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Geoclimatic risk factors for childhood asthma hospitalization in southwest of Iran

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Abstract

Background: Asthma is a chronic respiratory disease resulting from a complex interaction between genetic and environmental factors. Among environmental factors, climatic and geographical variations have an important role in increasing asthma hospitalization. The current study aimed to investigate the effect of geoclimatic factors on the occurrence of childhood asthma hospitalization in Fars province, southwest Iran.

Method: We mapped the addresses of 211 hospitalized patients with childhood asthma (2016–2019) and investigated the effects of different temperature models, mean annual rainfall and humidity, number of frosty and rainy days, evaporation, slope, and land covers on the occurrence of childhood asthma hospitalization using a geographical information system. The Kriging and Spline methods have been used for generating interpolated models. Data were analyzed using logistic regression.

Results: In the multivariate model, urban setting was recognized as the most important childhood asthma hospitalization predictor ($p < 0.001$, odds ration [OR] = 35.044, confidence interval [CI] = 9.096–135.018). The slope was considered the determinant of childhood asthma hospitalization when analyzed independently and its increase was associated with decreased childhood asthma hospitalization ($p = 0.01$, OR = 0.914, CI = 0.849–0.984).

Conclusion: In the current study, the urban setting was the most important risk factor associated with increased childhood asthma hospitalization.

KEYWORDS

asthma hospitalization, childhood asthma, geoclimatic factors, GIS

1 | INTRODUCTION

Asthma is the most common chronic disease among children, which affects about 7.5% of this population worldwide.[1] Asthma is associated with airway hyper-responsiveness that leads to recurrent episodes of wheezing, breathlessness, chest tightness, and coughing.[1] According to recent studies, its incidence has increased globally in the latter part of the 20th century, especially in developed countries and is associated with psychological and socioeconomic burdens for both children and their families.[2] In Iran, its prevalence was estimated at 4.36–8.8 for children.[3]

Zahra Kanannejad and Mohammad Shomali contributed equally to this study.

Childhood risk factors for asthma include environmental and genetic factors, immunologic parameters, diet and nutrition, decreased lung function in infancy, sex, and gender.[4] Environmental factors such as meteorological conditions, indoor and outdoor air pollution, house dust mites, and geoclimatic conditions play a significant role in the current pediatric asthma epidemic. Some studies have been carried out to investigate the association between asthma and allergies prevalence and such environmental factors throughout the world.[5–7] Geoclimatic conditions in which children live are considered one of the most important environmental factors that can affect asthma development and severity.[8] High air humidity and cold temperature, atmospheric pressure, and storms are all known to trigger asthma in susceptible individuals.[9,10] Climatic factors also can introduce their effects on the occurrence of asthma by determining vegetation type, and pollen season that are major triggers for asthma and allergy development.[11] In addition to climatic factors, geographical variation between different areas plays important role in asthma incidence. Considering that, Krstic[12] has shown an association between geographical latitude and asthma prevalence. López-Silvarrey-Varela et al.[13] also found a clearly defined geographic pattern in patients with asthma, with a higher prevalence in coastal areas than in the interior.

A variety of methods are employed to determine the relationship between the occurrence of asthma and geoclimatic factors. A geographic information system (GIS) can help health professionals to investigate the effect of geoclimatic parameters on the development of diseases.[14,15] In this way, specific diseases and health events can be mapped concerning their surrounding environment.

Childhood asthma is one of the main causes of hospitalization of children and has been increasing in recent years that are most affected by environmental factors.[16] Previous studies investigated the effect of environmental factors, including climatic conditions and air pollution on asthma admission in different areas of Iran (western,[17] southwest,[18] and southern Iran[19]). To the best of our knowledge, no attempt has been made to use GIS as an application for analyzing geoclimatic factors affecting the occurrence of asthma hospitalization in Iran. In this study, for the first time, we aimed to analyze the association between geoclimatic parameters and childhood asthma hospitalization using the GIS approach in Fars province, southwest Iran.

FIGURE 1 Iran map. Fars province is located in southwest Iran. Maps were created with ArcMap from ArcGIS 10.5.

2 | MATERIAL AND METHODS

2.1 | Study area

Fars province is located in southwest Iran, between a longitude of 27°31′ N to 31°42′ N and a latitude of 50°37′ E to 55°38′ E, and covers an area of about 122,608 km^2. Fars province location is illustrated in Figure 1. Fars has a total population of 4.6 million and is divided into 24 counties, and Shiraz is the provincial capital. There are three distinct climatic regions in Fars province: (1) the mountainous area of the north and northwest with moderately cold winters and mild summers, (2) the central region, with relatively rainy mild winters, and hot dry summers, and (3) the region located in the south and southeast with cold winters and hot summers. The average temperature of Shiraz is 16.8°C, ranging between 4.7°C and 29.2°C. Due to geographical and climatic variation of the province, the region encompasses a variety of landscapes from dense forests to bare plains and elevations of 115 to 3115 m above sea level.

2.2 | Study population

The study was conducted based on medical data collected at the Namazi Hospital, Shiraz, Iran from 2016 to 2019. This hospital is the leading reference center for pulmonary diseases in the Fars province and also neighboring provinces. The patients included in the study were selected according to the ICD10 classification (comprising code from group J45 or coexisting with J45 diseases). A database was created including 211 records of hospitalized patients with ages below 18 years. This study was approved by the local Ethics Committees, Shiraz University of Medical Sciences (IR. SUMS. REC.1399.869).

2.3 | Geospatial data

The residence point of each patient was recorded on the map of Fars province based on the latitudes and longitudes of the villages and cities where the patients were reported. The province and land cover vector layers (land cover is the physical material at the surface of the earth) besides the digital elevation model (DEM) raster layer were obtained from the Department of Natural Resources in Fars province. The slope (gradient of surface; degree unit) raster map was drawn through the spatial analyst tool, based on DEM, by calculating the maximal rate of alteration in value between each cell and its adjacent cells, and the land cover layer shows spatial data on the different physical characteristics of the surface of the province.

The meteorological data related to the time of the study were required from the Fars Province Weather Bureau. These data included values of the temperature, humidity, evaporation, and the frequencies of frosty and rainy days, from 18 synoptic meteorological stations, and rainfall data from 86 rain-gauge stations. Mean annual temperature (MAT), maximum mean annual temperature (max MAT), minimum mean annual temperature (min MAT), mean annual humidity (MAH), mean annual rainfall (MAR), mean annual evaporation (MAE), mean annual rainy (MARD) and frosty days (MAFD), and mean annual sunny hours (MASH) were calculated. The annual iso-hydral, iso-humid, and frost days' raster layers were generated using the Kriging interpolation model, and iso-thermal, iso-evaporation, and rainy days' raster layers using the tension based on the Spline interpolation model with a resolution grid of 2 × 2 km.

2.4 | Geospatial analysis

Statistical analysis was performed using ArcGIS version 10.5 to analyze geospatial and climatic data. The provincial villages and cities point shape file layer was extracted with the raster layers. The identity tool was used to compute the geometric intersection of the layer obtained from the extraction of all raster layers with NTR hazard (polyline) and land cover (polygonal) vector layers to develop the final layer in which each point represented the properties of all the overlapped identity features from the above-mentioned raster and vector layers. The attribute of this layer was converted to an Excel format for statistical analysis.

2.5 | Statistical analysis

The association between childhood asthma hospitalization and geoclimatic parameters was assessed after the spatial description of patients in Fars province. In this regard, residential points data including asthma reported and nonreported villages and cities were extracted from the final province villages/cities point layer and analyzed using univariate and multivariate logistic regression models. The statistical analyses were performed using SPSS version 21.

3 | RESULTS

3.1 | Characteristics of the study population

The mean age of the patients with childhood asthma was 9.19 ± 0.31 years. Boys comprised slightly more than half of the study population. Other characteristics of the study population are summarized in Table 1.

3.2 | Geoclimatic distribution of points with childhood asthma

A total of 211 patients with childhood asthma were identified from hospital records living in 56 points in the province. This population represented 0.68% of the 8191 villages and cities in Fars province. Childhood asthma cases were reported in regions with different geoclimatic conditions. Figure 2A, B illustrated the distribution of points with childhood asthma according to elevation (DEM) and slope parameters, respectively. Elevation and slope ranged from 391 to 2318 m and 0.114877° to 20.4°, respectively, for these points.

MAT, minMAT, and maxMAT varied from 13.8°C to 27°C, 6.4°C to 18.9°C, and 20.4°C to 32.2°C, respectively for points with asthma report (Figure 3A–C, respectively).

The range of MAE was between 1659.5 and 3291.5 mm, and MAH and MAR levels were between 31.7% and 42% and 137.7 and 523.4 mm, respectively (Figure 4A–C), and the MARD, MAFD, and MASH ranged between 18 and 60, 0.09 and 90.11 days, and 3227.17 and 3528.26 h, respectively within villages or cities with childhood asthma (Figure 5A–C respectively).

Figure 6 and Table 2 showed the distribution of points with childhood asthma within varied land covers. Childhood asthma was found in different land covers, and the highest ratio of asthma frequency was demonstrated in urban areas followed by the forth of the river and thin forest.

3.3 | Univariate logistic regression

The results of logistic regression for the single variable model are demonstrated in Table 3. The urban land cover and slope affected the occurrence of childhood asthma in Fars province. Increasing slope decreased the occurrence of childhood asthma hospitalization

TABLE 1 Characteristics of the study population.

Characteristic	
Age (mean ± SE)	9.19 ± 0.31
Sex, *N* (%)	
Female	67 (31.8)
Male	144 (68.2)
Number of hospitalization (mean ± SE)	2.07 ± 0.19
Duration of hospitalization (days) (mean ± SE)	3.1 ± 0.35

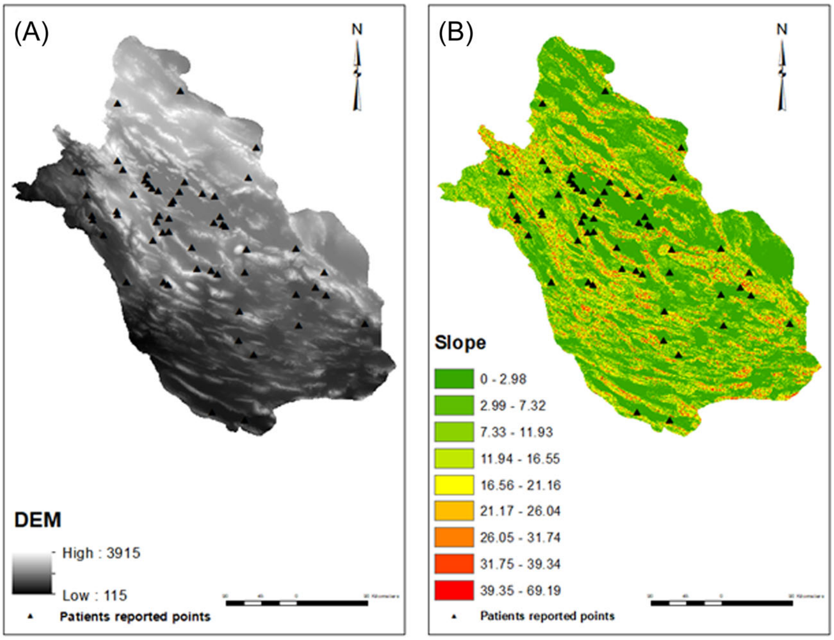

FIGURE 2 DEM (A) and slope (B) maps. Points with childhood asthma were shown by a triangle symbol. Maps were created with ArcMap from ArcGIS 10.5. DEM, digital elevation model.

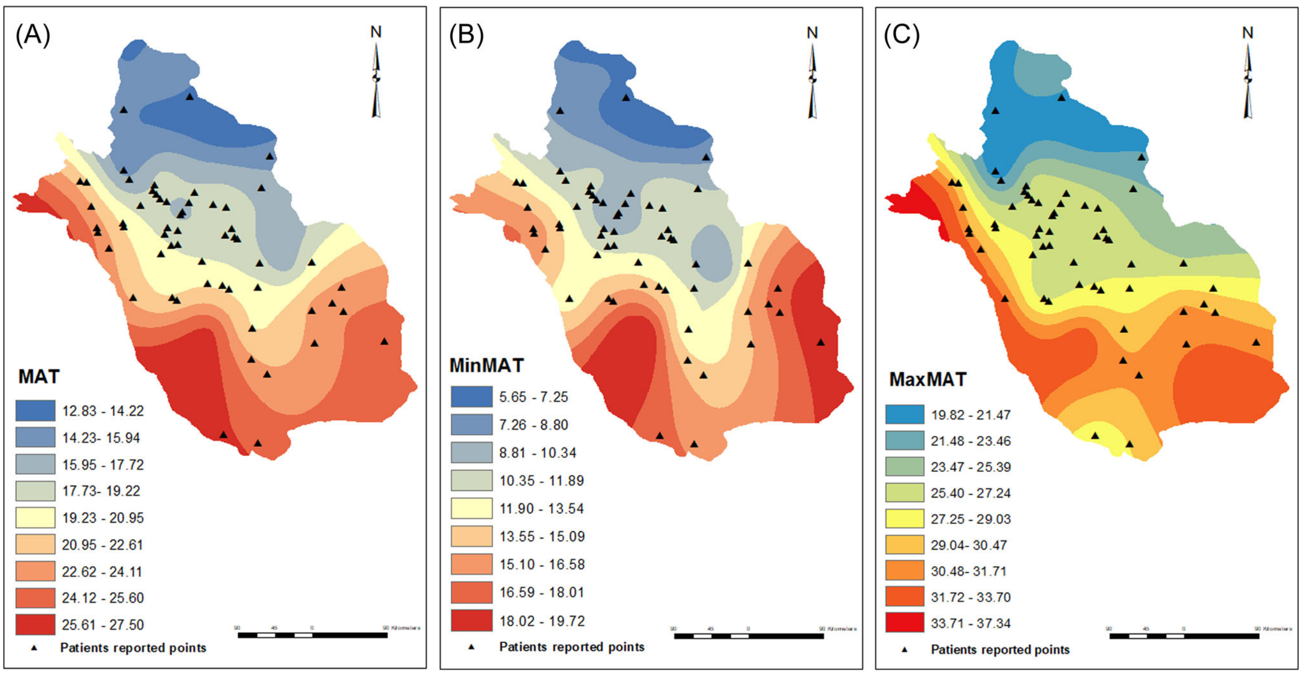

FIGURE 3 Isothermal models rasters; mean annual temperatures (A), minimum mean annual temperature (B), and maximum mean annual temperature (C). Points with childhood asthma were shown by a triangle symbol. Maps were created with ArcMap from ArcGIS 10.5. MAT, mean annual temperature; Max, maximum; Min, minimum.

($p = 0.01$, odds ratio [OR] = 0.914, confidence interval [CI] = 0.849–0.984), while urban setting ($p < 0.001$, OR = 45.880, CI = 12.920–162.918) showed direct effect on childhood asthma. An increase of one degree of slope decreased the possibility of childhood asthma by 8.6% MAH was borderline significant and other geoclimatic factors including MAT, maximum MAT, minimum MAT, MAR, elevation, MASH, and the number of frosty and rainy days had no significant effect on the occurrence of childhood asthma hospitalization in our study.

3.4 | Multivariate logistic regression model

The results of the multivariate logistic regression model are presented in Table 4. Among land covers and slope variables that were effective on the asthma occurrence in univariate models, urban feature ($p < 0.001$, OR = 35.044, CI = 9.096–135.018) was a significant variable that affected asthma in the multivariate logistic regression model.

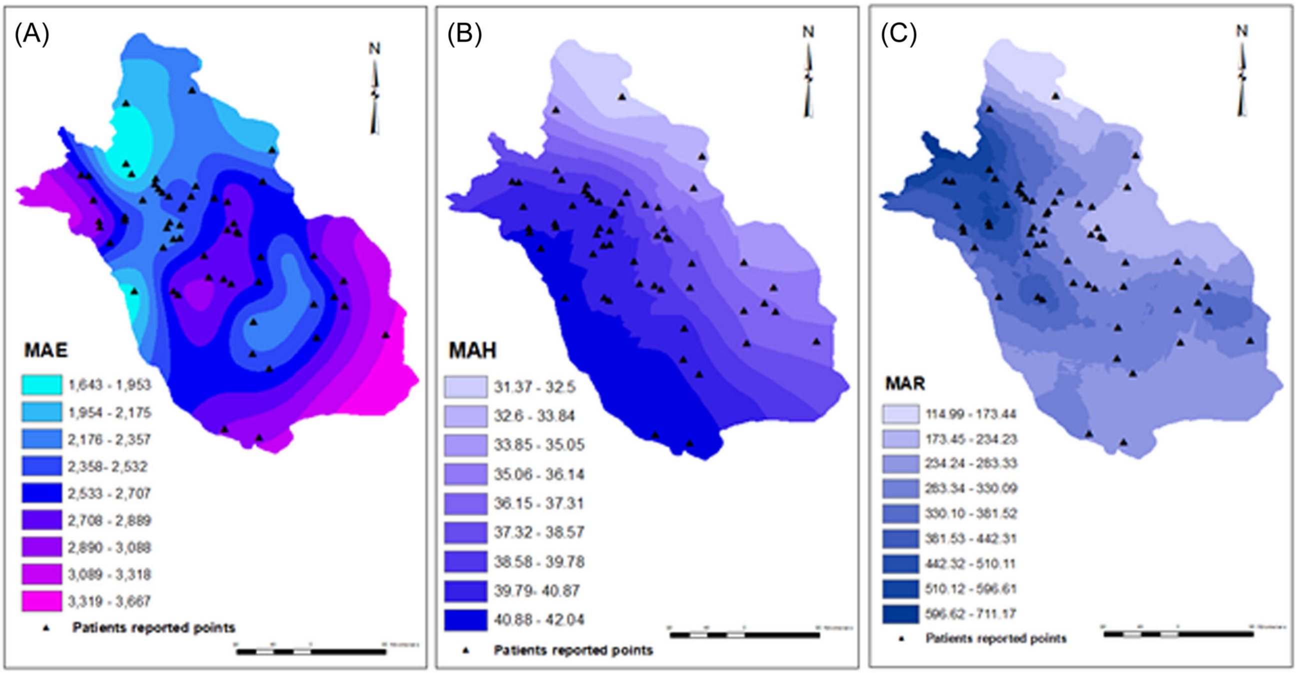

FIGURE 4 Evaporation (MAE) (A), humidity (MAH) (B), and rainfall (MAR) (C) raster models. Points with childhood asthma were shown by a triangle symbol. Maps were created with ArcMap from ArcGIS 10.5. MAE, mean annual evaporation; MAH, mean annual humidity; MAR, mean annual rainfall.

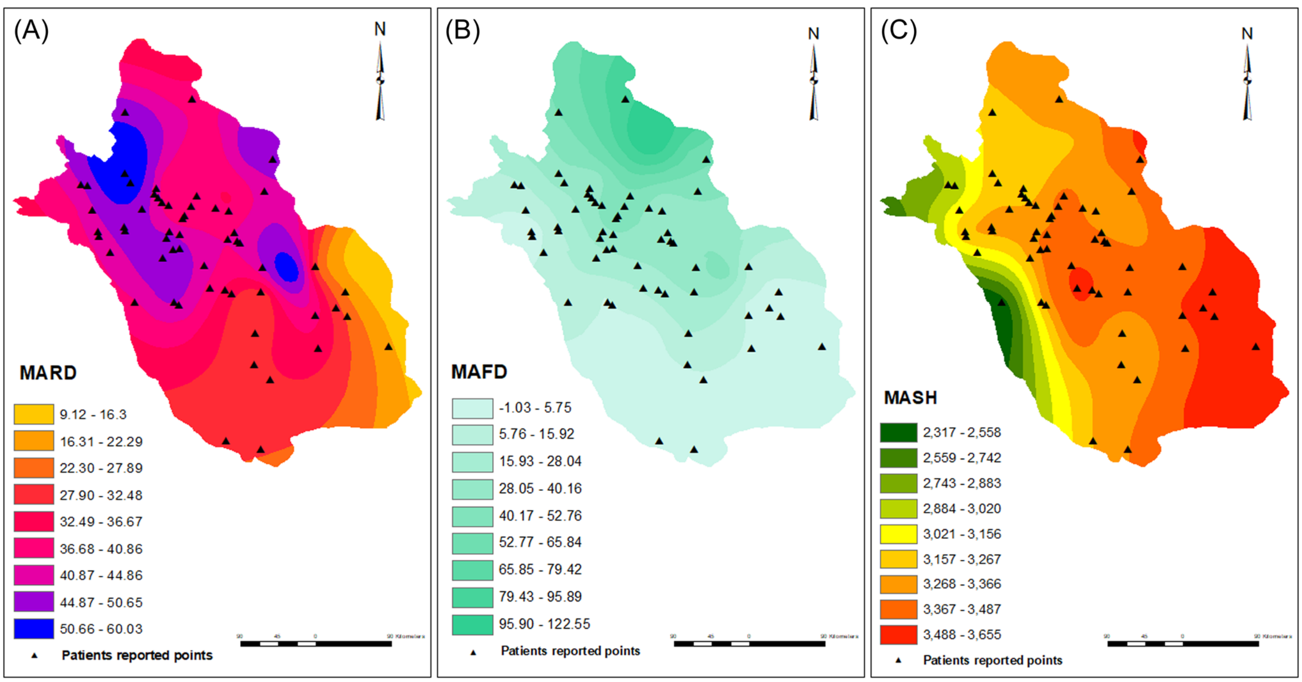

FIGURE 5 The raster maps of the MARD (A), MFAD (B), and MASH (C). Points with childhood asthma were shown by a triangle symbol. Maps were created with ArcMap from ArcGIS 10.5. MAFD, mean annual frosty days; MARD, mean annual rainy days; MASH, mean annual sunny hours.

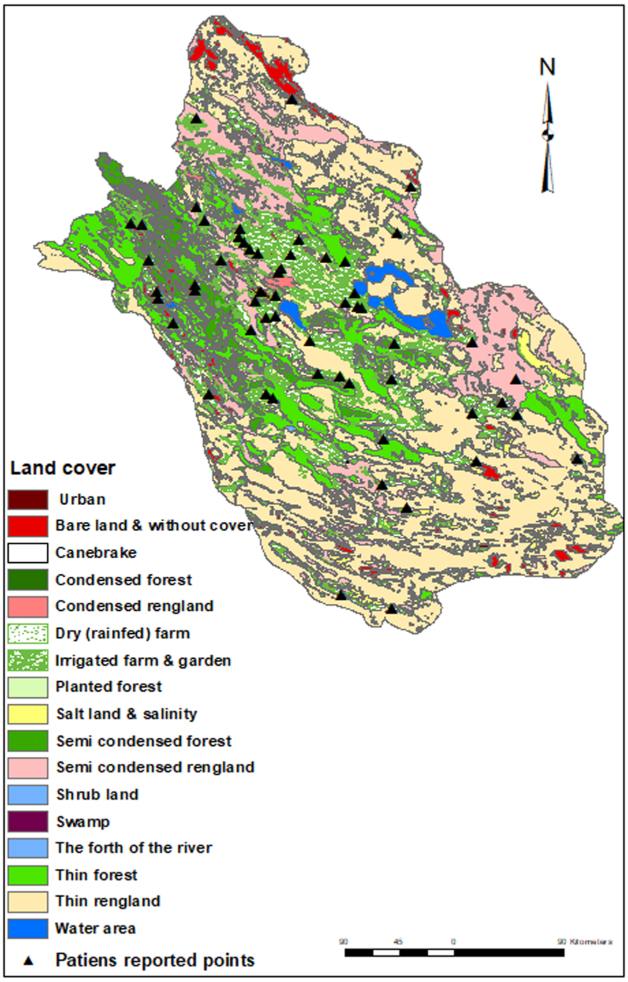

FIGURE 6 Land cover map of Fars province. Points with childhood asthma were shown by a triangle symbol. Maps were created with ArcMap from ArcGIS 10.5.

TABLE 2 The distribution of points with childhood asthma and all points and their ratios in various land covers of Fars province.

Land cover	Infected points per feature (%)	All points per feature (%)	Ratio
Urban	25	1.3	19.23
Condensed and semicondensed forest	1.78	5.21	0.34
Condensed and semicondensed rangeland	7.14	9.36	0.76
Thin rangeland	12.5	27.3	0.45
Dry farm	1.78	2.05	0.86
Irrigated farm	44.6	41.4	1.07
The forth of the river	1.78	0.6	2.9
Thin forest	10.15	5.35	1.89
Total	100	100	

TABLE 3 Evaluation of the effect of geoclimatic factors on childhood asthma in Fars province, southwest Iran by univariate logistic regression model.

Variable	*p* value	OR	CI
Thin forest	<0.001[a]		
Semicondensed forest	0.757	0. 699	0.073–6.744
Condensed forest	0.998	0.000	0.000
Thin rangeland	0.837	0.867	0.224–3.362
Semicondensed rangeland	0.595	1.503	0.335–6.737
Condensed rangeland	0.998	0.000	0.000
Dry (rainfed) farm	0.666	1.648	0.170–15.946
Irrigated farm and garden	0.245	2.039	0.614–6.770
Urban	**<0.001**	**45.880**	**12.920–162.918**
Bareland and salt area	0.996	0.000	0.000
Forth of river and water	0.213	4.250	0.436–41.444
MAT	0.48	0.974	0.906–1.047
MinMAT	0.47	0.972	0.901–1.049
MaxMAT	0.44	0.973	0.907–1.044
MAR	0.77	1.000	0.998–1.003
MAH	0.07	1.103	0.999–1.001
MAE	0.51	1.000	0.999–1.001
Rainy day	0.17	1.022	0.991–1.054
Elevation	0.796	1.000	0.999–1.000
Slope	**0.01**	**0.914**	**0.849–0.984**
Frost day	0.741	0.998	0.988–1.008
Sunny hours	0.45	1.001	0.999–1.002

Note: Bold values are significant variables.

Abbreviations: CI, confidence interval; MAE, mean annual evaporation; MAH, mean annual humidity; MAR, mean annual rainfall; MAT, mean annual temperature; MaxMAT, maximum mean annual temperature; MinMAT, minimum mean annual temperature, OR, odds ratio.

[a]Thin forest was fitted as the reference group for land covers.

4 | DISCUSSION

In the current study, we have shown that the occurrence of childhood asthma hospitalization in Fars province, southwest Iran, was affected mainly by an urban setting. In addition, our results have suggested that urban areas and slope affected the occurrence of asthma when assessed independently from other factors.

An urban setting was the most important factor affecting the incidence of childhood asthma hospitalization in this study. The urbanization effect is a global problem in the face of growing population, industrialization, and pollution. The socioeconomic dichotomy in the urban versus rural environment also affects access to quality health care. Urban locations generally tend to have the

TABLE 4 Evaluation of the effect of geoclimatic factors on childhood asthma in Fars province, southwestern Iran by multivariate logistic regression model.

Variable	*p* value	OR	CI
Thin forest (constant)	<0.001[a]		
Semicondensed forest	0.856	0.809	0.803–7.933
Condensed forest	0.998	0.000	0.000
Thin rangeland	0.670	0.740	0.186–2.953
Semicondensed rangeland	0.702	1.343	0.296–6.103
Condensed rangeland	0.998	0.000	0.000
Dry (rainfed) farm	0.824	1.299	0.130–13.016
Irrigated farm and garden	0.499	1.558	0.431–5.637
Urban	**<0.001**	**35.044**	**9.096–135.018**
Bareland and salt area	0.995	0.000	0.000
Forth of river and water	0.273	3.614	0.364–35.918
Slope	0.315	0.962	0.891–1.038

Note: Bold values are significant variables.
Abbreviations: CI, confidence interval; MAH, mean annual humidity; OR, odds ratio.
[a]Thin forest was fitted as the reference group for land covers.

prototype environment that can lead to the predisposition of asthma and it can be decreased if these environmental and socioeconomic issues are addressed. However, there are controversial data on the prevalence of asthma in urban versus rural areas in the literature. Consistent with our data, urban areas were reported as an important determinant of asthma in several studies.[20,21] Solé et al.[15] showed that the prevalence of asthma-related symptoms was higher among those living in the urban centers in comparison to the rural ones in Brazil. Ma et al.[20] also reported a lower prevalence of asthma and atopic sensitization in rural children compared with urban children in Beijing, China. An explanation for increased asthma and allergic diseases among children who were born and raised in urban areas, in comparison to those living in rural areas with farming environments, might be due to their less exposure to poultry and livestock in urban areas. Brau-Fahrlander et al.[21] reported a study of 1620 Swiss children aged 6–15 years showing farming as a parental occupation was significantly associated with lower rates of symptoms of allergic rhinitis and atopic sensitization.

Another explanation is related to “Hygiene Hypothesis” proposed by Strachan.[22] He proposed that infection in early childhood transmitted by unhygienic contact with older siblings or acquired prenatally from others by contact with older children may have a protective effect on the subsequent development of asthma and allergies. Indeed, exposure to microbes or microbial products in early life might prime the immune system toward T- helper (Th) 1 response and enhance interleukin (IL)−12 and interferon (IFN)-γ productions, which protect individuals against IgE-mediated atopic disorders. In a birth cohort study, the increased endotoxin exposure was associated with a reduced risk of allergic sensitization and eczema according to Hygiene Hypothesis.[23]

Pollution is another main reason for increased asthma occurrence in urban areas. Asthma is exacerbated by nitrogen dioxide, ozone, and respirable particulates. Exposure to a high level of pollutants such as heavy traffic is of particular concern, especially for children. Urban allergens, including cockroaches, mice, and rats, have also been reported as the risk factors for developing asthma.[24] Pollution in urban environments can decrease lung growth and function by narrowing the airways through the enzymes from dust mites that harm the lining of the airway and cause narrowing.[25]

On the other hand, the results of some studies are inconsistent with ours in that higher occurrence of asthma hospitalization has been shown in rural areas. In Mississippi, the lower socioeconomic and limited access to health care has been considered important factors which increase asthma prevalence in rural areas.[26] In Arkansas, where the asthma prevalence and health service were similar between representative rural and urban groups, lower socioeconomic and some cultural and health plan barriers in the medical care in rural areas have accounted for significantly higher asthma morbidity in the rural group than urban group.[27]

The results of the univariate model also found slope as a significant factor affecting asthma occurrence in Fars province, where more childhood asthma hospitalization reported in villages/cites were found on lower slopes. This is a novel finding not reported before. Historically, humans have established villages/cities in areas with low altitudes, which are often on the low slope. We hypothesize that higher populated density in regions with low slope is associated with more air pollutants, nanoparticles, and infectious viral diseases that it leads to more asthma occurrence in such areas. Similar to our results, previous studies have shown that the occurrence of asthma hospitalization has a positive relationship with population density.[28] Also, in our study urban setting, an indicator of high population density was identified as a significant parameter affecting asthma hospitalization.

MAH and MAR were not significant in the current study, while some studies have reported humidity and rainfall as the main factors influencing asthma occurrence and severity through increasing home dampness, house dust mite, and mold.[29,30] There was an increase in admissions for asthma with an increase in relative humidity after rainy periods in these studies. We failed to reach statistical significance regarding the effect of MAT on childhood asthma hospitalization. The effects of air temperature on asthma attacks have been somewhat controversial in previous studies.[31,32] Most studies reported low temperatures as a risk factor for acute exacerbations of asthma,[33,34] while warmer average temperatures were associated with an increase in asthma prevalence in some studies.[35] Nonsignificant results for climatic factors in the current study may be due to less exposure of children than adults to climatic variability.[36] We are sure that adult asthma was affected by some climatic factors (unpublished data).

The strength of this study comes from the ability to obtain highly accurate results based on GIS technology. Regarding the retrospective nature of the present study, some confounding factors in the hospitalization of patients, including poor adherence to prescribed medication and socioeconomic status, have not been considered. Also, some other environmental determinants like air pollution should be analyzed in future investigation.

5 | CONCLUSION

In conclusion, the current retrospective study has reported urban setting as an important factor affecting the occurrence of childhood asthma in Fars province, southwestern Iran. The univariate model showed slope as a significant variable which was not significant in the multivariate model.

Understanding the geographical factors determining childhood asthma may be helpful for disease control and management. In particular, more research with a greater sample size is needed on the relationship between location and occurrence of childhood asthma and the effect of changing lifestyles of asthmatic patients.

AUTHOR CONTRIBUTIONS

Zahra Kanannejad: Conceptualization (equal); data curation (equal); investigation (equal); methodology (equal); project administration (equal); writing—original draft (equal); writing—review and editing (equal). **Mohammad Shomali**: Conceptualization (equal); data curation (equal); investigation (equal); methodology (equal); project administration (equal); writing—original draft (equal). **Hossein Esmailzadeh**: Writing—review and editing (equal). **Seyed Hesamedin Nabavizadeh**: Writing—review and editing (equal). **Koorosh Nikaein**: Investigation (equal). **Zahra Ghahramani**: Data curation (equal). **Mohammad Amin Ghatee**: Formal analysis (equal); methodology (equal); software (equal); supervision (equal); writing—review and editing (equal). **Soheila Alyasin**: Funding acquisition (equal); project administration (equal); writing—review and editing (equal).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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