment, change to land use and natural resource use, and the character of the county's agriculture and ranching (table 2). The interview recordings were transcribed and analyzed for key themes using NVivo qualitative data analysis software (QSR International, Melbourne, Australia); then interviews were coded and representative quotations selected as evidence. A range of perspectives from these findings are summarized in table 3. Four main themes emerged.

Losing access to farmland, resources

Much of the agricultural community was concerned about the burgeoning cannabis industry impacting access to land and other natural resources. Across the three counties, interviewees often identified this concern in terms of an increased presence of corporate and financial interests from outside the county being attracted to the region to grow cannabis, and those interests' ability to compete with and displace members of the agricultural community. These "outsider" interests were frequently described as hedge fund managers, large corporations, cartels and black market interests with foreign ties, and wealthy individuals. As one interviewee described:

> *I had a guy that I talked to who's sort of almost a hedge fund manager type portfolio investor who's like, "I have $4.5 million to spend and I can't find anywhere to spend it. I literally cannot find property." Or that he could've purchased for cannabis operation that would meet all of the county's or the city's criteria. So there are people who are hovering and I think that Sonoma County is seen as a really desirable area.*

Those "hovering" prospective producers or landowners contrast with the cottage industry producers who have historically been the most common type of cannabis producer in the region.

Many interviewees mentioned they had heard rumors of Philip Morris and other corporate tobacco interests moving into the region to transition part of their business to cannabis. One interviewee said,

> *I've heard from [a county employee] that Philip Morris is poised for purchasing land in Humboldt soon. And where he's received that information, I don't know, but that's what he shared over dinner recently.*

In addition to Philip Morris, interviewees feared an influx of "mega-businesses," "the Walmart of weed" and nonspecific foreign interests:

> *I've heard of companies like in China and stuff like buying up big pieces of land, so I feel like some of the people that are coming here from foreign countries are actually coming to buy the land and do larger grow operations … that's definitely a possibility.*

While the majority of interviewees who discussed outside investment were concerned about its impact on food production, not all shared that concern. Particularly in Humboldt, a subset of interviewees felt that food production would not be impacted by legalization of recreational cannabis; they largely attributed their lack of concern to the significant role cannabis already plays in the county:

> *All of the real fertile, flat ground is still farmers' market people because they're family owned and stuff. In Humboldt County, it's not going to affect our food production that much. We don't have that much food production.*

Some interviewees highlighted how the regulations on the type of parcels that can be used to grow cannabis made finding suitable cannabis land difficult, implying that it should not put pressure on noncannabis producers:

> *This is the most highly regulated crop in the history of mankind. … So the properties that actually fit all the different restrictions [placed] on cannabis, they're few and far between … It's kind of like a needle in a haystack. Yeah. So those properties that can meet all the restrictions we've placed on cannabis cultivation are up in value. But not all ag land is seeing an increase in value because if it doesn't fit the parameters [placed] around cannabis cultivation you can't use it for cannabis cultivation…*

Navigating volatile land prices, lease transitions

A second key theme was interviewees' concern about how cannabis development might impact farmland prices and lease arrangements. Some interviewees emphasized that cannabis was not the only factor at play with the high land prices in Northern California:

> *It's been impossible to secure or rent ag land in Sonoma County for a long time, honestly. I mean this is a conversation that I've been having since I started farming 10 years ago. We're really lucky we farm on family land … but I've done a lot of work with California FarmLink and some of the organizations that have tried to connect farmers to land. And so it's a problem that we've identified and haven't really found an adequate solution to, quite frankly, for food farming and diverse ag. Before, the conversation was more about "food farming and diverse ag, how do we carve out space for that?" But now there's a conversation for "How do we carve out space for cannabis in light of sort of vineyards everywhere and then disallowing [cannabis operations] from being on rural residential and ag residential?"*

Many interviewees mentioned they had heard rumors of Philip Morris and other corporate tobacco interests moving into the region to transition part of their business to cannabis.

There were many reasons interviewees were concerned about recreational cannabis legalization inflating land prices further, but being outcompeted for all types of land was of particular import:

> *People who can come in and drop $10,000-plus an acre, cash, for landlocked parcels with no water typically aren't going to be your everyday farmer. [It's] people who want to be left alone and, typically, they're going to be growing cannabis … So if you were the base property owner and you see the gold rush that's happening, [then] you put property on the market and within 10 minutes it's sold. And it's been pretty quick.*

Or as another put it, per-acre revenue for cannabis has been exceeding the revenue for noncannabis crops for some time:

> *The only difference between home-grown tomatoes and home-grown cannabis is that if you've got a little raised bed the size of this table, you can grow enough tomatoes for a couple of weeks of salads … you could probably grow $100 worth of tomatoes. But cannabis, with just this amount of space, you're saying — even if it's just for your own consumption or your friend's consumption or whatever — you are saying the equivalent of thousands of dollars.*

Related to the increase in the value of land, there has been an increase in the cost of rents for leased ground. Many interviewees described lost leases or changing lease arrangements and pointed to the higher prices that cannabis growers pay as the main culprit:

> *And that's the other thing … that they've lost their leases that they've held for 25 or 30 years because this is the time where the base property owners are getting older, or the next generation doesn't want*

to keep it … And so they've seen those grapes get ripped out, and they put cannabis greenhouses and infrastructure and all that.

Lease challenges were of particular concern to interviewees in Sonoma and Mendocino counties, with one interviewee summing up how the small-scale and beginning farmers they work with face unique challenges:

A good majority of our farmers lease… the questions that our [small and beginning] farmers are facing … is, "How do I secure five acres? How do I afford five acres, period? If I can lease, how can I keep it?" The challenge is not just finding it, but then finding a secure, stable land because it's just coming and going all the time.

This prospect of small and beginning farmers competing with cannabis operations was often a key concern among interviewees; whereas, concerns about vineyards competing with cannabis operations were less prevalent and usually focused on competition over labor at harvesttime.

Overall, interviewees in each county most often expressed concern about the impacts of cannabis on their county's top crops. For Humboldt, this included livestock and timber land; for Mendocino and Sonoma, it was timber, grape and dairy production.

Overall, interviewees in each county most often expressed concern about the impacts of cannabis on their county's top crops (table 1). For Humboldt, this included livestock and timber land; for Mendocino and Sonoma, it was timber, grape and dairy production. Interviewees also described significant concerns about the impact of cannabis on low- (rural) and moderate-density residentially zoned land.

Fearing culture change

One of the most prominent themes across all three counties was the fear of major changes to the culture of the region. Interviewees in Humboldt and Mendocino counties, which both have a well-known cannabis history, were concerned that their county's name recognition could bring change to the culture and scale of cannabis cultivation as well as to general agriculture. One interviewee appraised the issue optimistically:

Realistically, I'm hoping that when it becomes legal and the feds approve it, then the [Central] Valley will take over and create the Bud and Coors versions. And then, [Mendocino County will be] the mom and pop places [and] do the boutique stuff. It'll be like what we do for wine, we'd do for pot.

Others emphasized the complexity of the situation and described how cannabis is just one change of many that agriculture has faced, although complications were mentioned around the social dynamic:

I mean, agriculture shifts. That's nothing new to us. There will be something that replaces wine grapes someday. Historically here, it was hops, and prunes, and pears, now it's grapes. We've seen the transitions here in the [Ukiah] valley … We've seen transitions from sheep ground and more intensive agriculture with wine grapes over in Anderson Valley, and that's the nature of the beast … And so, hell, for all we know, we could see, like I said, pears coming out and cannabis going in. We don't know. I mean there's kind of a social dynamic of that where people would have to accept growing cannabis and I think that's probably not going to happen anytime soon necessarily from our more traditional folks.

Across the three counties, the majority of interviewees agreed with the idea that shifts in cash crops were "nothing new," and some identified cannabis as the next frontier:

We're on that sort of edge of transition, just like my father-in-law was when he planted his orchards 40 years ago. My whole family property used to be prunes and pears. He learned that he could make more money on one acre of vineyard than he could on the entire property of hay, and prunes, and pears, which is what it was growing. So, of course, you try to keep a family property in the family.

Others echoed this sentiment yet hoped that the county could continue to have diverse food production:

We can't just be — many people have said this — we can't just be a county that supports inebriants [laughter]. *Beer, wine, cider, cannabis. Hard alcohol. And that is a huge part of our economy now, and what is attracting tourists and investors ... Where is the food going to come from?*

Another interviewee said,

I did the calculation … every single resident in Sonoma County could stay intoxicated — totally inebriated 24 hours a day, year-round — and we'd still have lots leftover.

Relatedly, a small number of interviewees in Humboldt and Mendocino lamented that their local farm supply stores did not always carry what they needed for raising crops or livestock but instead catered to the cannabis industry.

Hoping for economic and environmental benefits

Interviewees expressed hope that new revenue streams and development opportunities might exist for the agricultural community and the county, and that

environmental benefits would ensue from transitioning producers into the legal recreational cannabis system.

Regarding economic impacts, there was a balance of positive and negative opinions, the magnitude of which was often borne out in a discussion of labor costs:

> *For the vineyards, [the biggest impact] is going to be labor. Access to labor. Well, [livestock] too. I mean, if you can go in and — I can't remember what the numbers are, but you can make a lot more money picking buds than you can picking grapes or milking cows … and it's cash money.*

Several interviewees suggested that cannabis could be an opportunity for diversification, either by cultivation of cannabis or by leasing land to a cannabis grower. As one interviewee suggested, however, it is a thorny and uncertain opportunity:

> *We've got a lot of small producers that are growing produce, and whether they see this as an opportunity to supplement income, there's — and again, it just gets back to there's so much that's still out there about it still being federally illegal, and especially if you're connected to the vineyard industry and the wine industry, you got to be really careful about that. If you're using or incorporating THC products into your business model then you're jeopardizing your ability to market wine, that's what I'm hearing.*

Interviewees mentioned other potential negative economic impacts from the cannabis industry, including: the smell of cannabis cultivation pervading rural residential neighborhoods; guard dogs from illegal grows harassing and injuring livestock; and the complaint of "wine taint," or the smell of cannabis cultivation being found unintentionally, and to a negative outcome, in wine. In Mendocino, several interviewees mentioned a new cannabis regulation potentially affecting noncannabis producers and increasing their costs for certain types of farm infrastructure projects.

Many interviewees expressed hope that regulations for the legal sector would bring environmental benefits:

> *And, really, what they're trying to do is they want everybody to be in compliance. They're not trying to make everything shut down. There's a big issue here with the environmental degradation from the cannabis farming, and I would say I feel like having lived here when I was young and then being here now, there is a dramatic difference. Again … it seems like it's just a dramatically different cannabis industry here now than it was 30 years ago. And there is a lot more people coming in from out of the area and foreign countries to work here, and there's a lot more of those illegal grows that are inside and are using a lot of resources as well as dumping a lot of toxic material into local habitats, and that's very different than what I remember it being when I was younger.*

The uncertain future

The research findings suggest that a range of interactions have been evolving between cannabis growers and noncannabis farmers and ranchers in Humboldt, Mendocino and Sonoma counties. The noncannabis sector has faced many new challenges and uncertainties during the process in which recreational cannabis transitioned to legality. Accordingly, interviewees continued to express mixed feelings about how these actions would continue to unfold.

The comparison of cannabis growing to vineyards, while imperfect, was nonetheless generally useful for interviewees to begin to picture what types of landscape and community changes could come about, particularly in Mendocino and Sonoma counties. Lessons may be gleaned from the precedent of transitions to wine grape vineyards, and may be used to inform policy and community approaches to both harmonizing and mitigating impacts of cannabis on noncannabis communities. For example, when considering Sonoma's transition to wine grapes and the correlating increase in farmland prices, it would be useful to identify what strategies non–wine grape producers relied on to keep farming non-grape crops, and whether certain producers found ways to subsidize non-grape crops (e.g., renting part of their land to grape growers in order to subsidize their own maintenance of growing a non-grape crop).

Lessons may be gleaned from the precedent of transitions to wine grape vineyards, and may be used to inform policy and community approaches to both harmonizing and mitigating impacts of cannabis on noncannabis communities.

The experience of transitioning pear and apple orchards to wine grapes — the current paradigm of cash crop transition in this region — stands to be a useful parallel for policymakers when considering the range of possible changes that may occur within the landscape, community and economy as the potential result of further transitioning farmland to growing cannabis. Broader changes that resulted from the precedent of grapes, whether positive or negative, may stand to be a sobering example to consider for policymakers hoping primarily for economic gains to be had from expanded cannabis cultivation.

As several interviewees mentioned, cannabis does not fall under Right to Farm laws, or laws that protect

the right to conduct standard agricultural practices in a community. This highlights a key shortcoming of the cannabis and wine grapes analogy, as the expansion of the legal cannabis industry is not afforded the same rights as the expansion of wine grapes in an agricultural community. Nonetheless, in some areas legalization of recreational cannabis may bring with it an overhauling of the current landscape of food production, just as wine grapes did. The divide that some interviewees noted between wine producers and other food producers perhaps mirrors the divide between cannabis producers and noncannabis producers. Interestingly, wine producers — and, as previously mentioned, the alcohol industry in general — have already made various commercial connections with cannabis producers, with collaborations ranging from a "wine and weed" conference in Sonoma in summer 2017 to cannabis-infused beer and wine.

Newly developed regulations surrounding cannabis cultivation will have great significance for food producers in these counties. As they are refined, it is important that policymakers continue to involve the agricultural community and intentionally incorporate their perspectives. This should be done through outreach with individuals, organizations and food policy councils to ensure that new regulations for cannabis are not unintentionally spilling over into agriculture (as some interviewees suggested) or otherwise compromising the diversity of producers in these counties.

The interviews reported here establish a baseline knowledge of how legalized recreational cannabis intersects with agricultural communities. Future research could focus on investigating land sale and ownership data to see what land types are targeted by which type of investors in each county, and to then begin to determine what types of outcomes might be associated with these different types of investors. Meanwhile, the land situation during this transition period is fluid. In Humboldt County, after the end of the study reported here, a recent town hall meeting highlighted the economic crisis facing the community with the decline of the price of cannabis. Community members reported that property values had dropped and that large, and not small, cannabis businesses had generally been receiving the bulk of new permits (Futcher 2018).

In addition to more research, a renewed effort might be made to prioritize support for farm succession planning and explore creative approaches to transitioning key pieces of farmland to the next generation of farmers who identify with the noncannabis community. Such an initiative could bolster efforts to maintain diverse local food systems in Humboldt, Mendocino and Sonoma counties. CA

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RESEARCH ARTICLE

Growers say cannabis legalization excludes small growers, supports illicit markets, undermines local economies

The survey sample was small, but results suggest regulations may need to be modified to incentivize grower participation in state licensing programs.

by Hekia Bodwitch, Jennifer Carah, Kent M. Daane, Christy Getz, Theodore E. Grantham, Gordon M. Hickey and Houston Wilson

Abstract

In 2018, we surveyed cannabis growers about their experiences with California's commercial cultivation legalization system. Our results suggest high rates of noncompliance with the new regulations. Of the respondents, 31% reported income from cannabis and had not applied for cultivation licenses, indicating a violation of state regulations. These findings highlight the need to further explore conditions that might incentivize growers to apply for cultivation licenses. Respondents' answers and comments indicate modifications to cannabis cultivation licensing programs might be needed to reduce compliance costs and regulatory inconsistencies and to overcome threats of legal repercussions from enhanced bureaucratic oversight. Growers characterized legalization as a process that excludes small growers, contributes to an increase in black market sales and undermines the economies in rural communities. More research is necessary, including on the socioeconomic and environmental contributions that unlicensed small cannabis growers make to rural regions.

With the legalization of cannabis for recreational use in 2017 (State of California 2016a), the Government of California embarked on an unprecedented, multi-agency initiative to regulate the production of an agricultural crop worth up to $20 billion per annum (Arcview Market Research 2014), the largest cash crop in California (Carah et al. 2015). The state initially projected $1 billion in tax revenue from cannabis sales following legalization for recreational use (McGreevy 2018). Building off recent regulations for medical cannabis production (State of California 2016b), the state created a new licensing system for growers producing cannabis for recreational use, which like medical cannabis, would be distributed legally to the public through state-licensed dispensaries.

The CalCannabis Division of the California Department of Food and Agriculture (CDFA) issues cannabis cultivation licenses. To cultivate for legal markets for recreational (or medical) use, cannabis

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The state initially projected $1 billion in tax revenue from cannabis sales.

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growers are required to get a CDFA cultivation license and comply with State Water Resources Control Board (SWRCB), California Department of Fish and Wildlife (CDFW) and Department of Pesticide Regulation (DPR) requirements; all county and local regulations, including land use ordinances; and any additional mitigation stipulations necessary to obtain California Environmental Quality Act (CEQA) approval (CDFA 2019). Depending on farm location and cultivation practices, growers may also require road development permits, water diversion permits, wastewater discharge permits and CDFW lake and streambed alteration agreements.

CDFA has the authority to issue renewable annual cultivation licenses; it can also issue nonrenewable provisional licenses to growers who demonstrate that CEQA compliance is under way (State of California 2018a). Once growers have obtained a license for cultivation, they must, among other requirements, tag all plants with radio-frequency identification tags to track the product from its point of origin to commercial sale, maintain 24-hour video surveillance of all plants, record the names of and timestamp all individuals who enter the fenced cultivation area and report the weight of any discarded plant material (State of California 2017).

Prior to sale, growers are required to hire third-party testing laboratories to confirm that their crop meets quality assurance guidelines for cannabinoid levels, moisture content, residual solvents and processing chemicals, pesticides, microbial impurities, foreign material, terpenoids, mycotoxins and heavy metals (State of California 2018b). Growers must also pay state and county cultivation taxes. As of 2019, state cultivation taxes per dry weight ounce were $9.25 for flower, $2.75 for stem and $1.29 for fresh plant (CDTFA 2019). County cultivation taxes vary, and some counties have yet to develop cultivation license guidelines. Additionally, growers must pay licensed distributors to transport their cannabis from the farm to testing sites and dispensaries (State of California 2019a).

Counties and municipalities may enhance state cultivation requirements or ban cannabis production entirely within their jurisdiction (fig. 1). The SWRCB or CDFW may also effectively ban cultivation by refusing to issue licenses in locations where they determine cultivation may have an adverse environmental impact (CDFA 2019). Further, counties and municipalities may prohibit cannabis sales or impose business or sales taxes in addition to the state's retail sales tax rate of 15% (CDTFA 2019).

The cultivation licensing system was broadly intended to facilitate cannabis growers' entrance into the legal market while protecting public safety, limiting environmental impacts and preventing the distribution of illegally grown cannabis. However, the extensive cultivation and reporting criteria, coupled with

FIG. 1. Commercial cannabis cultivation and sales regulations in the 10 counties where growers participating in a survey reported growing cannabis, August 2018. Percentages indicate proportion of survey respondents per county (n = 34). Three counties — Siskiyou, Sacramento and Nevada — do not allow commercial cultivation aside from exemptions in unincorporated regions. Sources: Humboldt County 2019; Mendocino County 2018; Nevada County 2018; Sacramento County 2018; San Luis Obispo County 2018; San Mateo County 2018; Santa Cruz County 2018; Siskiyou County 2018; Sonoma County 2018; Trinity County 2018.

the high costs of obtaining licenses, may be creating disincentives for growers to comply with the regulations. Noncompliance increases the risk of failure in the state's policy to transition growers to legal markets. As of April 2018, the state had approved 3,490 temporary licenses for cultivation. (The state's ability to issue temporary licenses ended Jan. 1, 2019, after which date the state was authorized to issue provisional or annual licenses.) The president of the California Growers' Association estimated the number of the state's cannabis growers to be around 50,000 (Staggs 2018).

Compared to other forms of legal crop cultivation, little is known about cannabis production dynamics in California. The dearth of research is attributed to challenges in obtaining federal funding to study federally illicit activities and the disincentives for clandestine growers to share information with outside parties (Short Giannotti et al. 2017). Accounts that do exist characterize the industry as emerging in the 1960s with the back-to-the-land movement giving rise to a proliferation of small farms in California's North Coast region (Potter et al. 2011; Raphael 1985).

To avoid detection, cultivation took place in remote regions, including forested hillsides in Humboldt, Mendocino and Trinity counties known as the Emerald Triangle (Corva 2014). In 1983, California collaborated with the federal Campaign Against Marijuana Program (CAMP), deploying helicopters to eradicate plants on private property (Corva 2014). Enforcement efforts increased the crop's value in illicit markets, thereby incentivizing continued cultivation (Corva 2014; Polson 2019).

In 1996, the Compassionate Use Act decriminalized the use and cultivation of cannabis for medical purposes in California; it allowed counties to authorize production of up to 99 plants per medical card (State of California 1996). Accounts of medical cannabis cultivation describe small family farms, in contrast to the consolidated, intensively farmed industrial agricultural operations throughout California (Guthman 2004; Polson 2018; Raphael 2012; Walker 2004). In 2012 and 2013, Google Earth satellite images of Humboldt County landscapes suggested an average of 67 plants on outdoor grow sites (n = 2,407, standard deviation 75) and 86 smaller plants in greenhouses (n = 2,021, standard deviation 89) (Butsic and Brenner 2016).

A comparison of Google Earth images between 2012 and 2016 in Humboldt and Mendocino counties, however, documented an 80% increase in the number of cultivation sites and a 56% increase in the average number of total plants per site (Butsic et al. 2018). Although still small in scale compared to traditional agriculture, cannabis production was expanding, and it was expanding in part in ecologically sensitive remote watersheds, where histories of cultivation corresponded to concerns about ecological stress from water diversion and fragmented forested landscapes (Butsic and Brenner 2016; Butsic et al. 2018; Carah et al. 2015; Wang et al. 2017).

The increase in cultivation sites and production densities may be due to relaxed enforcement and subsequent increased market competition. In 2012, California abandoned CAMP and replaced it with a new program, the Cannabis Eradication and Reclamation Team (CERT), which effectively reduced enforcement and redirected it to public lands (Corva 2014; Polson 2019). In 2017, the Drug Enforcement Administration estimated that 70% of the nation's cannabis supply came from California (DEA 2017).

How legal cannabis production will develop remains unclear, but it will be strongly influenced by if and how existing growers participate in the state's cannabis regulatory system. The recreational cannabis market could create a demand for ecologically beneficial production (Bennett 2018). Access to legal markets might also create opportunities for growers to brand their products as socially or ecologically sustainable, or to emulate other forms of legal agriculture and organize collectively to overcome market competition (Cook 1995; Short Giannotti et al. 2017). Conversely, if regulations limit access to the legal market, growers may either cease production or cultivate for illicit markets.

To characterize the ecological and socioeconomic effects of cannabis policy changes and better understand cultivation practices, we conducted an anonymous survey of California cannabis growers from July 1 to Aug. 15, 2018. The objective was to document relationships between aspects of production and growers' experiences with the legalization system and the regulatory environment. Results on cultivation practices are covered in Wilson et al. 2019 (p. 119, this issue). Here, we report respondents' experiences with legalization.

Online anonymous survey

Given the legal risks cannabis growers might assume when reporting their practices, we deployed an online, anonymous survey to try to access a wide range of growers. We distributed the survey through the listservs of several prominent California cannabis grower organizations in July 2018. We administered the survey using the Qualtrics survey platform (Qualtrics, Provo, Utah), which encrypted participants' IP addresses so that responses were collected anonymously.

We estimated that 17,500 email addresses received the survey, not all of which necessarily represented cannabis growers or were active emails. Because we were unable to view the listservs or contact growers directly, and given the uncertainties surrounding estimates of the state's number of cannabis growers, we were unable to estimate a response rate. We were also unable to follow up with growers directly to increase participation. For a full discussion of the survey methods, see Wilson et al. 2019.

In the survey, we asked questions relating to compliance, including "Have you applied for a state or county license to grow cannabis?" We also asked growers to

report their income received from cannabis cultivation. We determined growers who had not applied for a license but who reported income received from cannabis to be out of compliance with state and county regulations.

Additionally, we asked growers three open-ended questions: respondents who indicated they had not applied for a license had an opportunity to explain why; growers were invited to comment on the state licensing system and how it could be improved; and they could share any additional information about their farms. We manually coded qualitative responses for thematic trends. We characterized farm size based on California state licensing criteria (State of California 2017): small farms were 10,000 square feet or less, medium farms were 10,001 to 22,000 square feet and large farms were those over 22,000 square feet. (1 acre = 43,560 square feet, 1 hectare = 107,639 square feet.)

We received 101 responses, with variations in response rates among questions. Within this group, 36 growers provided feedback about their participation in state and county licensing initiatives, and 35 on the income they received from cannabis cultivation. We received feedback about the ways in which the legalization system could be improved from 30 participants. Although this is a small number of cannabis growers compared to estimates of the grower population, preliminary conclusions regarding grower perceptions can be drawn from this sample for the purpose of guiding future research on California's cannabis policy.

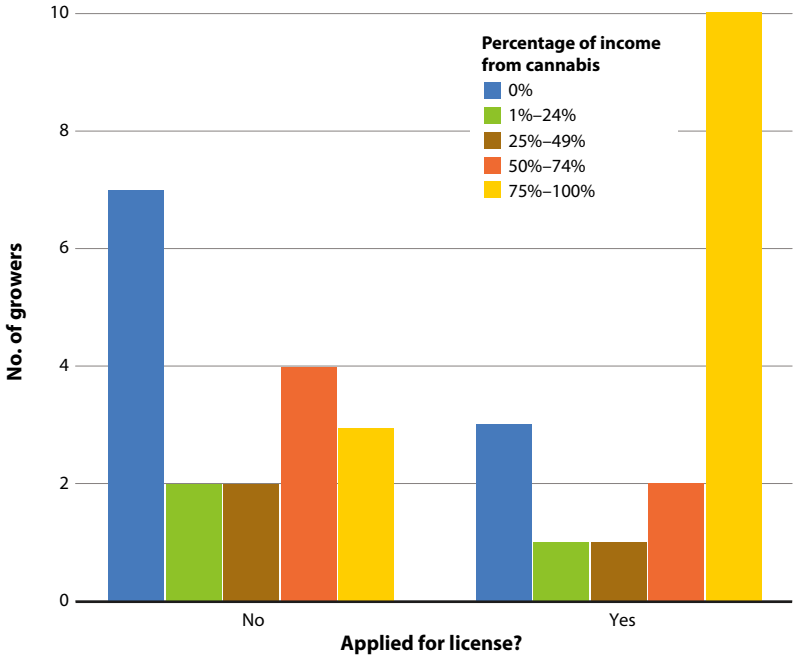

FIG. 2. Over half of survey respondents indicated that they had not yet applied for the necessary licenses to cultivate cannabis but received income from cannabis cultivation.

Demographics

Growers who answered the survey questions about compliance reported farming in 10 California counties: Siskiyou (3%), Humboldt (26%), Trinity (3%), Mendocino (30%), Nevada (17%), Sonoma (9%), Sacramento (3%), San Mateo (3%), Santa Cruz (3%) and San Luis Obispo (3%) (n = 34). Commercial cultivation and sales regulations varied between and within these counties (fig. 1). The growers who both answered questions about compliance and also provided feedback about the legalization system farmed cannabis for an average of 20 years (range: 3 to 50 years) (n = 30). Their ages ranged from 34 to 70, with an average age of 53 (n = 29); 69% identified as male, 28% as female and 3% as other (n = 32).

Compliance, cannabis income

Of the 36 growers who provided feedback on their participation in state or county licensing initiatives, over half (53%) reported that they had not participated in them (Wilson et al. 2019). Of the 35 growers who reported both on participation in licensing initiatives and income sources, 31% reported income from cannabis and had not applied for cultivation licenses, indicating their noncompliance with state and county regulations. Among the growers who had not applied for cultivation licenses and who also reported on income sources (n = 18), 39% indicated that they obtained no income from cannabis, 11% received less than a quarter of their income from cannabis, 11% received between a quarter and half, 22% received between half and three-quarters and 17% received more than three-quarters of their income from cannabis (fig. 2). Among those who had applied for state or county licenses and reported income sources (n = 17), 17% reported receiving no income from cannabis, 6% received a quarter or less, 6% received between a quarter and half, 12% received between half and three-quarters and 59% received all of their income from cannabis cultivation.

Nonlicensed growers who supported their livelihoods from cannabis cultivation and explained their noncompliance (n = 10) said they were unable to apply because of county cultivation bans or unformulated guidelines (70%) and cost constraints (40%). Additionally, 20% indicated they planned to apply. A small grower from Siskiyou County explained, "I live in a ban county. I plan to apply in a nearby city once the city puts a cultivation ordinance on the books." A small grower from Mendocino County specified that the plant "track and trace" provisions of the licensing system were cost prohibitive.

Disincentives to seek licenses

Compliant and nonlicensed growers also commented on the state's licensing system and how it could be improved (n = 30). All respondents except one (who

argued that the regulation favored larger corporations, without specifying how) identified specific limitations of the system related to at least one of three themes: costs, regulatory inconsistencies or alterations needed to production practices.

Costs

Of the growers who commented, 70% identified costs as inhibiting compliance with state legalization initiatives. A medium-sized grower from Mendocino County described the multi-agency licensing system as "Too many departments asking for too many fees." A small, nonlicensed grower from Nevada County attributed increased costs to regulations around sales and transport: "I would be willing to pay my fair share of taxes on products sold if I could continue to be responsible to test and transport my own product, deal directly with dispensaries as I did for years." Similarly, a small grower from Mendocino County, who had applied for a license, described lost profits from distributors controlling the pricing structure: "The distributor is controlling prices and gouging farmers because regulations prevent small farmers from taking their products to other licensees."

Regulation inconsistencies

Respondents (37%) identified possible inconsistency between county, regional and state production regulations as constraining their engagement with the legalization initiative. A large grower from Humboldt County said, "Often, one agency will approve a project, and the other agency involved doesn't. Then, you are in violation with the approving agency if you don't do the work, and in violation with the other agency if you do the work."

Standard practices illegal

Respondents (40%) identified difficulties in altering their production practices to comply with the new regulatory system. A small grower from Mendocino County indicated that new regulations made previous standard practices illegal: "My situation is totally standard: well fenced-in area, no environmental impact. I grow tomatoes, etc., in hoop houses, and now, because I applied for a license, I suddenly must get a permit for hoop houses that have been here for 15 years."

Effects on production

A group of growers (n = 32) also commented on the effects of state cannabis legalization on production. Their remarks focused on three themes: exclusion of small growers, an increase in unregulated market exchanges and alterations to local economies.

Exclusion of small growers

Respondents (50%) explicitly stated that legalization privileged larger, wealthier operations or put small organizations out of business (n = 32). A small grower from Humboldt County explained, "There was a pretense at both county and state levels of recognition that the transition to 'legal' pot (more correctly the transition from felony to misdemeanor pot regulation) should allow time for small producers to adapt, because the economic effect of wiping them out would devastate communities across the state. No such policy came into effect." Another experienced small grower in Humboldt County said, "Small farmers are being left out and corporations are taking over."

Respondents (50%) explicitly stated that legalization privileged larger, wealthier operations or put small organizations out of business.

An active unregulated market

Growers (19%) indicated that legalization corresponded to a rise in unregulated market exchanges (n = 32). A small grower from Siskiyou County argued that local bans "let the black market growers operate with impunity where I live…. I want a license. I have vended to the same dispensaries for 10 years. My cannabis has always been tested. I grow organically and conscientiously." A medium grower from Trinity County argued that the "thriving private [illicit] market has no incentive or ability to cross over." A small grower from Humboldt County reflected, "Only the large black market farms are surviving. All small cottage farms have closed up." A medium grower from Trinity County indicated that workers also avoid the legal market: "There is a labor shortage for on-the-books workers. The private [illicit] market is able to pay the same rate or more but taxes are taken out so workers look for unregulated farms to work at first."

Altered community economies

Respondents (25%) indicated that the legalization initiative was altering community economies (n = 32). A small grower from Nevada County argued, "Counties, by creating prohibitive (or no) ordinances that allow commercial cultivation, are disregarding the extent to which longstanding small cannabis businesses support their communities. We are already seeing the impact on local business — empty restaurants and storefronts in our once bustling town." A medium grower from Mendocino County, who had applied for the necessary state licenses, explained, "All cannabis farmers aren't rich outlaws. We are these communities."

Concern for the environment

Growers (33%) identified the environment as a concern or made note of their own practices relative to the environment (n = 32). A small grower from Humboldt County explained, "We love our home and have always practiced our business with the environment foremost in our mind. We are being blamed for the degradation of our home when it was logged several times and there were no fish when we got here. We have all worked

to heal this land and weed is the reason we had the time and resources." The concern for the environment reported in our survey suggests a willingness among growers to produce their crops in ecologically beneficial ways, regardless of their compliance status.

Potential regulatory improvements

Several survey participants suggested strategies for improving the regulatory system. A medium grower from Humboldt County, who had applied for two cultivation licenses, argued, "An opportunity to mitigate or a timeline to amortize costs will help small farmers who cannot afford the intense costs associated with regulations." A small grower from Sonoma County, who was not licensed, suggested, "Keeping grows limited in acreage so that smaller growers can compete is crucial in my mind and will lead to a more diversified agricultural system."

Legal and black market access

Growers' responses suggest high rates of noncompliance and characterize legalization as a system that legitimizes the cultivation activities of an exclusive set of growers: large growers with the financial resources to locate their farm in a legal jurisdiction, pay licensing fees, alter their practices and increase production to comply with new laws and remain competitive in legal markets. It is likely that rates of noncompliance within the broader cannabis grower population are even higher than reported in our data, as our survey reached only growers registered on industry listservs; and, even though it was anonymous, it covered illegal livelihood activities, creating potential disincentives to accurately declare practices.

Respondents' accounts of small growers' exclusion from newly regulated cannabis market opportunities — due to the misalignment of the regulations with existing practices and the costs of compliance — echo the literature on governmental and nongovernmental regulation and certification of production practices in other sectors, in which codification of regulations or standards has led to formal and informal exclusion of some growers from commodity markets (Bodwitch 2017; Côte and Korf 2018; Dwyer 2015; Getz and Shreck 2006; Lund 2011; Milgroom 2015; Putzel et al. 2015).

In the United States, for example, structural exclusion has been documented in the voluntary, third-party certification of organic agriculture, because its particular standards and onerous costs have facilitated the dominance of agribusiness at the expense of small growers (Buck et al. 1997). Similar exclusionary tendencies are also a defining effect of the rise of the food safety regulatory regime, comprised of both state regulations and market-driven audit requirements (Baur et al. 2017). Our research indicates similar patterns with the legalization of cannabis: the burden of compliance not only favors larger producers over smaller ones but also shifts the profit-making opportunities from producers to nonproducers (Foley and McCay 2014; West 2012).

The illicit market continues in California, and the two markets, legal and illicit, likely influence one another. Disincentives for small growers to participate in legal markets can also be attributed to, along with the factors already discussed, the demand for cannabis in the illicit market channels, both in and out of state (Caulkins et al. 2015; Klieman 2016; Short Gianotti et al. 2017). As of June 2019, 39 states had yet to legalize cannabis for recreational sales (Berke and Goulde 2019). In California, state and county taxes increase the legal cannabis price, and that higher price may also contribute to in-state illicit market demand. To meet industry analysts' estimates of $1 billion in tax revenue (McGreevy 2018), at least $7 billion of cannabis needs to be sold through legal markets (Kreiger 2019). In 2018, $2.5 billion was sold, and the state received $345 million in cannabis tax revenues (Kreiger 2019).

In 2018, $2.5 billion of cannabis was sold through legal markets, and the state received $345 million in tax revenues.

Hekia Bodwitch

Research needs, policy considerations

Accounts from noncompliant growers of the effects of legalization indicate a need to explore strategies that will incentivize growers' participation in legal markets.

Their accounts also raise questions for more research on the socioeconomic and environmental effects of the state's licensing system.

California's new cannabis regulations put limits on transportation and distribution (State of California 2017), and consolidate supply chains through a limited number of registered distributors (State of California 2019b). Further analysis on the effects of supply chain consolidation on compliance rates is needed to understand how nonenvironmental aspects of the licensing system influence cultivation practices.

Further research is also warranted on small-producer cooperatives, which in other agricultural sectors have improved the collective access of growers to information, credit and markets, while also enhancing regulatory compliance, community development and innovation (Fischer and Qaim 2012; Reed and Hickey 2016). Grower organizations in the cannabis industry include county and statewide policy and lobbying groups, as well as private marketing and environmental advocacy initiatives (Polson 2019). Yet, given the historically clandestine nature of production, industry-led cooperatives in the cannabis sector likely do not exhibit the political and economic influence at the state level that is exhibited by cooperatives in other sectors (e.g., almonds). At this point, producer organizing can receive only limited support from UC Cooperative Extension (UCCE) personnel because of the restrictions on use of federal funds for cannabis research or development.

Little is known about the ways in which noncompliant growers presently organize to access illicit markets. It is possible that a reliance on clandestine markets creates disincentives to collective production and market access strategies. Illicit growers may be more likely to organize their resources to avoid detection, and, without access to crop insurance or crime reporting, to protect their operations. Understanding forms of cooperation in clandestine markets may help identify social as well as economic factors most likely to facilitate compliance (Winter and May 2001).

State legalization of cannabis production presents an opportunity for growers to better manage risks and enhance returns. To this end, there is a need for further research and policy exploration of potential participation incentive mechanisms, such as tax credits, crop insurance, small business development grants, extension and training. These mechanisms could promote environmental objectives, community development goals and regulatory compliance. More understanding of what incentivizes growers would help UCCE identify extension efforts most likely to enhance growers' control over the distribution of economic benefits from legal cannabis cultivation. Analyses of relationships between land use zoning, farm licensing requirements and compliance costs would help inform outreach with state, county and municipal policymakers to promote regulations most likely to elicit compliance and reduce enforcement costs.

The high rates of nonlicensed production coupled with growers' accounts of the effects of legalization on communities indicate a need for more systematic research on the socioeconomic contributions that nonlicensed growers are making. Because cannabis has historically operated as a cash economy, it is likely that the majority of income from cultivation has been spent locally; cash from cannabis is difficult to transport and invest elsewhere (ERA Economics 2017).

These contributions to local communities were largely unaccounted for in the state's economic analysis of the medical cannabis cultivation regulations, on which the recreational cultivation licensing program was based (ERA Economics 2017). The analysis identified "significant costs" of regulation for growers, including costs related to local and state licensing, cultivation plan preparation, water and pesticide use approval, farm record maintenance, business license applications, track and trace system operation, processing, legal labor, consultants and farm inputs (ERA Economics 2017). The analysis did not address regional effects — for example, the possibility for decreased spending in places with histories of cannabis cultivation as cultivation expands elsewhere and intensifies market competition. Interviews with leaders of cannabis organizations and distributors, growers, and representatives from county employment and benefits departments, among others, to document the socioeconomic changes they experience and witness in this transition to a regulated cannabis market will help build this knowledge base.

The state's economic analysis suggested that labor compliance costs would be the most significant direct regulatory cost for growers (ERA Economics 2017). In-depth analyses with growers and workers are needed to illuminate the characteristics of the cannabis labor force and its trajectory since legalization (ERA Economics 2017). To mitigate the negative consequences of legalization for growers and rural communities, the exclusionary and racialized effects of regulation (Polson and Petersen-Rockney 2019, this issue; Polson 2019) also need to be better understood.

Improving social and environmental outcomes

Cannabis legalization in California could legally authorize the activities of tens of thousands of growers. However, our survey results suggest that the regulation structures and costs may be creating disincentives to participate in legal markets — in effect, incentivizing ongoing participation in the illicit market. Given the low number of respondents in our survey, more research is needed to understand the extent to which our results reflect broader trends. An improved understanding could inform efforts to ensure legalization corresponds to improved outcomes for growers as well as the environments and communities in which cannabis is grown. CA

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RESEARCH ARTICLE

Cannabis farmers or criminals? Enforcement-first approaches fuel disparity and hinder regulation

Siskiyou County, and many other counties, chose not to recognize cannabis cultivation as agriculture. This ethnographic study reveals the effects on parity in farmer rights and access to resources.

by Michael Polson* and Margiana Petersen-Rockney*

"It is not agriculture in any way, shape or form," said a senior Siskiyou County agricultural official in response to our questions about cannabis cultivation. Away from the green valleys of irrigated alfalfa and pasture, in the dry rocky hills, a new set of producers has gained public attention, who, the county agricultural official asserted, "are not farmers." According to Siskiyou's Planning Division, cannabis is a unique crop that "differs from … traditional crops like strawberries or alfalfa in that cannabis remains classified by the federal government as a Schedule I drug" (Siskiyou County 2017a, 3). Despite cannabis now being a legal commodity in the state, in many counties, including Siskiyou County, cannabis cultivation has been disqualified as agriculture and substantively recriminalized.

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Abstract

Since California's cannabis legalization, localities have played a central role in determining the regulatory terms of where, how and within what legal bounds cannabis cultivation occurs. Siskiyou County, a rural, conservative and majority white county in Northern California, chose not to recognize cannabis cultivation as agriculture. It drew up highly restrictive cannabis cultivation regulations, largely under the purview of law enforcement rather than civil agencies. Hmong-American cultivators, made highly visible through enforcement practices, policy forums and media discourses, have borne the brunt of this regulatory regime. Cannabis policy, especially in its ethnic-racial dimensions, has become symbolic of broader anxieties about cultural and agricultural change. We employed ethnographic methods to research the formation and enforcement of Siskiyou's restrictive cannabis cultivation regulations, and their differential effects across local populations. We found that the county's law enforcement–first regulatory approach blurred civil and criminal lines, made some cultivators more visible and vulnerable to enforcement, and promoted criminalizing approaches to cultivators, even among civil regulatory agencies. These developments hinder the ability of agencies (including the California Department of Food and Agriculture and the California Department of Fish and Wildlife) to ameliorate negative social and ecological effects of cannabis cultivation through civil regulation, support and services.

Many cannabis farms in Siskiyou County are located on mostly undeveloped subdivision lots, which are often sparsely vegetated, dry, hilly and small, making them highly visible from public roads, horseback, neighboring plots, helicopters and Google Earth.

Michael Polson and Margiana Petersen-Rockney

With the passage of Proposition 64 (see page 106), state voters elected to integrate cannabis into civil regulation. The California Department of Food and Agriculture (CDFA) oversees state-licensed cannabis cultivation and defined it as agriculture (California State Legislature 2017a). Prior to the possibility of state licensure for cultivators, however, counties can decide on other designations and implement strict limitations. In effect, local governments have become gatekeepers to whether and how cultivation of personal, medical or recreational cannabis can occur and the repercussions of noncompliance. When cannabis is denied a consistent status as agriculture, despite being a legal agricultural commodity according to the state, localities can determine who counts as a farmer and who is considered compliant, noncompliant and even criminal.

In Siskiyou County's unincorporated areas, the Sheriff's Office now arbitrates between the effectively criminal and agricultural. Paradoxically for this libertarian county, the furor around cannabis has seen calls for government intervention, and has led to officials passing highly stringent cannabis cultivation regulations that have been enforced largely by law enforcement, muddying the line between noncompliance and criminality. These strict regulations produced a situation where "not one person" has been able to come into compliance, according to a knowledgeable government official. Nonetheless, at the sheriff's urging, Siskiyou declared a "state of emergency" due to "nearly universal non-compliance" (Siskiyou County 2017b), branding cannabis cultivation an "out-of-control problem."

Such a strong reaction against cannabis can be understood in terms of cannabis's potential to reorganize Siskiyou's agricultural and economic landscape. According to some estimates, there are now approximately twice as many cannabis cultivators as noncannabis farmers and ranchers in Siskiyou (Siskiyou County 2017b; St. John 2017; USDA NASS 2017), a significant change from just a few years ago. Although cannabis has been cultivated in this mostly white county for decades, since 2015 it has become associated with an in-migration of Hmong-American cultivators. (Though interviewees referred to themselves often as "Hmong," we use the hyphenated descriptor to mark their status as U.S. citizens and residents.) Made highly visible through enforcement practices, policy forums and media discourses, Hmong-Americans have become symbolically representative of the "problem." This high visibility, however, obscures a deeper issue, what Doremus et al. (2003) see as a nostalgic, static conception of rural culture that requires defensive action as a bulwark against change. Such locally-defined conceptions need to be understood (Walker 2003), especially in how they are defined and defended and what effects they have on parity among farmers growing different types of crops.

Our goals in this study were to consider the consequences of an enforcement-first regulatory approach — a common regulatory strategy across California — and its differential effects across local populations. Using Siskiyou County as a case study, we paid attention to the public agencies, actors and discourses that guided the formation and enforcement of restrictive cannabis cultivation regulations as well as attempts to ameliorate perceptions of racialized enforcement. This study attends to novel postlegalization apparatuses, their grounding in traditional definitions of (agri)culture and the ways these dynamics reactivate prohibition.

Ethnographic study

We used qualitative ethnographic methods of research, including participant observation and interviews. In situations of criminalization, which we define not only as the leveling of criminal sanctions but being discursively labeled or responded to as criminal-like (Schneider and Schneider 2008), quantitative data can be unreliable and opaque, which necessitates the use of qualitative ethnographic methods (Clatts et al. 2002; Ferrell and Hamm 1998).

In 2018–2019, we talked to a wide range of people — including cannabis growers from a diversity of ethnic backgrounds, government officials, businesspeople, subdivision residents, farm service providers, medical cannabis advocates, realtors, lawyers, farmers and ranchers, and, with the assistance of a Hmong-American interpreter, members of the Hmong-American community. We also analyzed public records and county ordinances, Board of Supervisors meeting minutes and audio (meetings from 2015 to 2018), Sheriff's Office press releases and documents, related media articles and videos, and websites of owners' associations in the subdivisions where cannabis law enforcement efforts have focused.

Some cannabis cultivators regarded us suspiciously and were hesitant to speak openly, an unsurprising phenomenon when researching hidden, illegal and stigmatized activities, like "drug" commerce (Adler 1990; Bourgois 1995; Moore 1993; Northcote and Moore 2010). This circumspection was most intense among Hmong-American growers on subdivisions, who had been particularly highlighted through enforcement efforts and local, regional and national media accounts linking their relatively recent presence in Siskiyou to cannabis growing.

Human subjects in this research are protected under the Committee for Protection of Human Subjects, protocol number 2018-04-1136 (approved May 21, 2018), of the Office for Protection of Human Subjects at UC Berkeley.

(Agri)culture and cannabis

Siskiyou is a large rural county located in the mid-Klamath River basin in Northern California (fig. 1). Since the mid-19th century, inmigrants have historically engaged in agriculture, predominantly livestock grazing and hay production, and natural resource extraction, primarily timber and mining (Doremus et al. 2003). Public records demonstrate that although the value of the county's agricultural output and natural resource extraction is declining, these cultural livelihoods still shape the area's dominant rural values of self-reliance, hard work and property rights (CED 2012; Doremus et al. 2003; NoRTEC 2016). For instance, one county document stated that Siskiyou's cultural-economic stability depends on nonintervention from "outside groups and governments" and residents should be "subject only to the rule of nature and free markets" (Siskiyou County 1996, 25). Another document, a "Primer for living in Siskiyou County" from the county administrator, outlined "the Code of the West" for "newcomers," asserting that locals are "rugged individuals" who live "outside city limits," and that the "right to be rural" protects and prioritizes working agricultural land for "economic purpose[s]" (Siskiyou County 2005).

We heard a common refrain that localities will eventually succumb to the allure of a taxable, profitable cannabis industry. Indeed, interviewees in Siskiyou universally reported economic contributions from cannabis cultivation, especially apparent in rising property values and tax rolls and booming business at horticultural, farm supply, soil, generator, food and hardware stores (see Stoa 2018). However, a belief in an inevitable free market economic rationality may underestimate the deep cultural logics that have historically superseded economic gains in regional resource conflicts (Doremus et al. 2003). As one local store

owner told us, "I'd give up this new profit in a heartbeat for the benefit of our society."

Many long-time farming and ranching families remain committed to agricultural livelihoods for cultural reasons (Reinhart and Barlett 1989), even as the economic viability of family farms is threatened by increasing farmland financialization (Fairbairn 2014), corporate consolidation (Hossein and Elsheikh 2015) and biophysical decline (Pathak et al. 2018). Many interviewees felt that the recent rapid expansion of county cannabis cultivation and corresponding demographic changes were a visible marker of broader tensions of (agri)cultural continuity and endangerment. As the sheriff expressed, cannabis cultivation would "jeopardize our way of life … [and] the future of our children" (SCSO 2017a).

This sense of cultural jeopardy (see Tarlock 1999), echoed by numerous interviewees, materialized in a range of negative quality-of-life comments about cannabis cultivation: noisy generators, increased traffic, litter and blighted properties, and unsafe conditions for residents. Noncannabis farmers also reported farm equipment and water theft, livestock killed by abandoned dogs, wildfire danger, illicit chemical use and poisoned wildlife.

Some noncannabis farmers expressed a sense of regulatory unfairness — that their farms were subject to onerous water and chemical use regulations while cannabis growers "don't need to follow the government's regulations." Enabling cannabis cultivators to pursue state licensure would facilitate just such civil regulation, but some feared that regulating this crop as agriculture would threaten "the loss of prime agriculturally productive lands for traditional pursuits" (Siskiyou County 2017a, 4). If nothing less than the county's culture and agricultural order were considered at stake, it is no wonder that absolute, even prohibitionist, solutions emerged in Siskiyou, with the Sheriff's Office having a central role in defending local (agri)culture.

Early, collaborative regulation

Siskiyou's sparsely populated landscape has been home to illegalized cannabis cultivators at least since the late 1960s, largely in remote, forested, and public lands in the western part of the county. Medical cannabis's decriminalization in 1996 inaugurated a modest expansion of cannabis gardens throughout the county (fig. 2). However, for the next 19 years, Siskiyou did not establish regulations for medical cannabis, in line with locally dominant ideologies of personal freedoms and property rights. Instead, the county relied on de facto management of cultivation by law enforcement and the court system's strict interpretation of state law (Boerger 2007).

In 2015, informed by public workshops held by the Siskiyou County Planning Division, supervisors passed the county's first medical cannabis ordinance, which seemingly balanced concerns of medical cultivators and other county residents. Regulation would be overseen by the Planning Division, which placed conditions on cultivation (e.g., property setbacks), limited plant numbers to parcel size and would establish an administrative abatement and hearing process for complaints.

The Planning Division, however, had been without code enforcement officers since 2008 budget cuts. Though the county authorized the hiring of one civil code officer in 2015, the Sheriff's Office felt that the Planning Division "needed outside help" and moved to assist. Soon, the county's limited abatement capacities were overwhelmed by vigorous enforcement and a wave of complainants. County supervisors, responding to the sheriff's 2015 reports on the "proliferation" of cannabis gardens on private property, moved to heighten penalties for code violations, place numerous new restrictions on indoor growing and ban all outdoor growing (SCSO 2015; table 1).

These strict county measures, which discarded and replaced publicly developed regulations, stoked reaction. When the Siskiyou County Board of Supervisors met in December 2015 to vote on these measures, advocates and cultivators presented 1,500 signatures to

FIG. 1. Siskiyou County is a large, rural California county. Its residents are mostly white. Compared to other California counties, it has relatively high unemployment, a low violent crime rate and low median household income.

FIG. 2. Timeline of cannabis activities in Siskiyou County.

1996	Voters approve Proposition 215, Compassionate Use Act.
2004	Medical Marijuana Program Act provides statewide guidance for medical marijuana.
2014	Siskiyou Alternative Medicine founded to advocate for medical marijuana rights.
2014–2015	Siskiyou Planning Division holds public workshops about medical cannabis.
March 2015	Agricultural commissioner states cannabis is not agriculture (Siskiyou County 2015).
April 2015	Siskiyou's first medical marijuana regulations passed.
2015	Interviewees describe and property records show increased Hmong-American in-migration to the county (from other states or California towns).
Late 2015	Hmong-Americans begin to attend county Board of Supervisor meetings, and organize countywide advocacy.
September 2015	Medical Marijuana Regulation and Safety Act passes, regulating medical cannabis businesses at state level.
December 2015	Siskiyou's Board of Supervisors bans outdoor cultivation and tightens cannabis ordinances and enforcement; advocates present 1,500 signatures in opposition.
January 2016	Advocates collect 4,000 signatures to place stricter ordinances on 2016 county voter ballot.
March 25, 2016	Sheriff's Office releases strategic plan with state and federal agencies to "attack illegal grows" and enforce civil regulations.
May 25, 2016	Sheriff's Office releases study reporting rising crime rates and attributes them to "the #1 public enemy to Siskiyou citizens . . . criminal marijuana cultivation."
June 5, 2016	Sheriff's Office accompanies state voter fraud investigators to properties of Hmong-Americans, resulting in voter intimidation lawsuit.
June 7, 2016	Siskiyou voters approve more restrictive cannabis cultivation ordinances.
July 2016	Sheriff's Office founds Siskiyou Interagency Marijuana Investigation Team with district attorney, soon enlists National Guard, Cal Fire and California Highway Patrol in cannabis enforcement activities.
September 2016	Siskiyou Alternative Medicine brings lawsuit against county alleging constitutional violations and harassment by Sheriff's Office.
November 2016	California and Siskiyou voters approve Proposition 64, Adult Use of Marijuana Act (AUMA) legalizing recreational cannabis.
Winter 2016–2017	Three people die of carbon monoxide in substandard housing on cannabis grow sites.
June 2017	State merges medical and recreational regulatory systems in the Medical and Adult Use Cannabis Regulation and Safety Act (MAUCRSA).
June–December 2017	Local, regional and national papers highlight conflict between Hmong-Americans and law enforcement.
July 2017	Planning Division submits study to supervisors on potential for commercial recreational and medical regulatory system, recommends against agricultural zoning.
August 8, 2017	Siskiyou passes moratorium on all recreational and medical cannabis commerce.
August 2017	Cultivators in cannabis operation arrested for bribing sheriff for exemption from county cannabis ban.
September 5, 2017	Siskiyou issues state of emergency declaration regarding cannabis cultivation.
September 16, 2017	CDFA declares "cannabis is an agricultural product."
September 2017	Hmong-American voter intimidation lawsuit against county dismissed.
October 2017	City of Mt. Shasta, in Siskiyou, passes municipal ordinance allowing cannabis commerce.
December 2017	Siskiyou's City of Dunsmuir passes municipal ordinance allowing cannabis commerce.
January 2018	California's cannabis commerce regulations take effect.
April 2018	Siskiyou's City of Weed passes municipal ordinance allowing cannabis commerce.
May 2018	Sheriff's Office hosts first Hmong-American and County Leaders Town Hall Meeting.
Summer 2018	Sheriff's Office continues building enforcement alliances with other agencies (County Animal Control Department, California Department of Toxic Substances Control, State Water Resources Control Board, California Department of Fish and Wildlife).
June 2018	Sheriff's Office hires first Hmong-American sheriff's deputy in Siskiyou.
August 2018	Supervisors tighten penalties, timeframes and appeal processes for civil code violations, and formalize and expand powers for enforcement officers.
June 2019	County implements permanent prohibition of all commercial cannabis activity in unincorporated areas.

forestall its passage, a supermajority (110–6) of attending residents indicated opposition, and supervisors had to curtail 3 hours of public comment to vote. Despite this showing, supervisors passed the restrictive measures, prompting cannabis advocates to collect 4,000 signatures in 17 days to place the approved ordinances on the June 2016 ballot. Meanwhile, the Sheriff's Office enforced the new stricter regulations (SCSO 2016a).

Blurring civil and criminal lines

The Sheriff's Office assumption of code enforcement blurred the line between noncompliance with civil codes and criminal acts. Stricter ordinances, still in effect in Siskiyou, created a broad, nearly universal category of "noncompliance." No one we interviewed, including officials at the Planning Division and Sheriff's Office, knew of a single cultivator officially in compliance. One interviewee estimated that growing 12 indoor plants (the maximum allowed for personal, nonmarket use) would cost $40,000 in physical infrastructure, in addition to numerous licensing and inspections requirements, effectively prohibiting self-provisioning.

The Sheriff's Office notified the public that it would initiate criminal charges against "noncompliant" cultivators, specifically those suspected of cultivation for sale (e.g., growing an amount "reasonably inconsistent with" medical needs), child endangerment (e.g., presence of a minor near a Schedule I drug) (SCSO 2015) or suspected drug trafficking (the criteria for which includes being in possession of too much unlicensed cannabis) (SCSO 2016b). Since the county regulations produced a situation where no one could comply, law enforcement could effectively criminally pursue any cultivator.

The slippage from civil noncompliance to criminality was mirrored in enforcement practices. Investigations were "complaint driven," meaning not only that warrants could be issued in response to disgruntled neighbors upset about a barking dog on a cultivation site, as one person reported, but that police officers could serve as a kind of permanent, general complainant and take "proactive action" when they spotted code violations (SCSO 2015). Administrative warrants allowed deputies to enter properties with a lower evidentiary bar than they would have needed for criminal warrants, leading one patients rights group — Siskiyou Alternative Medicine — to file a lawsuit alleging county violations of Fourth Amendment protections against unreasonable search and seizure (later dismissed because plaintiffs were fearful of identifying themselves).

In effect, cannabis's criminal valences in the county endured through California's shift of cannabis from criminal to civil provenance. Formerly illegal activities continued to be formally or informally treated as criminal matters, as researchers have noted with other stigmatized activities and groups, for example, after the decriminalization of sex workers in Mexico (Kelly 2008). Also, enforcement of civil matters can lead to substantive criminalization when those matters are stigmatized, as in the regulation of homelessness (Walby and Lippert 2012). While it is not unique for police officers to enforce civil codes, what is unique in Siskiyou County is the assumption of the entire civil process (complaints, inspection, abatement, sanctions) under the sheriff's authority.

Visibility, race and crime

To understand how this civil process became criminally inflected, in a county that voted for statewide cannabis legalization in 2016, one must first understand significant contextual shifts in who was growing cannabis where — and the challenge this posed to

TABLE 1. Cannabis-related ordinances passed by Siskiyou County since 2015

Passed	Ordinance title	Impact
04/2015	15-04 Medical Marijuana Cultivation (1)	Established plant allowance based on parcel size, some property requirements, and an abatement/hearing process for complaints.
12/2015	15-18 Medical Marijuana Enforcement	Medical grows must hold license. Civil penalty of code violation with daily fee. Option for hearing. Voters approved in June 2016.
12/2015	15-19 Medical Marijuana Cultivation (2)	Restrictive set of permitting, inspection and property requirements. Limited plants to 12 per parcel. Voters approved in June 2016.
08/2017	17-11 Moratorium on Commercial Cannabis Activities (and its extension 17-12 in 09/2017)	Prohibits commercial production, whether or not profit is intended, for 1 year.
09/2017	Local State of Emergency: Proliferation of Illegal Cannabis Cultivation	Citing 2,000+ private grows, over 100,000 plants seized on public land in 2016, and nearly universal noncompliance allowed the Sheriff's Office to harness other agency, state and federal resources.
12/2017	17-14 Cannabis Cultivation	Amending 15-19 to extend restrictive requirements to personal cannabis cultivation. Exemption for six or fewer plants on private residence in locked facility not visible from public space.
07/2018	18-05 Interim Zoning/Urgency Extending the Commercial Cannabis Moratoriums Currently in Place	Extended moratorium for second and final year to allow county time to develop and adopt permanent ordinance. Passed due to "current and immediate threat posed by commercial cannabis land uses."
08/2018	18-06 Amending Citation Procedures for Code Enforcement Processes and Fines	Shortened compliance and appeal time from 14 to 7 days; expanded fines for some penalties to $1,000/day; expanded enforcement officer's power for immediate citation and discretion to determine fine amount; required advance deposit for fines prior to hearing; expanded county's power to place liens on property for nuisance violations; lowered bar for violation notifications; enabled county prosecutors to reduce misdemeanors (with jail time) to infractions.
06/2019	19-07 Commercial Cannabis Activities Prohibited	"To prohibit, to the greatest extent that is compatible and consistent with state law, Commercial Cannabis Activity within the unincorporated County and to preclude businesses engaging in such activities from procuring a business license or a land use entitlement from the County."

dominant ideas of land use, agriculture and culture. Since 2014, cannabis gardens have emerged on many of the county's undeveloped rural subdivisions in unincorporated areas of Siskiyou. Subdivided into over 1,000 lots each in the 1960s, these subdivisions contain many parcels that are just a few acres in size and relatively inexpensive. Previously populated mostly by white retirees, squatters and a few methamphetamine users and makers, the parcels were often bought sight-unseen as investments or potential retirement properties, with most remaining unsold and undeveloped until the mid-2010s.

In 2014, these subdivisions became destinations for Hmong-Americans from several places, including Minneapolis, Milwaukee and Fresno; many of them cultivated cannabis. The inexpensive, sparsely populated, rural subdivisions enabled Hmong-Americans to live in close proximity to ethnic and kin networks, which multiple interviewees expressed was especially important for elders who had migrated to the United States as refugees after the Vietnam War. The county sheriff estimated that since the mid-2010s around 6,000 Hmong-Americans had moved to Siskiyou, purchasing approximately 1,500 parcels (St. John 2017). In an 86.5% white county with just 745 noncannabis farms (USDA NASS 2017) and fewer than 44,000 people (US Census Bureau 2017), this constituted a major demographic shift. Hmong-American residents found themselves susceptible to scrutiny by white neighbors and officials.

Cannabis growers in Siskiyou's subdivisions are especially vulnerable to detection. The subdivisions are often sparsely vegetated, dry and hilly, making them not only unproductive as agricultural lands but also highly visible from public roads, horseback, neighboring plots, helicopter and Google Earth. Green screen fencing, wooden stakes, portable toilets, generators, campers, plywood houses, or water tanks and trucks often signal cannabis cultivation but would be necessary for many land uses, especially since many lots are sold without infrastructure like water, sewer or electrical access.

If detection of code violations depends upon visibility, Hmong-Americans on subdivisions have been made especially visible and vulnerable to detection. One lawyer, for instance, reported that 90% of the defendants present at administrative county hearings for code violations in fall 2015, when the first complaint-driven ordinance was put in place, were Hmong-American. One Hmong-American resident reported being stopped by police six times in 3 months (his wife three times) and subjected to unfriendly white neighbors patrolling on horseback for cannabis — one of whom made a complaint for a crowing rooster, a questionable nuisance in this "right to farm" county. Numerous Hmong-Americans and sympathetic whites echoed these experiences. County residents confirmed their antagonism toward Hmong-Americans by characterizing them in interviews and public records as dishonest, thieves, polluters, negligent parents and unable to assimilate, and making other racializing and racist characterizations.

While written regulations and enforcement profess race neutrality, in a nuisance enforcement regime based on visibility, Hmong-Americans were more visible than others, leading many to argue that they were being racially profiled. Rhetoric emerging from the county government amplified racial tensions and visibilities. Numerous Sheriff's Office press releases located the "problem" in subdivisions and attributed it to "an influx of people temporarily moving to Siskiyou" (SCSO 2015) who were "lawbreakers" from "crime families" with "big money" (SCSO 2016a) and who threatened "our way of life, quality of life, and the health and safety of our children and grandchildren" (SCSO 2016b).

Just 2 days before the June 2016 ballot on the strict cannabis ordinances, state investigators responded to county reports that newly registered Hmong-American voters might be fraudulent or coerced by criminal actors and visited Hmong-American residences to investigate, accompanied by sheriff's deputies (who some reported had guns drawn). The voter fraud charges were later countered by a lawsuit alleging racially motivated voter intimidation; the suit was eventually dismissed for failing to meet the notoriously difficult criteria of racist intent. The raids may have discouraged some Hmong-Americans from voting, charges of fraud may have boosted anticannabis sentiment, and, one government official explained, "creative balloting" measures enabled some municipal voters in conservative localities to vote while others in more liberal places could not.

The voter fraud charges, raids and legal contestation drew widespread media attention that further linked Hmong-Americans and cannabis. Amidst these now-overt racial tensions, the restrictive June 2016 ballot measure passed, allowing the Sheriff's Office to gain full enforcement power over the "#1 public enemy to Siskiyou citizens … criminal marijuana cultivation" (SCSO 2016b).

Shortly after the June 2016 ballot measure affirmed stricter regulations, the Sheriff's Office formed the Siskiyou Interagency Marijuana Investigation Team (SIMIT) with the district attorney to "attack illegal marijuana grows" (SCSO 2016a) "mostly" around rural subdivisions (SCSO 2017b). Within a month, SIMIT had issued 25 abatement notices and filed 20 criminal charges, in addition to confiscating numerous plants. Meanwhile, the Planning Division's role had diminished — code enforcement officers were relegated to addressing violations not directly related to cannabis (illegal encampments, debris piles, etc.).

Postlegalization prohibition

The November 2016 state legalization of recreational cannabis prompted Siskiyou to examine a possible licensure and taxation system for local growers (Siskiyou County 2017a). Amidst sustained, vocal opposition, the proposal stalled for several reasons that further aggravated cultural and racial tensions: A key proponent of licensure was discovered to be running an unauthorized grow, three Hmong-Americans died of carbon monoxide poisoning due to heaters in substandard housing, and a cannabis cultivation enterprise run by two Hmong-Americans attempted to bribe the sheriff.

These developments were interpreted not as outcomes of restrictive regulations and criminalizing strategies, but as proof that, in the words of one supervisor, regulation was impossible until the county could "get a handle on the illegal side of things." The sheriff encouraged this interpretation, arguing in an interview that statewide legalization was "just a shield that protects illegal marijuana" and efforts to regulate it would always be subverted by criminals.

This antiregulatory logic prevailed in August 2017 when the county placed a moratorium on cannabis commerce. Still, the sheriff argued for stronger powers, citing an "overwhelming number of cannabis cultivation sites," which, according to the Sheriff's Office, continued to "wreak … havoc [with] potentially catastrophic impacts" across the region (SCSO 2017b). Just 1 month later, at the sheriff's urging, the Siskiyou Board of Supervisors declared a "state of emergency" aimed at garnering new resources and alliances to address the cannabis cultivation problem. Soon, the Sheriff's Office enlisted the National Guard, Cal Fire and the California Highway Patrol in enforcement efforts, and, by 2018, numerous other agencies joined, including

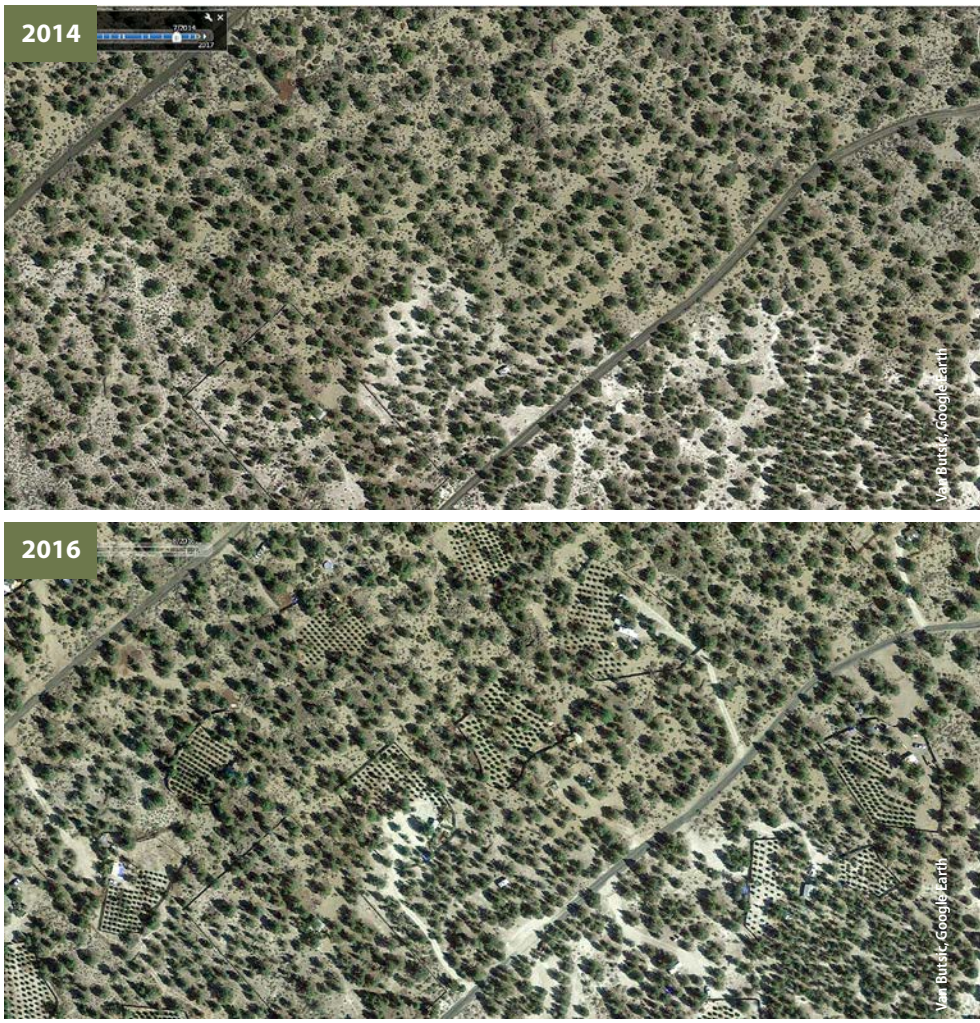
the Siskiyou County Animal Control Department, California Department of Toxic Substances Control, State Water Resources Control Board, California Department of Fish and Wildlife and a CDFA inspection station. These alliances multiplied the civil and criminal charges cultivators might face (e.g., toxic dumping, wildlife endangerment).

Ironically, California's cannabis legalization has enabled a kind of multi-agency neoprohibitionism at the county level, one that reinforces older criminal responses with new civil-administrative strategies and authorities. The need to "get a handle" might be regarded as a temporary emergency measure, but it may also propagate new criminalizing methods and institutional configurations. The more enforcement occurs, the bigger the problem appears, requiring more resources and leading to a logic of escalation symmetrical to the much-critiqued War on Drugs (Heyman 1999; Johns 1992; Polson 2018). And the more cannabis cultivators are viewed as criminal, the less likely they are to be addressed as citizens, residents and farmers.

Cultural misunderstandings

Given concerns about biased county policy and enforcement, the Sheriff's Office held the first Hmong-American and Siskiyou County Leader Town Hall in May 2018 to "foster a closer, collaborative relationship with members of the Hmong-American community," exchange information about Hmong and Siskiyou culture and educate attendees on county policies (SCSO 2018). According to public records, racial tensions surfaced at this meeting when some white participants expressed that "our county" had been "invaded" and that Hmong-Americans were not fitting into local cultural norms (Shulman 2018). Meeting leaders — both government officials and Hmong-Americans — however, identified cultural misunderstanding, rather than criminalization and racialized claims by whites on what constitutes local culture, as the core problem to be addressed. (Accordingly, the Sheriff's Office hired a Hmong-American deputy to address perceptions of racialized enforcement and work more closely with the Hmong-American community, yet enforcement-first policies that disproportionately affect Hmong-Americans have continued.)

"Misunderstanding" was an inadequate framing, given that Hmong-Americans had attempted to make themselves understood by attending public meetings, forming advocacy groups, signing petitions, demanding interpreters and administrative hearings, and registering to vote since their arrival in Siskiyou. At the 2018 town hall, and numerous prior meetings, they emphasized their status as legitimate community members — veterans, citizens, consumers of county goods, local property owners, "good" growers and medical users — not nuisances, criminals, foreigners or outsiders. In interviews and public forums many Hmong-American cultivators expressed a desire to comply with the rules.



Images from Google Earth show the establishment of new cannabis cultivation sites between 2014 and 2016 at a Siskiyou County subdivision.

Their efforts, however, they said, were frustrated not only by linguistic and cultural differences, but also understaffed and underfunded permitting, licensing and community services agencies. (The Sheriff's Office continues to consume the majority of the general fund.) Hmong-American cultivators routinely told us about their desires to settle down, build homes and plant other crops. "I'm growing watermelons, pumpkins and tomatoes," one cultivator told us, but he was waiting for a permit to build his house, a process another interviewee reported took 3 years.

Though the town hall meeting sought to address cultural misunderstanding, this framing overlooks how misunderstanding — of Hmong-Americans or cannabis producers generally — is produced by criminalizing enforcement practices. Properties given as gifts in the Hmong-American community were seen as evidence of criminal conspiracy, not generous family assistance; land financing networks evidenced drug trafficking organizations, not kin-based support and weak credit access; repetitive farm organization patterns suggested "organized crime" (SCSO 2016b), not ethnic knowledge-sharing circuits. When Hmong-Americans, leery of engagement with government agencies and unfriendly civic venues, self-provisioned services,

including firefighting teams, informal food markets and neighborhood watches, these actions were taken to confirm suspicions that they could not assimilate. Now that some Hmong-Americans are considering, or already are, moving away in response to county efforts, the sheriff's prior description of them as temporary residents seems prophetically manufactured.

Disparities and uneven development

These stigmatizing views of Hmong-American cultivators affect all cannabis growers. Anticannabis pressure creates a precarious state of impermanence — a season's crop might be destroyed, infrastructure confiscated and investments of limited resources lost at any moment, disallowing longer-term investments. The impermanence makes noncompliance and deleterious environmental and health effects more likely, thereby perpetuating perceptions of cannabis cultivators as nuisances and dangers.

As enforcement makes private land cultivation more risky, cultivators move "back up the hill," namely onto ecologically sensitive public lands, thus substantiating characterizations of cannabis growers as criminal polluters. These stigmas even spread to county residents who do not grow cannabis themselves but if perceived to assist cannabis cultivation can face social sanctions. One agriculturalist reported receiving death threats after selling water to cannabis cultivators.

Meanwhile, well-resourced cultivators have an advantage over small-scale producers. They can protect their crops from visibility and complaints by concealing them on large plots of land or inside physical infrastructures (like warehouses); and for white growers there is the anonymity of not being marked as ethnically different and therefore subject to heightened scrutiny. Greater access to capital, land and racial privileges insulates some from visibility and criminalization, resulting in uneven development and disparities in California's expanding cannabis industry. Additionally, jurisdictions like the Siskiyou municipalities of Mt. Shasta and Weed are welcoming regulated cannabis commerce, thus capitalizing on its expulsion from the rest of Siskiyou and benefiting entrepreneurs with social capital and network access to successfully navigate complex public regulatory systems.

Ironically, California's cannabis legalization has enabled a kind of multi-agency neoprohibitionism at the county level.

Agricultural leadership

After a century of cannabis's criminal exclusion in California, state voters have elected to integrate cannabis farmers into civil regulation. An important facet of evolving cannabis regulations is local determination. As one interviewee pointed out, a 1-acre farm might be permitted in rural San Joaquin County but would not make sense in downtown San Diego. Yet, when cannabis cultivation is disqualified from consideration as agriculture by localities, as it has been in Siskiyou County, it can be substantively recriminalized and placed beyond the regulatory reach of civil institutions. Prohibitionist strategies that blur lines between civil and criminal enforcement lead to penetrating forms of visibility and vulnerability that produce inequity and disparity. The result, as this case illustrates, can be a narrow, exclusive definition of agriculture that affirms dominant notions of land use and community.

The definition of cannabis cultivation as agriculture by the CDFA creates an opportunity for service providers and regulators — including agricultural institutions, public health departments and environmental agencies — to craft programs and policies that openly address the negative impacts of production. Owley (2018, 1,675) advises that "if we treat cultivation of marijuana the same as we treat cultivation of other agricultural crops, we gain stricter regulation of the growing process, including limits on pesticide usage, water pollution, wetland conversion, air pollution, and local land-use laws." Presently, however, many agencies are being enlisted in locally crafted criminalizing efforts, thus limiting their ability to work cooperatively with cultivators and address issues through customary civil abatement processes. Though unregulated cannabis cultivation can pose threats to public health, safety and welfare, police enforcement is only one of many possible ways to address it.

Siskiyou's cannabis cultivators experience familiar agricultural challenges around access to land, water and credit. These challenges are amplified without technical assistance or institutional support. If recognized statewide as farmers, these cultivators would be better positioned to access agricultural training and support services, thus addressing ecological and social concerns around cannabis production. Additionally, new cannabis cultivators might be considered "beginning" farmers according to the CDFA, and minority farmers, including Hmong-Americans, who experience poverty at twice the national rate (Pew Research Center 2015), would be considered "socially disadvantaged" under the California Farmer Equity Act of 2017 (California State Legislature 2017b). Farmers with these designations would, in fact, be prioritized for technical assistance and support from farm service providers — if, that is, they were recognized as farmers.

Uniformly treating cannabis cultivation as (legal) agriculture would also help enable the collection of accurate and robust data by researchers. This information base is necessary if agricultural institutions are to take an assistive and educational orientation toward cannabis farmers. Continued enforcement tactics that amplify distrust, frustration and confusion will further hinder data collection (by academics, journalists, government officials, etc.), leaving little basis to understand basic dynamics of complex, interdisciplinary systems

like agriculture (Gianotti et al. 2017). In a criminalized situation, it is inevitable that information is metered and brokered by community leaders in ways that inhibit full understanding of cannabis cultivation.

We suggest, for all these reasons, that a decisive break with enforcement-led, prohibitionist trajectories is needed and that agricultural institutions lead civil policy development and support farmers who cultivate cannabis. Agricultural service providers could play a leadership role in addressing the pressing needs of farmers — both those impacted by and engaging in cannabis cultivation. Yet, UC Agriculture and Natural Resources (UC ANR) Cooperative Extension advisors, for instance, consistently report that they are currently prohibited from engaging with cannabis issues (see issue introduction). Additionally, many county-based agricultural commissions, Siskiyou County's included, feel that cannabis is not an agricultural enterprise and therefore do not see its cultivators as their clientele.

Without leadership from agricultural institutions and agencies, the expanding cannabis cultivation industry is left to develop unevenly across the state — with wealthy private interests capitalizing in some locales while vulnerable and unregulated growers may retreat, to avoid criminalization, into ecologically sensitive areas. UC ANR and CDFA have an opportunity to fulfill their missions and facilitate, for a burgeoning farming population, greater parity in farmer rights, capacities and resource access. CA

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Upcoming UC and UC ANR events

2019 Annual Alfalfa and Forage Field Day

https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=30497

Date: September 19, 2019
Time: 7:00 a.m. to 1:00 p.m.
Location: UC Kearney Agricultural Research and Extension Center, Parlier
Contact: Nick Clark neclark@ucanr.edu or 559-852-2788

Prescribed Fire on Private Lands Workshop - Sonora

https://ucanr.edu/sites/forestry/Wildfire/Prescribed_fire/Rx_workshop/

Date: October 8, 2019
Time: All day
Location: Ambulance, Fire and EOC Facility, 18440 Striker Court, Sonora, CA
Contact: Susie Kocher sdkocher@ucanr.edu or 530-542-2571

Hemp Breeding and Seed Production

http://sbc.ucdavis.edu/Courses/Hemp_Breeding_and_Seed_Production/

Date: October 29–30, 2019
Time: 8:00 a.m. to 5:00 p.m.
Location: UC Davis (Activities and Recreation Center, Ballroom)
Contact: Julie Tillman jtillman@ucdavis.edu