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Research article

A theory of geo-social marginalization: A case study of the licensed cannabis industry in California

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ABSTRACT

The licensed cannabis industry represents one of the top five most economically valued agricultural commodities in California, yet farming largely remains on remote, environmentally sensitive, "marginal" lands. Using mixed methods, this paper examines the determinants of this marginalization, their embedded elaboration, and their relation to historical policy regimes. We used Generalized Additive Models (GAMs) to determine the most important predictors of licensed cannabis industry development since the inception of a statewide licensing program in 2018 and to compare the distribution of licensed cannabis to other forms of rural agriculture, including vineyards and pasture, to understand landscape factors and environmental sensitivity of land uses. We found that a county's median income and the extent of traditional (non-cannabis) agriculture, as measured by the proportion of on-farm (non-cannabis) employment, were both negatively associated with its amount of licensed cannabis agriculture. Ethnographic data suggests that cannabis is often excluded from traditional agricultural areas, through formal local-level bans, restrictive zoning, high "prime" farmland values, and cultural exclusions from other powerful resource users. The resulting relegation to "marginal" lands foments conflicts with amenity land users and environmentalists, even as it partly supports "legacy" cultivators whose farms were established under prior policy regimes. Results suggest that cannabis is more likely to be grown under conditions that introduce regulatory hurdles, including farming on steeper slopes, with natural streams onsite, and without access to large groundwater aquifers for irrigation. Our findings suggest that failure to allow licensed cannabis farming in traditional agriculture regions has led to a self-fulfilling prophecy wherein cannabis cultivation is largely relegated to environmentally sensitive areas where cultivation activity has an elevated tendency for environmental impacts.

1. Introduction

As of 2023, California (USA) is the single largest producer of legal cannabis globally (Long, 2023). Legalization stimulated an increase in new production and a trend toward larger-scale farming (Dillis et al., 2021a). California's licensed cannabis industry has become one of the state's top five grossing agricultural products, affirming its economic importance (Dillis et al., 2023). Given California's general agricultural importance, and the size and history of its cannabis market, the state's efforts to regulate cannabis hold global significance (Polson et al., 2023). The development of this young agricultural sector has been fraught with challenges for policymakers and cannabis farmers alike (Bodwitch et al., 2019). Arguably, no other issue has been as intractable or controversial as *where* this major, "new" industry and its cultivation sector will take place (Heddleston, 2013; Polson, 2015; Freisthler et al., 2017; Unger et al., 2020).

With voter passage of Proposition 64 in 2016, the State of California was tasked with creating a licensed cannabis industry, including a regulatory framework for cultivation. In the years prior to legalization (2012–2016) cannabis cultivation expanded most rapidly in remote areas with steep slopes and near critical habitat for threatened and endangered salmonid fish species (Butsic et al., 2018). Concerns for negative impacts from illicit cannabis cultivation drove stringent environmental regulations when the licensed cannabis industry launched in 2018 (Dillis et al., 2021a). Continued concern for environmental impacts exist in the form of soil erosion due to farming on steep grades

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(Carah et al., 2015), water quality degradation due to sediment input into onsite and nearby watercourses (Bauer et al., 2015), and the extraction of groundwater outside of regulated aquifers for the purposes of irrigation (Dillis et al., 2021b). The geographic distribution of new licensed farms suggested responsiveness to regulations almost immediately. A substantial shift occurred within the first two years of legalization, in which the majority of cultivated acreage developed in areas where terrain characteristics - like flatter parcels with fewer onsite streams - rendered sites easier to permit (Dillis et al., 2021c). The development of industrial-scale cannabis farming served to consolidate production comparable to that of an entire region (i.e., the historic production of the North Coast) into a small number of farms in these more agriculturally-amenable areas. Yet, there have been significant constraints limiting these opportunities for the vast majority of farmers. Many areas already dominated by agricultural commodity production on "prime" agricultural land remain largely unavailable to cannabis cultivation due to restrictive zoning, persistent stigmas, and local cultivation bans.

To date, there has been no large-scale analysis of economic or demographic factors moderating the spatial distribution of cannabis production in California. Furthermore, there has been no comparison between cannabis and other rural agriculture in terms of land characteristics and potential for environmental impacts. This study uses state cannabis licensing data and county-level economic and demographic data to ask whether demographic factors influence the extent to which licensed cannabis cultivation occurs in a given county. We further explore how the geographic distribution of licensed cannabis farming shapes potential environmental impacts, relative to other forms of rural agriculture such as vineyards or pasture grazing, using spatial data to describe the terrain on which farming occurs. We pair these analyses with qualitative data collected across "ban" and "permit" counties, as we consider the prevalent factors shaping jurisdictional decisions about whether to allow licensed cultivation and, if so, where cultivation is sited. Mixed-method approaches such as this have proven useful in capturing the complexity of land use issues, specifically regarding cannabis (Parker-Shames et al., 2023). Drawing from the accumulated data, we reflect on the relation of "marginal lands" to social processes of marginalization and how legalization, perhaps unexpectedly, creates new marginalizing dynamics. We formally ask three research questions:

1) What factors contribute to the geographic distribution of licensed cannabis farming?
2) How does cannabis compare with other forms of agriculture based on metrics for potential environmental impact?
3) What social and political-economic factors contribute to the geographic distribution and land features of licensed cannabis agriculture?

Our findings suggest that cultivation's emerging geography is not a result of rational, economistic planning for ecological or agricultural outcomes. As many of our interlocutors have pithily observed, if those rationales prevailed, cannabis production would likely be located in the established agricultural zones of the Central Valley. Instead, cultivation geographies are rooted in demographic, economic, and political dynamics that make particular jurisdictions more or less likely to permit cannabis. The legalization of cannabis cultivation did not eliminate the marginalization of cannabis and those who cultivate it, but *did* transform how marginality appears. Under California legalization, we argue, new marginalities are emerging – marginalities that are geographic and social. Understanding how cannabis is both relegated to and retained in marginal geographies can help to provide new frames for regulatory and public discussions of cultivation, the environment, and industrial structure. The case of licensed cannabis cultivation captures how marginality of lands, people, plants, and regions are co-constituted through historical, ecological, political, medical, legal, and, above all, social processes.

While "marginal lands" have largely been construed as a biophysical and sometimes economic fact (see below), we offer a conceptual model that also accounts for the social ways marginality is produced, maintained, and geographically emplotted. The case of ongoing cannabis marginalization through legalization illuminates three dynamics of "geo-social" marginalization: a) biophysical marginalization, as uses and users are sited on or directed toward non-prime lands with sensitive ecologies and inferior soils, geologies, slopes, and climatic conditions; b) socio-economic marginalization, or the ways users are relegated to lands that can only assume economically or socially marginal purposes; and c) socio-political marginalization, or the social and political subordination of certain uses and users to others (such as growing cannabis vs. other agricultural products). Instead of discrete categorizations, these dynamics are non-exclusive and often overlap and articulate with one another. They can be deduced as facts, criteria and characteristics via quantitative analyses and as dynamic processes via qualitative study, as we demonstrate in this mixed method paper that synthesizes work from three interrelated but separate studies. The processual dynamics described in this model – biophysical, land use, and socio-political marginalization – make marginalized populations and land uses available for controlling interventions. These criteria point to what relative values, entities or uses lands are marginal to (Nalepa et al., 2017; Shortall and Helliwell, 2021; Tsing, 1994) and ask how land uses and users are relegated to marginality at all. This approach may produce more circumspect, historically informed, and socially-attuned policy and environmental management practices.

We begin by providing historical context outlining three important regulatory shifts that have shaped the social and spatial marginalization of cannabis cultivation in California: prohibition, medical decriminalization, and commercial/recreational legalization. We then highlight literature that theorizes "marginal lands" in order to extend this literature to account for legal-social processes. This background contextualizes our quantitative and qualitative results and key findings with the aim of developing a holistic understanding of the antecedents and consequences of continued marginalization of cannabis agriculture.

1.1. Background: The grounds of cannabis marginalization

Over the past century, changing cannabis policy in California has resulted in three distinct developments in the spatial patterning of cultivation. For much of the 20th century, prohibition consigned cannabis to co-produced geographic, social, and legal margins, which extended across supply chains from the remote watersheds of largely-white, low-income, rural areas to deindustrialized, neglected and racially-marked urban territories. Like other illicit crops globally (Lu et al., 2022; McSweeney et al., 2014; McSweeney, 2023), cultivation of cannabis was pushed to remote, environmentally sensitive lands, often borderlands on the edges of state control where growers could evade detection and enforcement (Butsic et al., 2018; Corva, 2014; Polson, 2021). With prices inflated from the risks of cultivating a prohibited crop, cannabis cultivation provided livelihoods for marginalized populations, especially in rural areas affected by deindustrialization and downturns in other commodity markets like timber and beef (Kelly and Formosa, 2020). During 20th century cannabis prohibition, cultivation often occurred on land with little competition or surveillance from other land users, such as lands that were publicly owned, degraded by prior industrial uses, and remote with steep slopes (Corva, 2014). The impacts of crop activity on these environmentally sensitive lands - such as erosion and water overdraft or pollution - proved an enduring justification for dedicating public resources and support to prohibitionist policy and enforcement efforts (Polson, 2019; Lu et al., 2022).

In the mid 1990s, California medicalization gradually shifted the spatial patterning of cultivation as collectives and buyers clubs enlisted patient-cultivators into medical supply chains throughout the state (Lee, 2012). After a pivotal 2008 court case nullifying size limits on medical gardens, medicalized cultivation increased greatly, an expansion aided by a concurrent economic crisis that spurred more people to pursue livelihoods in cultivation (Polson, 2020). Medical decriminalization both de-stigmatized and re-stigmatized cannabis as medical patients and patient-cultivators became a cause for sympathy and further marginalization (Chapkis and Webb, 2008; Heddleston, 2013). Cultivators found themselves caught in a contested legal gray area, with irregular state guidance, continued federal illegality, persistent social stigma, and frequent conflict with police (Short Gianotti et al., 2017; Polson, 2020). Larger remote grows thrived in these gray zones while many patient-cultivators restricted themselves to small gardens (under the 99-plant threshold for federal prosecution) across urban, suburban, and rural sites (Corva, 2014; Wang et al., 2017). Localities were leery of regulating cultivation for fear of federal consequences, and many localities consigned cultivation and retail to industrial and other marginal zones. These zones presumably minimized aesthetic and nuisance issues, but they were also spatially patterned by deeper dynamics of "vice zoning," or the relegation of morally marked activities and land uses – like tattoo parlors, sex work, gay bathhouses, and homeless encampments – to social and spatial margins (Giarmarino and Loukaitou-Sideris, 2023 Laing and Cook, 2014; Prior and Crofts, 2011; Salkin, 2011). Following 2014 legislation restricted federal enforcement against medical cannabis (and, in California, 2015 legislation that fully regulated medical cannabis, clarifying its legally gray tones), the spatial patterning of cannabis cultivation shifted again, this time under state-level adult-use legalization approved by voters in 2016.

Legalization of the entire cannabis supply chain granted localities a high degree of control over the crop's regulation, including the capacity to entirely ban cultivation. This cleaved California's geography into areas that allowed cultivation and those that excluded it. As of June 2023, 69% of counties and cities in the state had banned commercial cultivation altogether (DCC, 2023). People who continue to grow in ban jurisdictions are subject to legal and financial consequences, often compounding pre-existing socio-economic vulnerabilities. Furthermore, strict enforcement in ban counties pushes cultivators to operate (as with prohibition) in more remote, ecologically-sensitive places, and can incentivize more extractive, intensive growing methods with adverse effects on workers and the environment (Polson and Petersen-Rockney, 2019). Bans once again relegate cannabis cultivation to the geographic, ecological, and social margins, leaving governments with few options for civil regulation.

Permit jurisdictions allow cannabis, but often through restrictive zoning and high compliance standards. The State of California defined cannabis as an "agricultural product" (not a "crop"), a statutory designation that excluded cannabis from protections and capacities granted to non-cannabis agriculture. For example, many cannabis farms in California must navigate an individual CEQA process and track and trace each plant, none of which are required for growing other crops (Bodwitch et al., 2021). Unique statutory designation predisposed cannabis to be grown away from "prime" lands prioritized for agricultural uses and enabled application of novel environmental protections. While cannabis's absolute and relative draw on environmental resources is not particularly great (Wartenberg et al., 2021; excluding energy for indoor cultivation, see Mills and Zeramby, 2021), the environmental issues that do arise are largely a matter of *where* the farm is sited – that is, on marginal lands where they have been pushed. These landscapes are often rocky or tree-covered, with steep slopes vulnerable to erosion, and abundant ephemeral streams that provide critical habitat to protected aquatic species including endangered salmonids (Carah et al., 2015). These lands were "marginal" for growing most crops, but were, under prohibition, "prime" sites for cannabis cultivation, as they were often remote and more difficult for enforcement to detect. Such sites were well-suited to high-value, low-quantity production typifying many gardens before legalization. After legalization, enforcement pressures lessened, prices dropped, pressure to scale up production increased, and regulatory costs (especially for ecologically sensitive lands) proved significant, even prohibitive. It was difficult for cultivators to persist in legacy cultivation landscapes. Caught between outright spatial bans, definitional and regulatory barriers to agricultural operation, and relegation to marginal lands, licensed cultivators are highly restricted in terms of where they can establish and operate cannabis farms. Furthermore, the enduring federal illegality of cannabis and its cultivation adds an additional liability for operating in plain sight.

Unprecedented, stringent environmental standards for cannabis, compared to other crops, were politically possible because cannabis farmers did not have the political power that other agriculturalists had long wielded to gain regulatory exemptions that apply to non-agricultural industries (Bodwitch et al., 2021; Petersen-Rockney et al., 2021). Exceptional requirements precipitated new conflicts over resource and land uses, as a retinue of lawsuits and policy delays around the California Environmental Quality Act (CEQA) attest. Aggressive enforcement alienated permitted growers and reinforced long-standing conflicts from prior policy regimes (Elmahrek et al., 2022). Additionally, cannabis became the latest, and often unwelcome, water user in a "first in use, first in right" water policy regime (Doremus and Tarlock, 2008) at a time when the state faced tremendous drought pressure (Williams et al., 2022). Conflict between cannabis cultivation and environmental concerns is not due to inherent qualities of cannabis farming or the resource intensity of the crop in terms of absolute crop area or relative to other crops (Wartenberg et al., 2021), but instead, we argue, conflict is a product of the political-economic processes that has pushed cultivation of this crop onto environmentally sensitive landscape margins.

The margins of agricultural production are increasingly central to debates about land use planning, the imperatives of climate change adaptation and mitigation, and persistent anxieties about global resource provisioning (Kang et al., 2013; Csikós and Tóth, 2023). Situated between "prime" agricultural land and "unproductive" land (Csikós and Tóth, 2023), "marginal" land provides critical ecosystem services like wildlife habitat, water filtration, and carbon storage (ibid). They have long been home to smallholder and subsistence farmers, especially those excluded or dispossessed from prime lands and licit agricultural livelihoods (Peluso and Vandergeest, 2011; Ybarra, 2016; Grimmelmann et al., 2017), much like the frequently minoritized smallholders who grow illicit crops across the globe (Lu et al., 2022). Today, these lands are viewed by nation-states and international organizations like the Food and Agriculture Organization (FAO) as potential sites for alternative development projects to increase food production (often by industrializing farming practices), meet conservation mandates (through, for example, afforestation projects), and grow bioenergy crops (Csikós and Tóth, 2023; MAGIC, 2022).

Definitions of marginal lands that focus on physical properties, such as soil quality and slope, and economic returns, such as yield potential, are widely used for resource management and development purposes (Kang et al., 2013; Csikós and Tóth, 2023). Such definitions generally *exclude* the social, economic, and political processes through which lands are rendered marginal (Nalepa et al., 2017; Shortall and Helliwell, 2021). Since the early 19th century, the concept of "marginal land" has been foundational to Euro-centric economic valuations of land and rent (Hollander, 1895; Ricardo, 1821). It drew from liberal philosophies identifying unproductive, or "wasted," lands, as "barren, rough, inaccessible, or possessed of other undesirable characteristics or relationships" (Peterson and Galbraith, 1932, p. 295) that ostensibly required (colonial) improvement (Goldstein, 2013; Nichols, 2018). The social construction of certain lands as idle, underutilized, or degraded marks certain types of farming practices (e.g., those not market-oriented) and certain farmers (i.e. minoritized, peasant, and poor farmers) as inefficient or substandard. Such designations justify smallholder exploitation and dispossession, as well as projects that dictate "better" uses and users, often leading to land consolidation and agricultural intensification (Graddy-Lovelace, 2017; Li, 1999; Nalepa et al., 2017; Tsing, 1994; Urteaga-Crovetto and Segura-Urrunaga, 2021).

Definitions of marginal lands that exclude their social production can project an objective certainty, though the formation of these marginal lands is dependent on location, type of agriculture, and shifting political, economic and ecological dynamics (Csikós and Tóth, 2023). More broadly, margins, whether social or biophysical, are relational, contested spaces where meaning is made, older marginalities are grappled with, and the distinction between margins and centers can be assessed, challenged, and transformed (Tsing, 1994; Galemba, 2013). Margins are sites – conceptual and, in the case of land, physical – where the limits and practices of states and capital are tested and innovated. Conceptions of "margins" help elucidate how licensed, prohibited, and medicalized cannabis cultivation becomes a staging ground for state and capital projects, helping to construct and maintain society's central capacities (Das and Poole, 2004; Galemba, 2013; Li, 2014).

At the social and geographic margins, cannabis has been central to state-making innovations in racial policing and urban governance (Lassiter, 2015), immigrant control (Gieringer, 1999), and colonialism and international policy regimes (Richert and Mills, 2021). As cannabis is drawn into legal market systems, its margins are retrenched and transformed. Novel forms of marginalization emerge as policy networks innovate new forms of agricultural regulation, environmental policing, rights claims, de- and re-criminalization, and "equitable" and "sustainable" markets. California cannabis cultivation offers an ideal case to extend the literature on marginality and marginal land by expanding definitions of marginal lands to include "marginal land use." These uses are not incidental to marginal lands but are historically, socially, and politically entwined with how marginality of lands and peoples are co-produced and managed. Robustly accounting for marginal land *uses* will enable policymakers and environmental managers to approach this novel policy realm in conscientious, informed ways that ameliorate, rather than compound, further marginalization.

1.2. Methods

Qualitative and quantitative data were collected and analyzed concurrently. Quantitative analyses enabled exploration of broad level patterns in California's cannabis licensing geography and qualitative analyses were used to determine how cannabis farming geographies are shaped by social and political dynamics. The first two research questions reflect the former, with statistical modeling addressing factors that influence the geographic distribution of cannabis farming and its potential for environmental impacts relative to other agricultural sectors. The third research question draws on interview data collected across ban and permit counties throughout the state.

What factors contribute to the geographic distribution of licensed cannabis farming?

The number of cultivation licenses (n = 14,017) in each of California's 58 counties was estimated using demographic and economic predictors. Data for this cross-sectional analysis included all cultivation licenses, active as of February 2023. Because of the large subset of counties with complete bans on cannabis cultivation, the data were zero-inflated and necessitated the use of hurdle models. Within many "ban" counties there are cities that allow permitted cultivation (Table S1; DCC, 2023), which complicates an entirely binomial approach. Therefore, many ban counties contain permitted cannabis cultivation. Industry development was characterized using a numerical count of licenses. Each hurdle model therefore had two components: a binomial model predicting whether or not a county had any licenses, and a negative binomial model predicting the number of licenses in a county, contingent on the presence of licenses.

Cannabis cultivation license data were downloaded from California's Department of Cannabis Control (DCC) license search tool on January 9, 2023 (State of California, 2023). These included all licenses issued since cannabis licensing began in 2018 and remaining active as of February 2023. Cultivation licenses were aggregated by county, which were each characterized by several variables. The county-level legal status of cannabis cultivation was obtained from the California DCC (DCC, 2023) and used to generate the variable *CultivationBan*. To account for existing county-specific cannabis cultivation permitting programs (State of California, 2015a; State of California, 2015b) prior to statewide licensing, the variable *PreExistingCannabis* was also considered.

Two variables were considered as potential metrics of socio-economic marginalization: the median income of the county (*MedianIncome*) and the percentage of the population of retirement age (over the age of 65; PopulationOver65). Median income was calculated with 2018 data downloaded from the Franchise Tax Board (State of California Franchise Tax Board, 2023). The proportion of county population over the age of 65 was calculated using data downloaded from the 2020 US Census (United States Census Bureau, 2023). An additional two variables were considered as potential metrics of socio-political marginalization: the political leaning of the county (*ProportionConservative*) and the presence of non-cannabis agriculture (*ProportionFarmEmployment*). The proportion of registered voters in each county who identify as Republicans was established using voter registration totals reported by the 2018 Statement of Vote (State of California, 2018a) to calculate *ProportionConservative*. *ProportionFarmEmployment* was determined with data from the Employment Development Department from 2018 (State of California Employment Development Department, 2023).

Generalized additive models (GAMs) were used for both components of the hurdle model to account for spatial autocorrelation. The binomial component of the hurdle model was fit using the mgcv package (Wood et al., 2016) with R Statistical Software (R Core Development R Core Team, 2018), predicting whether or not a county had cultivation licenses. The model used county cultivation ban status (*CultivationBan*; B_i) and presence of pre-existing cannabis permitting (*PreExistingCannabis*; X_i) for the binomial prediction of cannabis licenses (P_i), represented by the following equation:

$$\mathrm{logit}(p_i) = \boldsymbol{\alpha} + \boldsymbol{\beta}_{\mathrm{d}}\mathrm{B}_{\mathrm{i}} + \boldsymbol{\beta}_{\mathrm{x}}\mathrm{X}_{\mathrm{i}} + \boldsymbol{\Sigma\beta}_{29} + \boldsymbol{\varepsilon} \quad (1)$$

The intercept ($\boldsymbol{\alpha}$) is added to coefficients for CultivationBan (β_b) and *PreExistingCannabis* (β_x), and the sum of coefficients for 29 basis functions ($\boldsymbol{\Sigma\beta}_{29}$) to produce a log-odds estimate of a county having at least a single cannabis license. Coefficient estimates were considered reliable in cases where 95% confidence intervals constructed from standard errors did not overlap zero.

The negative binomial component of the hurdle model was fit with the mgcv package in R Statistical Software, to predict the count of cannabis cultivation licenses (L_i) in each county that had such licenses. The negative binomial model used a county's proportion of voters registered as Republicans (*ProportionConservative*; C_i), proportion of jobs on-farm (*ProportionFarmEmployment*; F_i), median income (*MedianIncome*; M_i), percentage of population over 65 (*PopulationOver65*; O_i), and presence of existing cannabis permitting (*PreExistingCannabis*; X_i). An additional variable was added to account for counties that issued a small number of primarily indoor cultivation licenses. Counties in which indoor licenses represented more than 75% of the total were designated as *IndoorCultivationCounty* (N_i). The full iteration of the negative binomial model, was thus represented by the following equation:

$$log(L_i) = \boldsymbol{\alpha} + \boldsymbol{\beta}_c C_i + \boldsymbol{\beta}_f F_i + \boldsymbol{\beta}_m M_i + \boldsymbol{\beta}_a O_i + \boldsymbol{\beta}_x X_i + \boldsymbol{\beta}_n N_i + \boldsymbol{\Sigma\beta}_{29} + \boldsymbol{\varepsilon} \quad (2)$$

The intercept ($\boldsymbol{\alpha}$) is added to coefficients for *ProportionConservative* (β_c), *ProportionFarmEmployment* (β_f), *MedianIncome* (β_m), PopulationOver65 (β_o), *PreExistingCannabis* (β_x), *IndoorCultivationCounty* (β_n), and the sum of coefficients for 29 basis functions ($\Sigma\beta_{29}$) to produce a log estimate of the number of licenses in a county. Coefficient estimates were considered reliable in cases where 95% confidence intervals constructed from standard errors did not overlap zero.

How does cannabis compare with other forms of agriculture based on metrics for potential environmental impact?

Cannabis was compared to other agricultural forms using the locations of license data obtained from the DCC (described above) and randomly sampled spatial crop data downloaded from the California

Department of Water Resources i15 Crop Mapping Layer (CDWR, 2018). Vineyards and pasture (excluding hay crops and open rangeland) were sampled specifically for their tendency to occur in rural areas. An aggregate of all other crops besides vineyards, pasture, and cannabis was sampled to represent agriculture in general, yielding four categories: *cannabis*, *vineyard*, *pasture*, and *general crops*. Cannabis license data were georeferenced by matching parcel numbers to county parcel shapefiles obtained from the National Parcelmap Data Portal (Boundary Solutions, 2020). Any parcels (n = 3316) containing multiple cannabis licenses were considered as a single data point. An equal number of farms (n = 3316) were randomly sampled from the CDWR Crop Mapping Layer Raster for each remaining crop type (*vineyard*, *pasture*, and *general crops*; Fig. 1).

Potential for environmental impact was assessed using spatial variables calculated for each agricultural type, including: *average parcel slope*, presence of *watercourse*, and underlying *groundwater basin*. *Average parcel slope* was considered given that farming on slopes tends to increase erosion (Carah et al., 2015). Slope was calculated using Digital Elevation Model (DEM) data from the National Elevation Dataset (USGS, 2020). Presence of *watercourse* was included as a metric of potential

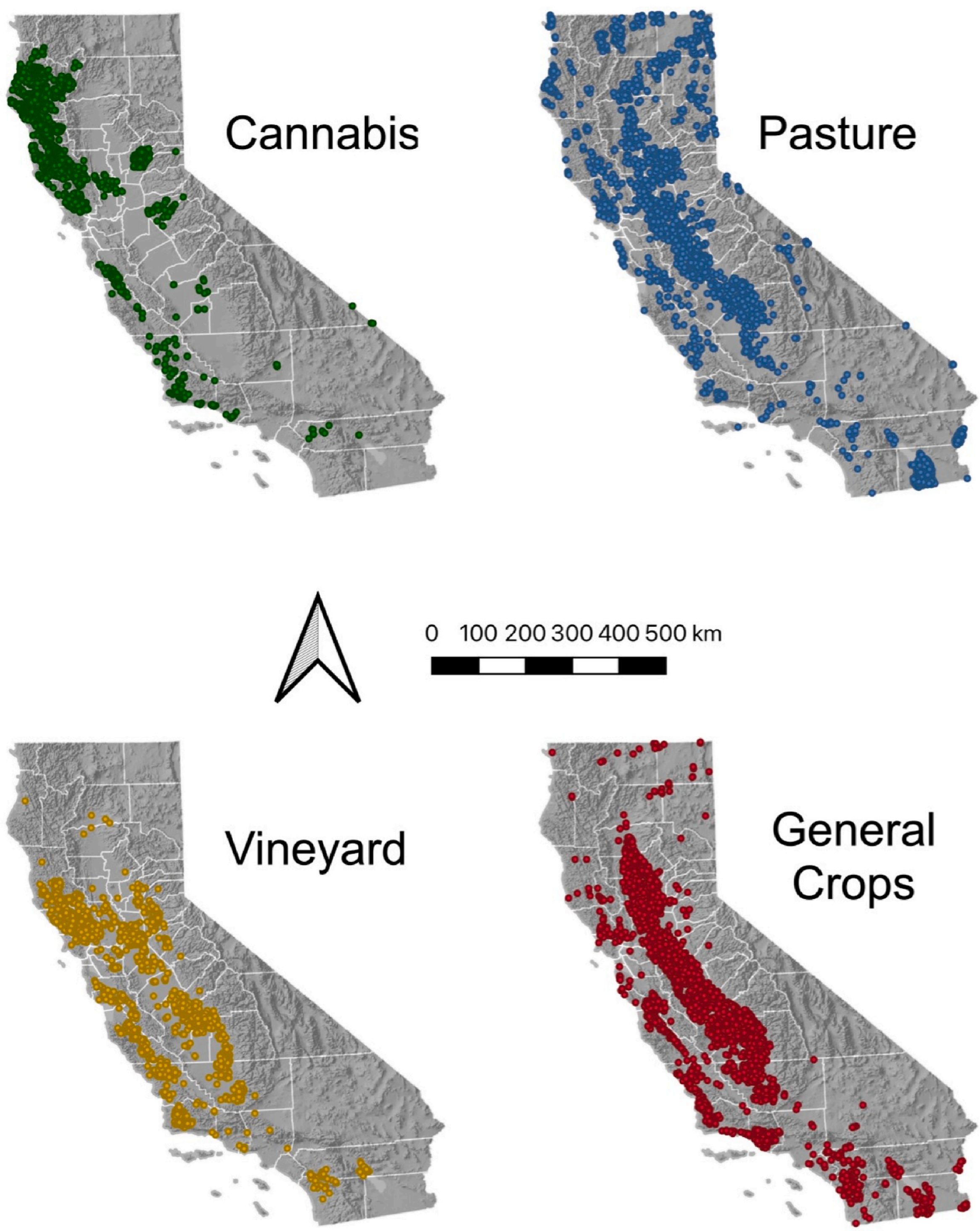

Fig. 1. Study Area Map. The four agriculture types: Cannabis, Pasture, Vineyard, and General Crops are depicted individually on duplicate maps of California.

environmental impact, including direct sediment input into aquatic ecosystems (Bauer et al., 2015). Parcels that intersected a perennial, ephemeral, or intermittent stream, mapped in the National Hydrography Dataset (USGS, 2019), were designated as having a *watercourse*. The presence of an underlying *groundwater basin* was considered because rural agriculture, particularly cannabis, is often irrigated with groundwater outside of regulated groundwater basins (Dillis et al., 2021b). Farms outside of regulated groundwater basins have an elevated tendency to draw from natural streams either directly or through groundwater-surface water interactions. Spatial data from the California Department of Water Resources (State of California, 2019) were used to identify groundwater basins regulated under the Sustainable Groundwater Management Act (SGMA; State of California, 2014) to determine presence/absence of a *groundwater basin* for each farm.

GAMs for each environmental impact metric were fit using the mgcv package (Wood et al., 2016) in R Statistical Software. The use of GAMs for comparisons between crop types was necessary to account for spatial autocorrelation. The first GAM used a log link function to estimate a beta distribution for *average parcel slope* (A_i) based on crop *type* (T_i), while the remaining GAMs used logit link functions to estimate binomial distributions for *watercourse* (W_i) and *groundwater basin* (G_i):

$$\log(A_i) = \boldsymbol{\alpha} + \boldsymbol{\beta}_t \, \mathrm{T_i} + \boldsymbol{\Sigma\beta}_{29} + \boldsymbol{\varepsilon} \tag{3}$$

$$logit(W_i) = \boldsymbol{\alpha} + \boldsymbol{\beta}_t T_i + \boldsymbol{\Sigma\beta}_{29} + \boldsymbol{\varepsilon} \tag{4}$$

$$logit(G_i) = \boldsymbol{\alpha} + \boldsymbol{\beta}_t T_i + \boldsymbol{\Sigma\beta}_{29} + \boldsymbol{\varepsilon} \tag{5}$$

Log estimates of A_i, and log-odds estimates of W_i and G_i, for each crop type are produced by adding the coefficient for crop type ($\boldsymbol{\beta}_t$) and the sum of coefficients for 29 basis functions ($\boldsymbol{\Sigma\beta}_{29}$) to the intercept ($\boldsymbol{\alpha}$), with cannabis serving as the reference level. For all GAMs, coefficient estimates were considered reliable in cases where 95% confidence intervals constructed from the standard errors did not overlap zero.

What social and political-economic factors contribute to the geographic distribution and land features of licensed cannabis agriculture?

We draw on longitudinal, qualitative data of cannabis cultivation across California. Qualitative work is essential to study stigmatized and hidden activity (Adler and Adler, 1998; Werth and Ballestero, 2017), like cannabis cultivation. While authors of this study have conducted research on cannabis cultivation in California for a combined 18 years, our qualitative data comes from two primary projects – ___'s ethnographic work on cultivation in one "ban" county and six "permit" counties on the North Coast and in the Sierra Nevadas (Sierra, Trinity, Mendocino, Humboldt, Calaveras, Nevada, El Dorado counties) and ___ and ___'s ethnographic work on cultivation bans in four ban counties (Siskiyou, Napa, Yuba, San Bernardino).

In total, ___ and ___ conducted over 200 ethnographic interactions, including semi-structured, in-depth interviews, group discussions, and more informal participant engagements. We used a purposive sampling frame (Yung and Belsky, 2007) to identify participants representing a range of perspectives and experiences related to cannabis cultivation and environmental impacts. We interviewed cannabis cultivators, government officials and staff, advocates for and against cannabis, and non-cannabis land users, including farmers and retirees. We used a snowball recruitment method, which helped us trace network relations (Parker et al., 2019). Most interviews were conducted in person and lasted 60–90 min (with some interviews conducted online with public officials). Recorded interviews were transcribed using happyscribe.com software and edited for accuracy by undergraduate research apprentices. Participant observation included attending local community events and meetings and visiting grower supply stores and other locales where cultivators gather. We analyzed public and policy documents, including local government meeting minutes (county websites), reports (county and state websites), news articles (Newsbank), and public comments related to cannabis cultivation (county website and Facebook pages). Public documents were downloaded and organized chronologically for each county by undergraduate research apprentices who retrieved mentions of cannabis cultivation. These were then reviewed by lead researchers using a content analysis approach.

___ and ___ practiced collaborative team ethnography (Clerke and Hopwood, 2014; Rappaport, 2008; Scales et al., 2011), entailing a recursive loop of research, analysis, refinement, and further research. This approach included: navigation of differences in interpretation (Wasser and Bresler, 1996) and subjectivity (Gerstl-Pepin and Gunzenhauser, 2002); using field notes as communicative-deliberative documents (Creese et al., 2008); the building of trust, navigation of conflict, and construction of consensus (Sanders and Cueno, 2010; Agar, 1996; Erickson and Stull, 1998); and the division of research roles according to experiences, subjectivities, and knowledge. We collaborated with community partners and key informants, including lawyers, journalists, consultants, and advocates, as we shared and discussed preliminary findings and hypotheses and recursively adjusted our research inquiries. Resultant findings are substantiated by the coding of qualitative data, which we conducted with assistance from graduate student researchers. Research was conducted under an Institutional Review Board protocol from UC Berkeley (#051499-001 & #051482-001)

1.3. Results

What factors contribute to the geographic distribution of licensed cannabis farming?

In the binomial model *CultivationBan* was the only reliable predictor, with a negative influence on a county having at least one cannabis license (Maximum Likelihood Estimate = −3.22; Standard Error = 1.11; $p < 0.01$; Table 1). There were three reliable predictors of the number of cannabis cultivation licenses in a county (*MedianIncome, ProportionFarmEmployment, and PreExistingCannabis*), indicated by the negative binomial model (Table 1, Fig. 2). *MedianIncome* had a reliably negative effect (MLE = −1.07; SE = 0.31; $p < 0.001$) on the estimated number of cannabis licenses in a county, as did *ProportionFarmEmployment* (MLE = −11.71; SE = 4.30; $p < 0.01$). In contrast, PreExistingCannabis had a reliably positive effect on the estimated license total (MLE = 1.54; SE = 0.76; $p = 0.04$). In summary, counties were less likely to have at least a single license if there was a county-level cannabis cultivation ban and the number of cannabis licenses in a county was greater if median incomes were lower, there was less non-cannabis agricultural employment, and there were no state cannabis permitting programs prior to statewide cultivation licensing.

How does cannabis compare with other forms of agriculture based on metrics for potential environmental impact?

The raw data indicated the potential that cannabis was divergent from other agriculture based on the three environmental impact metrics: *average parcel slope*, presence of *watercourse*, and an underlying *groundwater basin* (Figs. 3–5). The *average parcel slope* for cannabis farms (Median = 13.76%; IQR = [5.51, 18.67]) was greater than that of *pasture* (Median = 0.31%; IQR = [0.13, 1.03]), *vineyards* (Median = 1.79%; IQR = [0.29, 6.98]), and *general crops* (Median = 0.33%; IQR = [0.13, 1.47]). There were many more cannabis farms with a *watercourse* onsite (62.06%) than for *pasture* (13.99%), *vineyards* (1.72%), or *general crops* (6.48%). Cannabis farms were also less often underlain by *groundwater basins* (27.17%) than were pasture (90.74%), vineyards (72.83%), or general crops (89.88%).

Generalized Additive Models for each environmental impact metric demonstrated that cannabis had higher potential for impacts, even after adjusting for spatial clustering (Table 2). Coefficient estimates for the *average parcel slope* GAM indicated that *pasture* (MLE = −0.99; SE = 0.02; $p < 0.001$; Slope = 2.34%), *vineyards* (MLE = −0.45; SE = 0.04; $p < 0.001$; Slope = 3.94%), and *general crops* (MLE = −0.79; SE = 0.03; $p < 0.001$; Slope = 2.85%) are typified by flatter parcels than *cannabis* (Intercept MLE = −2.74; SE = 0.02; $p < 0.001$; Slope = 6.07%; Fig. 3). The GAM for *watercourse* estimated that *cannabis* farms were more likely

Table 1
Hurdle model component coefficient estimates.

	Binomial Model			Negative Binomial Model		
Variable	MLE	SE	p	MLE	SE	p
Intercept	**2.90**	**1.03**	**<0.01**	**6.05**	**1.29**	**<0.001**
CultivationBan	**−3.83**	**1.10**	**<0.01**	na	na	na
PreExistingCannabis	15.68	2306.10	0.99	**1.54**	**0.77**	**0.04**
ProportionConservative	na	na	na	−0.70	3.16	0.82
ProportionFarmEmployment	na	na	na	**−11.71**	**4.30**	**<0.01**
MedianIncome	na	na	na	**−1.07**	**0.31**	**<0.001**
PopulationOver65	na	na	na	<0.01	0.07	0.92
IndoorCultivationCounty	na	na	na	−0.61	0.49	0.21

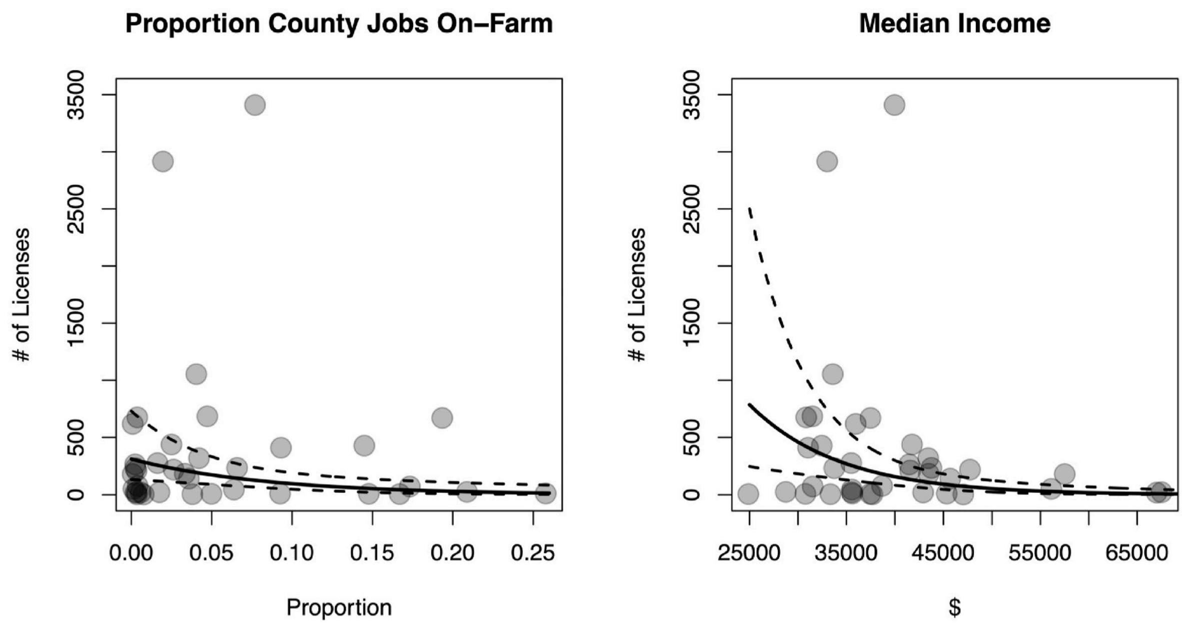

Fig. 2. Negative binomial model estimates. Only statistically reliable continuous predictors are included. The mean estimated effects of *ProportionFarmEmployment* (county proportion of jobs on-farm), and *MedianIncome* (county median income) on the number of cannabis cultivation licenses in counties with licensed cultivation are depicted as solid lines. Dashed lines indicate the 95% confidence interval of the mean estimate.

to have a stream on-parcel (Int MLE = −0.35; SE = 0.07; $p < 0.001$; Likelihood = 41.29%) than were *pasture* (MLE = −1.50; SE = −0.09; $p < 0.001$; Likelihood = 13.53%), *vineyards* (MLE = −3.98; $p < 0.001$; SE = 0.16; Likelihood = 1.29%), or *general crops* (MLE = −2.07; SE = 0.11; $p < 0.001$; Likelihood = 8.17%; Fig. 4). Finally, the GAM for *groundwater basin* estimated that *cannabis* farms were less likely to overlay groundwater basins (Int MLE = 1.10; SE = 0.10; $p < 0.001$; Likelihood = 75.10%) than were *pasture* (MLE = 1.90; SE = 0.11; $p < 0.001$; Likelihood = 95.28%), *vineyards* (MLE = 0.62; SE = 0.09; $p < 0.001$; Likelihood = 84.86%), or *general crops* (MLE = 2.04; SE = 0.12; $p < 0.001$; Likelihood = 95.86%; Fig. 5).

What social and political-economic factors contribute to the geographic distribution and land features of licensed cannabis agriculture?

Ethnographic results suggest several social factors that shape the geographic distribution and land features of licensed cannabis agriculture. Across ban and permit counties three factors arise as especially important influences: competing agricultural land uses; concerns over natural resources and environmental effects; and the presence and mobilization of politically-active, often conservative, amenity landscape users (i.e., residents whose land use is predicated on the consumption "of the 'rural" and 'natural' aesthetic qualities of [the] landscape [Walker and Fortmann, 2003: 482]).

Efforts to move cultivators into more prime agricultural flatlands have been largely unsuccessful. Partly, this is due to cannabis's exclusion from statutory definition of agricultural crops, which raises licensing barriers and gives non-cannabis agriculture relative financial and operational advantages (Bodwitch et al., 2021). Non-cannabis cultivators are better positioned to access and maintain land in agricultural areas due to the public resources that benefit commodity farmers, including federal USDA programs, like crop insurance, low-interest loans, and technical assistance offered by public institutions (Ayazi and Elsheikh, 2015). Without these support programs, those who cultivate cannabis face additional barriers to accessing prime agricultural lands. Even when permit counties technically allow cannabis to be grown in agriculturally zoned lands, the relative restrictions placed on cannabis and stalled permitting programs hinder this movement in actuality.

While structural disadvantages typify exclusion from agricultural lands in permit counties, exclusion from agricultural lands in ban counties is more evidently political. In ban counties opposition to cannabis – and support for bans – often comes from competing agricultural sectors seeking to protect control of local land and water resources. In Napa County, for example, the winegrape industry expressed concern over contamination of its grape crops and economic impacts on the winegrape industry, including reduced tourism, corrupted "viewscapes," encroachment on *terroir* branding, and competition for land and labor. In Yuba County, rice and other "flatland" farmers opposed irrigated cultivation in the foothills, which served as important watershed catchment basins for their water-intensive crops. In Siskiyou County, politically entrenched ranching and farming families expressed concern over disruption to their activities by new, ethnically- and culturally-

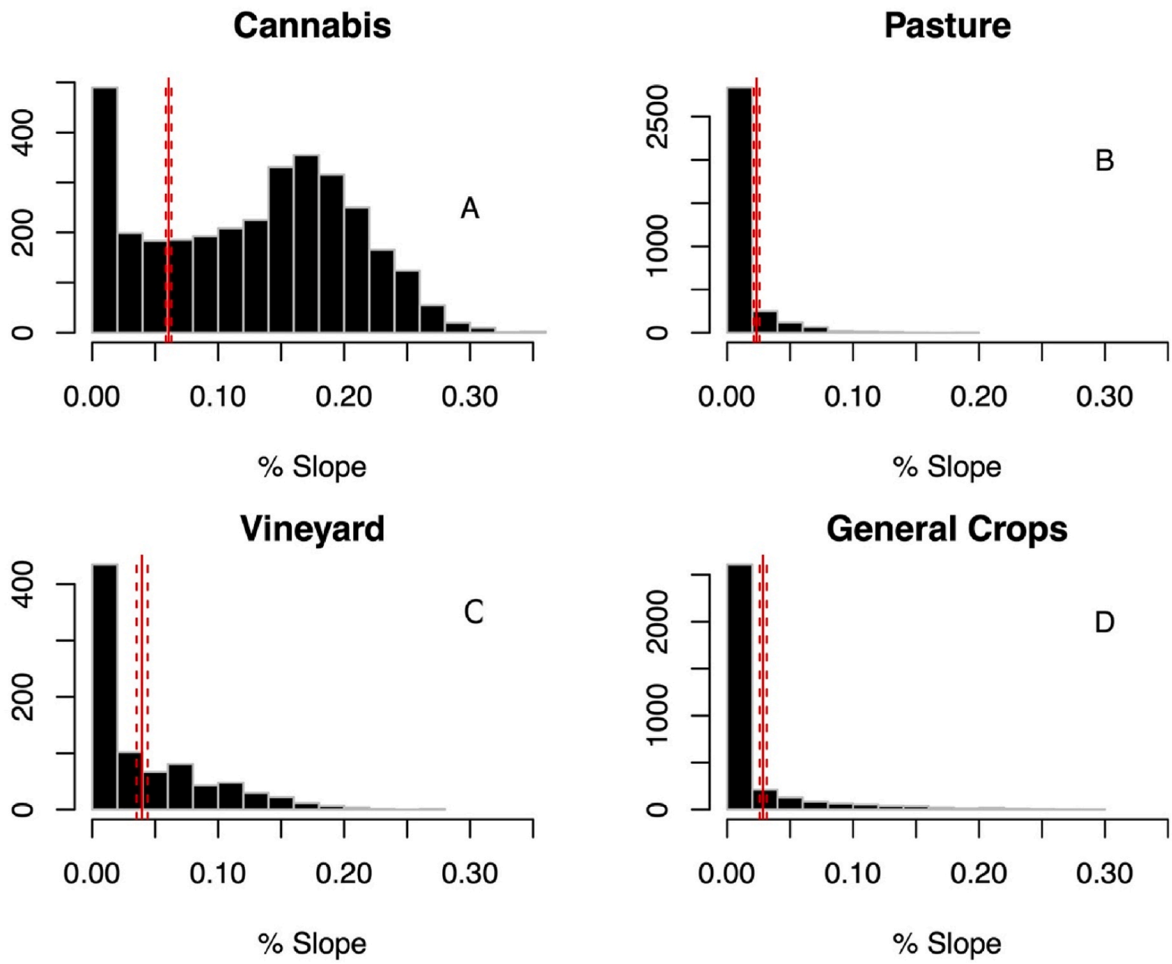

Fig. 3. Average parcel slope by crop type. The GAM model estimates are overlaid on the raw average slope data (depicted in black) for each farm type. Solid red lines depict the maximum likelihood estimates of the model while red dashed lines indicate the 95% confidence interval of the mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

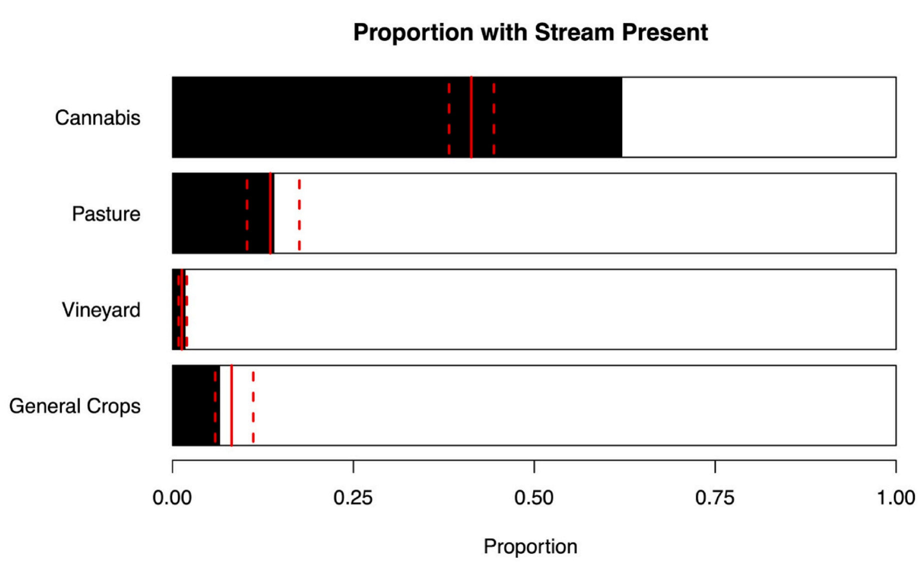

Fig. 4. Watercourse presence by crop type. The GAM model estimates are overlaid on the raw proportion (depicted in black) of farms with watercourses on site for each type. Solid red lines depict the maximum likelihood estimates of the model while red dashed lines indicate the 95% confidence interval of the mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

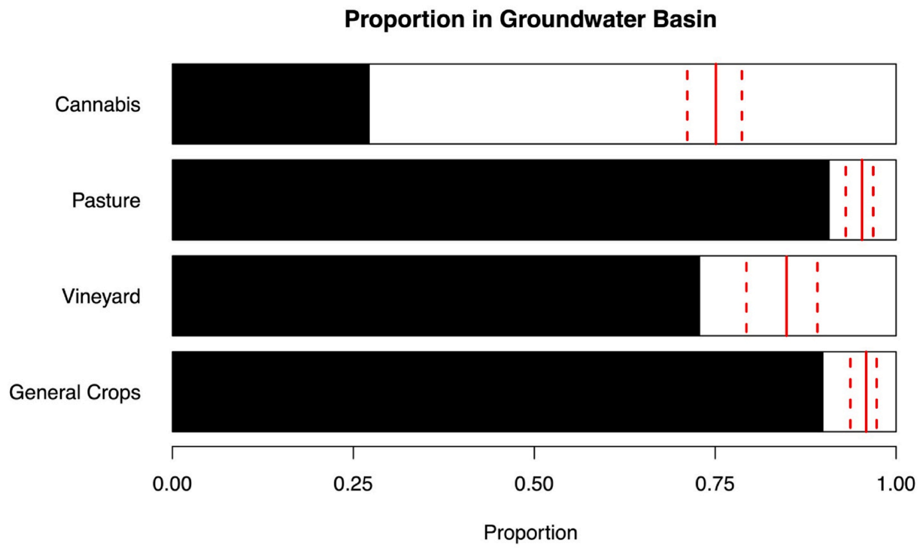

Fig. 5. Groundwater basin presence by crop type. The GAM model estimates are overlaid on the raw proportion (depicted in black) of farms underlain by groundwater basins for each type. Solid red lines depict the maximum likelihood estimates of the model while red dashed lines indicate the 95% confidence interval of the mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Coefficient estimates for environmental impact metric models.

	MLE	SE	p
Average Parcel Slope			
Intercept	−2.74	0.02	<0.001
Type: Pasture	−0.99	0.03	<0.001
Type: Vineyard	−0.45	0.04	<0.001
Type: General Crops	−0.79	0.03	<0.001
Watercourse			
Intercept	−0.35	0.07	<0.001
Type: Pasture	−1.50	0.09	<0.001
Type: Vineyard	−3.98	0.16	<0.001
Type: General Crops	−2.07	0.11	<0.001
Groundwater Basin			
Intercept	1.10	0.10	<0.001
Type: Pasture	1.90	0.11	<0.001
Type: Vineyard	0.62	0.09	<0.001
Type: General Crops	2.04	0.12	<0.001

differentiated farmers growing cannabis, a high-value crop and unwelcome claimant on limited water resources, the use of which was recently curtailed due to drought conditions, irrigation overdrafts, and climate change-induced reductions in snowpack (Polson and Petersen-Rockney, 2019; Lu et al., 2022). When cannabis threatened to move into arable, agricultural lands (or adjacent areas), as exemplified in Yuba, Napa, and Siskiyou, conflict intensified and bans gathered support with the advocacy of farmers, ranchers, and vintners, all of whom held significant sway in county politics.

As a new claimant on land and water resources on marginal, sensitive lands, cannabis cultivation has become an object of intensive environmental scrutiny. Tensions over resource use that festered under prohibition were laid bare after legalization, as environmental regulatory agencies sought to address long-standing concerns via new regulatory capacities. Encounters between cannabis cultivators and officials often remain antagonistic as government agencies juggle regulatory responsibilities with environmental policing. The location of cultivation on marginal lands also led to heightened conflicts with environmental organizations, resulting in lawsuits and controversies over environmental review processes that have stymied regulatory programs in five of six permit counties studied.[2] Marginal sites exposed growers to a heavier burden of compliance and controversies over matters like hydrologically connected water sources in Humboldt, oak tree and bullfrog protections in Mendocino, water contamination in Calaveras, and a uniquely extensive environmental review process in Trinity created in the wake of a lawsuit by environmentally-concerned residents. Compliance costs to ensure proper grading of roads, culvert construction, and water forbearance systems, along with studies of sensitive species and additional environmental requirements are prohibitively expensive for cultivators (often hundreds of thousands of dollars) – expenses aggravated by their exclusion from many formal lending institutions. Cultivators report a sense that these environmental conflicts and barriers are rooted in a historical stigma against cannabis, a postulation supported in socio-political discourses (Bodwitch et al., 2021; Polson, 2019; Petersen-Rockney et al., 2021). The relegation of permitted cultivation to marginal lands thus pushes producers into a kind of social marginality of zealous regulation, lawsuits, high compliance costs, and stigma-driven suspicions about resource use.

Because cannabis was pushed out of areas with groundwater basins and into areas with surface waterways, water was a consistent point of conflict in drought-stricken California. Across research sites, however, water concerns (and opposition to cultivation) were enrolled in agendas beyond conservation. In Yuba, for example, one water agency emphasized cannabis' water use to restrict its distribution and, purportedly, to sell that water out of the region for a profit. In Yuba, Siskiyou, and San Bernardino, efforts to blame (unlicensed) cannabis water users for water misuse served to enlist state and local resources in anti-cannabis enforcement. These claims often relied on unsubstantiated notions that cannabis was especially water thirsty and grown in significant quantities relative to other crops, and that growers were "criminals" associated with "cartels" that illegally drew on water resources. With other agendas – especially those of agricultural irrigators – taking

[2] Lawsuits in Humboldt, Mendocino, Trinity. Environmental review in Nevada County postponed regulation for a year and environmental controversy led to Calaveras' temporary repeal of its program. Other examples of environmental conflict can be found in Sonoma and Yolo counties.

precedence over environmental outcomes, the consistent solution to stated concerns over environmental impacts and resource use has been to privilege water rights for entrenched resource entitlement holders. To exclude cannabis from water prioritized for agriculture, some counties have passed local ordinances explicitly prohibiting groundwater use for cannabis cultivation, such as Humboldt in hydrologically connected conditions. A majority of localities in the state have simply banned cannabis altogether, sidestepping broader regulatory and adjudication questions. Several counties - Siskiyou and its neighbor Shasta - have not only banned cannabis cultivation, but also passed local ordinances explicitly prohibiting the use of groundwater to grow cannabis. These regulations currently allow local law and code enforcement to place additional large fines on cultivators for both growing cannabis and watering that cannabis and, if pending legislation in the state senate (SB753) passes, localities would be able to charge cultivators with felonies for using groundwater.

Finally, the presence of politically-active, often retired, and politically conservative (i.e., libertarian or moral conservative) natural amenity consumers is another factor in the siting of cannabis farms. Amenity migrants or landscape consumers move to rural areas for their natural/aesthetic beauty and recreational opportunities, such as hiking, fishing, and hunting. Cannabis cultivation is often regarded by these populations as aesthetically objectionable and an unwelcome land use, especially by retirees who value particular viewscapes, and by conservatives who hold a nostalgic imaginary of “rural” life that excludes “drugs” and the threats of urban-racial taint they carry (Polson, 2020). In addition to relative newcomers, some cannabis opponents are long-term residents, who hold culturally specific views of “local culture,” often defined in terms of what populations, aesthetic sensibilities, and land uses are considered to belong.

Pro-cannabis policies in both ban and permit counties have faced intense opposition from these residential populations, who often mobilize “environmental” discourses that are equally rooted in desires for unimpeded consumption of amenity landscapes. In permit counties, anti-cannabis advocates have vied for zoning restrictions on cannabis cultivation, as in Trinity County’s cannabis “opt-out” zones (demanded by an organization of politically conservative retirees), in residential subdivisions of Nevada County (where retirees and other landscape consumers live), by efforts to roll back cultivation permitting in Humboldt County (notably by more liberal retirees and residents), and through the overturning of Calaveras County’s regulatory program by exurban residents upset at cultivation “blight” that became evident after fires leveled the area. At times, rural amenity consumers have mobilized and supported intensified policing of legally permissible cultivation, as in Sierra County’s demolition of medically-allowed cultivation sites. Meanwhile, in most ban counties (four of five sampled), these residents played a pivotal role in demanding and shaping cultivation bans. In San Bernardino’s High Desert area, for example, long-time local residents worked with law enforcement to instigate intensive anti-cannabis enforcement campaigns. In Yuba, Sierra, and Siskiyou Counties, recent in-migrants (in tandem with “good ol’ boy” networks of local elites) drew cultural boundaries of belonging to exclude people who grew cannabis via bans and regulatory ordinances. Across ban and permit counties, conflicts emerged when cannabis cultivation became visible or detectable, especially when it interfered with the production of natural landscape amenities or fixed ideas of “community.”

Across ban and permit counties, agricultural, environmental, and amenity landscape actors and dynamics exerted a *push* factor on cannabis (as demonstrated in local resistance to and conflict around cannabis cultivation), yet there is also a *pull* emanating from legacy producers. Concentrated communities of “legacy,” or pre-legalization, producers – often located in remote, environmentally-sensitive, marginal lands – were a significant factor in steering many jurisdictions toward regulation (instead of bans) and encouraging the maintenance of cultivation in legacy cultivation areas, where cannabis had been pushed under prior policy regimes. Cultivators variously expressed concerns about the unaffordability and disruptiveness of moving farms and the value of maintaining dense cultivator communities and the terroir and knowledge they stewarded. Legacy cultivators generally desired to maintain their livelihoods and communities in the places where they had historically cultivated (indeed, the bulk of state-licensed producers hail from legacy areas, see Dillis et al., 2021c). A second pull factor emanates from municipalities in ban counties. Cities that allow cultivation within ban counties are themselves often marginalized places – economically, racially, or politically.[3] Whether emanating from marginalized municipalities or legacy cultivators, the pull of cannabis to marginalized places dovetailed with the push of cannabis out of others. The push-pull dynamic largely mapped onto pre-legalization cultivation geographies, where cannabis was claimed by and located in marginalized communities and repelled by the conservative communities that were historically and currently resistant to legalization. This cannabis geography may open up opportunities for development of and resources for marginalized communities, though it is not clear that this will be the case as sensitive ecosystems carry higher regulatory standards for these communities and cannabis markets face an uncertain economic future (Kamal, 2023).

1.4. Discussion and conclusions: from marginal lands to geo-social margins

This study used a mixed-methods approach to document and interrogate the geographic distribution of cannabis licenses across California’s newly-legalized landscape. We acknowledge that there are inherent limitations associated with combining quantitative and qualitative analyses. For instance, our quantitative analysis was limited to variables gleaned from the data available, without the capacity to generate our own large-scale spatial datasets tailored to our research questions, like those associated with our qualitative analysis. Additionally, the two qualitative projects that provided data for this paper are necessarily limited by the case studies analyzed, the period of analysis, and the subjectivities of the ethnographic researchers. However, the capacity for a mixed-methods approach to holistically examine complex research topics suggests the need for more research that brings together quantitative work and qualitative ground-truthing.

We found that multiple factors contribute to the number of cannabis licenses likely to be issued in a given county, but that two factors were particularly notable. Namely, counties with higher median incomes and those with a greater proportion of on-farm employment (a proxy for non-cannabis agriculture)[4] were statistically predicted to have fewer cannabis cultivation licenses. Such factors correspond to qualitative findings that highlight the importance of opposition from entrenched agriculturalists and rural amenity land users in reducing the number of licenses. That is, both quantitative and qualitative results demonstrated evidence of socio-political and socio-economic marginalization of licensed cannabis agriculture in California.

The siting of cannabis cultivation in turn made it statistically more likely to occur on lands with steeper slopes, natural watercourses on site, and outside of regulated groundwater basins. Cultivation on such environmentally sensitive lands carries significant compliance burdens (Bodwitch et al., 2021), activates concerns about ecological impacts, and dovetails with other anxieties (e.g., over cannabis, cultural-racial change, cartels and immigration, climate change) (Polson, 2019;

[3] While legalized cultivation can be a developmental boon for these marginalized cities, it can also intensify existing patterns of marginalization and inequality through corruption and resource grabs, environmental harms, elevated property markets, and the offloading of other externalities, such as increased energy demands and pollution, onto surrounding publics.

[4] We note that these variables are somewhat correlated and can vary across cases, as in low-income counties or counties with little agricultural lands that implement bans.

Polson and Petersen-Rockney, 2019). These factors can amplify zealous enforcement, ecologically driven lawsuits, and reintensified stigma, which all resulted from the intense opposition to cannabis policies discussed in the Results. Thus, previous policies relegating cannabis to social and spatial margins echo through post-legalization landscapes (Polson et al., 2023), producing new forms of marginalization for cannabis and those who grow the plant.

Since legalization, the statutory designation of cannabis as an agricultural "product" (and not a "crop") made cannabis an exception to agricultural regulations, supports, and capacities, and subjected the plant to different, higher, and more costly compliance standards. These factors combine with the propensity of other land users, especially non-cannabis agriculturalists, to exclude cannabis cultivation from agricultural zones..[5] Cannabis is also repelled from other rural amenity landscapes by the "last-comer," "gangplank," or "drawbridge" phenomenon, wherein the most recent arrivals fashion themselves as protectors against even-newer arrivals (Cadieux, 2011). This perceived newcomer status combines with aesthetic concerns and racial-economic tensions around cannabis to produce both exclusion from, and significant conflict within, these places (Polson, 2015, 2020; Polson and Petersen-Rockney, 2019). Environmental agencies and advocates are left to manage the impacts of these exclusions, often in conflictive terms that further stigmatize cannabis producers as environmentally and socially polluting. Environmental impacts and conflicts can be worsened by bans, which forfeit governmental capacities to regulate and ameliorate negative effects and resource overuse, and push unlicensed cannabis cultivation to more hidden, ecologically-sensitive and marginal lands that are spatially, but not ecologically, removed from other resource users.

1.4.1. Considerations of geo-social marginalization and its perpetuation

Legacy cannabis cultivators and communities are caught in a paradox. While prohibition incentivized cultivation on remote, sensitive lands and provided a boon for surrounding communities, with legalization, the benefits of remote cultivation on marginal lands become deficits. Marginal lands often carry: high compliance costs; conflict over environmental impacts; longer distances to markets; less formal infrastructure for and resulting bottlenecks in processing and distribution; and the need, under falling wholesale prices, to expand cultivation footprints and intensify growing methods in ecologically and geographically constrained places. The latter factor only increases conflicts with neighboring residents, often tapping into community memories of industrial extraction and pillaging (Polson, 2019). The consequent decline of smaller farms degrades communities built around legacy production (Polson and Bodwitch, 2021), even as larger farms open in select agricultural zones and indicate possible industrial consolidation (Dillis et al., 2021a).

This paper highlights the connection between marginal lands and social processes of marginalization. Marginal lands cannot be fully defined without understanding the processes of "geo-social marginalization" that relegate some uses and users to these lands. Geo-social marginalization is a term intended to reflect how "margins" – of lands and societies – are comprised through interwoven biophysical, land use and social processes. In contrast to definitions of marginal lands that revolve around seemingly objective criteria (i.e., economic, ecological, geophysical, and soil quality; Csikós and Tóth, 2023), we urge grappling with the ways geo-social marginalization cuts across, and is distinct from, these definitions. Just as "urban renewal" projects leverage logics of underutilized and misused spaces to clear the urban poor, similar technical, non-social, and uncritical definitions of marginal lands erase or reframe land histories to further stigmatize certain land uses and populations, justifying their dispossession. Efforts to ecologically protect or economically develop "marginal lands" are not simply technical matters (Li, 2014), but rather are always already political. Only by ignoring the marginalized populations and land uses present on marginal lands – and the histories and processual dynamics that relegated them there – are projects to improve or protect these lands possible. Whether through prohibition, medicalization, or legalization, policy regimes reflect dominant values and actively shape how marginal lands and uses are defined, how marginalized users are imagined and treated, and how people and ecosystems are impacted and intertwined. The relegation of cannabis to marginal lands under prohibition and legalization is not an ahistorical accident; rather, the uses and users of cannabis-related marginal lands are products of social processes that create particular geographies, incite conflicts, and generate new processes of marginalization. Subsequent policies and management practices around marginal lands should take into account the historical and ongoing social and political dynamics that located users and uses on those lands. This is especially so as cannabis emerges from a century of prohibition.

This paper's caution to approach "marginal lands" circumspectly does not dispute the environmental sensitivities of land where California cannabis is commonly grown. Rather, this case illuminates the co-constitution of marginal lands with geo-socially marginalized land users and uses. Doing so allows us to see how cannabis cultivators (and marginal land users, generally) are ensnared in multiple marginalities. These marginalities are primarily the product of historical and ongoing policy regimes, not the environmental or social deviance of particular actors, as they are often framed in public discourse. This reframing is critical today, as Polson and Petersen-Rockney (2019) note, because of the (re-)formation of "neo-prohibitionist" politics through an amalgam of ecological concern, anti-drug conservatism, exclusionary visions of rurality and aesthetic order, and a grab for control of fiscal and natural resources under aggravating conditions of climate change. As a global prohibition regime, the War on Drugs marginalized cannabis as a plant, just as it marginalized and managed populations proximate to the plant (Polson, 2021). That historical inertia dies hard and is rapidly taking on new forms. To work against this historical pressure, it is necessary to interrogate and challenge how contemporary legal and policy systems produce new margins. Otherwise, legalization may simply produce renovated forms of inequality that target the same marginalized populations harmed by the War on Drugs.

Even as state agencies and policymakers attempt to inject some repair and justice into current policy regimes, it remains to be seen whether legalization facilitates outcomes other than new methods of extraction, dispossession and control. Without a shift in policy and environmental management, it may be that the geographic and social marginalization of most cultivators is just a preamble to corporate consolidation. Yet, cannabis cultivation policy in California (and beyond) is not yet entrenched. Legalization, as a new policy regime, presents opportunities to create more just and sustainable geographies, where centers and margins dissolve into a multi-centered geography of difference (Gilmore, 2002; Harvey, 1996), where drug war harms can be repaired, and where new visions for equitable and sustainable agricultural systems can be located.

CRediT authorship contribution statement

Chris Dillis: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Margiana Petersen-Rockney:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project

[5] We note that some agriculturally intensive counties (e.g., Yolo, Imperial, San Joaquin) have technically integrated cannabis into agricultural land use systems, though these counties have permitted few farms. Two exceptions are Monterey and Santa Barbara counties, which are younger, more Democratic, and center on ag industries (i.e. flowers) that were in crisis and had indoor cultivation infrastructure that preempted some environmental conflict. Notably, these two counties have led the state in reproducing agricultural patterns of consolidation and increasing farm size (Dillis et al., 2021a, 2021b).

administration, Writing – original draft, Writing – review & editing. **Michael Polson:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interestsChristopher Dillis reports financial support was provided by California Department of Cannabis Control. Margiana Peterson-Rockney reports financial support was provided by California Department of Cannabis Control. Michael Polson reports financial support was provided by California Department of Cannabis Control.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Adler, P.A., Adler, P., 1998. Peer Power: Preadolescent Culture and Identity. Rutgers University Press.
Agar, M., 1996. The Professional Stranger: an Informal Introduction to Ethnography (No Title).
Ayazi, H., Elsheikh, E., 2015. The US Farm Bill: Corporate Power and Structural Racialization in the US Food System.
Bauer, S., Olson, J., Cockrill, A., Van Hattem, M., Miller, L., Tauzer, M., Leppig, G., 2015. Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four northwestern California watersheds. PLoS One 10 (3), e0120016.
Bodwitch, H., Carah, J., Daane, K., Getz, C., Grantham, T., Hickey, G., Wilson, S., 2019. Growers say cannabis legalization excludes small growers, supports illicit markets, undermines local economies. Calif. Agric. 73 (3), 177–184.
Bodwitch, H., Polson, M., Biber, E., Hickey, G.M., Butsic, V., 2021. Why comply? Farmer motivations and barriers in cannabis agriculture. J. Rural Stud. 86, 155–170.
Boundary, Solutions, 2020. National Parcelmap Data Portal. https://www.boundarysolutions.com/BSI/page1.php.
Butsic, V., Carah, J.K., Baumann, M., Stephens, C., Brenner, J.C., 2018. The emergence of cannabis agriculture frontiers as environmental threats. Environ. Res. Lett. 13 (12), 124017.
Cadieux, Kirsten Valentine, 2011. Competing discourses of nature in exurbia. GeoJournal 76 4, 341–363.
California Division of Water Resources (CDWR), 2018. Division of Regional Assistance Regional Offices: Northern, North Central, South Central and Southern Regional Offices, and Water Use Efficiency Branch i15 Crop Mapping Layer. https://gis.data.ca.gov/datasets/66744a45fa8748c7ba1c3ef0be938da5_0/explore.
Carah, J.K., Howard, J.K., Thompson, S.E., Short Gianotti, A.G., Bauer, S.D., Carlson, S. M., Dralle, D.N., Gabriel, M.W., Hulette, L.L., Johnson, B.J., Knight, C.A., 2015. High time for conservation: adding the environment to the debate on marijuana liberalization. Bioscience 65 (8), 822–829.
Chapkis, W., Webb, R.J., 2008. Dying to Get High: Marijuana as Medicine. NYU Press.
Clerke, T., Hopwood, N., 2014. Doing Ethnography in Teams: A Case Study of Asymmetries in Collaborative Research. Springer Science & Business Media.
Corva, D., 2014. Requiem for a CAMP: the life and death of a domestic US drug war institution. Int. J. Drug Pol. 25 (1), 71–80.
Creese, A., Bhatt, A., Bhojani, N., Martin, P., 2008. Fieldnotes in team ethnography: researching complementary schools. Qual. Res. 8 (2), 197–215.
Csikós, N., Tóth, G., 2023. Concepts of agricultural marginal lands and their utilization: a review. Agric. Syst. 204, 103560.
Das, V., Poole, D., 2004. Anthropology in the Margins. School of American Research Seminar, Santa Fe.
DCC, 2023. California Department of Cannabis Control. https://cannabis.ca.gov/cannabis-laws/where-cannabis-businesses-are-allowed/.
Dillis, C., Butsic, V., Martin, J.V., Reiman, A., Starrs, G., Grantham, T.E., 2023. Wildfire smoke exposure has significant economic impacts on California's licensed cannabis industry. Environ. Res. Letters 18 (9), 094069.
Dillis, C., Polson, M., Bodwitch, H., Carah, J., Power, M.E., Sayre, N.F., 2021a. Industrializing cannabis?: socio-ecological implications of legalization and regulation in California. In: The Routledge Handbook of Post-Prohibition Cannabis Research. Routledge, pp. 221–230.
Dillis, C., Butsic, V., Carah, J., Zipper, S.C., Grantham, T., 2021b. Cannabis farms in California rely on wells outside of regulated groundwater basins. Environmental Research Communications 3 (7), 075005.
Dillis, C., Biber, E., Bodwitch, H., Butsic, V., Carah, J., Parker-Shames, P., Polson, M., Grantham, T., 2021c. Shifting geographies of legal cannabis production in California. Land Use Pol. 105, 105369.
Doremus, H., Tarlock, A.D., 2008. Water war in the Klamath Basin: macho law, combat biology, and dirty politics. Environ. Health Perspect. 116 (9). A402-A402.
Elmahrek, A., Lopez, R.J., Vives, R., 2022. Why legal weed is failing in one of California's legendary pot-growing regions. https://www.latimes.com/california/story/2022-12-09/legal-weed-failing-california-county.
Erickson, K.C., Stull, D.D., 1998. Doing Team Ethnography: Warnings and Advice. (No Title).
Freisthler, B., Gaidus, A., Tam, C., Ponicki, W.R., Gruenewald, P.J., 2017. From medical to recreational marijuana sales: marijuana outlets and crime in an era of changing marijuana legislation. J. Prim. Prev. 38, 249–263.
Galemba, R.B., 2013. Illegality and invisibility at margins and borders. PoLAR: Political and Legal Anthropology Review 36 (2), 274–285.
Gerstl-Pepin, C.I., Gunzenhauser, M.G., 2002. Collaborative team ethnography and the paradoxes of interpretation. Int. J. Qual. Stud. Educ. 15 (2), 137–154.
Giamarino, C., Loukaitou-Sideris, A., 2023. "The Echoes of Echo Park": Anti-homeless Ordinances in Neo-Revanchist Cities. Urban Affairs Review, 10780874231162936.
Gianotti, A.G.S., Harrower, J., Baird, G., Sepaniak, S., 2017. The quasi-legal challenge: assessing and governing the environmental impacts of cannabis cultivation in the North Coastal Basin of California. Land Use Pol. 61, 126–134.
Gieringer, D.H., 1999. The forgotten origins of cannabis prohibition in California. Contemp. Drug Probl. 26 (2), 237–288.
Gilmore, R.W., 2002. Fatal couplings of power and difference: notes on racism and geography. Prof. Geogr. 54 (1), 15–24.
Goldstein, Jesse, 2013. Terra economica: waste and the production of enclosed nature. Antipode 45 (no. 2), 357–375.
Graddy-Lovelace, G., 2017. The coloniality of US agricultural policy: articulating agrarian (in) justice. J. Peasant Stud. 44 (1), 78–99.
Grimmelmann, K., Espinoza, J., Arnold, J., Arning, N., 2017. The land-drugs nexus: how illicit drug crop cultivation is related to access to land. Alternative development: practices and reflections 61, 75.
Harvey, D., 1996. Justice, Nature and the Geography of Difference.
Heddleston, T., 2013. A tale of three cities: medical marijuana, activism, and local regulation in California. Humboldt J. Soc. Relat. 35, 123–143.
Hollander, J.H., 1895. The concept of marginal rent. Q. J. Econ. 9 (2), 175–187.
Kamal, S., 2023. Despair in Emerald Triangle as CA legal cannabis collapses. Cal Matters.
Kang, S., Post, W.M., Nichols, J.A., Wang, D., West, T.O., Bandaru, V., Izaurralde, R.C., 2013. Marginal lands: concept, assessment and management. J. Agric. Sci. 5 (5), 129.
Kelly, E.C., Formosa, M.L., 2020. The economic and cultural importance of cannabis production to a rural place. J. Rural Stud. 75, 1–8.
Laing, M., Cook, I.R., 2014. Governing sex work in the city. Geography Compass 8 (8), 505–515.
Lassiter, M.D., 2015. Impossible criminals: the suburban imperatives of America's war on drugs. J. Am. Hist. 102 (1), 126–140.
Lee, M.A., 2012. Smoke Signals: A Social History of Marijuana-Medical, Recreational and Scientific. Simon and Schuster.
Li, T.M., 1999. Marginality, Power, and Production: Analyzing Upland Transformations. Transforming the Indonesian uplands, pp. 1–44.
Li, T.M., 2014. What is land? Assembling a resource for global investment. Trans. Inst. Br. Geogr. 39 (4), 589–602.
Long, A., 2023. How Big Is California's Cannabis Market? Think a Small Nation. MJBizDaily.com. June 27.
Lu, J., Dev, L., Petersen-Rockney, M., 2022. Criminalized crops: environmentally-justified illicit crop interventions and the cyclical marginalization of smallholders. Polit. Geogr. 99, 102781.
MAGIC, 2022. Marginal Lands for Growing Industrial Crops [WWW Document]. URL. https://magic-h2020.eu/.
McSweeney, K., 2023. Prohibition geographies: afterward to special issue on "Illicit geographies and contested environments". Polit. Geogr. 101, 102835.
McSweeney, K., Nielsen, E.A., Taylor, M.J., Wrathall, D.J., Pearson, Z., Wang, O., Plumb, S.T., 2014. Drug policy as conservation policy: narco-deforestation. Science 343 (6170), 489–490.
Mills, E., Zeramby, S., 2021. Energy use by the indoor cannabis industry: inconvenient truths for producers, consumers, and policy makers. In: The Routledge Handbook of Post-Prohibition Cannabis Research. Routledge, pp. 243–265.

Nalepa, R.A., Gianotti, A.G.S., Bauer, D.M., 2017. Marginal land and the global land rush: a spatial exploration of contested lands and state-directed development in contemporary Ethiopia. Geoforum 82, 237–251.
Nichols, R., 2018. Theft is property! The recursive logic of dispossession. Polit. Theor. 46 (1), 3–28.
Parker, C., Scott, S., Geddes, A., 2019. Snowball Sampling. SAGE research methods foundations.
Parker-Shames, P., Bodwitch, H., Brashares, J.S., Butsic, V., 2023. Where money grows on trees: a socio-ecological assessment of land use change in an agricultural frontier. Landsc. Urban Plann. 237, 104783.
Peluso, N.L., Vandergeest, P., 2011. Political ecologies of war and forests: counterinsurgencies and the making of national natures. Ann. Assoc. Am. Geogr. 101 (3), 587–608.
Petersen-Rockney, M., Baur, P., Guzman, A., Bender, S.F., Calo, A., Castillo, F., De Master, K., Dumont, A., Esquivel, K., Kremen, C., LaChance, J., 2021. Narrow and brittle or broad and nimble? Comparing adaptive capacity in simplifying and diversifying farming systems. Front. Sustain. Food Syst. 5, 564900.
Peterson, G.M., Galbraith, J.K., 1932. The concept of marginal land. J. Farm Econ. 14 (2), 295–310.
Polson, M., 2015. From outlaw to citizen: police power, property, and the territorial politics of medical marijuana in California's exurbs. Territory, Politics, Governance 3 (4), 387–406.
Polson, M., 2019. Making marijuana an environmental issue: prohibition, pollution, and policy. Environ. Plann.: Nature and Space 2 (2), 229–251.
Polson, M., 2020. Buttressed and breached: the exurban fortress, cannabis activism, and the drug war's shifting political geography. Environ. Plann. Soc. Space 38 (4), 626–645.
Polson, M., 2021. Breaks, continuities, and the shifting terms of racial-capitalist governance. In: The Routledge Handbook of Post-prohibition Cannabis Research.
Polson, M., Bodwitch, H., 2021. Prohibited commoning: cannabis and emancipatory legalization. Elem Sci Anth 9 (1), 00054.
Polson, M., Petersen-Rockney, M., 2019. Cannabis farmers or criminals? Enforcement-first approaches fuel disparity and hinder regulation. Calif. Agric. 73 (3).
Polson, M., Bodwitch, H., Biber, E., Butsic, V., Grantham, T., 2023. After legalization: cannabis, environmental compliance, and agricultural futures. Land Use Pol. 126, 106531.
Prior, J., Crofts, P., 2011. Queerying Urban Governance: the Emergence of Sex Industry Premises into the Planned City. Queerying Planning: Challenging Heteronormative Assumptions and Reframing Planning Practice, pp. 185–208.
R Core Team, 2018. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org.
Rappaport, J., 2008. Beyond participant observation: collaborative ethnography as theoretical innovation. Collaborative anthropologies 1 (1), 1–31.
Ricardo, David, 1821. On the Principles of Political Economy. J. Murray, London.
Richert, L., Mills, J. (Eds.), 2021. Cannabis: Global Histories. MIT Press.
Salkin, P., 2011. Regulating controversial land uses. R. Estate Law J. 39, 526.
Sanders, C.B., Cuneo, C.J., 2010. Social reliability in qualitative team research. Sociology 44 (2), 325–343.
Scales, Kezia, Bailey, Simon, Lloyd, Joanne, 2011. Separately and together: reflections on conducting a collaborative team ethnography in dementia care. Enquire 6, 24–49.
Shortall, O., Helliwell, R., 2021. Marginal land for bioenergy crop production: ambiguities, contradictions, and cultural significance in policy and farmer discourses. In: Political Ecology of Industrial Crops. Routledge, pp. 77–94.
State of California, 2014. Department of Water Resources. Sustainable Groundwater Management Act. http://leginfo.legislature.ca.gov/faces/codes_displayexpandedbranch.xhtml?tocCode=WAT&division=6.&title=&part=2.74.&chapter=&article.
State of California. Order No. 2015-0023, Waiver of Waste Discharge Requirements and General Water Quality Certification for Discharges of Waste Resulting from Cannabis Cultivation and Associated Activities or Operations with Similar Environmental Effects in the North Coast Region. https://www.waterboards.ca.gov/northcoast/board_decisions/adopted_orders/pdf/2015/15_0023_Cannabis_Order.pdf.
State of California, 2015a. Order R5-2015-0113, Waste Discharge Requirements General Order for Discharges of Waste Associated with Medicinal Cannabis Cultivation Activities. https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2015-0113.pdf.
State of California, 2018. California Secretary of State, Statement of Vote. https://elections.cdn.sos.ca.gov/sov/2018-general/sov/2018-complete-sov.pdf.
State of California, 2019. California State Geoportal. 2019 SGMA Basin Prioritization Map. Retrieved from. https://gis.data.ca.gov/datasets/5c27c2ea54444fb5bd543828f9689b96_0.
State of California, 2023. Department of Cannabis Control. Cannabis unified license search. https://search.cannabis.ca.gov. (Accessed 5 April 2022).
State of California Employment Development Department. 2023. Employment by Industry Data. https://labormarketinfo.edd.ca.gov/data/employment-by-industry.html.
State of California Franchise Tax Board, 2023. Personal Income Tax Data. https://data.ftb.ca.gov/stories/s/2it8-edzu#california-median-income-by-county.
Tsing, A.L., 1994. From the margins. Cult. Anthropol. 9 (3), 279–297.
Unger, J.B., Vos, R.O., Wu, J.S., Hardaway, K., Sarain, A.Y.L., Soto, D.W., Rogers, C., Steinberg, J., 2020. Locations of licensed and unlicensed cannabis retailers in California: a threat to health equity? Preventive medicine reports 19, 101165.
United States Census Bureau, 2023. https://data.census.gov/table?q=median+age+by+county&y=2020&tid=ACSST1Y2021.S0101.
Urteaga-Crovetto, P., Segura-Urrunaga, F., 2021. Transforming nature, crafting irrelevance: the commodification of marginal land for sugarcane and cocoa agroindustry in Peru. In: Political Ecology of Industrial Crops. Routledge, pp. 97–123.
U.S. Geological Survey, 2019. USGS TNM Hydrography (NHD). accessed March 1, 2020 at. https://viewer.nationalmap.gov/basic/.
U.S. Geological Survey, 2020. USGS TNM elevation (NED). accessed March 1, 2020 at. https://viewer.nationalmap.gov/basic/.
Wang, I.J., Brenner, J.C., Butsic, V., 2017. Cannabis, an emerging agricultural crop, leads to deforestation and fragmentation. Front. Ecol. Environ. 15 (9), 495–501.
Wartenberg, A.C., Holden, P.A., Bodwitch, H., Parker-Shames, P., Novotny, T., Harmon, T.C., Hart, S.C., Beutel, M., Gilmore, M., Hoh, E., Butsic, V., 2021. Cannabis and the environment: what science tells us and what we still need to know. Environ. Sci. Technol. Lett. 8 (2), 98–107.
Wasser, J.D., Bresler, L., 1996. Working in the interpretive zone: conceptualizing collaboration in qualitative research teams. Educ. Res. 25 (5), 5–15.
Werth, R., Ballestero, A., 2017. Ethnography and the governance of il/legality: some methodological and analytical reflections. Soc. Justice 44 (147), 10–35, 1.
Williams, A.P., Cook, B.I., Smerdon, J.E., 2022. Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. Nat. Clim. Change 12 (3), 232–234.
Wood, S.N., Pya, N., Säfken, B., 2016. Smoothing parameter and model selection for general smooth models. J. Am. Stat. Assoc. 111 (516), 1548–1563.
Ybarra, M., 2016. "Blind passes" and the production of green security through violence on the Guatemalan border. Geoforum 69, 194–206.
Yung, L., Belsky, J.M., 2007. Private property rights and community goods: negotiating landowner cooperation amid changing ownership on the Rocky Mountain. Front. Society and natural resources 20 (8), 689–703.