Spatial autocorrelation patterns and factors associated with regular alcohol consumption behaviour among Thai men

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Abstract

Alcohol consumption is a major health concern in Thailand contributing to addiction and disease. With 17 million Thai men regularly drinking alcohol, cultural norms and environmental factors influence consumption patterns. Geographic Information Systems (GIS) research has established connections between alcohol outlet density and increased drinking. Using Moran's *I*, Local Indicators of Spatial Association (LISA), and spatial regression models, spatial clusters of alcohol consumption were identified across Thai provinces, with Chonburi Province showing the highest rate at 72.2% and Yala the lowest at 28.6%. Regular alcohol consumption among Thai men exhibited a positive spatial correlation, with Moran's *I* equal to 0.477. Bivariate analysis found significant spatial autocorrelation between alcohol outlet density (0.301), population density (0.237) and access to medical facilities (0.290), showing high-high clusters in urbanized areas and low-low clusters in southern regions. Spatial regression using the Spatial Lag Model (SLM) demonstrated that alcohol outlet density, population density and the proportion of the population to medical facilities are significant factors influencing alcohol consumption, explaining 49.2% of the variation in alcohol consumption. The findings suggest the need for targeted public health interventions in high-risk areas, especially in regions with dense alcohol outlets and urban populations, alongside developing policies to promote healthier behaviours and limit alcohol access.

Introduction

Alcohol consumption constitutes a significant global health burden associated with multiple adverse outcomes, including dependency, hypertension, diabetes, and psychiatric disorders. According to the World Health Organization (WHO), alcohol contributes to 5.3% of all global deaths and 5.1% of the global disease burden, with Southeast Asia bearing a disproportionately high share due to limited access to treatment and prevention (WHO, 2024). Between 2015 and 2021, Thailand recorded an estimated annual average of 20,039 alcohol-attributable deaths, with males accounting for the vast majority (17,726 deaths or 6.5% of the total annual male deaths) and females accounting for 2,312 deaths (1.1%) (Thailand National Statistics Office, 2021). While there was a temporary decline during the COVID-19 pandemic, recent

national surveys indicate a resurgence of the problem, especially among young adult males (Wiedemann *et al.*, 2024). By 2014, Thailand had risen to the position of second globally in alcohol consumption rate (Chaiyasong & Thamarangsi, 2016). The leading causes of alcohol-attributable mortality include road traffic injuries, cirrhosis, other liver diseases and other unintentional injuries, highlighting the multifaceted health burden of alcohol consumption in the Thai population (Nontarak *et al*., 2025).

Masculine traditional norms, such as self-sufficiency, emotional restraint and competitive behaviour, exert considerable influence patterns of alcohol consumption. frequently correlate with alcohol consumption (Iwamoto *et al.*, 2011). This association between alcohol use and masculine identity is particularly pronounced among adolescent males navigating the transition between childhood and adulthood, and it is further reinforced through media representations that portray alcohol consumption as an integral component of an engaging social lifestyle (Iwamoto & Smiler, 2013). Social influence from peer groups and the desire for acceptance within predominantly male social environments further compound this issue, contributing to alcohol-related interpersonal violence and domestic disturbance (Sontate *et al.*, 2021). In addition to psychosocial and cultural influences, environmental and spatial factors also shape alcohol use and related behaviours.

Geographic information systems methodology has emerged as a valuable analytical framework for investigating spatial patterns of alcohol consumption (Kassew *et al.*, 2022). Research demonstrates that elevated densities of alcohol retail establishments, particularly those within one-kilometre proximity to residential areas, correlate with increased alcohol consumption (Martín-Turrero *et al.*, 2022). Within Thailand, investigations have established significant associations between alcohol outlet density and heavy consumption patterns among student populations (Vichitkunakorn *et al.*, 2024). However, few studies have spatially analysed adult male alcohol use across the general population at the national level. Existing research is either population-specific or geographically limited, leaving a gap in understanding broader geospatial dynamics of alcohol use. The present study aimed to explore the spatial distribution of regular alcohol consumption among Thai males and to examine how geographic, social and demographic factors interact to influence alcohol use patterns. Using GIS-based methods integrated with nationally representative survey data, this study offers a novel spatial epidemiological approach to understanding alcohol consumption, a methodological innovation that enables identification of high-risk areas and informs place-based public health interventions.

Materials and Methods

Study area

Thailand, located in Southeast Asia, comprises diverse geographic and socio-economic characteristics. It shares borders with Myanmar to the West and North, Laos to the Northeast, Cambodia to the Southeast and Malaysia to the South. The country covers approximately 513,120 km^2 and is administratively divided into 77 provinces, which vary in population density, economic activities and urbanization levels. Thailand's geography consists of four major regions: the mountainous North, the fertile Central Plains, the arid Northeast (Isan) and the tropical South with extensive coastlines. These regional disparities significantly influence socioeconomic conditions, cultural practices and health behaviours, including patterns of alcohol consumption.

Independent variables

This study incorporated five key spatial independent variables: i) alcohol sales points density that is operationalized to the proportion of licensed establishments selling alcoholic beverages both domestic and imported per km^2 with data (obtained from the Alcohol Research Centre (https://kb.hsri.or.th/dspace/handle/11228/11?locale-attribute=en): ii) population density represented by the number of people per km^2 in each province measured as a ratio scale (data sourced from the National Statistics Office (2021)): iii) industrial plant density accounts for the number of industrial plants per km^2 within each province, also measured as a ratio scale, (data retrieved from the National Statistics Office (2021)); iv) proportion of population to medical facilities that is the ratio of the total population to the number of medical facilities in each province, reflecting healthcare accessibility (data obtained from the Department of Health Services Support (https://mrd.hss.moph.go.th/mrd1_hss/); and 5) tourism revenue index represents the total tourism revenue in each province, measured in the Thai baht currency, as documented by the Ministry of Tourism and Sports (https://www.mots.go.th/news/category/628)

Dependent variable

The outcome measure comprised the absolute number of male alcohol consumers per province, extracted from the Population Health Behaviour Survey 2021 by the Thailand National Statistics Office (2021).

Data collection

The raw data for this study was prepared, validated and cleaned thoroughly ensuring its accuracy and reliability. After validation, spatial and non-spatial data were integrated using Quantum GIS (QGIS) version 3.36 creating a shapefile visualizing the prevalence of regular alcohol consumption in Thailand that was used for a detailed spatial analysis carried out. GeoDa version 1.22.

Data analysis

Univariate and bivariate methodology

Global Moran's *I* (1948) was employed to detect broad trends of regular alcohol consumption across the entire country while Local Moran's *I* (Anselin, 1995) was used to pinpoint clusters or hotspots at the local areas. The former was calculated by the following equation:

$$I = \frac{n}{S_0} * \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2} \quad \text{(Eq. 1)}$$

and the latter by:

$$I_i = Z_i \sum_j W_{ij} Z_j \quad \text{(Eq. 2)}$$

where n represents the total number of districts; S_0 the sum of all spatial weights ($S_0 = \sum_i \sum_j w_{ij}$); Z_i and Z_i the standardized deviation of the variable from its mean value $(Z_i = \frac{x_i - \bar{x}}{\sigma})$; and W_{ij} the spatial weight between district i and j.

This study employed Anselin's (1995) local indicators of spatial association to assess the spatial autocorrelation of regular alcohol consumption prevalence among the provinces. Additionally, the LISA framework was also applied to determine whether individual regions were part of a spatial cluster with similar regular alcohol consumption rate values (*i.e.* the High-High (HH) or Low-Low (LL) clusters) or to explore spatial outliers (*i.e.* High-Low (HL) or Low-High (LH) clusters). A spatial weight matrix was constructed using the k-nearest neighbours (k=3) approach based on centroid-to-centroid Euclidean distances between provinces (Tabera Tsilefa & Raherinirina, 2024). The resulting spatial weights were row-standardized to ensure comparability across provinces with varying numbers of neighbours. This matrix was applied in both univariate and bivariate LISA analyses. A total of 999 random permutations were conducted to assess the statistical significance of the local Moran's *I* values, with a threshold of $p< 0.05$ indicating significant clustering.

Spatial regression analysis methodology

In addition, three spatial regression models were considered: Ordinary Least Squares (OLS) that was estimated as a baseline model to examine the linear relationships between alcohol consumption and independent variables. Since OLS does not account for spatial dependence, the diagnostic tests Moran's *I* on residuals and Lagrange Multiplier (LM) tests were performed to determine the need for spatial models. When significant spatial dependence was detected, the spatial lag model was applied. The SLM incorporates a spatially lagged dependent variable to capture spill-over effects. The model equation is given as

$$Y = \rho Wy + X\beta + \varepsilon \quad \text{(Eq.3)}$$

where Y represents the dependent variable (number of male alcohol consumers) and ρWy captures spill-over effects, with W representing the spatial weight matrix and ρ (Rho) the spatial autoregressive coefficient. X is the independent variables; β the coefficient vector; and ε the error term. Alternatively, if spatial dependence was identified in the error terms rather than in the dependent variable, the Spatial Error Model (SEM) was employed. This model accounts for spatial autocorrelation in the residuals using the equation:

$$Y = X\beta + u;\ u = \lambda Wu + \varepsilon \quad \text{(Eq.4)}$$

where λ (lambda) represents the spatial error coefficient that indicates the extent of spatial correlation in the model's residuals. The model selection was based on the Akaike Information Criterion (AIC), Log-Likelihood (LL) and Likelihood Ratio (LR) to determine the best-fit spatial model. To ensure the robustness of the results, the Variance Inflation Factor (VIF) analysis was conducted to assess multicollinearity among the independent variables, while spatial Durbin models were tested to evaluate the presence of indirect effects from neighbouring regions.

Results

The prevalence of regular alcohol consumption among Thai men was 49.6%. The highest provincial prevalence was observed in Chonburi (72.2%), while the lowest was in Yala (28.6%). Provinces were categorized into 10 deciles based on prevalence rates. The highest quintile (57.1%–72.2%), which is represented in the dark red colour in Figure 1, included Chonburi, Buriram, Sa Kaeo, Rayong, Pathum Thani, Phuket, Phrae, and Nong Khai. Conversely, the lowest quintile (28.6%-39.7%), shown in the green colour in the figure, comprised Yala and other southern provinces (Figure 1).

The study reveals a positive spatial correlation for regular alcohol consumption and Thai men, as evidenced by Moran's *I* value of 0.477, a value suggesting moderate spatial autocorrelation, with a significant spatial pattern. HH clusters characterized by elevated alcohol consumption rates were identified in several provinces, including Chonburi, Nakhon Ratchasima, Chanthaburi, Lampang, Chachoengsao, Prachinburi, Rayong and Samut Prakan. Conversely, LL clusters, indicating notably lower consumption rates, were found in the provinces of Songkhla, Surat Thani, Yala, Phatthalung, Chai Nat, Pattani and Narathiwat (Table 1 and Figure 2). The bivariate analysis examining the relationship between the density of alcohol outlets and regular alcohol consumption among Thai men demonstrated moderate spatial autocorrelation, as indicated by Moran's *I* value of 0.301. This finding suggests that areas with either high or low alcohol consumption are more likely to be spatially clustered rather than randomly distributed. HH clusters, characterized by both a high density of alcohol outlets and elevated alcohol consumption, were observed in the provinces of Chonburi, Rayong, and Samut Prakan. Conversely, LL clusters, where there is a low density of alcohol outlets and lower rates of alcohol consumption, were identified in the provinces of Songkhla, Surat Thani, Yala,

Table 1. Spatial distribution of regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.477	Chonburi*	Songkhla*			0.05*
	NakhonRatchasima*	SuratThani*			0.01**
	Chanthaburi**	Yala***			0.001***
	Lampang*	Phatthalung*			
	Chachoengsao***	ChaiNat*			
	Prachinburi***	Pattani**			
	Rayong*	Narathiwat***			
	SamutPrakan*				

HH, high-high clustering; LL, low-low clustering; *low-level significance; **moderate level of significance; ***strong level of significance.

Phatthalung, Chai Nat, Pattani, and Narathiwat (Table 2 and Figure 3).

Moran's *I* for the bivariate analysis of population density and regular alcohol consumption among was 0.237, indicating moderate spatial autocorrelation. Here HH clusters were observed in provinces such as Chonburi and Samut Prakan, urbanized areas where alcohol consumption rates are relatively high, likely due to greater access to alcohol outlets. Conversely, LL clusters, were identified in provinces such as Songkhla, Surat Thani, Yala, Phatthalung, Chai Nat, and Narathiwat (Table 3 and Figure 4).

The relationship between industrial density and regular alcohol consumption among Thai men produced a Moran's I value of 0.060 indicating very weak spatial autocorrelation and implying that variations in alcohol consumption across regions are not strongly influenced by industrial density patterns, and that the distribution of alcohol consumption are more random (Table 4 and Figure 5). With regard to the proportion of the population to medical facilities and regular alcohol consumption among Thai men Moran's *I* was 0.290 indicating moderate spatial autocorrelation. Notably, HH clusters, characterized by both a high proportion of the population to medical facilities and elevated alcohol consumption, were identified in provinces such as Nakhon Ratchasima and Lampang, while LL clusters were located in Yala, Phatthalung, Chai Nat, Pattani, and Narathiwat (Table 5 and Figure 6).

The bivariate analysis of tourism revenue and regular alcohol consumption among Thai men yielded a Moran's I value of 0.052 indicating a weak spatial autocorrelation. This suggests that the relationship between tourism revenue and alcohol consumption does not exhibit a clear spatial clustering pattern (Table 6 and Figure 7).

The spatial modelling results from OLS regression indicated that the density of alcohol outlets, population density, and the proportion of the population to medical facilities were significant factors influencing regular alcohol consumption among Thai men. The OLS model explained 24.5% of the variation in alcohol consumption (R^2=0.2448). The SLM and SEM approaches enhanced the explanatory power, with the former accounting for 49.2% of the variation (R^2=0.4919) and the latter for 48.0% (R^2=0.4803). The values of the AIC, as well as the Bayesian Information Criterion (BIC) indicated that SLM performed best (AIC = 487.447, BIC = 503.853), with SEM resulting in AIC = 488.542 and BIC = 502.605. Therefore, SLM with the highest R^2 value (49.2%), was considered the most effective in explaining the spatial distribution of regular alcohol consumption among Thai men (Table 7).

Discussion

The results reported above shows that the prevalence of regular alcohol consumption among Thai men exhibits significant provincial variation throughout the country, with Chonburi Province recording the highest prevalence and Yala Province the lowest. In

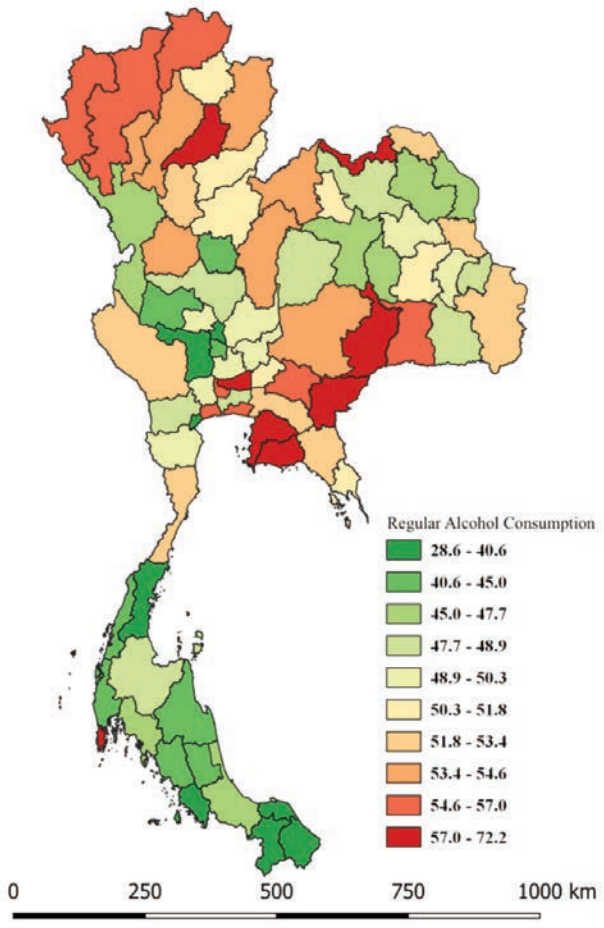

Figure 1. Spatial distribution of regular alcohol consumption prevalence among Thai males by province (quintile classification). Provinces are grouped into 10 deciles based on the prevalence of regular alcohol consumption, ranging from lowest (28.59%-39.71%) to highest (57.12%-72.23%). Each decile is represented by a distinct colour gradient, with red colour indicating higher prevalence rates.

Table 2. Bivariate analysis of density of alcohol outlets and regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.301	Chonburi*	Songkhla*	NakhonRatchasima*		0.05*
	Rayong*	SuratThani*	Chanthaburi**		0.01**
	SamutPrakan*	Yala***	Lampang*		0.001***
		Phatthalung*	Chachoengsao***		
		ChaiNat*	Prachinburi***		
		Pattani**			
		Narathiwat***			

HH, high-high clustering; LL, low-low clustering; LH, outlier clustering (low-high); *low-level significance; **moderate level of significance; ***strong level of significance.

numerous regions, alcohol constitutes a central element of socialization and community traditions as cultural and traditional factors significantly influence these patterns. In the North, consuming boiled liquor during community events and ceremonies is considered essential to social gatherings (Moolasart & Chirawatkul, 2012). Furthermore, the colder climate in certain northern regions contributes to alcohol consumption preferences, as it is traditionally believed to provide warmth. This practice is transmitted intergenerationally and continues to shape contemporary drinking behaviours (Ventura-Cots *et al.*, 2019). Overall, the intertwining of cultural traditions, environmental conditions, and historical practices highlights the complexity behind alcohol consumption patterns, demonstrating how deeply embedded these practices are in regional identities and social structures.

Accessibility of alcohol within different regions can indeed influence consumption patterns significantly. In the Northeast of Thailand, where alcohol production is more concentrated, the ease of access can lead to higher consumption rates, as locally produced beverages are more readily available and potentially cheaper. This can result in alcohol becoming a more integral part of social and community activities. In contrast, the northern region's fewer official production sites may limit accessibility to commercially pro-

Table 3. Bivariate analysis of population density and regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.237	Chonburi*	0.05*	NakhonRatchasima*	Pattani**	0.05*
	SamutPrakan*	0.01**	Rayong*		0.01**
		0.001***	Chanthaburi**		
			Lampang*		0.001***
			Chachoengsao***		
			Prachinburi***		

HH, high-high clustering; LL, low-low clustering; LH, outlier clustering (low-high); *low-level significance; **moderate level of significance; ***strong level of significance.

Table 4. Industrial plant density and regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.060	Chonburi*	Songkhla*	NakhonRatchasima*		0.05*
	Rayong*	SuratThani*	Chanthaburi**		0.01**
	SamutPrakan*	Yala***	Lampang*		
		Phatthalung*	Chachoengsao***		0.001***
		ChaiNat*	Prachinburi***		
		Pattani**			
		Narathiwat***			

HH, high-high clustering; LL, low-low clustering; LH, outlier clustering (low-high); *low-level significance; **moderate level of significance; ***strong level of significance.

Table 5. Proportion of population to medical facilities and regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.290	NakhonRatchasima*	Yala***	Chonburi*	Songkhla*	0.05*
	Lampang*	Phatthalung*	Rayong*	SuratThani*	0.01**
		ChaiNat*	Chanthaburi**		0.001***
		Pattani*	Chachoengsao***		
		Narathiwat***	Prachinburi***		
			SamutPrakan*		

HH, high-high clustering; LL, low-low clustering; LH, outlier clustering (low-high); *low-level significance; **moderate level of significance; ***strong level of significance.

Table 6. Proportion of tourism revenue and regular alcohol consumption among Thai men.

Moran's *I*	Local indicators of spatial association (LISA)				P-values
	HH	LL	LH	HL	
0.052	Chonburi*	SuratThani*	Chanthaburi**	Songkhla*	0.05*
	NakhonRatchasima*	Yala***	Lampang*		0.01**
	Rayong*	Phatthalung*	Chachoengsao***		0.001***
		ChaiNat*	Prachinburi***		
		Pattani**	SamutPrakan*		
		Narathiwat***			

HH, high-high clustering; LL, low-low clustering; LH, outlier clustering (low-high); *low-level significance; **moderate level of significance; ***strong level of significance.

duced alcohol, possibly leading to different patterns of consumption, such as reliance on locally brewed or unregulated products (Talek *et al.*, 2024). The lack of regulations in production can also influence the types of alcohol consumed and the safety of these products. These regional differences in accessibility are crucial in understanding and addressing patterns of alcohol consumption and their social impact.

Tourism and economic factors also contribute to alcohol consumption behaviours. Provinces with high tourist influxes, such as Phuket, experience increased alcohol consumption due to higher population density and enhanced socialization opportunities (Örnberg & Room, 2014). Local economies dependent on tourism often demonstrate elevated alcohol consumption rates. Conversely, in certain southern regions of Thailand where religious practices, like those of some Buddhist communities, have a strong influence, alcohol consumption may be lower. Religious and cultural beliefs can often lead to stricter social norms and reduced accessibility to alcohol (Phoosuwan, 2019). These communities may enforce prohibitions or discourage drinking, resulting in different consumption behaviours compared to more tourist-driven areas. Overall, the interplay between tourism, local economic dependence on alcohol sales, and cultural or religious factors creates a diverse landscape of alcohol consumption patterns across different regions. The bivariate analysis and LISA results indicated moderate spatial autocorrelation, suggesting clustering patterns in alcohol consumption and outlet density. HH clusters were identified in highly urbanized and tourism-centric provinces, suggesting a relationship wherein outlet availability facilitates consumption. The strong positive correlation between alcohol outlet density and consumption implies that alcohol accessibility constitutes a primary driver of regular consumption patterns in these regions. A key contributing factor is the concentration of alcohol production in the central region, leading to greater availability and competitive pricing (Jernigan & Babor, 2015). Additionally, socio-cultural factors and tourism-driven economies in eastern provinces likely contribute to normalized alcohol consumption, particularly among younger populations. These findings align with research conducted in Spain that established a positive relationship between alcohol

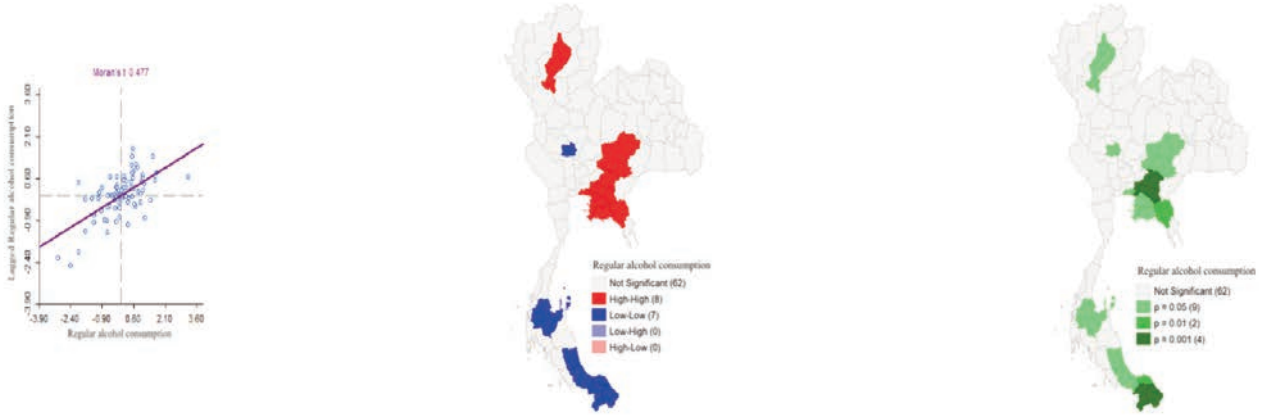

Figure 2. Moran's *I* and LISA analysis of regular alcohol consumption among Thai men.

Table 7. Spatial regression models that influence the regular alcohol consumption of Thai men.

Spatial factors	OLS	Spatial regression model	
		SLM	SEM
Density of alcohol outlets	1.830**	1.505***	1.506**
Population density	-0.013**	-0.011**	-0.009**
Population to medical facilities proportion	0.0004*	0.0003*	0.0002
Constant	45.304	20.947	46.660
ρ (the spatial autoregressive coefficient)	-	0.514	-
Lamda (the spatial error coefficient)	-	-	0.213
R^2	24.48	49.03	48.03
AIC (the Akaike information criterion)	509.086	487.547	488.542
BIC (Bayesian information criterion)	523.149	503.853	502.605
Moran's *I*	4.321***		
SLM	3.061***	49	
SEM	15.869***		

OLS, ordinary least squeres; SLM, spatial lag model; SEM, spatial error model; *correlation significance at the 0.05 level; ** correlation significance at the 0.01 level; *** correlation significance at the 0.001 level.

outlet density and consumption (Marco *et al.*, 2017). Moreover, the cultural acceptance of drinking in certain Thai regions integrates alcohol consumption into social practices, especially in tourist areas (Pedrero-García, 2018). Addressing alcohol consumption in such contexts necessitates both access control and public education to mitigate potential health risks.

The moderate spatial autocorrelation observed between population density and alcohol consumption suggests clustering of regions with similar consumption behaviours based on population density. HH clusters in urban provinces, such as Chonburi and Samut Prakan, reflect urbanization processes where population density facilitates access to alcohol outlets. This relationship indicates how urbanization and higher population densities may create increased opportunities for alcohol consumption through greater availability and social interactions. However, the weak negative correlation between population density and alcohol consumption

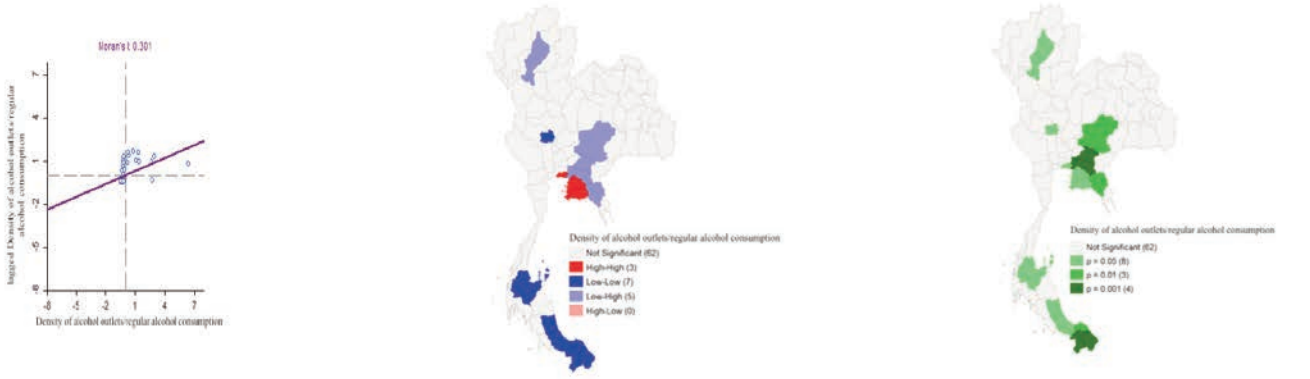

Figure 3. Moran's *I* and LISA analysis of density of alcohol outlets and regular alcohol consumption among Thai men.

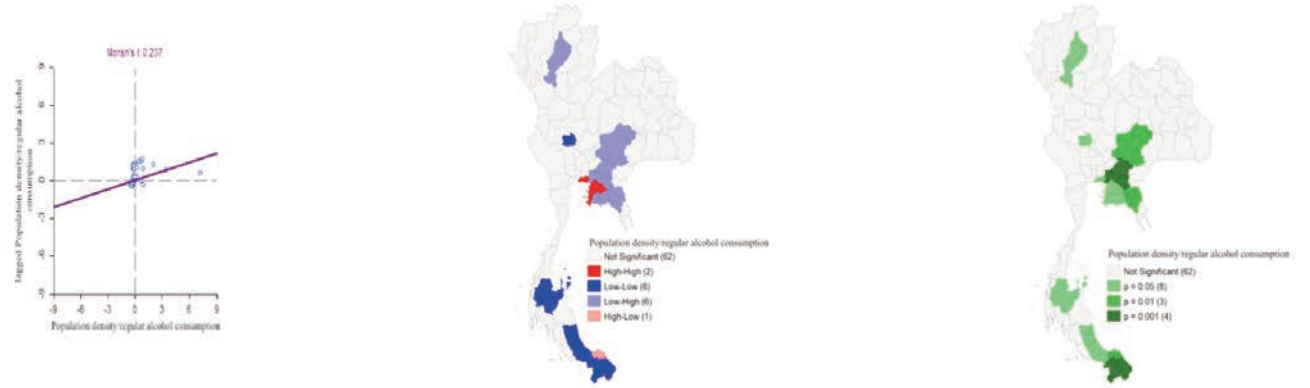

Figure 4. Moran's *I* and LISA analysis of population density and regular alcohol consumption among Thai men.

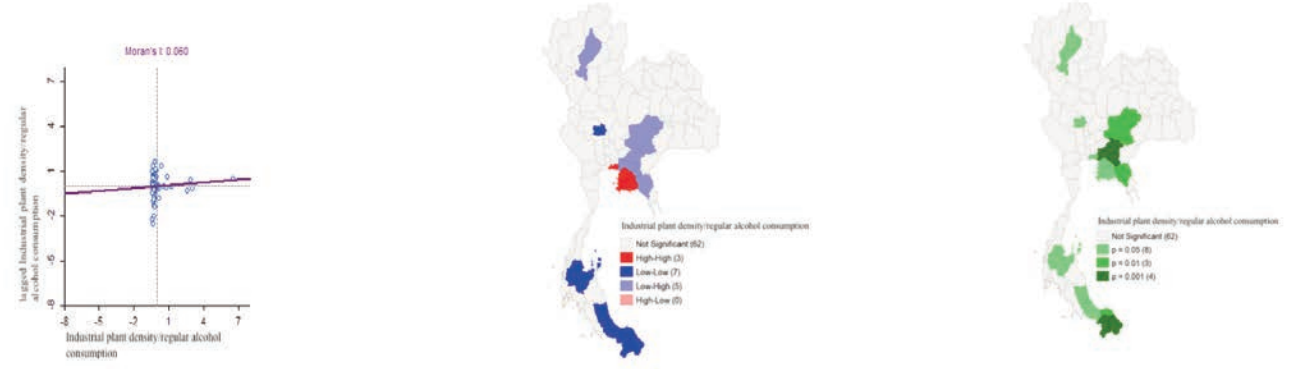

Figure 5. Moran's *I* and LISA analysis of industrial plant density and regular alcohol consumption among Thai men.

suggests that population density itself is not a significant driver of consumption patterns. While urban areas may have more outlets, the relationship with alcohol consumption may be overshadowed by other factors such as cultural attitudes, local regulations, and alcohol availability (Dixon & Chartier, 2016). The weak correlation further suggests that in densely populated areas, alcohol consumption might be influenced more by socio-economic status, educational attainment, and lifestyle factors rather than population numbers alone. This finding aligns with previous research indicating that urbanization can have variable effects on alcohol consumption, with social factors exerting greater impact than population density (Collins, 2016; Sun *et al.*, 2019). The absence of a stronger correlation suggests that while population density may increase social interactions, it is not the primary factor driving alcohol consumption in these regions. Instead, a combination of social, economic, and cultural factors appears to exert a greater impact on these behaviours. This complex interplay suggests that interventions to moderate alcohol consumption need to consider a broad range of contextual factors beyond merely controlling population density or urbanization.

The bivariate analysis between the proportion of population to medical facilities and alcohol consumption demonstrated moderate spatial autocorrelation (Moran's I = 0.290), with clustering of regions exhibiting both high population-to-medical-facility ratios and high alcohol consumption rates, as observed in provinces like Nakhon Ratchasima and Lampang. However, the negligible positive correlation (0.0003) between medical facility availability and alcohol consumption suggests limited direct influence of healthcare infrastructure on consumption behaviours. This finding indicates that while healthcare access is essential for public health promotion, it does not significantly impact alcohol consumption independently, particularly in areas where healthcare services may be underutilized or where consumption is predominantly influenced by cultural factors (Sudhinaraset *et al.*, 2016). Limited access to timely health services in rural or remote regions could exacerbate alcohol-related harm due to insufficient infrastructure and personnel for effective health education campaigns (Davis & O'Neill, 2022). Inadequate healthcare access in certain regions may contribute to insufficient alcohol-related education and prevention efforts, increasing vulnerability to alcohol-related health issues (Manthey *et al.*, 2023). Furthermore, the mere availability of medical facilities may not translate into effective interventions unless

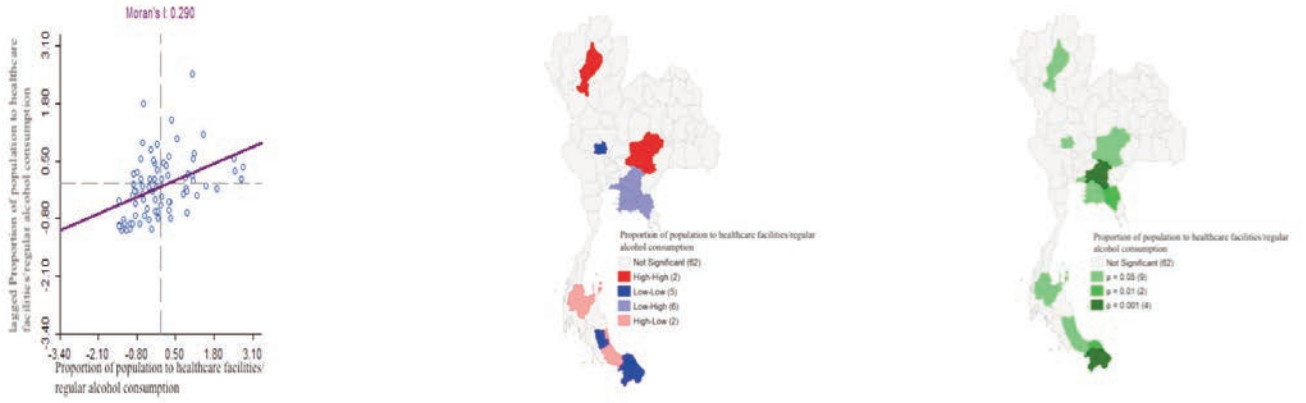

Figure 6. Moran's *I* and LISA analysis of the proportion of population to healthcare facilities and regular alcohol consumption among Thai men.

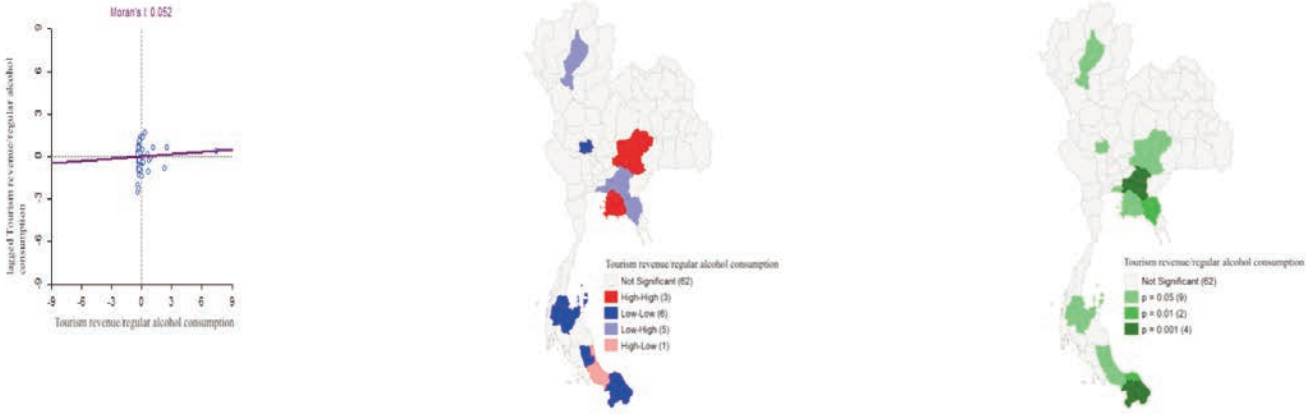

Figure 7. Moran's *I* and LISA analysis of tourism revenue and regular alcohol consumption among Thai men.

complemented by targeted public health campaigns addressing local beliefs and behaviours. In areas where alcohol consumption is influenced by cultural, social, and religious factors, merely increasing healthcare access may be insufficient to reduce consumption. Therefore, enhancing healthcare infrastructure, while integrating public health education with cultural understanding, could more effectively reduce alcohol consumption in these regions.

Strength and limitations

This study employs advanced spatial analysis techniques, providing a detailed understanding of the geographical distribution of alcohol consumption patterns in Thailand. The identification of HH and LL consumption clusters across provinces offers valuable insights for targeted interventions and resource allocation. By examining multiple factors such as alcohol outlet density, population density, industrial plant density, medical facilities, and tourism revenue, the study presents a comprehensive analysis of influences on alcohol consumption. The spatial regression models, SLM and SEM in particular, enhance the explanatory power of the analysis and provide a robust understanding of spatial dependencies in consumption patterns. Nevertheless, several limitations warrant consideration. For example, the reliance on provincial-level data potentially obscures finer variations in alcohol consumption within individual areas. In addition to the factors studied, socio-economic status, education levels, and local regulations, which may significantly influence consumption patterns, remain unexamined. The analysis of tourism revenue, which demonstrated no significant spatial autocorrelation, suggests that tourism may not directly impact alcohol consumption patterns in the studied regions, indicating possible limitations in tourism revenue measurement methodology or its actual influence on consumption behaviours.

Conclusions

This study provides a comprehensive analysis of the spatial distribution and factors influencing regular alcohol consumption among Thai men. The findings highlight the significance of alcohol outlet density, population density, and access to medical facilities as contributors to consumption patterns. Areas with higher alcohol outlet density and urbanization demonstrated higher consumption levels. The spatial regression models, particularly SLM, underscored the importance of spatial dependencies in explaining provincial variation in alcohol consumption. The results emphasize the need for targeted public health interventions in high-risk provinces and areas with high alcohol outlet densities. Future research should consider longitudinal data to better understand causal relationships and incorporate additional socio-economic and cultural factors.

References

Anselin L. 1995. Local indicators of spatial association—LISA. Geograph Anal 27:93-115.

Chaiyasong S, Thamarangsi T. 2016. Provincial alcohol index and its relationship to alcohol-related harm in Thailand: implications for subnational alcohol policy development. BMC Public Health 16:541.

Collins SE. 2016. Associations between socioeconomic factors and alcohol outcomes. Alcohol Res 38:83-94.

Davis CN, O'Neill SE. 2022. Treatment of alcohol use problems among rural populations: a review of barriers and considerations for increasing access to quality care. Curr Addict Rep 9:432-444.

Dixon MA, Chartier KG. 2016. Alcohol use patterns among urban and rural residents: demographic and social influences. Alcohol Res 38:69-77.

Iwamoto DK, Smiler AP. 2013. Alcohol makes you macho and helps you make friends: The role of masculine norms and peer pressure in adolescent boys' and girls' alcohol use. Substance Use Misuse 48:371-8.

Iwamoto DK, Cheng A, Lee CS, Takamatsu S, Gordon D, 2011. "Man-ing" up and getting drunk: the role of masculine norms, alcohol intoxication and alcohol-related problems among college men. Addict Behav 36:906-11.

Jernigan DH, Babor TF. 2015. The concentration of the global alcohol industry and its penetration in the African region. Addiction 110:551-60.

Kassew T, Liyew B, Tarekegn GE, Wondie M, Alamneh TS, Asnakew S, Shumet S, 2022. Spatial distribution and determinants of alcohol consumption among pregnant women in Ethiopia: Spatial and multilevel analysis. PLoS One 17:e0279405.

Manthey J, Kokole D, Riedel-Heller S, Rowlands G, Schäfer I, Schomerus G, Soellner R, Kilian C, 2023. Improving alcohol health literacy and reducing alcohol consumption: recommendations for Germany. Addict Sci Clin Pract 18:28.

Marco M, Freisthler B, Gracia E, López-Quílez A, Lila M, 2017. Neighborhood characteristics, alcohol outlet density, and alcohol-related calls-for-service: A spatiotemporal analysis in a wet drinking country. ISPRS Int J Geo-Informat 6:380.

Martín-Turrero I, Valiente R, Molina-de la Fuente I, Bilal U, Lazo M, Sureda X, 2022. Accessibility and availability of alcohol outlets around schools: An ecological study in the city of Madrid, Spain, according to socioeconomic area-level. Environ Res 204:112323.

Moolasart J, Chirawatkul S. 2012. Drinking culture in the Thai-Isaan context of northeast Thailand. Southeast Asian J Trop Med Public Health 43:795.

Nontarak J, Rehm J, Rovira P, Assanangkornchai S, 2025. Alcohol-attributable deaths in Thai people from 2015 to 2021 using the comparative risk assessment approach. Alcohol Clin Exper Res 49:142-52.

Örnberg JC, Room R, 2014. Impacts of tourism on drinking and alcohol policy in low-and middle-income countries: a selective thematic review. Contemporary Drug Problems 41:145-69.

Pedrero-García E. 2018. Nightlife and alcohol consumption among youths: the botellón phenomenon in Spain. Sage Open 8:2158244018800903.

Phoosuwan N. 2019. Prevalence and factors related to alcohol consumption among undergraduate students in a Northeast Thailand province. Public Health J Burapha University 14(1).

Sontate KV, Rahim Kamaluddin M, Naina Mohamed I, Mohamed RMP, Shaikh MF, Kamal H, Kumar J. 2021. Alcohol, aggression, and violence: from public health to neuroscience. Front Psychol 12:699726.

Sudhinaraset M, Wigglesworth C, Takeuchi DT. 2016. Social and cultural contexts of alcohol use: influences in a social-ecological framework. Alcohol Res 38:35-45.

Sun Y, Li J, Jin X, Xiao H, He Z, Su S, Weng M. 2019. Intra-urban excessive alcohol drinking: Geographic disparities, associated neighborhood characteristics and implications for healthy city planning. Sustainable Cities Soc 46:101414.

Tabera Tsilefa S, Raherinirina A. 2024. Spatial Markov matrices for measuring the spatial dependencies of an epidemiological spread : case Covid'19 Madagascar. BMC Public Health 24:2243.

Talek M, Vichitkunakorn P, Assanangkornchai S, Wichaidit W, 2024. Global alcohol policy implementation in Thailand: a narrative review. Int J Alcohol Drug Res 12:S18-S27.

Thailand National Statistics Office. 2021. Health behavior of population survey. Available from: https://www.nso.go.th/nsoweb/nso/survey_detail/w6?set_lang=en

Ventura-Cots M, Watts AE, Cruz-Lemini M, Shah ND, Ndugga N, McCann P, Barritt ASt, Jain A, Ravi S, Fernandez-Carrillo C, Abraldes JG, Altamirano J, Bataller R, 2019. Colder weather and fewer sunlight hours increase alcohol consumption and alcoholic cirrhosis worldwide. Hepatology 69:1916-30.

Vichitkunakorn P, Assanangkornchai S, Thaikla K, Buya S, Rungruang S, Talib M, Duangpaen W, Bunyanukul W, Sittisombut M. 2024. Alcohol outlet density and adolescent drinking behaviors in Thailand, 2007-2017: A spatiotemporal mixed model analysis. PLoS One, 19:e0308184.

WHO. 2024. Alcohol. Available from: https://www.who.int/news-room/fact-sheets/detail/alcohol

Wiedemann A, Jones PB, Burn AM. 2024. Impact of the COVID-19 pandemic on young adults' mental health and beyond: a qualitative investigation nested within an ongoing general population cohort study. Soc Psychiatry Psychiatr Epidemiol 59:2203-13.