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EXPLORING CLIMATIC AND GEOGRAPHICAL DRIVERS OF HEPATITIS B VIRUS SPREAD IN KOHGILUYEH AND BOYER-AHMAD PROVINCE, IRAN

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Abstract

Background: *Hepatitis B virus remains a major public health concern worldwide. Environmental and geographical factors might influence its transmission dynamics in certain regions. This study examines the impact of climatic and geographical determinants on Hepatitis B virus incidence in Kohgiluyeh and Boyer-Ahmad Province, Iran, using geographical information system mapping.*

Methods: *Data on 741 Hepatitis B virus -positive patients over 2013-2022 were obtained from the Provincial Health Center, and their residential addresses were mapped for spatial analysis. Climatic variables, including mean annual temperature, maximum mean annual temperature, minimum mean annual temperature, mean annual evaporation, mean annual sunny days, mean annual frosty days, mean annual humidity, mean annual wind speed and mean annual rainfall as well as geographical variables such as elevation, slope, and land cover types, were analyzed using univariate and multivariate logistic regression models.*

Results: *Patients came from 129 points, including villages, towns, and cities. In the univariate analysis, mean annual humidity, mean annual rainfall, and mean annual wind speed demonstrated a protective effect, while increased mean annual sunny days was associated with a higher risk of Hepatitis B virus. Geographical factors revealed that urban areas, irrigated farm regions, and areas with lower elevations and slopes were at higher risk. In multivariate analysis, urban land cover and irrigated farmland, mean annual humidity, slope, and elevation were shown as the most important determinants.*

Conclusion: *Environmental factors appear to impact the transmission of Hepatitis B virus in Kohgiluyeh and Boyer-Ahmad Province by influencing human behaviors and activity and virus survival in the different geoclimatic conditions. These data support the development of public health messaging to include environmental risks in programs to prevent Hepatitis B virus.*

Keywords: *hepatitis B, climatic determinants, geographical factors, environmental health, geographical Information system, epidemiology, Iran*

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INTRODUCTION

Hepatitis B virus (HBV) infection remains a significant global health challenge, particularly in low- and middle-income countries. WHO estimates that 254 million people were living with chronic hepatitis B infection in 2022, with 1.2 million new infections each year [*Manikat et al., 2024*]. In 2022, hepatitis B resulted in an estimated 1.1 million deaths, mostly from cirrhosis and hepatocellular carcinoma (primary liver cancer) [*Manikat et al., 2024*]. Despite the availability of an effective vaccine, the disease burden remains disproportionately high in certain geographical regions, suggesting that more consideration should be given to environmental factors that may play a critical role on the host behavior and the transmission dynamics of disease [*Hu et al., 2014, Uwishema et al., 2023*]. Climate plays an important role in pathogen life and survival and also shaping the patterns of human activities and behaviors, such as lifestyles and physical exercise that can influence the transmission of infectious diseases[*Viboud et al., 2004, Uwishema et al., 2023*].

The transmission of hepatitis B is traditionally attributed to direct human-to-human contact via vertical transmission, unsafe medical practices (e.g., unscreened/poorly screened blood), and other risk behaviors, notably unprotected sex [*Nelson et al., 2016a*]. However, emerging research has begun to explore the potential influence of environmental and population determinants on hepatitis B transmission [*Hu et al., 2014, Wang et al., 2023*]. Research conducted in China has found that climate changes, including temperature and precipitation, played roles in the transmission of HBV; namely, a lower incidence of hepatitis B was associated with higher precipitation and lower temperatures in some regions [*Zhao et al., 2023, Sun et al., 2024, Li et al., 2021*]. Additionally, geographical features may alter the distribution and persistence of pathogens [*Rosenthal, 2009*]. In the context of Hepatitis B Virus infection, some previous studies showed that urbanization, population density, geographic isolation, and proximity to healthcare facilities play a crucial role in influencing Hepatitis B Virus incidence [*Danbuzu and Umar, 2015, Wang et al., 2023, Hu et al., 2014*]. Urban populations tend to have a higher prevalence of Hepatitis B Virus compared to rural populations. This might be partly explained by the heavy concentration of the population in the main cities and by extensive population movement due to trade with neighboring countries [*Makuwa et al., 2009*]. Proximity to healthcare facilities is crucial for managing HBV infections. Areas with limited access to medical care often report higher incidence rates due to delayed diagnosis and treatment. Studies have shown that individuals living closer to healthcare resources are more likely to receive vaccinations and screenings, reducing the incidence of HBV [*Harris* ет ал,, *2016*].

Geographical Information Systems offer a powerful tool for investigating the spatial distribution of diseases and identifying environmental risk factors [*Fradelos et al., 2014, Huang et al., 2022*]. By incorporating climatic data such as temperature, humidity, altitude, rainfall, and geographical-based and spatial features, Geographical Information System allows researchers to visualize and analyze the patterns of disease incidence about these variables [*Kanannejad et al., 2020, Ghatee et al., 2018*]. This spatial approach can help identify regions where environmental factors may enhance the transmission of Hepatitis B Virus, thus guiding targeted public health interventions.

Understanding the interplay between environmental variables and hepatitis B incidence is crucial for tailoring public health interventions. This study aims to investigate the relationship between geoclimatic variables and the incidence of hepatitis B in Kohgiluyeh and Boyer-Ahmad province in southwest Iran, providing insights that may enhance disease prevention strategies in vulnerable regions.

MATERIALS AND METHODS

Patients: Based on Iranian Health Ministry protocol, all hepatitis B cases who have been detected in governmental and private clinics and medical centers that were confirmed by laboratory results should be reported to the Provincial Health Center. In the current study, data on all 930 patients confirmed positive for Hepatitis B Virus over the 2013-2022 were obtained from the Provincial Health Center of Kohgiluyeh and Boyer-Ahmad Province. However, owing to incomplete data for 189 of these patients, they were excluded from the study, leaving a final sample of 741 patients who were included in the analysis. Patients' residential addresses were mapped onto the province's political map, covering both villages and cities. This study was approved by the Yasuj University of Medical Sciences Ethics Committee (Ethics Approval No: IR.YUMS. REC.1402.155). As a retrospective study, all patient data were anonymized under ethical standards and Health Center guidelines and the requirement for obtaining patient consent was waived.

Study Area: s conducted in the Kohgiluyeh and Boyer-Ahmad province, lies between latitude 30.9◦ and 31.32◦ N (north latitude) and longitude 49.57◦ and 50.42◦ E (east longitude) in southwestern Iran, with Yasuj as its capital. The province spans 15,563 square kilometers and lies within different climatic zones, from warm to mountainous cold areas. It includes some of the highest elevations in the central Zagros Mountain range, characterized by substantial annual snowfall and rainfall. The area is also home to Dena Peak, the seventh-highest peak in Iran, at 4,409 meters. The region's diverse ecosystem supports around 2,000 plant species.

Geographical and meteorological data: Meteorological data for 2013-2022, including temperature, rainfall, humidity, evaporation, and wind speed, were gathered daily from the 6 synoptic and 45 rainfall assessment stations by the Weather Bureau in Kohgiluyeh and Boyer-Ahmad Province. Annual averages were calculated for each variable and recorded as the mean annual temperature (MAT), maximum mean annual temperature, minimum mean annual temperature, mean annual evaporation, mean annual sunny days, mean annual frosty days, mean annual humidity, mean annual wind speed and mean annual rainfall. Geographical data, including a digital elevation model raster layer and a land cover vector layer, were provided by the Department of Natural Resources in Kohgiluyeh and Boyer-Ahmad. A slope raster layer was generated using the digital elevation model map via the spatial analyst tool to determine the maximum gradients between each cell and its neighboring cells.

Geospatial analysis: Iso-hydral and iso-humid raster layers were generated using the Kriging interpolation technique, while iso-thermal, iso-evaporation, and iso-wind speed layers were developed through the tension-based Spline interpolation model, following evaluations of different interpolation methods. All layers were created on a 1 × 1 km resolution grid. Village and town point layers for the study areas were extracted with these raster layers. The identity tool was then used to determine the geometric intersections between the resulting layer and the land cover vector layer, forming the final layer. This final layer incorporated both geographical and climatic data derived from the overlapping raster and vector layers for each location. To examine the relationship between geographical and climatic factors and hepatitis B, the geographic distribution of hepatitis B cases within Kohgiluyeh and Boyer-Ahmad province was compared between reported and unreported cities and villages. These data were analyzed using univariate and multivariate logistic regression models in SPSS version 21.

RESULTS

Geographic and climatic features of Hepatitis B Virus -affected regions

In this study, 741 patients from 129 locations across a total of 2,207 city/village points in the province were included. The geographical distribution of Hepatitis B Virus cases within Kohgiluyeh and Boyer-Ahmad Province is presented in Fig.1.

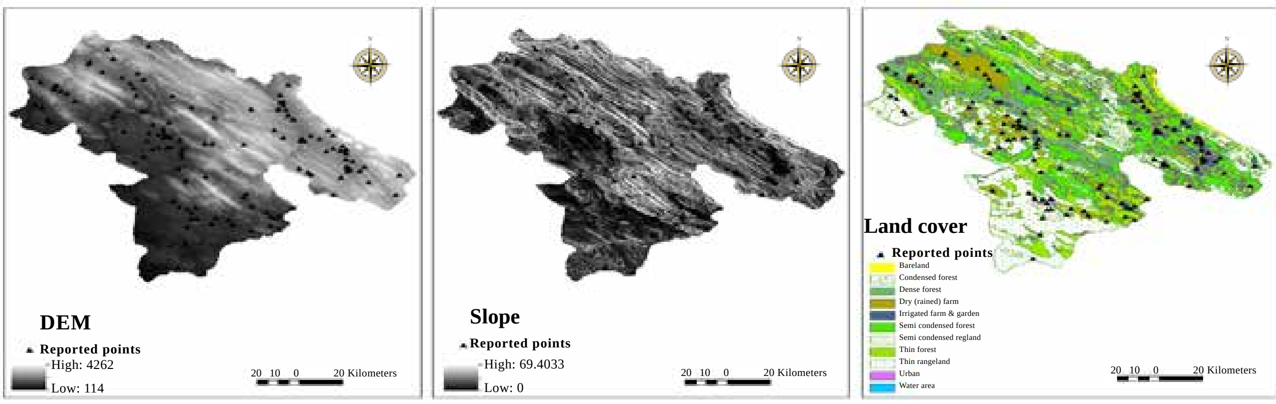

FIGURE 1. Geographical distribution of infected points in Kohgiluyeh and Boyer-Ahmad province. Points with HBV cases were shown by triangle symbol on the digital elevation model (DEM).

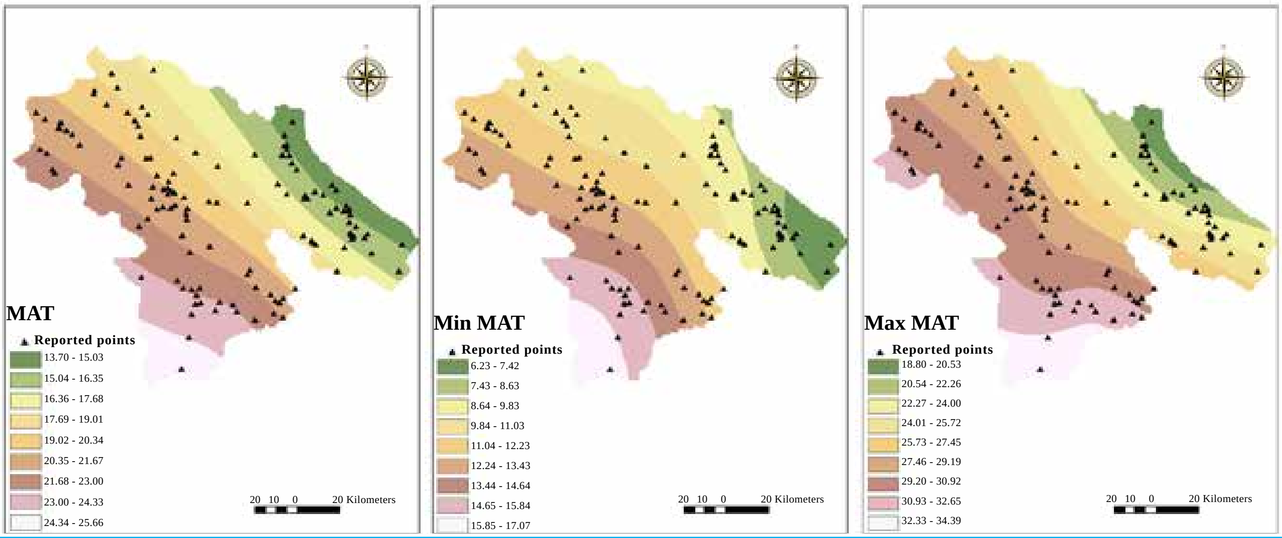

FIGURE 2. *Mean annual temperature (MAT), Minimum mean annual temperature (MinMAT) and Maximum mean annual temperature (MaxMAT) raster models. Points with HBV cases were shown by triangle symbol.*

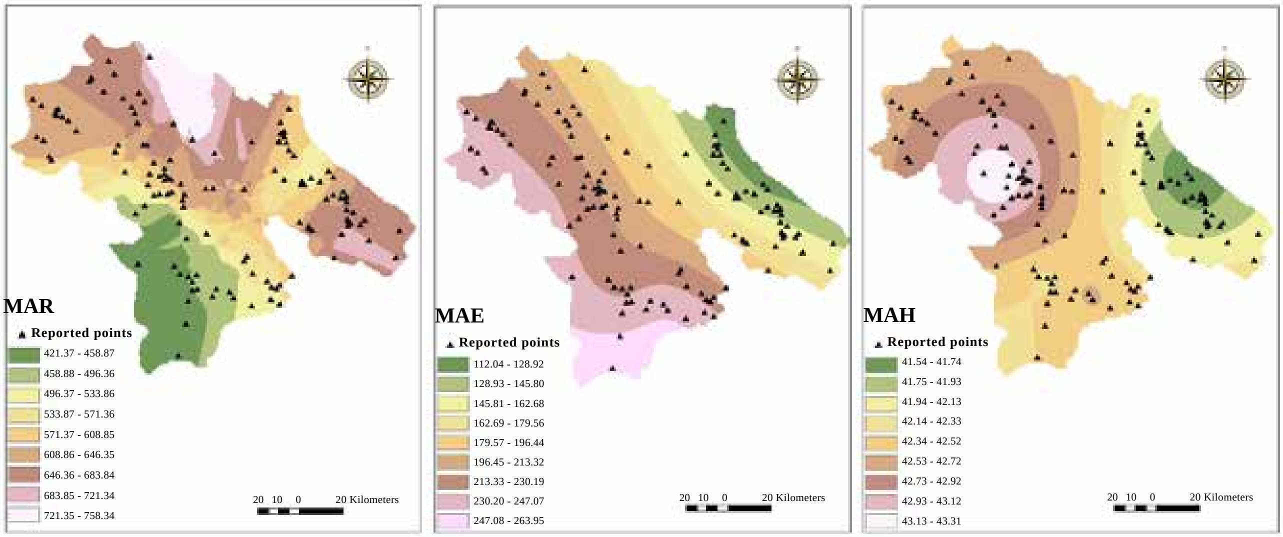

FIGURE 3. *Mean annual rainfall (MAR), Mean annual evaporation (MAE), and Mean annual humidity (MAH) (c) raster models. Points with HBV cases were shown by triangle symbol.*

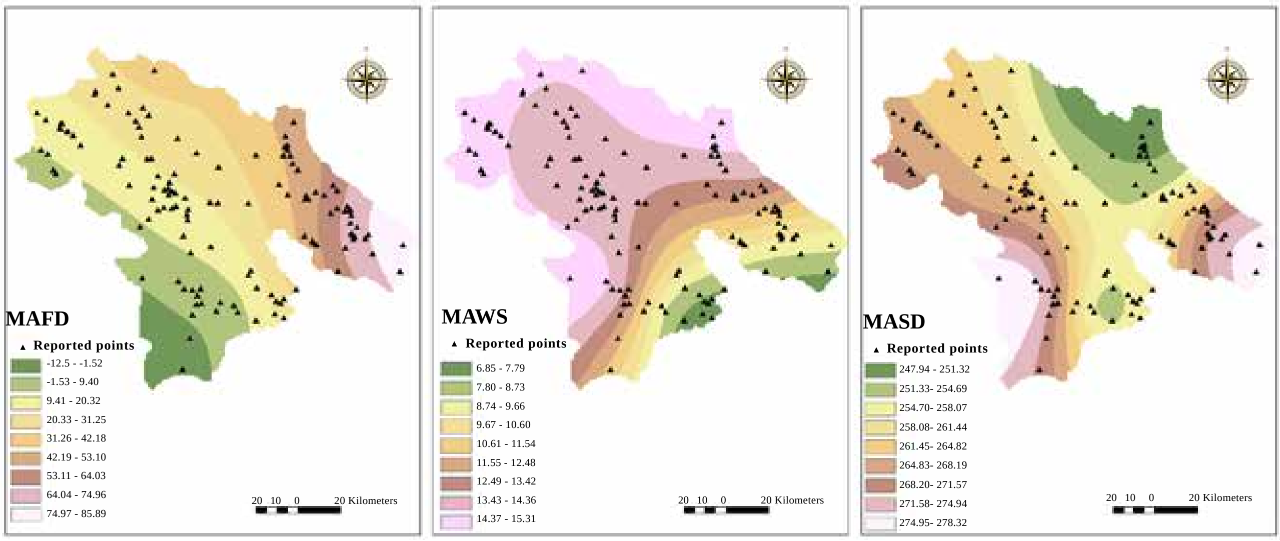

FIGURE 4. *. Mean annual frosty days (MAFD), Mean annual wind speed (MAWS), and Mean annual sunny days (MASD) raster models. Points with HBV cases were shown by triangle symbol.*

These locations span diverse climatic features, as shown in Figures 2-4.

The effects of geographical and climatic determinants on hepatitis B occurrence

The effect of climatic and geographical features on Hepatitis B Virus occurrence was analyzed using univariate and multivariate models.

Climatic factors: Univariate analysis of the climatic determinants showed that Mean annual rainfall, Mean annual humidity, Mean annual wind speed, and Mean annual sunny days were significantly associated with hepatitis B occurrence (Table 1). Mean annual rainfall had a slight inverse association with hepatitis B occurrence, while Mean annual humidity had a strong inverse association. Mean annual wind speed also demonstrated a protective effect. On the other hand, Mean annual sunny days was positively associated with increased Hepatitis B Virus infection risk. Other climatic variables, such as mean annual temperature, mean annual evaporation, and frosty days, were not statistically significant predictors of HBV occurrence ($p > 0.05$).

Geographical factors: The univariate analysis of geographical features identified urban areas as having a dramatically increased risk for hepatitis B (OR = 89.950, 95% CI: 26.028–310.859, $p < 0.001$), followed by irrigated farm and garden areas (OR = 4.480, 95% CI: 2.081–9.647, $p < 0.001$) (Table 2). In contrast, thin rangeland showed a positive but lower association with HBV (OR = 2.425, 95% CI: 1.018–5.775, $p = 0.046$). The other land cover types, such as dry farm, condensed rangeland, and condensed forest, did not show significant associations ($p > 0.05$). Digital elevation model and slope were also significant geographical determinants negatively associated with hepatitis B occurrence in the study area: OR=0.999, 95% CI: 0.999-1.000, $p<0.001$, OR=0.879, 95% CI: 0.864-0.914, $p < 0.001$, respectively.

TABLE1.
The effect of climatic factors on Hepatitis B Virus occurrence by univariate analysis

Mean annual climate parameters	P value	Odds Ratio	Confidence Interval
Temperature	0.733	1.013	0.939-1.093
Min-temperature	0.754	1.015	0.923-1.117
Max-temperature	0.723	1.011	0.953-1.071
Rainfall	< **0.001**	0.995	0.993-0.997
Evaporation	0.762	0.999	0.994-1.005
Humidity	**0.001**	0.488	0.319-0.746
Frosty day	0.170	1.007	0.997-1.017
Sunny day	**0.003**	1.04	1.013-1.068
Wind speed	**0.001**	0.880	0.814-0.951

TABLE 2.
The effects of geographical features on hepatitis B occurrence by univariate analysis

Factors	P value	OR	CI
DEM	< **0.001**	0.999	0.999-1.000
Slope	< **0.001**	0.879	0.864-0.914
Land covers			
Thin forest (constant)	0.000		
Semi condensed forest	0.053	0.268	0.07-1.019
Condensed forest	0.700	1.21	0.459-3.186
Rangelands			
Thin	0.046	2.425	1.018-5.775
Semi condensed	0.711	0.807	0.260-2.505
Condensed	0.559	0.535	0.660-4.363
Dry farm	0.075	2.083	0.929-4.672
Irrigated farm and garden	< **0.001**	4.480	2.081-9.647
Urban	< **0.001**	89.95	26.03-310.9
Bare & water areas	0.999	0.000	0.000

NOTES: Digital elevation model (DEM)

Multivariate Analysis: Forward stepwise multivariate analysis revealed that urban land cover (OR = 72.514, 95% CI: 19.753–266.208, $p< 0.001$) and irrigated farm and garden areas (OR = 3.555, 95% CI: 1.598–7.911, $p = 0.002$) were the strongest geographical predictors of HBV occurrence (Table 3). Slope also showed a protective effect (OR = 0.942, 95% CI: 0.904–0.983, $p = 0.006$), while digital elevation model had a small but significant protective effect (OR = 0.999, 95% CI: 0.998–1.000, $p = 0.013$). Mean annual humidity remained protective against hepatitis B (OR = 0.297, 95% CI: 0.139–0.632, $p= 0.002$), while other factors, such as MAR and sunny days, were not significant in the multivariate model ($p > 0.05$).

DISCUSSION

This study assessed the effects of environmental determinants on hepatitis B occurrence within Kohgiluyeh and Boyer-Ahmad Province, Southwest Iran. Urban setting, irrigated farms and gardens, humidity, slope, and altitude were the most important independent determinants in the study area, whilst rainfall, wind speed, sunny days, and thin rangeland were suggestive factors in the univariate analysis.

TABLE 3.

Forward stepwise multivariate analysis of the effects of geographical and climatic factors on Hepatitis B Virus

Factors	P value	OR	CI
Mean annual climate parameters			
Sunny day	0.733	1.005	0.975-1.037
Humidity	**0.002**	0.297	0.139-0.632
Rainfall	0.902	1.0	0.996-1.004
Digital elevation model	**0.013**	0.999	0.998-1.000
Slope	**0.006**	0.942	0.904-0.983
Land cover			
Thin forest (constant)	0.000		
Semi condensed forest	0.201	0.411	0.105-1.608
Condensed forest	0.353	1.633	0.580-4.594
Rangelands			
Thin	0.388	1.540	0.578-4.100
Semi condensed	0.807	0.864	0.268-2.785
Dense	0.718	1.490	0.171-12.978
Dry farm	0.087	2.120	0.897-5.009
Irrigated farm and garden	**0.002**	3.555	1.598-7.911
Urban	**<0.001**	72.51	19.75-266.21
Bare and water areas	0.999	0.000	0.000

Urbanization is the most critical geographical determinant influencing Hepatitis B Virus transmission, mainly due to the demographic and behavioral changes associated with urban environments. Urban areas typically have higher population densities, which increase the likelihood of close contact among individuals, thus facilitating the spread of Hepatitis B Virus. High-density environments also often see greater social interactions and mobility, contributing to more opportunities for Hepatitis B Virus exposure. For instance, *Wang et al.* reported that urban areas in China experienced higher hepatitis B incidence, attributing this pattern to increased population density and the consequent rise in social contacts in cities [*Wang et al., 2023*]. However, three studies demonstrated that the HBsAg positive rates were higher in rural areas compared to those in urban areas [*Liu et al., 2022, Ma et al., 2019, Zhang et al., 2020*], while two other studies demonstrated no statistical differences between rural and urban groups[*Tan et al., 2016, Zhang Li et al., 2016*].

Urban areas often attract migrants from rural regions, which can influence hepatitis B epidemiology. Migrant populations may have varied vaccination coverage and may face barriers to healthcare, increasing Hepatitis B Virus transmission risk. Urbanization can also contribute to behaviors associated with higher Hepatitis B Virus risk, such as unprotected sex and substance use due to social pressures and lifestyle changes in urban settings. According to *He et al.*, migration and high-risk behaviors associated with urban life were linked to hepatitis B outbreaks in urban regions in Asia [*He Li et al., 2019*]. Moreover, urban settings can exhibit stark socioeconomic differences, affecting hepatitis B incidence. Low-income urban areas may experience overcrowding and limited healthcare access, contributing to increased transmission. *Nelson et al.* discussed how socioeconomic factors in urban environments create health disparities that impact hepatitis B prevalence, especially in marginalized populations with reduced access to preventive healthcare and vaccination programs [*Nelson et al., 2016b*].

The results of this study indicate a statistically significant association between irrigated farm and garden areas and higher hepatitis B incidence. Many farms and gardens are situated in rural areas that are close enough to urban centers for easy commuting. People frequently travel between residential areas and these locations for various reasons, including work, recreation, and picnics. Irrigated farms and gardens tend to attract seasonal or permanent labor forces, often involving workers from diverse locations who live in close proximity to each other. These environments can create high-density living situations where frequent social interactions, shared housing conditions, and engaging in unprotected and high-risk contacts increase opportunities for Hepatitis B Virus transmission.

In this study, mean annual rainfall and mean annual humidity emerged as significant climatic determinants of hepatitis B. Mean annual rainfall exhibited an inverse relationship with disease occurrence, suggesting that increased rainfall may limit transmission pathways. This protective association might reflect reduced outdoor human activity or limited social interactions during rainy days, potentially decreasing opportunities for hepatitis B transmission. These findings align with previous research linking rainfall with disease incidence, whereby higher rainfall levels correlate with lower transmission rates due to decreased outdoor exposure in high-rainfall periods. For example, *Chan et al.* showed a decreased rate of social contact and transmission of infectious diseases on weekends with heavy rain [*Chan et al., 2015*]. *Lowen et* *al.*, demonstrated that influenza transmission rates were reduced during rainy days as fewer people engaged in outdoor activities, decreasing the potential for viral spread in public spaces [*Lowen et al., 2007*]. Sun et al. also showed the protective effect of rainfall on the hepatitis B prevalence [*Sun et al., 2024*]. Research specifically linking rainfall directly to hepatitis B occurrence is limited and is an area for more research.

Similarly, mean annual humidity demonstrated a significant protective effect against HBV. There are limited studies assessed the relation between humidity and hepatitis B occurrence. Another study by Ning et al. examined the epidemiological characteristics of hepatitis in China during 2002-2021. They showed an inverse association between humidity and HBV cases in northeast China [*Ma et al., 2019*]. Humidity can be related to rainfall, so reduced outdoor human activity or limited social interactions in the areas with higher rainfall. In humid regions, seasonal changes can sometimes impact healthcare access, particularly in rural areas with limited infrastructure. Reduced access to vaccination and healthcare services during high-humidity seasons may indirectly contribute to HBV prevalence. On the other hand, a study by *Zhao et al.* in China highlighted that humidity was directly related to hepatitis B, while rainfall was not associated with this disease [*Zhao et al., 2023*].

Our results also suggest that increased wind speed may play a role in reducing hepatitis B transmission. One possible explanation is that higher wind speeds could decrease outdoor gathering and social interactions, thereby reducing opportunities for HBV transmission through close contact or high-risk behaviors associated with viral spread [*Lin et al., 2024*].

Mean annual sunny days was another significant determinant in our study associated positively with HBV occurrence. In contrast to rainfall, humidity, and wind speed, sunny days often lead to increased outdoor activities, social gatherings, and travel. This heightened social interaction can elevate the risk of HBV transmission in settings where high-risk behaviors are more prevalent, such as crowded public places, social events, and transportation hubs [*Chan et al., 2015*]. Sunny weather may lead to increased participation in activities that carry higher risks of HBV transmission, such as sharing personal items, increased alcohol consumption, or engaging in unprotected sexual activities during social gatherings.

We also showed a statistically significant, inverse relationship between elevation and the incidence of HBV. Given the mountainous terrain of the study area, people tend to reside at lower elevations where population density is higher. Thus, the effect of elevation may indirectly reflect the impact of population density, resulting in more frequent person-to-person contact in densely populated areas. Supporting this is a study by *Ghatee et al.* that reported decreased visceral leishmaniasis prevalence with increasing elevation [*Ghatee et al., 2013*]. However some studies showed that various factors such as immunomodulation, hypoxia, physiological adaptation, and harsh environmental stressors at high altitude may enhance susceptibility to pathogens [*Ericsson et al., 2001*].

Moreover, environmental conditions at higher elevations, such as lower temperatures, may also contribute to reduced HBV incidence. Previous studies have shown that HBV's stability and persistence in the environment are temperature-dependent. This may be more important for HBV transmission from infected objects like needles and hairdressing tools. For example, *José et al. (2005)* reported that the HBV virus remains viable at temperatures between 5 and 25 ^{0}C for at least 28 days, suggesting that lower temperatures may inhibit HBV survival [*José et al., 2005*]. Indeed, as altitude increases, the environment is characterized by more drastic changes in temperature between night and day, higher air dryness, and higher levels of ultraviolet (UV) light radiation [*Arias-Reyes et al., 2021*]. In particular, UV light radiation was considered an important natural sanitizer at altitude that may shorten the half-life of some viruses like Influenza and SARS-CoV-2 [*Zubieta-Calleja and Zubieta-DeUrioste, 2017, Andrade, 2020, Zubieta-Calleja, 2020, Fischer et al., 2022*]. In addition, solar radiation is more intense at higher altitudes, and a recent study reported that this may be a key factor leading to the deactivation of the virus [*Asyary and Veruswati, 2020, Li et al., 2020*]. Taken together, these factors may lead to a gradual reduction of the "survival" and "virulence" capacity of the virus as altitude progresses. Finally, the size of the virus inoculum in the air should gradually decrease as the barometric pressure decreases and the distance among air molecules increases. This aligns with the notion that climatic and environmental conditions at higher elevations may create less favorable conditions for the virus, indirectly reducing the likelihood of transmission [*Peterson et al., 2016, Arias-Reyes et al., 2021*].

Based on our results, slope also appears to have a statistically significant protective effect on Hepatitis B Virus transmission, with areas of steeper slopes showing a reduced incidence of Hepatitis B Virus. Slope could affect HBV transmission indirectly through various demographic, environmental, and accessibility factors. Steeper slopes are often associated with lower population density, as these areas are generally less suitable for large-scale residential or urban development. This pattern aligns with findings that higher population density can increase the risk of infectious disease transmission [*Wang et al., 2023*]. In addition, the environmental conditions associated with steeper slopes, such as temperature, humidity, and sunlight exposure, may also play a role in reducing HBV incidence [*Andrade, 2020*]. Steeper slopes are often found at higher elevations, where cooler temperatures could reduce the viability of the HBV virus on surfaces, further limiting transmission risks [*José et al., 2005*]. Although HBV is not primarily an environmentally transmitted virus, such conditions may still influence its persistence and indirect exposure risks. Our study did not include an index of population, which is a limitation and should be incorporated in future studies on Hepatitis B Virus transmission and environmental and climatic factors.

The associations identified in this study underscore the importance of accounting for environmental determinants in public health strategies for Hepatitis B Virus prevention and control. Specifically, targeted interventions in urban areas, where population density increases Hepatitis B Virus transmission risk, could involve increased vaccination coverage, widespread screening programs, and educational campaigns on safe health practices. Prioritizing HBV screening and vaccination initiatives in these areas could help address the healthcare disparities that often accompany geographical isolation. In the current study we could not quantify the effect of environmental factors on the host behavior or on the virus viability. Host immunity was also a confounding factor that we could not control for.

Conclusion

In conclusion, our study shows that both climate and geography have significant effects on HBV spreads in our study area. Urban setting, irrigated farms and gardens, humidity, slope, and altitude were the most important determinants in the study area, respectively. More effects seem to be attributed to the role of these factors on the human populations and their reaction to these geoclimatic factors. Moving forward, more research in this field could help us learn how changing geographical and climatic patterns may affect the spread of hepatitis B. This would allow public health officials to amend hepatitis B prevention and control plans to consider environmental factors.

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THE NEW ARMENIAN MEDICAL JOURNAL

Volume19 (2025). Issue 3

CONTENTS

4. ***Avagyan A.S., Muradyan A.A., Makletsova M.G., Poleshchuk B.B., Zilfyan A.V.***
THE ROLE OF ALIPHATIC POLYAMINES AND A-SYNUCLEIN IN THE FORMATION OF PERIPHERAL MECHANISMS INVOLVED IN THE PARKINSON'S DISEASE INDUCTION

17. ***Shuliatnikova O.A., Karakulova Y.V., Batog E.I., Rogoznikov G.I.***
STUDY OF THE COMORBID ASSOCIATION OF INFLAMMATORY PERIODONTAL DISEASES AND PATHOLOGY OF THE NERVOUS SYSTEM

23. ***Bari Md.N., Anwar Md., Ansari Md.R., Osman. E.H.A., Alfaki, M.A., Mohammad I.***
A COMPLICATED SITUATION OF DIAGNOSIS OF BIOMARKERS IN ALCOHOLIC LIVER CIRHOSIS INJURY BY ROUSSEL UCLAF CAUSALITY ASSESSMENT METHOD

30. ***Gavanji S., Bakhtari A., Baghshahi H., Hamami Chamgordani Z., Gavanji J., Sinaei J., Hassani D.***
COMPARING THE ANTI-CANDIDA ALBICANS EFFECT OF ZINGIBER OFFICINALE WITH COMMON ANTIFUNGAL DRUGS

37. ***Masnavi E., Hasanzadeh S.***
FREQUENCY OF AMINOGLYCOSIDES RESISTANCE GENES (ANT(4')-IA, APH(3')-IIIA, AAC-(6')-IE-/APH]2) IN STAPHYLOCOCCUS AUREUS ISOLATED FROM SURGICAL AND RESPIRATORY SITE INFECTIONS

44. ***Shahsafi M., Madrnia M., Mohajerani H.R., Akbari M.***
EVALUATION OF THE ANTIBACTERIAL ACTIVITY OF CYNARA SCOLYMUS EXTRACT AND ITS WOUND HEALING POTENCY AGAINST MULTIDRUG-RESISTANT *ACINETOBACTER* BAUMANNII, *In vitro* AND *In Vivo* STUDY

57. ***Kanannejad Z., Hosseini S.F., Karimpour F., Taylor W.R, Gevorgian L., Ghatee M. A.***
EXPLORING CLIMATIC AND GEOGRAPHICAL DRIVERS OF HEPATITIS B VIRUS SPREAD IN KOHGILUYEH AND BOYER-AHMAD PROVINCE, IRAN

67. ***Sametzadeh M., Roghani M., Askarpour S., Shayestezadeh B., Hanafi M.G.***
NON-ENHANCED CT FINDINGS IN PATIENTS SUSPECTED OF ACUTE APPENDICITIS WITH NON-DIAGNOSTIC ULTRASONOGRAPHY

75. ***Zharfan A.S., Airlangga P.S., Santoso K.H., Fitriati M.***
PERIOPERATIVE MANAGEMENT OF CESAREAN SECTION IN A PATIENT WITH SEVERE SCOLIOSIS: A CASE REPORT

82. ***Mohammadi Arani F., Shirmohammadi M., Tavakol Z., Karami M., Raeisi Shahraki H., Khaledifar A.***
EFFECTIVENESS OF COGNITIVE BEHAVIORAL THERAPY ON SEXUAL SELF-EFFICACY IN REPRODUCTIVE-AGED WOMEN WITH CARDIOVASCULAR DISEASE (A RANDOMIZED CLINICAL TRIAL STUDY)

91. ***Maghakyan S.A., Aghajanova E.M., Khachaturyan S.R., Hrantyan A.M., Melkonyan N.R., Aleksanyan A.Y., Barseghyan E.S., Muradyan A.A.***
ASSOCIATION OF PRIMARY HYPERPARATHYROIDISM AND PAPILLARY THYROID CARCINOMA IN A PATIENT WITH BROWN TUMOR AND PARKINSONISM: CASE REPORT

97. ***Martirosyan D. A., Muradyan A. A.***
COVID-19 ASSOCIATED INCRUSTING CYSTITIS: A CASE REPORT

102. ***Faghihrad H.R., Sheikhbagheri B., Roknabadi M., Shapouri R.***
HERBAL OINTMENT BLEND AND ANTIBACTERIAL ACTIVITY

108. ***Fanarjyan R.V., Zakaryan A.V., Kalashyan M.V., Zakaryan A.N.***
ACUTE INTRATUMORAL HEMORRHAGE IN A MENINGOTHELIAL MENINGIOMA: A CASE REPORT OF EMERGENCY RESECTION

112. ***Mkrtchyan R.A., Ghardyan G.K., Abrahamyan L.R., Karalyan N.Yu., Abrahamyan S.H., Abrahamyan R.A.***
SIRENOMELIA: A UNIQUE CONGENITAL ANOMALY (CLINICAL CASE)

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