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Spatial association of socioeconomic and health service factors with antibiotic self-medication in Thailand

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Abstract

Antibiotic Self-Medication (ASM) is a major contributing factor to Antimicrobial Resistance (AMR) that can lead to both mortality and long-term hospitalizations. High provincial ASM proportions associated with mortality due to AMR have been observed in Thailand but there is a lack of studies on geographic factors contributing to ASM. The present study aimed to quantify the distribution of ASM in Thailand and its correlated factors. Socioeconomic and health services factors were included in the spatial analysis. Moran's *I* was performed to identify global autocorrelation with the significance level set at p=0.05 and spatial regression were applied to identify the factors associated with ASM, the proportion of which is predominant in the north-eastern, central and eastern regions with Phitsanulok Province reporting the highest proportion of Thailand's 77 provinces. Autocorrelation between Night-Time Light (NTL) and the proportion of ASM was observed to be statistically significant at p=0.030. The Spatial Lag Model (SLM) and the Spatial Error Model (SEM) were used with the latter providing both the lowest R^2 and Akaike Information Criterion (AIC). It was demonstrated that the proportion of alcohol consumption significantly increased the proportion of ASM. The annual number of outpatient department visits and the average NTL decreased the proportion of ASM by 1.5% and 0.4%, respectively. Average monthly household expenditures also decreased the ASM proportion. Policies to control alcohol consumption while promoting healthcare visits are essential strategies to mitigate the burden of AMR in Thailand.

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Introduction

Antibiotic Self-Medication (ASM), *i.e.* the use of antibiotics without a physician's prescription significantly impacts society by promoting antibiotic resistance, especially in low- and middle-income countries where it is particularly common (Torres *et al.*, 2019). This practice burdens healthcare systems with higher costs leads to ineffective treatments and increases the prevalence of Antimicrobial Resistance (AMR) which can spread widely (Sachdev *et al.*, 2022). Contributing factors include limited access to healthcare, unregulated drug availability and insufficient awareness of the dangers of antibiotic misuse (Ayukekbong *et al.*, 2017). According to the World Health Organization (WHO), ASM is a growing problem which contributes to higher mortality rates and longer hospitalizations (Najmi *et al.*, 2019; Touat *et al.*, 2021). Patients infected by bacteria resistant to several different antibiotics require more effective treatment, which results in higher treatment costs (Imai *et al.*, 2022). ASM users also experience adverse drug reactions which may delay appropriate diagnosis and treatment (Belkina *et al.*, 2014; Rabin *et al.*, 2013). Addressing these issues through public education and improved healthcare policies is essential to reduce self-medication and its societal consequences (Rather *et al.*, 2017).The ASM proportion rates in Africa are estimated at a broad rangebetween 12.1% and 93.9% (Yeika *et al.*, 2021). Similarly, the overall ASM proportion in Asia has been estimated at 85.6% (Nepal & Bhatta, 2018). Previous studies report ASM proportions in Thailand at ≥37.7% (Sirijoti *et al.*, 2014). Urban areas and monthly income are variables associated with ASM behaviour (Ayana *et al.*, 2021; Ocan *et al.*, 2015), while poor knowledge regarding antibiotic use contributes significantly (Mate *et al.*, 2019; Mboya *et al.*, 2018). Urbanization is a geographical factor associated with socioeconomic and factors as well as health status. Night-Time Light (NTL) serves as an indicator representing urbanization and city growth (Sutton *et al.*, 1997). Moreover, NTL is also related to people's circadian rhythms as well as health problems, such as shown for COVID-19 and chronic respiratory infections (Inthisorn & Puttanapong, 2022; Laohasiriwong *et al.*, 2017). Alcohol consumption is likewise associated with urbanization and often with serious physical and mental health problems (Dixon & Chartier, 2016). Furthermore, urbanization increases the capacity of health services and works to improve healthcare access. Thus, higher ability to access healthcare services might decrease health risk behaviours (Shao *et al.*, 2022).

Research carried out so far has focused on population proportions of ASM and contributing factors; nevertheless, there is a lack of studies that mention geographical factors associated with ASM. Identifying such variables can help policymakers establish specific policies to control and mitigate ASM behaviour. The present study aimed to identify the association of the provincial ASM proportion in Thailand with socioeconomic and health service factors through the application of spatial analysis techniques commonly used to quantify the association between geographical factors and the health status in populations.

Materials and Methods

Study area

Thailand, a middle-income country located in Southeast Asia around latitude 15°00' N and longitude of 100°00', E comprises an area of 513,120 km^2 with 66.05 million people across 77 provinces. It shares borders with Cambodia, Malaysia, Laos and Myanmar. The western part of the country adjacent to the Andaman Sea boasts a coastline of 1,660 km. The country also includes several islands in the Gulf of Thailand and the Andaman Sea, with Phuket being the largest. The total territory is divided into four regions: Central, North, Northeast and South (Figure 1). Its climate is influenced by monsoon winds resulting in three distinct climate conditions: the rainy season, winter and summer. Bangkok's metropolitan area serves as the capital city and is home to the largest population in the country.

Variables used, data extraction and sources

To study the distribution and correlation of the provincial presence of ASM, we focused on two groups of factors: A) socioeconomic and B) health services factors. The former group included amount of grocery store income; level of average household expenditures, level of alcohol consumption; amount of informal labour; level of poverty; and amount of NTL, while the latter comprised density of drug stores; ratio of physicians per population; nurses per population; health officers per population; and village health volunteer per population; plus annual number of visits to Outpatient Departments (OPD) and prevalence of two common infections: pneumonia and pharyngitis.

All data were extracted in 2021 from the following sources in Thailand. ASM proportions were obtained from the microdata of the 2021 Health and Welfare Survey conducted by the Thai National Statistical Office (NSO). The number of populations, area size, poverty line and monthly household expenditure in each province are publicly available from the NSO. The number of drug stores, including antibiotic sales, was extracted from the Food and Drug Administration. Annual income of grocery stores and the density of drug stores was taken from the Department of Business Development. The proportion of alcohol consumption in each province is publicly available in the Provincial Alcohol Report 2021 (Wijitkunakorn & Tanaree, 2021). The number of public health staff, including village health volunteers, was extracted from the Thailand Health Data Center (HDC). The number of OPD visits, measured as the number of visits per person per year, was also retrieved from HDC. The prevalence rates of pneumonia and acute pharyngitis came from another HDC website. NTL was extracted in TGZ file format (*i.e.* a GZIP compressed TAR archive) from the Earth Observation Group website and was transformed into the average number of light intensities using the zonal statistic function in Quantum QGIS version 3.16.

Figure 1. Map of Thailand.

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Statistics

Spatial autocorrelation

The overall autocorrelation was investigated by Global Moran's *I* that demonstrates the correlation between the value of factors among nearby locations in space(as per equation 1) akin to the Pearson correlation coefficient. Global Moran's *I* ranges between -1 (no clustering effect) and +1 (a clear clustering effect) and was determined using the following equation based on the work by Pfeiffer *et al.* (2008):

$$I = \frac{n\sum_i \sum_j W_{ij}(Z_i - \overline{Z})(Z_j - \overline{Z})}{(\sum_i \sum_j W_{ij})\sum_k (Z_k - \overline{Z})^2} \quad \text{(Eq. 1)}$$

where z_i is the observed value of area *i*; z_j the observed value of area *j* (which is the neighbour of area *i*); *n* the number of study areas; W_{ij} the spatial weight matrix; and $\overline{z}$ the average value of all observed values. The spatial weight matrix was determined using the distance-band weight method. This study was demonstrated with 999 permutation simulations at a significance level of p=0.05. Global Moran's *I* was also depicted as Moran's scatter plot using GeoDa version 1.2.

Spatial regression analysis

Various regression models were used to evaluate the association between various factors and ASM. Ordinary least squares (OLS) regression was initially used as it is the traditional method for comparing and verifying the spatial models:

$$Y = B_0 + B_1X + e \quad \text{(Eq. 2)}$$

where *Y* (ASM prevalence)is the dependent variable; *X* each of the independent variables (the socioeconomic and health service factors); B_0 the y-intercept; B_1 the effect of the independent variable (*X*) on *Y*; and *e* the error term. We relied mainly on the spatial lag model (SLM)and the spatial error model (SEM), the former of which has the following equation:

$$Y = B_0 + B_1X + \rho WY + e \quad \text{(Eq. 3)}$$

which utilizes two additional parameters: the spatial autoregressive parameter ρ and the spatially lagged dependent variable *WY* according to (Anselin & Griffith, 1988).
The spatial error model (SEM) has the following formula:

$$Y = B_0 + B_1X + \lambda W\varepsilon + e \quad \text{(Eq. 4)}$$

where λ is the spatial error coefficient and $W\varepsilon$ the spatially autocorrelated error term (Suwanlee, 2021).

Following confirmation of spatial autocorrelation, the regression models were employed to explore the association between ASM and the various socioeconomic and health service factors. Akaike's Information Criterion (AIC) (1981) coefficients of determination (R^2) were applied to select the best spatial model (Chicco *et al.*, 2021).

Results

Distribution of ASM in Thailand

Although Global Moran's *I* was negative (-0.049), the value was sufficiently close to zero to be interpreted a sa dispersed pattern for the distribution of ASM in Thailand (Figures 2 and 3). The 10 provinces with the highest ASM rates in proportion to their

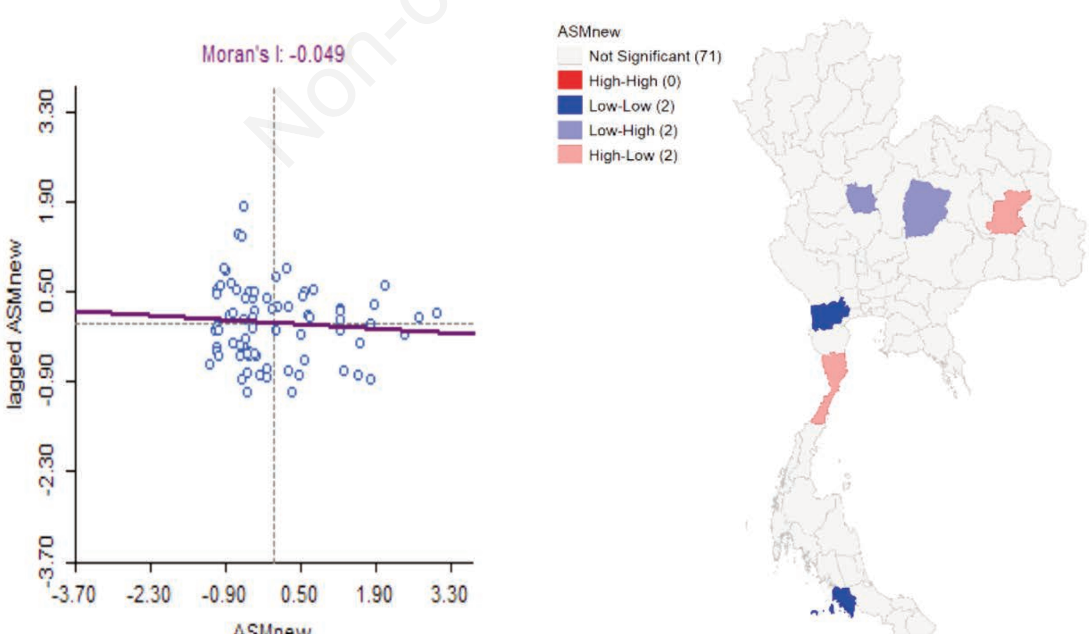

Figure 2. Spatial autocorrelation of the proportion of ASM in the Thai provinces.

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provincial population were Phitsanulok, Ang Thong, Narathiwat, Phetchabun, Sa Kaeo, UbonRatchathani, Chachoengsao, KhonKaen, Nan and Nakhon Phanom, whereas the 10 with the lowest proportion rates were Phatthalung, Lamphun, Phetchaburi, MahaSarakham, Nakhon Nayok, Mukdahan, Ranong, Songkhla, Phang Nga and Samut Sakhon.

Effect of socioeconomic factors onthe provincial distributionof ASM

As seen in Supplementary Materials, Figure 1, the annual income of grocery stores showed a positive autocorrelation (0.010) with the provincial ASM proportion, while the average monthly household expenditure showed a negative autocorrelation (-0.001), and so did the NTL measure (-0.128). Also, the proportion of informal labour provided a negative autocorrelation (-0.009)with the ASM provincial proportion, whereas a positive autocorrelation pattern was observed with regard to population density (0.032). The proportion of poverty level and alcohol consumption showed a negative autocorrelation (-0.052 and -0.041, respectively).

Effect of health-related factors on the provincial distribution of ASM

As seen in Supplementary Materials, Figure 2, positive autocorrelation by Global Moran's *I* was observed between the density of drug stores and the provincial proportion of ASM (0.060), and so was the case for the annual number of OPD visits (0.033), whereas the ratio of physicians per population exhibited a negative autocorrelation pattern (-0.099). A negative autocorrelation was also noted for the number of nurses per population (-0.101), number of public health officers (-0.110) and number of village health volunteers (-0.017)per population served. While the prevalence of pneumonia was positively correlated (0.135), that of acute pharyngitis showed a negative autocorrelation pattern (-0.089).

Spatial regression analysis

All independent variables investigated were subjected to regression using the three spatial models. NTL showed statistical significance using the SLM approach (p=0.006), accounting for 18.6% of the ASM proportion. SEM exhibited the lowest AIC (336.186) and R^2=0.179. SEM revealed that NLT and the number of OPD visits decreased the proportion of ASM by 0.4% and 1.5%, respectively. The average monthly household expenditures also decreased the provincial ASM proportionwith statistical significance, while alcohol consumption increased it,a value also demonstrating statistical significance (p = 0.014) (Table 1).

Discussion

The provinces with high ASM proportions dominate in the north-eastern, central, and eastern regions of Thailand. The overall outcome as judged by AIC and R^2 indicated the SEM would be the preferable technique in this case. Importantly, alcohol consumption was identified as the most important factor in promoting the growth of ASM while increased numbers of OPD visits and increased NTL levels kept it down, demonstrating the need for specific health education programs in these regions to mitigate and control ASM behaviour and related AMR infections in Thailand. The three regression methods used showed similar results, particularly OLS and SEM.

NTL serves as a geographical indicator of city growth and urbanization and was one of the more important geographical factors related to ASM proportion in our study since it also reflects human behaviour associated with health issues (Xu *et al.*, 2016). The proportion of ASM is less in the populations in urban areas than in rural areas due to high density of health clinics and medical services (Ternhag *et al.*, 2014). People living in rural areas mainly resort to ASM due to the long distances to healthcare facilities (Kassie *et al.*, 2018). Differences and variation in health risk behaviour due to location are thus associated with health inequity. Although urbanization leads to better support through healthcare, it also leads to environmental hazards because of industrial growth. Atmospheric Particle Matter (PM), particularly $PM_{2.5}$ is a major consequence of industrial combustion processes that induce acute and chronic diseases, such as bronchitis, hypertension and cardiovascular disease (Pryor *et al.*, 2022).

The average monthly household income and expenditures play an important role with regard to ASM since a better economy is associated with a higher level of using medical services and, thus decreasing the proportion of ASM usage. A study in Japan (Hamada *et al.*, 2019) determined the relationship between household income and health service utilization among elderly people with middle to high household income finding them more likely to utilize OPD services. In addition, they were less likely to visit community drug stores compared to those with low household

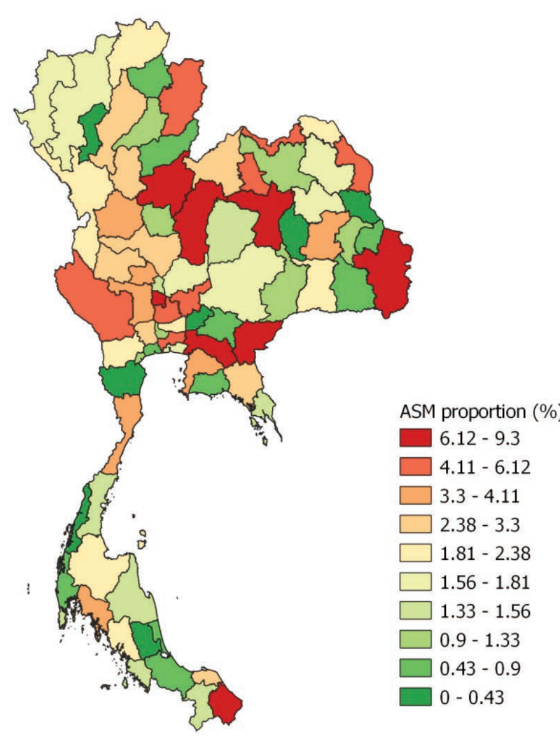

Figure 3. Percentage distribution of ASM proportionby province in Thailand.

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Table 1. Spatial regression of factors investigated reaching statistical significance for association with the provincial ASM proportion.

Factor	OLS (SE)	p	SLM (SE)	p	SEM (SE)	p
Density of drug stores	9.129 (20.554)	0.658	10.334 (19.603)	0.598	13.309 (19.210)	0.448
Number of OPD visits	-1.536 (0.781)	0.053	-1.493 (0.744)	0.044	-1.476 (0.744)	0.047
Monthly household expenditure	-0.00017 (0.0000694)	0.015	-0.00017 (0.0000661)	0.008	-0.00017 (0.0000651)	0.007
Level of alcohol consumption	0.074 (0.029)	0.015	0.073 (0.028)	0.010	0.066	0.014
Level of night-time light (NTL)	-0.459 (0.186)	0.013	-0.482 (0.175)	0.006	-0.440	0.007
ρ	-		-0.130		-	
λ	-		-		-0.107	
Fisher statistic (F-stat)	2.957		-		-	
R^2	0.172		0.185		0.179	
Log-likelihood	-162.331		-161.883		-162.092	
AIC	336.661		337.766		336.186	

SE, standard error; OPD, outpatient departments; ρ, spatial autoregressive parameter; λ, spatial error coefficient; R^2, coefficient of determination; AIC, Akaike's information criterion; Levels of significance:p<0.05, p<0.01**, p<0.001***.*

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income. However, the latter can also be associated with living far from healthcare facilities, which is not uncommon for low-income areas in the U.S. (Guo *et al.*, 2022). Furthermore, lower household income status is also related to illiteracy, a variablenot necessarily associated with geography, which also contributes to inappropriate medical service use (Lazar & Davenport, 2018).

Previous studies reveal that chronic alcohol consumption is highly associated with ASM in people with mental health problems, especially those with suicidal tendencies (Bolton *et al.*, 2006). Similarly, a study from Canada report raised proportions of ASM among individuals with alcoholism and mood swings (Bolton *et al.*, 2009). Alcohol drinkers are commonly medication consumers, a habit that includes antibiotics, often obtained from family members, friends, and other drug users. Moreover, they also tend to keep leftover antibiotics for future use (Starrels *et al.*, 2009). Alcohol consumption is thus likely to increase the proportion of ASM in the population. Moreover, this disorder also contributes to lower access to healthcare facilities, reducing the probability of receiving appropriate medical treatment (Ford *et al.*, 2005). Lower healthcare seeking among individuals with alcoholism has been reported in a study in China (Li & Sun, 2022). In fact, a large number of patients with overconsumption of alcohol never utilized proper healthcare services during their lifetime (Oleski *et al.*, 2010). The reason for thishas been attributed to long waiting times for services and beliefs that healthcare workers provide inappropriate treatment (Starrels *et al.*, 2009).

Our study also revealed that OPD visits decreased ASM proportion by 1.5%. Physicians in primary care units or hospitals prescribe antibiotics appropriately based on rational drug use guidelines that regulate and control the rate of antibiotic prescriptions in healthcare (Thailand Ministry of Public Health, 2016). Pharmacists in hospitals or PCUs provide health knowledge regarding antibiotic use to prevent irrational use among the Thai population (Thailand Ministry of Public Health, 2016). Hospitals and PCUs have developed interventions to control ASM behaviour, and several interventions, such as clinical supervision, manuals, and health interventions, aim to regulate provider prescriptions. Some interventions address ASM regulation, such as market control strategies and limiting drug advertisements, an approach that could reduce prescription and self-medication rates if perused stronger (Bbosa *et al.*, 2014). In addition, healthcare providers, including village health volunteers, also influence access to healthcare for community members. Healthcare providers in rural areas strive to reduce healthcare access barriers, such as cooperation between local administrators and PCU staff to support transportation to healthcare facilities. The use of technology, such as telemedicine or telehealth that were first implemented during the COVID-19 pandemic (Hoffman, 2020; Turnbull et al., 2024) could improve healthcare access and potentially reduce ASM proportion.

Conclusions

Associations between socioeconomic and health services factors and ASM proportion were illustrated in this study. Alcohol consumption increased ASM proportion, while other variables, particularly NTL, average monthly household expenditure and the annual number of OPD visits decreased it. Alcohol consumption should be regulated, with only social drinking promoted, as this can potentially reduce the rate of antibiotic consumption. Community-based healthcare services should be considered and distributed to rural areas to improve healthcare access among the Thai population. Future research and projects should focus on integrated health services, including the delivery of health education, to mitigate ASM proportion and AMR infection-related mortality in Thailand.

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Online supplementary materials

Figure 1. Spatial autocorrelation between the socioeconomic factors investigated and the provincial proportions of ASM.

Figure 2. Spatial autocorrelation betweenthehealth-related factors investigated and the provincial proportions of ASM.