BMJ Public Health

Unequal access: cross-sectional associations of deprivation, racial composition and independent and joint cannabis and alcohol outlet densities among Michigan census block groups

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To cite: Myers MG, Sadler RC, Margerison CE, *et al*. Unequal access: cross-sectional associations of deprivation, racial composition and independent and joint cannabis and alcohol outlet densities among Michigan census block groups. *BMJ Public Health* 2026;**4**:e004190. doi:10.1136/bmjph-2025-004190

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjph-2025-004190).

Received 6 October 2025
Accepted 24 July 2026

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ABSTRACT

Introduction Cannabis and alcohol outlets may independently and jointly influence the health of those in their surrounding neighbourhoods. State and local policy determines the establishment of cannabis and alcohol outlets in Michigan, potentially leading to their inequitable distribution and contribution to health disparities. This ecological study examined associations among deprivation, racial makeup and the individual and joint densities of cannabis and alcohol outlets within Michigan.

Methods We analysed State of Michigan cannabis and alcohol outlet licensing data within 7988 (95.3%) Michigan census block groups (CBGs) in 2023. We linked measures of CBG deprivation and per cent minority population. We used spatially structured negative binomial models to examine relationships among deprivation, racial makeup and cannabis and alcohol outlet density per capita. We also created a novel measure of CBG cannabis and alcohol outlet co-density and used spatially structured multinomial logistic regressions to characterise co-density groups.

Results We identified 789 distinct cannabis outlets within 553 CBGs and 16 050 distinct alcohol outlets within 5407 CBGs. Greater deprivation was associated with greater cannabis (incident rate ratio (IRR): 1.24; 95% CI 1.16 to 1.33) and alcohol outlet density (IRR: 1.08; 95% CI 1.06 to 1.10). We found an inverse association between the rate of non-white population per 10 people and alcohol outlet density (IRR: 0.95; 95% CI 0.93 to 0.97). High-cannabis/high-alcohol co-density CBGs were more deprived than low-cannabis/low-alcohol and low-cannabis/high-alcohol CBGs.

Conclusions Cannabis and alcohol outlets independently and jointly overburden Michigan's most deprived CBGs. State and local policymakers may consider these findings when designing cannabis and alcohol outlet policy that prioritises public health equity.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Cannabis and alcohol outlets are social determinants of health. Prior research, nationwide and in select geographies, commonly indicates relationships between vulnerable populations and the independent locations of cannabis and alcohol outlets.

WHAT THIS STUDY ADDS

⇒ This study is the first to examine the spatial distribution of cannabis and alcohol outlets within Michigan and to test their associations with vulnerable populations. We also introduce and examine a novel measure of cannabis and alcohol outlet co-density.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This work provides evidence to guide the equitable distribution of cannabis and alcohol outlets. This work also encourages future research and policy making to further consider the public health implications of local outlet co-density.

INTRODUCTION

The spatial ecology of cannabis and alcohol outlets is increasingly recognised as an important aspect of the built environment and as a social determinant of health.[1 2] Greater neighbourhood density and proximity to cannabis outlets are associated with increased cannabis use behaviours, such as past-month use and frequent use within the past month,[2] and are linked to adverse health outcomes including cannabis use disorder,[3] pregnancy complications[4] and traffic crashes.[5] Alcohol outlets are similarly associated with greater alcohol use[6] and with adverse consequences of use, including assault[7] and traffic crashes.[8] The inequitable distribution of cannabis and alcohol outlets across neighbourhoods contributes to health disparities,[9 10] which may be particularly detrimental to vulnerable communities, including those that are economically disadvantaged or heavily minoritised, underscoring the importance of examining the within-state spatial ecology of cannabis and alcohol markets.

Among states with both legal cannabis and alcohol marketplaces, examining their combined retail availability in close proximity, or co-location, has important implications for public health. Oversaturation of cannabis and alcohol outlets within the same neighbourhood increases the potential for co-use behaviours, which are more harmful than use of either substance in isolation.[11] Cannabis and alcohol outlet co-location has an amplified impact on public health, yet their co-location is rarely regulated,[12] and the literature has yet to explicitly examine the combined spatial ecology of cannabis and alcohol outlets and their relation to neighbourhood structural vulnerabilities.

In the United States of America (USA), within-state policy largely influences where cannabis and alcohol outlets are geographically distributed. Most states permitting the use and sale of cannabis allow municipal governments to oversee the establishment of cannabis and alcohol outlets within their borders through zoning regulations, leading to a within-state patchwork of cannabis and alcohol policies and resulting outlet densities.[13] In some states, cannabis sales taxes are distributed to local governments in proportion to the number of outlets present. As a result, more-resourced municipalities are better suited to reject or limit the establishment of cannabis outlets.[14]

The locations of cannabis and alcohol outlets may also be driven by market practices. To maximise profit, cannabis and alcohol outlets are theoretically more likely to be located in areas with the lowest operating costs and with the greatest demand.[14,15] Property costs are cheapest in economically deprived neighbourhoods, and prior evidence shows that both cannabis and alcohol outlets are associated with local economic deprivation.[9,16–19]

Given recent national estimates on cannabis and alcohol use by race,[20] the economic principle of demand posits that neighbourhoods with a higher prevalence of non-white population would be positively associated with cannabis outlet density and inversely associated with alcohol outlet density. This is not always the case. Among all states with an adult-use cannabis policy, cannabis outlets were more likely to be located in higher-minority census tracts,[21,22] but this relationship was not found in Maryland[23] or Denver, Colorado.[24] Relationships between neighbourhood racial makeup and alcohol outlets are similarly inconsistent.[18,25,26] Inequitable distribution of cannabis and alcohol outlets within vulnerable or prominently non-white neighbourhoods is a potential source of environmental injustice that may contribute to existing health disparities. Differences in sociopolitical and economic structures exist between and within states, leading to heterogeneity in local cannabis and alcohol outlet landscapes and what place-based factors characterise those landscapes. Public health and other leaders should be aware of such conditions within their jurisdiction to make informed policy decisions.

Michigan was the first state in the Midwest region of the USA to legalise both medical (2008) and adult-use (2018) of cannabis. In Michigan, medical and adult-use cannabis outlets became operational in 2016 and 2019, respectively, and individual municipalities regulate the establishment of cannabis and alcohol outlets within neighbourhoods. The spatial patterning of cannabis and alcohol outlets and their relationship to neighbourhood vulnerability in Michigan has not been examined in the literature. Describing these dynamics in Michigan using both empirical and spatial representations is critical to inform within-state public health applications. Michigan is a diverse state in terms of urban/rural and demographic variation, and results drawn from this work may further contextualise between-state discrepancies in the literature.[27,28] The present study uses 2023 cannabis and alcohol outlet licensing data to examine the independent and combined cannabis and alcohol landscapes within Michigan, and their relationships with neighbourhood vulnerabilities (ie, deprivation and non-white population). We further expand on the current literature by examining relationships between measures of neighbourhood vulnerabilities and cannabis and alcohol outlet co-density. Findings from this study are relevant to public health and policy officials, both locally and broadly, who seek to mitigate potential health disparities associated with neighbourhood cannabis outlet density and combined cannabis and alcohol outlet co-density.

MATERIALS AND METHODS

Study design and population

In this cross-sectional ecological study, we examined the cannabis, alcohol, and joint cannabis and alcohol outlet densities within Michigan neighbourhoods in the fourth quarter (Q4; October–December) of 2023. Specifically, we examined independent associations between structural neighbourhood vulnerability (ie, deprivation, non-white population) and cannabis, alcohol and combined cannabis and alcohol outlet density per capita. We use census block groups (CBGs) as the geographic unit of analysis, as they are commonly used to define neighbourhoods, and capture spatial variation masked at larger spatial scales. All Michigan CBGs were considered for analysis (n=8386). CBGs with fewer than 100 people, fewer than 30 housing units or more than 33% of the population living in group quarters had suppressed census data and were excluded from analyses, resulting in the final analytic sample of 7988 CBGs (95.3%).

Materials

Cannabis outlet data

We obtained publicly available records of adult-use and medical cannabis outlet licensing data published by the State of Michigan Cannabis Regulatory Agency. We used the United States Census Geocoder to geocode and assign the addresses of active cannabis outlets in Q4 of 2023 to CBGs. A total of 76 outlet addresses (9.6%)

were not successfully geocoded in this process but were hand geocoded using Google Maps by verifying street addresses and outlet names. All cannabis outlets were successfully assigned to CBGs. We then counted all active cannabis outlets within each CBG. Sub-analyses individually examined outlets licensed for (1) only adult-use cannabis (ie, adult-use retailer, adult-use class A microbusiness, adult-use microbusiness, adult-use consumption establishments), (2) only medical cannabis and (3) both adult-use and medical cannabis.

Alcohol outlet data

We obtained publicly available alcohol outlet licensing data from the State of Michigan Department of Licensing and Regulatory Affairs in December 2023. Using the United States Census Geocoder, we geocoded the addresses of active on-premises and off-premises retail alcohol outlets at the CBG level. A total of 1515 (10.6%) license addresses were not initially geocoded and were hand geocoded by verifying addresses and outlet names using Google Maps. Alcohol outlet coordinates were assigned to CBGs using the US Census Geocoder and resulted in a 99.9% geocoding success rate. We then counted the addresses of all active alcohol outlets within each CBG. Sub-analyses independently examined on-premises and off-premises alcohol outlets, as determined by state records. On-premises licenses included hotels, taverns, restaurants, golf clubs, brewpubs, clubs and retirement centres; whereas, off-premises licenses included convenience stores, grocery stores and gas stations.

Cannabis and alcohol outlet co-density

We created a novel nominal measure of cannabis and alcohol co-density per capita by categorising CBGs into one of four categories: (1) high-cannabis/high-alcohol outlet density, (2) high-cannabis/low-alcohol outlet density, (3) low-cannabis/high-alcohol outlet density or (4) low-cannabis/low-alcohol outlet density. To control for CBG edge effects in our co-density measure, the cannabis and alcohol outlet densities were calculated as the number of outlets within each CBG and a surrounding one-mile buffer, divided by CBG population. We categorised CBGs as having either high or low cannabis and alcohol outlet density using median cut-off values within CBGs containing at least one respective outlet. This allowed for a more meaningful representation of areas with high outlet densities beyond measuring the presence or absence of a cannabis outlet. Median cut points allow for the greatest stability and interpretability by maximising variability in our categorical variable. In primary analyses, the median cut-off values for cannabis and alcohol outlet density categorisation were 2.09 and 15.36 outlets per 1000 population, respectively.

In a sensitivity analysis to examine the robustness of our median-split co-density variable, we used cut points at the 75th percentiles of cannabis and alcohol outlet density within CBGs containing at least one respective outlet to similarly categorise CBGs into four distinct co-density categories. The 75th percentile cut-off values for cannabis and alcohol outlet density categorisation were 4.17 and 29.41 outlets per 1000 population, respectively.

Area Deprivation Index

We obtained publicly available Area Deprivation Index (ADI) data from the Neighbourhood Atlas.[29] The ADI is a validated, factor-based index of 17 United States Census American Community Survey (ACS) socioeconomic indicators related to poverty, housing, employment and education.[29] We analysed the Michigan-specific 2022 CBG ADI decile rankings. Scores range from 1 (least deprived) to 10 (most deprived).

Racial composition

To examine the racial composition of Michigan CBGs, we obtained 5-year 2023 ACS estimates that draw on 2019–2023 ACS data to provide stable and precise estimates among small populations.[30] The rate of non-white population was calculated as the population of individuals reporting their race and ethnicity as anything but 'white alone' divided by CBG population and multiplied by 10.

Urbanicity covariate

We identified CBG urbanicity using 2020 United States Census Bureau urban-rural classification data at the census block level. We classified each CBG as urban or rural based on whether the majority of their population resided in census blocks designated as urban or rural, accordingly.

Spatially lagged covariates

To account for spatial spillover effects in analyses, we included spatially lagged values for ADI and rate of non-white population. Using the 'spdep' package in R, we calculated lagged covariates as the weighted average of each measure in contiguous municipalities (ie, first-order queen contiguity). Weights allow for equal influence from all units sharing a boundary or vertex. CBGs averaged 6.2 contiguous units (range 1–17).

Analytic methods

We began by creating a map that depicted the point locations of cannabis and alcohol outlets within Michigan, as well as choropleths showing distributions of ADI, racial composition and cannabis and alcohol outlet co-density categorisations among Michigan CBGs. To examine the associations of neighbourhood vulnerability and cannabis and alcohol outlets, we then independently modelled cannabis and alcohol outlet counts using separate negative binomial generalised additive models. Akaike Information Criterion (AIC) and theoretical variable inclusion guided model selection. Negative binomial models were selected because they more appropriately modelled overdispersion in cannabis and alcohol counts compared with Poisson models. After model fitting, we assessed potential zero inflation by testing whether the observed fraction of zeroes exceeded those assumed under each model using the R package DHARMa.[31] In all cases, there was no evidence of zero inflation (ie, p>0.7). Each model included a covariate for urbanicity and a CBG population offset term to effectively model population-standardised cannabis and alcohol densities. Structural vulnerability measures, including ADI and non-white composition, were included as independent variables. To account for edge effects and spatial spillover, we included spatially lagged ADI and non-white population variables in each model. In primary models, we also included two-dimensional thin plate smoothing splines at the coordinates of CBG centroids. The smoothing spline functions analogously to a spatial random effect and models residual spatial variation and unmeasured spatial confounding.[32] We also report results from analogous but spatially unstructured models in the online supplemental appendix. To assess residual spatial autocorrelation for each model, we calculated Moran's I statistics using Pearson residuals and a first-order queen contiguity spatial weight matrix.

We examined the crude relationship between neighbourhood structural vulnerabilities and our novel cannabis and alcohol co-density measure by first calculating mean ADI and non-white composition per co-density category. We then used multinomial logistic generalised additive models to model adjusted relationships between neighbourhood structural vulnerability and cannabis and alcohol co-density groups. To estimate relationships between each co-density group, we refit the model with distinct outlet co-density reference groups: low-cannabis/low-alcohol, low-cannabis/high-alcohol and high-cannabis/low-alcohol to allow estimation of covariate effects on each contrast between categories. In alignment with the individual outlet density models, we included ADI and racial composition variables, their sp 1.Wood S, Wood MS. Package 'mgcv'. R package version. 2015;1:29. atial lags, a covariate for urbanicity, and the two-dimensional thin plate smoothing spline in each multinomial logistic regression. We used ArcGIS to create all maps, and all generalised additive models were performed using R package 'mgcv'.[32]

Secondary and sensitivity analyses

We modelled relationships between structural vulnerability measures (ADI and racial composition) and the count of specific cannabis outlet licences (ie, medical, adult-use and both medical and adult-use) and alcohol outlet licences (on-premises and off-premises) using separate negative binomial generalised additive models that were structured analogously to the primary models.

We conducted a sensitivity test that examined the associations of CBG vulnerability measures and the cannabis and alcohol outlet co-density variable that was created using the 75th percentile split. In analogous methods to the main analysis, we described each co-density group and estimated adjusted associations using multinomial logistic generalised additive models.

Patient and public involvement

This ecological study assessed sociodemographic characteristics of the public and built environment aspects of Michigan in 2023. Members of the public were not directly involved in the design, conduct, reporting, or dissemination planning of this research. Results from this work are intended to inform public health planning and is disseminated through open-access publication.

RESULTS

Sample characteristics

As of Q4 of 2023 and among the 7988 Michigan CBGs analysed, we identified 789 distinct cannabis outlets within 553 CBGs and 16 050 distinct alcohol outlets within 5407 CBGs. The maximum number of cannabis and alcohol outlets present in one CBG was 9 and 56, respectively. We describe CBG sample characteristics in online supplemental table 1. Figure 1 depicts point locations of cannabis and alcohol outlets. Online supplemental figures 1 and 2 depict CBG measures of ADI and the rate of non-white population, respectively. Deprivation was highest within city centres and in rural areas, and greater proportions of non-white populations were primarily located in city centres.

Independent relationships between measures of structural vulnerability and cannabis and alcohol outlet densities

Results from primary spatially structured models (table 1) are largely comparable to those from spatially unstructured models (online supplemental table 2) and they show improved AIC model fit statistics and reduced Moran's I measures of residual spatial autocorrelation. Cannabis and alcohol outlet density are independently associated with ADI (table 1). A one decile increase in a neighbourhood's ADI was associated with a 24% increase in the per capita rate of cannabis outlets (incident rate ratio (IRR): 1.24; 95% CI 1.16 to 1.33) and an 8% increase in the per capita rate of alcohol outlets (IRR: 1.08; 95% CI 1.06 to 1.10). Results for spatially lagged ADI terms indicate that a one-step increase in average neighbouring ADI was associated with a 14% increase in cannabis outlet density (IRR: 1.14; 95% CI 1.03 to 1.25) and a 4% decrease in alcohol outlet density (IRR: 0.96; 95% CI 0.93 to 0.98). A 10% increase in the rate of non-white population was associated with a 5% decrease in alcohol outlet density (IRR: 0.95; 95% CI 0.93 to 0.97), and spatially lagged terms for the rate of non-white population were associated with an 11% decrease in cannabis outlet density (IRR: 0.89; 95% CI 0.80 to 0.98).

Relationships between structural vulnerabilities and cannabis and alcohol outlet co-density

We categorised 1280 (16.0%) CBGs as high-cannabis/high-alcohol outlet density, 190 (2.4%) as high-cannabis/low-alcohol outlet density, 2667 (33.4%) as low-cannabis/high-alcohol outlet density and 3851 (48.2%) as low-cannabis/low-alcohol outlet density and visualised these classifications in figure 2. Shown in table 2, high-cannabis/

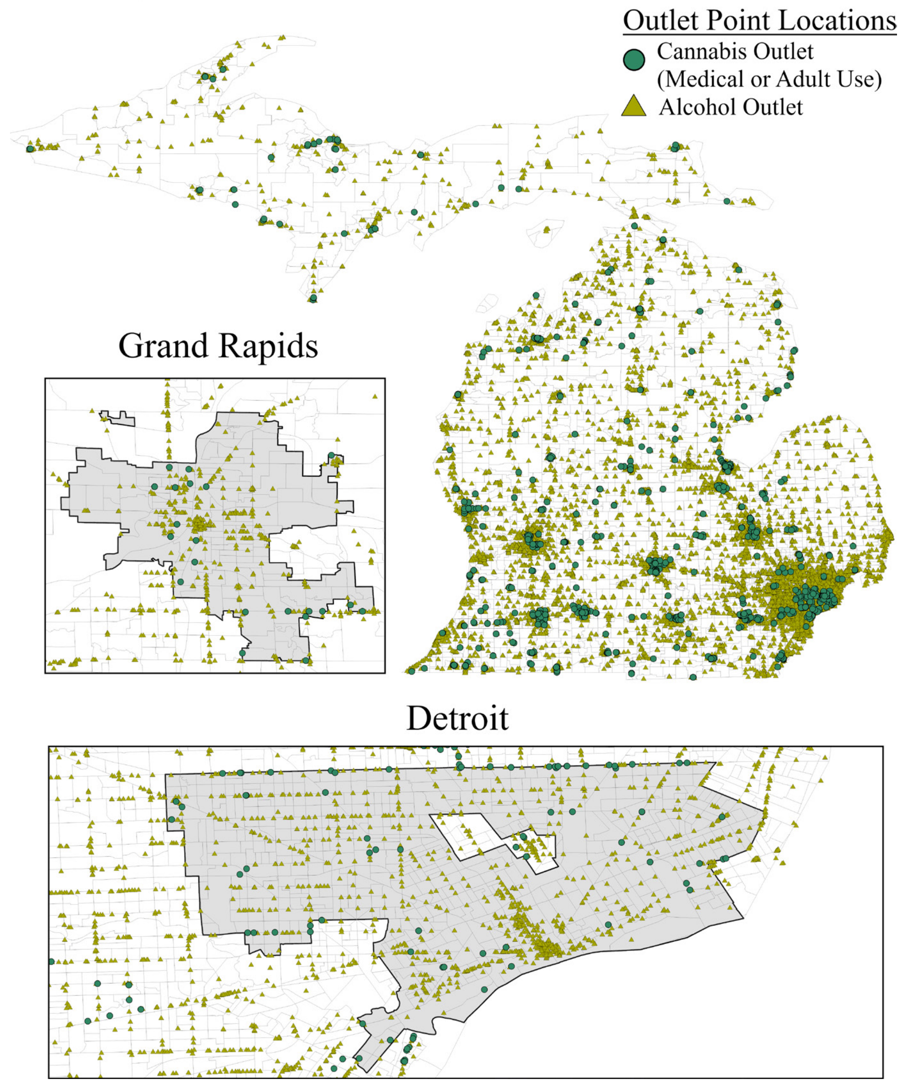

Figure 1 Point locations of cannabis and alcohol outlets in Michigan, 2023 Q4.

Table 1 Independent associations between Area Deprivation Index, per cent of non-white block group population and cannabis and alcohol outlet density among Michigan census block groups, 2023 Q4 (n=7988).

	Cannabis outlet density, incident rate ratio (95% CI)	Alcohol outlet density, incident rate ratio (95% CI)
Area Deprivation Index	**1.24 (1.16 to 1.33)**	**1.08 (1.06 to 1.10)**
Spatially Lagged Area Deprivation Index	**1.14 (1.03 to 1.25)**	**0.96 (0.93 to 0.98)**
Rate of non-white block group population (per 10 people)	1.05 (0.97 to 1.13)	**0.95 (0.93 to 0.97)**
Spatially lagged rate of non-white block group population (per 10 people)	**0.89 (0.80 to 0.98)**	1.00 (0.97 to 1.03)
Akaike Information Criterion (AIC)	4640.98	30688.27
Moran's I	0.08	0.09

Cannabis outlet density includes medical and adult-use cannabis outlets.
Negative binomial regressions include a block group population offset, a covariate for urbanicity, and a two-dimensional thin plate smoothing spline.
Bold font indicates a statistically significant incident rate ratio at α=0.05.
CI, confidence interval .

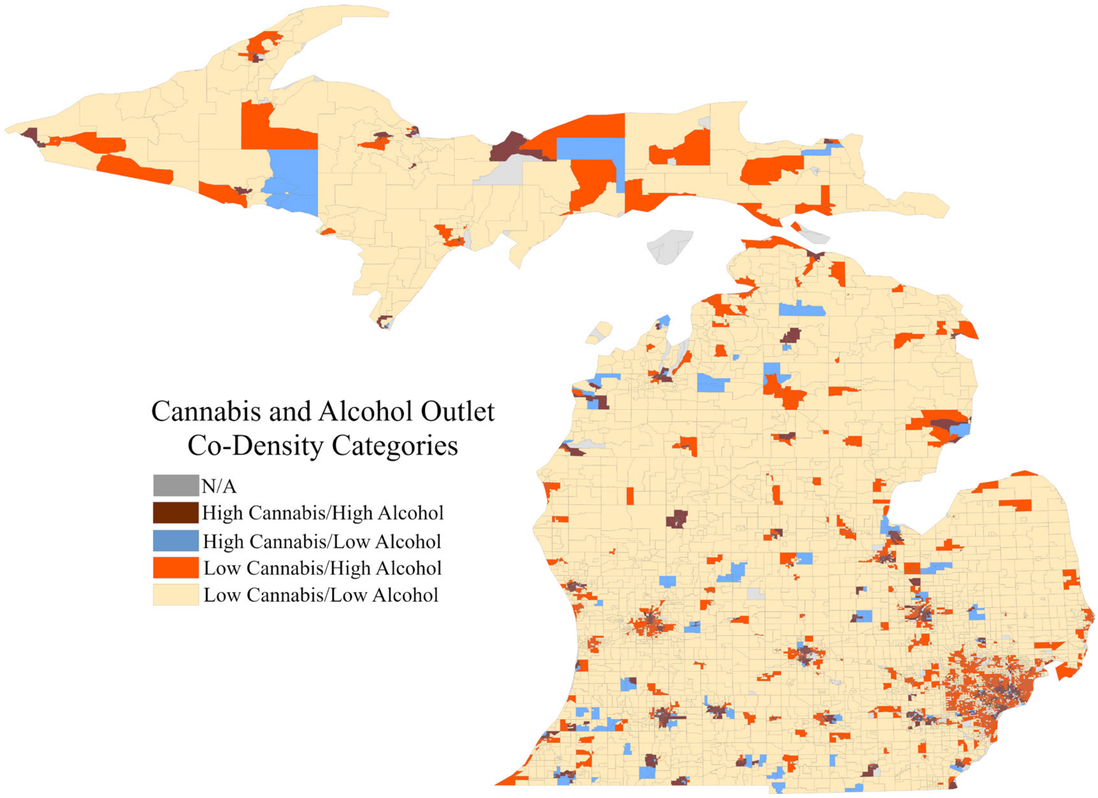

Figure 2 Cannabis and alcohol outlet co-density categorisation of Michigan census block groups, 2023 Q4 (n=7988).

high-alcohol CBGs had the highest average ADI (7.45; SD 2.70) and rate of non-white population (4.12; SD 3.25). Low-cannabis/low-alcohol CBGs showed the lowest average ADI (4.67; SD 2.61) and rate of non-white population (1.68; SD 2.03).

In table 3, we present results from the multinomial logistic regressions describing relationships between neighbourhood structural vulnerability measures and co-density categories. A one-step increase in ADI was associated with a 12% higher likelihood of being a high-cannabis/high-alcohol CBG than a low-cannabis/low-alcohol CBG (relative risk ratio (RRR): 1.12; 95% CI 1.05 to 1.19). Referent to low-cannabis/low-alcohol CBGs, higher neighbouring ADI was associated with a 120% increased risk of being a high-cannabis/high-alcohol CBG (RRR: 2.20; 95% CI 2.00 to 2.42), a 60% increased risk of being a high-cannabis/low-alcohol CBG (RRR: 1.60; 95% CI 1.46 to 1.75) and a 42% greater risk of being a low-cannabis/high-alcohol CBG (RRR: 1.42; 95% CI 1.18 to 1.71). Referent to low-cannabis/low-alcohol CBGs, the rate of non-white population (per 10 people) was associated with a 14% lower risk of being classified as high-cannabis/high-alcohol (RRR: 0.86; 95% CI 0.81 to 0.92).

Table 2 Average census block group Area Deprivation Index and rate of non-white population by cannabis and alcohol co-density category, 2023 Q4 (n=7988).

	Area Deprivation Index (mean, SD)	Rate of non-white population (per 10 people) (mean, SD)
High-cannabis/high-alcohol (n=1280)	7.45 (2.70)	4.12 (3.25)
High-cannabis/low-alcohol (n=190)	6.56 (2.48)	2.40 (2.84)
Low-cannabis/high-alcohol (n=2667)	5.69 (2.83)	3.16 (2.94)
Low-cannabis/low-alcohol (n=3851)	4.67 (2.61)	1.68 (2.03)
Entire state (n=7988)	5.50 (2.87)	2.58 (2.76)

SD, standard deviation.

Referent to low-cannabis/high-alcohol CBGs, a one-step increase in spatially lagged ADI was associated with a 50% higher likelihood of being a high-cannabis/high-alcohol CBG (RRR: 1.50; 95% CI 1.27 to 1.78).

Referent to high-cannabis/low-alcohol CBGs, a one-step increase in ADI was associated with a 6% higher likelihood of being classified as high-cannabis/high-alcohol (RRR: 1.06; 95% CI 1.02 to 1.10). Spatially lagged ADI was similarly associated with a 37% increased risk of being classified as high-cannabis/high-alcohol than high-cannabis/low-alcohol (RRR: 1.37; 95% CI 1.29 to 1.46). The rate of non-white population (per 10 people) was associated with a 13% lower likelihood of being classified as high-cannabis/high-alcohol than high-cannabis/low-alcohol (RRR: 0.87; 95% CI 0.83 to 0.91).

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Table 3 Results from multinomial logistic regressions examining relationships between structural social vulnerability measures and cannabis and alcohol co-density categories, 2023 Q4 (n=7988).

		High-cannabis/ high-alcohol	High-cannabis/ low-alcohol	Low-cannabis/ high-alcohol
Reference group	**Structural social vulnerability independent variable**	**Relative risk ratio (95% CI)**	**Relative risk ratio (95% CI)**	**Relative risk ratio (95% CI)**
Low-cannabis/ low-alcohol	Area Deprivation Index	**1.12 (1.05 to 1.19)**	1.06 (0.99 to 1.13)	1.09 (0.97 to 1.24)
	Spatially Lagged Area Deprivation Index	**2.20 (2.00 to 2.42)**	**1.60 (1.46 to 1.75)**	**1.42 (1.18 to 1.71)**
	Rate of non-white block group population (per 10 people)	**0.86 (0.81 to 0.92)**	0.99 (0.94 to 1.05)	0.93 (0.82 to 1.06)
	Spatially lagged rate of non-white block group population (per 10 people)	0.92 (0.84 to 1.00)	0.94 (0.87 to 1.01)	0.94 (0.79 to 1.12)
Low-cannabis/ high-alcohol	Area Deprivation Index	1.03 (0.92 to 1.16)	0.98 (0.87 to 1.10)	–
	Spatially Lagged Area Deprivation Index	**1.50 (1.27 to 1.78)**	1.12 (0.94 to 1.34)	–
	Rate of non-white block group population (per 10 people)	0.93 (0.81 to 1.06)	1.06 (0.93 to 1.21)	–
	Spatially lagged rate of non-white block group population (per 10 people)	1.08 (0.90 to 1.28)	1.09 (0.91 to 1.29)	–
High-cannabis/ low-alcohol	Area Deprivation Index	**1.06 (1.02 to 1.10)**	–	–
	Spatially Lagged Area Deprivation Index	**1.37 (1.29 to 1.46)**	–	–
	Rate of non-white block group population (per 10 people)	**0.87 (0.83 to 0.91)**	–	–
	Spatially lagged rate of non-white block group population (per 10 people)	0.98 (0.91 to 1.04)	–	–

Multinomial logistic regressions include a two-dimensional thin plate smoothing spline and a covariate for urbanicity.
Bold font indicates a statistically significant relative risk ratio at α=0.05.
CI, confidence interval.

Secondary and sensitivity analyses

We present results from secondary analyses examining relationships between structural vulnerabilities and specific cannabis outlet licence densities (medical, adult-use and locations with both medical and adult-use outlets) in online supplemental table 3. Medical cannabis outlet density was not associated with ADI or the rate of minority population. A one decile increase in a CBG's ADI was associated with a 22% (IRR: 1.22; 95% CI 1.13 to 1.32) increase in the per capita rate of adult use-only cannabis outlets, and a 26% (IRR: 1.26; 95% CI 1.14 to 1.40) increase in rate of outlets licensed for both medical and adult-use cannabis. A one decile increase in a CBG's neighbouring ADI and neighbouring rate of minority population was associated with a 13% increase (IRR: 1.13; 95% CI 1.00 to 1.26) and 12% decrease (IRR: 0.88; 95% CI 0.77 to 0.99) in the rate of adult-use only cannabis outlet density, respectively.

We present results from sub-analyses describing relationships between structural vulnerabilities and specific alcohol outlet licence densities (on-premises and off-premises) in online supplemental table 4. ADI was associated with a 4% higher rate of on-premises alcohol outlets (IRR: 1.04; 95% CI 1.01 to 1.07) and a 9% higher rate of off-premises alcohol outlets (IRR: 1.09; 95% CI 1.06 to 1.11). Spatially lagged ADI was associated with a 7% decrease in on-premises alcohol outlets (IRR: 0.93; 95% CI 0.90 to 0.97) and a 4% decrease in off-premises alcohol outlets (IRR: 0.96; 95% CI 0.93 to 0.99). The rate of non-white population (per 10 people) was associated with a 7% decrease in on-premises outlets (IRR: 0.93; 95% CI 0.91 to 0.96) and a 5% decrease in off-premises outlets (IRR: 0.95; 95% CI 0.93 to 0.97).

In the co-density sensitivity analysis using 75th percentile cut points, rather than median, ADI and non-white composition remained highest in high-cannabis/high-alcohol CBGs and lowest in low-cannabis/low-alcohol CBGs (online supplemental table 5). Adjusted associations were largely consistent with primary findings and few differences in associations were observed (online supplemental table 6). One association was attenuated and no longer statistically significant; whereas, three positive associations reached statistical significance. Overall patterns and interpretation of results were unchanged, supporting the robustness of results at higher co-density thresholds.

DISCUSSION

Findings from this study suggest a potential inequitable distribution of cannabis and alcohol outlets across Michigan CBGs in 2023. Results from spatially structured and adjusted models described positive associations between socioeconomic deprivation and cannabis and alcohol outlet densities, analysed independently and in combination, in Michigan CBGs. We failed to find a significant relationship between non-white population and cannabis outlet density; however, the rate of non-white CBG population was inversely associated with alcohol outlet density.

This is the first study to examine structural neighbourhood vulnerability and cannabis and alcohol outlet landscapes in Michigan. Results presented here were generally expected, given that relationships between local socioeconomic status and cannabis outlets were found nationally in the USA[21 22] and in specific states like Colorado,[33] Washington,[16] California,[34] Oregon.[35] Moreover, local socioeconomic status and alcohol outlets are similarly associated with one another in North Carolina,[36] Maryland,[9] in urban centres across the USA,[9 18] and in international locations such as New Zealand[17] and Canada.[19] Importantly, greater exposure to either cannabis or alcohol outlets may increase population-level prevalences of use,[1 37] potentially magnifying adverse health outcomes among Michigan's most economically vulnerable neighbourhoods. Future investigations should quantify the degree to which cannabis and alcohol outlet densities contribute to health disparities.

After controlling for deprivation, we did not find a statistically significant relationship between racial composition and cannabis outlet density. These results align with recent work examining associations of non-white population and cannabis outlets across the USA that similarly conclude that cannabis outlet locations are likely driven by socioeconomic factors, as opposed to community racial composition.[22]

We found a negative association between the rate of non-white population and alcohol outlet density. These results were robust to both on-premises and off-premises outlets and are contrary to most prior work.[9 18 26] These findings may be explained by differences in local demand. According to nationally representative data, non-white populations have a lower prevalence of past-month alcohol use than white populations.[20] Moreover, minority-prominent neighbourhoods in Michigan have experienced historic disinvestment, resulting in economic and social deterioration. As a result, these neighbourhoods may be less able to support retail establishments, including alcohol outlets. Overall, these results imply that alcohol outlet market practices in Michigan appear more strongly driven by socioeconomic conditions rather than race.

Cannabis outlet densities in Michigan were highest in and around deprived CBGs. This may be the result of state and local zoning ordinances that restrict outlets away from highly resourced residential neighbourhoods, or from market driven practices that seek to maximise profit by locating in neighbourhoods with lower operating costs.

Furthermore, alcohol outlet density was highest in deprived areas and around more resourced neighbouring areas, consistent with the prior national and international literature base.[17–19] Contrary to the maturing cannabis marketplace in Michigan, the alcohol marketplace is largely established. This finding may reflect a history of city zoning practices that restrict undesirable alcohol outlets from entering affluent neighbourhoods, resulting in their concentration in resource-deprived neighbourhoods without zoning restrictions.[38] This effect may disproportionately burden disadvantaged neighbourhoods, as alcohol outlets are linked to adverse health outcomes.[6–8]

This study expanded on the literature by examining a novel measure of cannabis and alcohol outlet co-density. In Michigan, CBGs with greater deprivation are exposed to greater concentrations of both cannabis and alcohol outlets. We largely found negative relationships between co-density categories and racial composition, implying that socioeconomic deprivation plays a stronger role in outlet co-density. This may be a function of mixed land use patterns, such as commercial and industrial zoning, being more common in lower income municipalities, and may represent an inequity of the built environment with the potential to further perpetuate health disparities. The public health implications associated with local outlet co-density are largely unexplored. Emerging research in California has shown that alcohol outlets increase the risk for self-harm outcomes (independent of cannabis outlets),[39] and the presence of adult-use cannabis outlets is associated with non-firearm assault injuries (independent of alcohol outlets).[40] Despite these initial findings, cannabis and alcohol co-density is likely to influence substance (co-) use behaviours and potentially other adverse health outcomes.[11 37] Further research is needed to more broadly understand the public health implications of local outlet co-density.

In Michigan, the distributions of cannabis and alcohol outlet licences are independently governed by the Cannabis Regulatory Agency and the Michigan Liquor Control Commission, respectively. Outlets must meet state and local criteria to be licensed. The state of Michigan currently has per-capita quotas on many alcohol outlet licences; yet, certain mechanisms allow for alcohol licences to be granted over quota limits.[41] Municipal governments can set cannabis outlet quotas; however, they are rare, as they limit cannabis-related tax revenue. Michigan, like all states permitting the establishment of alcohol and cannabis outlets, should develop policies that support equitable outlet distribution, such as robust outlet quota systems that limit the number of outlets that are able to be adopted. Equitable cannabis tax distribution processes that de-emphasise the number of outlets in a jurisdiction may also reduce tax-based motivations for excess cannabis outlet adoption.

Limitations

This work is subject to limitations. We were unable to account for municipality-level zoning that ultimately governs the locations of cannabis and alcohol outlets. To better inform future cannabis and alcohol outlet policy making, future work may examine local level cannabis and alcohol outlet policy mechanisms that drive the relationships between vulnerability and outlet density found here. Prior work has shown that demand for cannabis and alcohol is an important predictor of where outlets are located, and this work was unable to measure demand. This analysis benefits from the inclusion of spatially lagged independent variables, allowing our models to control for the influence of spatial edge effects. Despite this, we acknowledge the potential for broader uncontrolled spatial spillover effects. Cannabis outlet locations may be influenced by markets in bordering states. Future work may examine inter-state spillover effects and their influence on cannabis outlet density. Among the 8386 CBGs in Michigan, we excluded 4.7% with missing Census data from this analysis, which may introduce selection bias if the excluded CBGs are systematically different from the CBGs included in this analysis. Even so, an observation of the locations of these excluded CBGs suggests that most are in non-residential areas that would therefore not be relevant to our analyses. Finally, this is a cross-sectional investigation of cannabis and alcohol outlets, and we are unable to examine the temporal relationships that influence where outlets are located and whether outlets are associated with changes in local vulnerability. Compared with alcohol, cannabis is a burgeoning industry in Michigan, and substantial changes in the cannabis regulatory and outlet landscape may occur in the time following this analysis. Future work should continue to monitor Michigan's evolving cannabis environment and its disparate integration with vulnerable neighbourhoods.

Conclusion

Cannabis and alcohol outlets are important aspects of the built environment that play an independent and combined role in the health of the communities where they are positioned. Findings from this study show that cannabis and alcohol outlets are disproportionately located in the most socioeconomically deprived neighbourhoods in Michigan. Future work is needed to examine the public health effects that disproportionate access to cannabis and alcohol outlets has had on Michigan neighbourhoods. Local policymakers should be aware of these findings, as current regulatory frameworks may help perpetuate health disparities related to substance use.

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Acknowledgements Research reported in this publication was supported by the National Institute on Drug Abuse of the National Institutes of Health under Award Number F31DA062439. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Contributors MGM is the article guarantor and was responsible for the conceptualisation, data curation, methodology, software, visualisation, formal analysis, writing and funding acquisition. RCS was responsible for methodology, validation, writing – review and editing and visualisation. CM was responsible for methodology, validation and writing – review and editing. CNM was responsible for methodology, validation and writing – review and editing. JG was responsible for methodology, validation and writing – review and editing. KMB is an article guarantor and was responsible for conceptualisation, validation, resources, writing – review and editing and project administration.

Funding This work was supported by National Institute on Drug Abuse of the National Institutes of Health (grant number 1F31DA062439-01A1).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethics approval for this project was waived by the Michigan State University Institutional Review Board, as this work was deemed non-human subjects.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data are publicly available, but are available upon reasonable request.

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