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Mortality due to noninfectious lower respiratory diseases: A spatiotemporal, cross-sectional study

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Abstract

Background and Aims: Geography plays an important role in the incidence of respiratory diseases. The aim of this study was to investigate the epidemiology and geographical distribution of death due to noninfectious lower respiratory diseases (NILRDs).

Methods: Data related to all death due to NILRD in Kerman Province between 2012 and 2018 were extracted from the National Mortality Registry. The underlying causes of death were extracted from the registry based on the assigned codes from ICD-10 (International Classification of Diseases 10th Revision) classification. The existence of spatial clusters and outliers was evaluated using local indicators of spatial association statistics.

Results: The frequency of death due to NILRD was 8005 persons during the 7 years of the study. The main cause of death was chronic lower respiratory disease (54.2%). Other causes of death were, respectively, lung diseases due to external agents (1.09%), other respiratory diseases mainly affecting the interstitium (1.16%), other diseases of pleura (0.57%), and other diseases of the respiratory system (42.13%). The age- and sex-adjusted mortality rates due to NILRD in the north and center of the province increased significantly from 2012 to 2018. Also, the results of cluster analysis identified northern regions as the clustered areas of NILRD.

Conclusions: Our findings showed a significant increase in mortality due to NILRD in Kerman Province during the 7 years of the study. To reduce this type of death, health policymakers should have environmental health plans and basic solutions, such as a warning system to reduce the commuting on highly air-polluted days and to control pollutants, especially in the industrial areas of the north of this province.

KEYWORDS

geographical information systems, lower respiratory diseases, mortality, spatial analysis, spatial clustering

1 | INTRODUCTION

Respiratory diseases are among the major public health issues in the world.[1] After 2019, a clear example of a respiratory disease that threatened all the people in the world was coronavirus disease 2019 (COVID-19).[2] Before the outbreak of COVID-19, respiratory diseases were much more neglected than other noncommunicable diseases such as cardiovascular diseases, cancers, and diabetes.[3] Nearly 9.5 million people worldwide die from respiratory diseases annually.[4] A study published in 2019 reported that approximately 10% of annual deaths in Iran are due to respiratory diseases.[5] In Tehran, the capital and most populous city of Iran, almost 5000 people die every year due to respiratory diseases.[6] Furthermore, in the last 10 years, a significant increase in the rate of death due to respiratory diseases has been reported in Tehran.[7] According to the statistics published by International Lung Association in 2017, respiratory diseases such as asthma, pneumonia, and chronic obstructive pulmonary disease (COPD) are among the most common noninfectious lower respiratory diseases (NILRD) in the world.[8]

According to World Health Organization (WHO) in 2016, air pollution caused 14% of premature respiratory death around the world.[9] Because of the high mortality rate due to respiratory diseases, several studies have investigated the associated risk factors such as smoking, urban air quality, industrial activities, and so on. Environmental factors such as motor vehicles, industrial tools, forest fires, and home heating services can also increase the risk of respiratory diseases.[10,11] In 2016, an emphasis on geographic disparities was cited as the key to reducing respiratory disease mortality worldwide.[12] To reduce mortality, in recent decades, WHO and other health organizations consistently use spatial mapping and analysis to visualize and manage the distribution of health conditions.[13]

The geographical characteristics of residents can be effective in the incidence of diseases.[14,15] Geographical Information System (GIS) is a powerful tool for identifying high-risk areas and understanding the pattern of diseases by combining spatial and temporal data.[16] Also, the Geographic Information System (GIS) is a helpful tool for investigating how humans interact with their environment and measuring the effect of environmental changes on the health status of society.[17] A recent study in Tehran reported the spatial distribution of death from respiratory diseases and a significant increase in mortality rate during the 10 years.[7] Qanbarnezhad et al.[18] conducted spatial clustering of tuberculosis cases in southern Iran and studied the role of spatial factors such as population density in the incidence of tuberculosis. Sharifi et al.[19] used a cluster sampling method in five provinces of Iran (especially Kerman) and showed a significant reduction in COPD when individuals had less exposure to environmental risk factors.

The high amount of dust in the air of Kerman[20] and the presence of Iran's largest metal mines in this province[21] have led to an increase in the level of heavy metals in the dust[22] and ultimately leading to an increase in death.[23] Studies have indicated a direct relationship between air pollution in Kerman and the rate of adult mortality[24] and hospitalization due to respiratory problems.[25] Various GIS studies have been conducted in Kerman with other objectives such as identifying priority areas for maternal health centers[26] as well as implementing a GIS system using medical records of traffic accident victims,[27] the spatial distribution of brucellosis[28] and geographical distribution of cancer deaths.[29] However, our team found no study on the spatial–temporal patterns of death caused by noninfectious diseases of the lower respiratory tract in Kerman Province. While similar studies have been conducted in other provinces of Iran such as Tehran, Shiraz, and Mashhad,[1,7,30] this research aimed to examine the geographical distribution of NILRD-induced death in Kerman using GIS tools.

2 | MATERIALS AND METHODS

2.1 | Study area

Kerman Province has an area of 183.285 km^2 and covers more than 11% of the area of Iran.[31] Kerman Province is located between 53′ and 26′ to 59′ and 29′ east longitude and 25′ and 55′ to 32′ north latitude in the southeast of the central plateau of Iran (Figure 1). According to the population and housing census of 2016, the population of Kerman Province was 3,164,718.[32] Also, according to the latest divisions of the country, Kerman Province has 23 counties, 67 cities, 57 towns, and 162 villages.[31] The city of Kerman is the capital of Kerman Province. Kerman is a dry province in Iran and surrounded by deserts with the highest amount of dust in the air.[22] Moreover, this province has the largest metal mines in Iran,[23] which leads to an increased level of heavy metals in the dust.[24]

2.2 | Data collection and preparation

To record all the death and related causes in Kerman Province, the mortality registry systems with the embedded classification of causes of death have been implemented since 1992. This system is approved by the Ministry of Health and information related to all cases of death in the province. This database is not a public one, but access to anonymous data of deceased patients is provided to the researchers. Causes of death are coded based on ICD-10 (International Statistical Classification of Diseases and Related Health Problems 10th Revision). In total, five death registry works in Kerman Province registers the incidence of death in their areas. To extract death, the codes related to the underlying cause of death were considered. All the deaths due to NILRD with ICD-10 codes of J40–J47 (chronic lower respiratory diseases), J60–J70 (lung diseases due to external agents), J80-J84

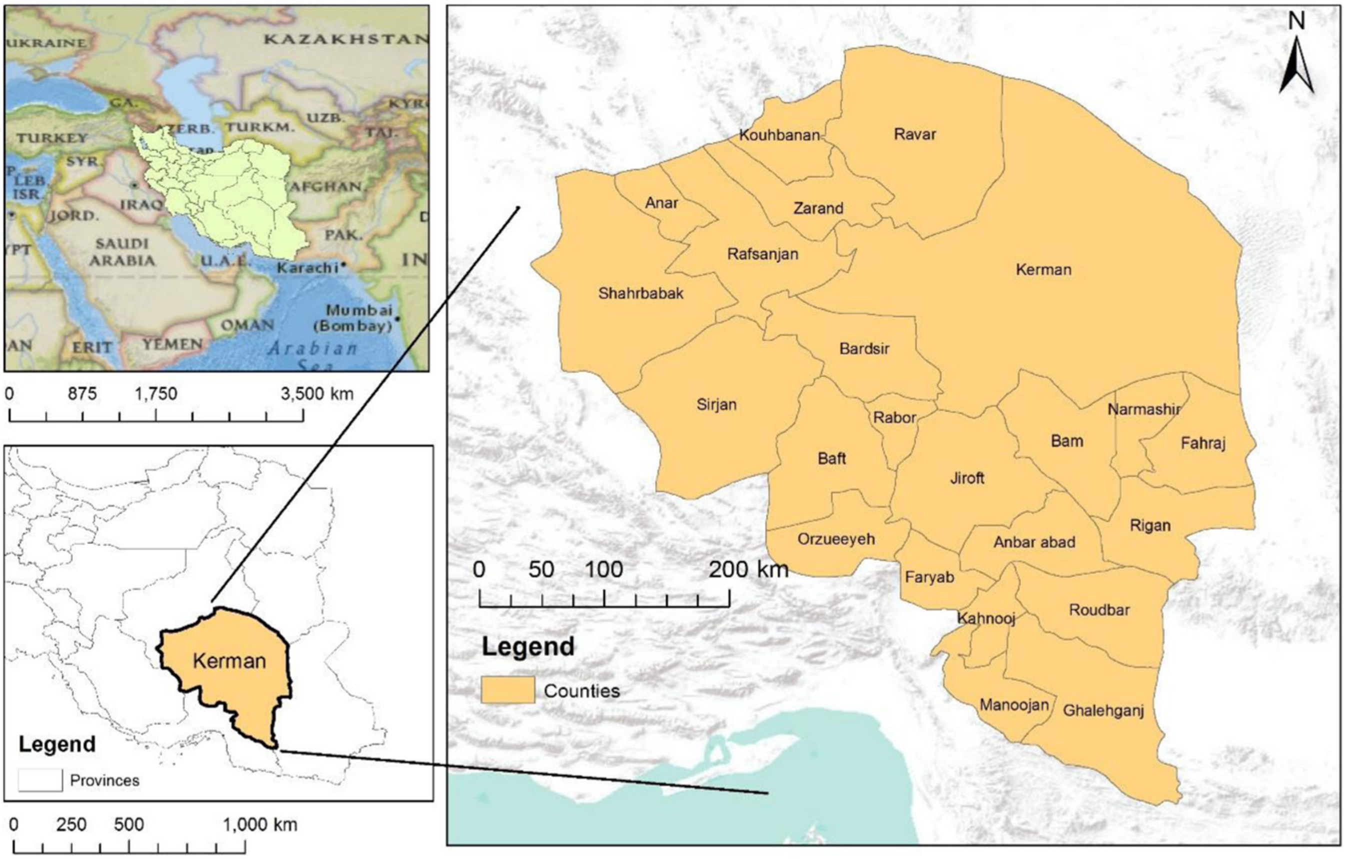

FIGURE 1 Twenty-three counties of Kerman. The authors acknowledge the Kerman Municipality for providing the shape file of Kerman counties used to create this map. The shape file is freely available from https://map.kerman.ir. The elevation data are freely available from https://earthexplorer.usgs.gov. The image was created by ArcGIS 10.5 (ESRI, Redlands, CA, USA).

(other respiratory diseases mainly affecting the interstitium), J90–J94 (other diseases of pleura), and J95–J99 (other diseases of the respiratory system) were extracted from the mortality registry of Kerman Province from January 2012 to December 2018. The mortality registry system was started in 2012. At the beginning of the research, the data were recorded in this system only until 2018. The extracted data included age, date of death, place of residence, and underlying cause of death according to ICD-10 codes. Age was reported in six age groups: 0–14, 15–24, 25–44, 45–64, 65–79, and <79, and three-digit code level was considered for the causes of death. Mortality data of people from other provinces, the death of whom was recorded in the registry, and people of unknown gender were excluded from the study. Census data were also obtained from the Statistics Center of Iran.[33]

2.3 | Spatial analysis

In the first step of the spatial analysis, spatial autocorrelation of NILRD rates was examined using the global Moran's index. The global Moran's *I* is a measure of the overall clustering of the spatial data. The null hypothesis states that the attribute is randomly distributed. Having a −1 to +1 scale, global Moran's *I* measures the degree to which the value of a variable in a region is similar to its neighboring regions, as the closer the index gets to +1, the higher the probability of having a positive spatial autocorrelation and the more similar the neighboring regions would be in terms of the target attribute.[34]

In the next step, the existence of spatial clusters and outliers was evaluated using local indicators of spatial association (LISA). LISA is a statistic that meets these two requirements:

1. The LISA for each observation shows the extent of significant spatial clustering of similar values around the observation.
2. The sum of LISAs for all the observations is proportional to a global indicator of spatial association.

To express LISA for variable y_i, observed at location i, as a statistic L_i, such that

$$L_i = f(y_i, y_{j_i}), \tag{1}$$

where f is a function and y_{j_i} is the value observed in the neighborhood J_i for i. Among the statistics that satisfy the requirement of LISA, the local Moran's *I* is a popular one.

A local Moran statistic for an observation i is defined as

$$I_i = z_i \sum_j w_{ij} z_j, \quad (2)$$

where observations z_i, z_j are in deviations from the mean and the summation over j is such that only neighboring values $j \in J_i$ are included. Using z-score and p value, local Moran's I can discover similarity (a spatial cluster) or dissimilarity (spatial outlier) for each spatial unit.[35] Results of cluster and outlier analysis identify four types of regions: "high–high (HH)" and "low–low (LL)" regions show the clustered regions and high-low and low-high regions show the outlier regions of respiratory mortality rate. A p value of less than 0.05 was considered as significant in this study.

2.4 | Software

All the spatial analyses were performed in ArcGIS 10.5 and the descriptive analyses were conducted by Microsoft Excel 2020. We used a crude incidence per 10,000 and the age-standardized rate (ASR) per 10,000 death for the descriptive statistics.

2.5 | Ethical considerations

Before starting, the study was approved by the Ethics Committee of Kerman University of Medical Sciences (IR.KMU.REC.1399.157). All the methods were performed in accordance with the regulations of the Ethical Research Committee of Kerman University of Medical Sciences (code: 98000974). All the mortality cases were reported in the groups only and no identifiable information was extracted from the mortality registry.

TABLE 1 Incidence of noninfectious lower respiratory diseases mortality rates per 10,000 people from 2012 to 2018 in Kerman province, Iran

	Mortality number			
Period	Female	Male	Crude rate	ASR
2012	228	372	2.39	2.388
2013	284	359	2.37	2.370
2014	505	678	4.04	4.037
2015	636	808	4.56	4.563
2016	630	819	4.24	4.239
2017	580	679	3.41	3.411
2018	653	769	3.57	3.567

Abbreviation: ASR, age-standardized rate.

3 | RESULTS

3.1 | Descriptive results

In 23 cities of Kerman province, a total of 8005 individuals died due to NILRD from 2012 to 2018. The incidence of crude and ASR mortality rate per 10,000 people is shown in Table 1. From 2012 to 2018, the ASR increased from 2.388 to 3.567. During these 7 years, the average mortality due to NILRD was 3 per 10,000 and men (56.04%) were more at risk than women (43.96%) ($p < 0.05$). In total, 17.56% of death occurred in the age group of 80 years and older. Figure 2 shows mortality due to NILRD in different counties of Kerman Province; the city of Kerman had the highest (36.49%) and Faryab had the lowest mortality rate (0.01%).

3.2 | Causes of death

The main groups of underlying causes of death due to NILRD according to ICD-10 were chronic lower respiratory diseases (54.2%), lung diseases due to external agents (1.09%), other respiratory diseases mainly

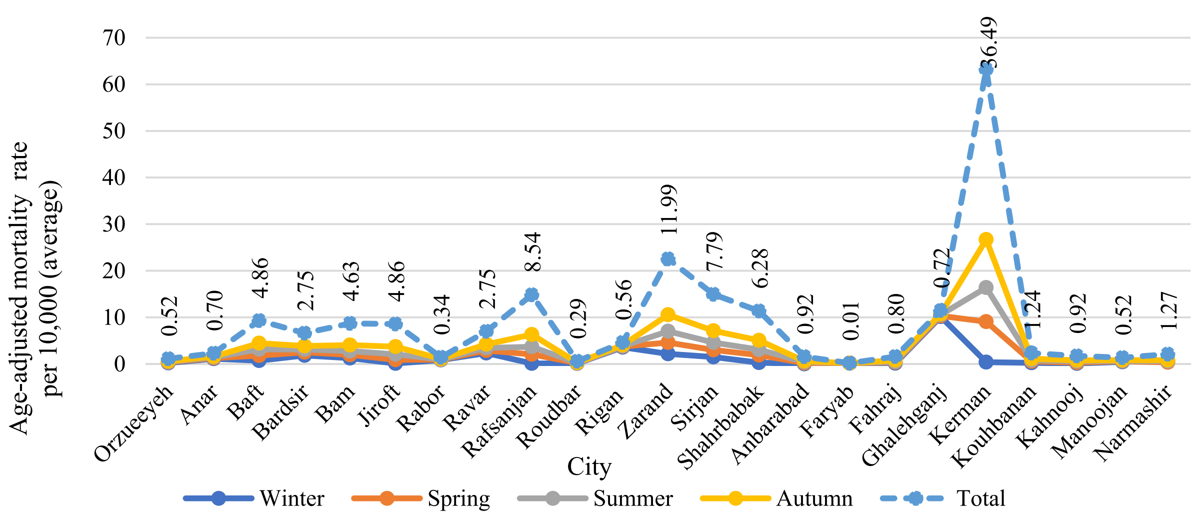

FIGURE 2 Age-adjusted annual and seasonal mortality rates of respiratory diseases per 10,000

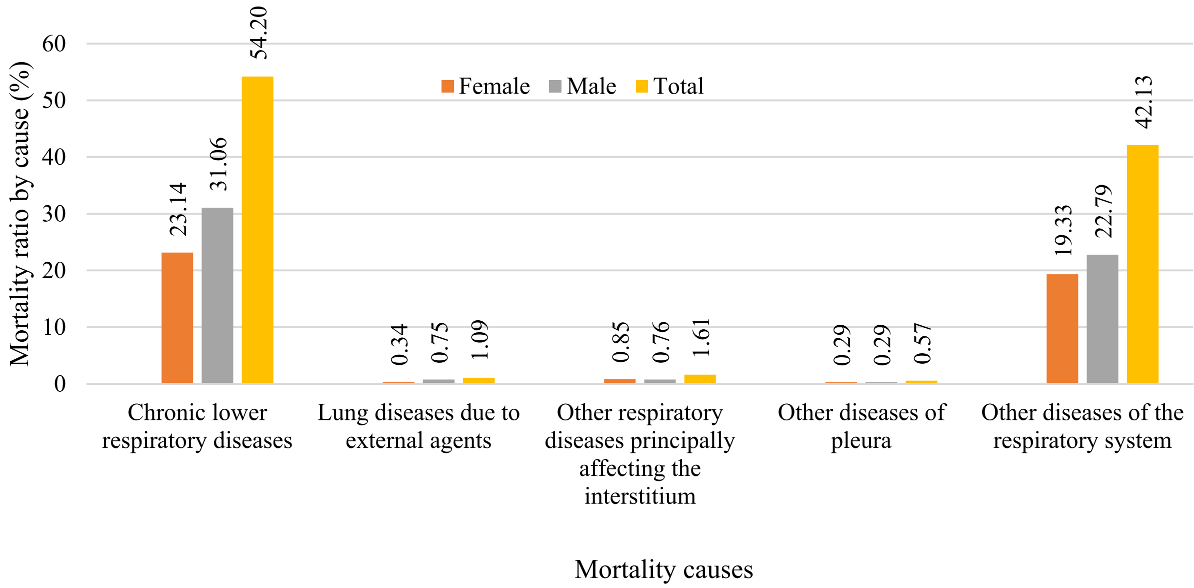

FIGURE 3 Noninfectious lower respiratory diseases mortality rates per gender, Kerman, 2012–2019

affecting the interstitium (1.16%), other diseases of pleura (0.57%), and other diseases of the respiratory system (42.13%) (Figure 3).

3.3 | Spatial analysis results

3.3.1 | Disease mapping

Descriptive maps of Figure 4 show the age- and sex-standardized mortality rates due to NILRD from 2012 to 2018 in 23 counties of Kerman Province. During this period, the mortality rates due to NILRD in the north and center of the province increased from 2012 to 2018. However, this pattern was relatively similar for the southern regions with lower rates of NILRD. The overall geographical distribution of mortality also increased from 7 to 13 high-rate areas during the study period.

3.3.2 | Spatial clustering

The spatial clustering results showed that the global Moran's index was 0.32 ($p < 0.01$), thus showing positive spatial autocorrelation for death due to respiratory diseases. Figure 5 demonstrates the results of local Moran *I* to identify the clusters and outliers. This figure confirms that the incidence of mortality in the north of the province was significantly higher than in other areas. However, as cluster maps show, in 2013, HH clusters in the northern part of the province belonged to the cities of Ravar, Rafsanjan, Kuhbanan, and Zarand. But since 2014, Zarand was no longer among the HH clusters. In 2018, none of the counties was in HH clusters. In addition, there were LL clusters in the southern part of the province, especially in the county of Anbarabad, Faryab, Rudbar, Kuhbanan, Manojan, and Qala-e-Ganj during the entire 7-year study period, except for 2018.

4 | DISCUSSION

The main purpose of this study was to discover the spatiotemporal patterns of mortality due to NILRD on a geographical scale. In the present study, the highest prevalence of mortality due to NILRD was in the north and center of the province and the lowest in the south of the province. The main underlying cause of death in this province was chronic lower respiratory diseases (54.2%), which were diagnosed more in the elderly (≥80). It seems that more research is needed in high-risk areas in the future to determine the cause of death. According to previous studies, the priority of this research should be given to environmental risk factors such as air pollution[36,37] and the presence of heavy metals in the air.[38,39]

So far, several studies have examined the effects of air pollution on human health among different age and sex groups.[40–42] In the present study, men were more at risk of dying from NILRD than women. A study in Kerman showed a significantly positive relationship between increased respiratory mortality in men and increased dust, but this relationship was not observed in women.[43] These results could be related to men's jobs in occupations such as industry or more outdoor activities that expose them to more air pollution.[43,44] Our study also showed that older people (over 80 years old) are more prone to mortality from NILRD. These findings are consistent with previous studies showing that older people are more prone to outdoor air pollution.[42,45–47]

Evidence shows that the north and center of Kerman Province have the highest mortality rate from NILRD during these 7 years. Since this province ranks fourth in mineral and industrial products in Iran,[48] the first and most important reason can be the location of most mines in the northern and central regions.[49] According to previous works, living in industrial areas can lead to respiratory diseases.[50–52] The second reason could be the location of the Lut Desert (the 27th largest desert in the world) in the northeast and east of Kerman Province.[53] Drought and

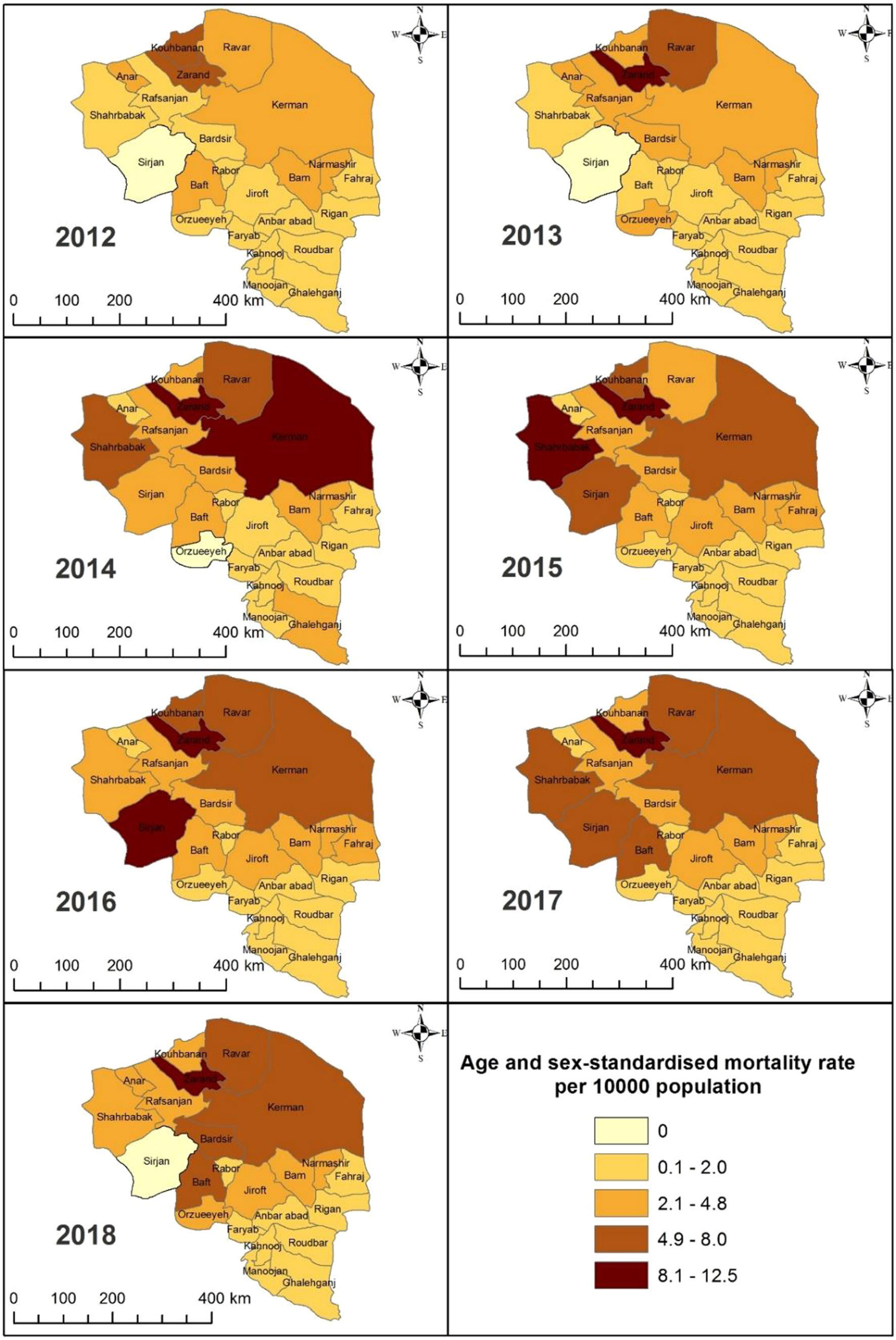

FIGURE 4 Age- and sex-standardized mortality rate map at the county level in the province of Kerman, Iran

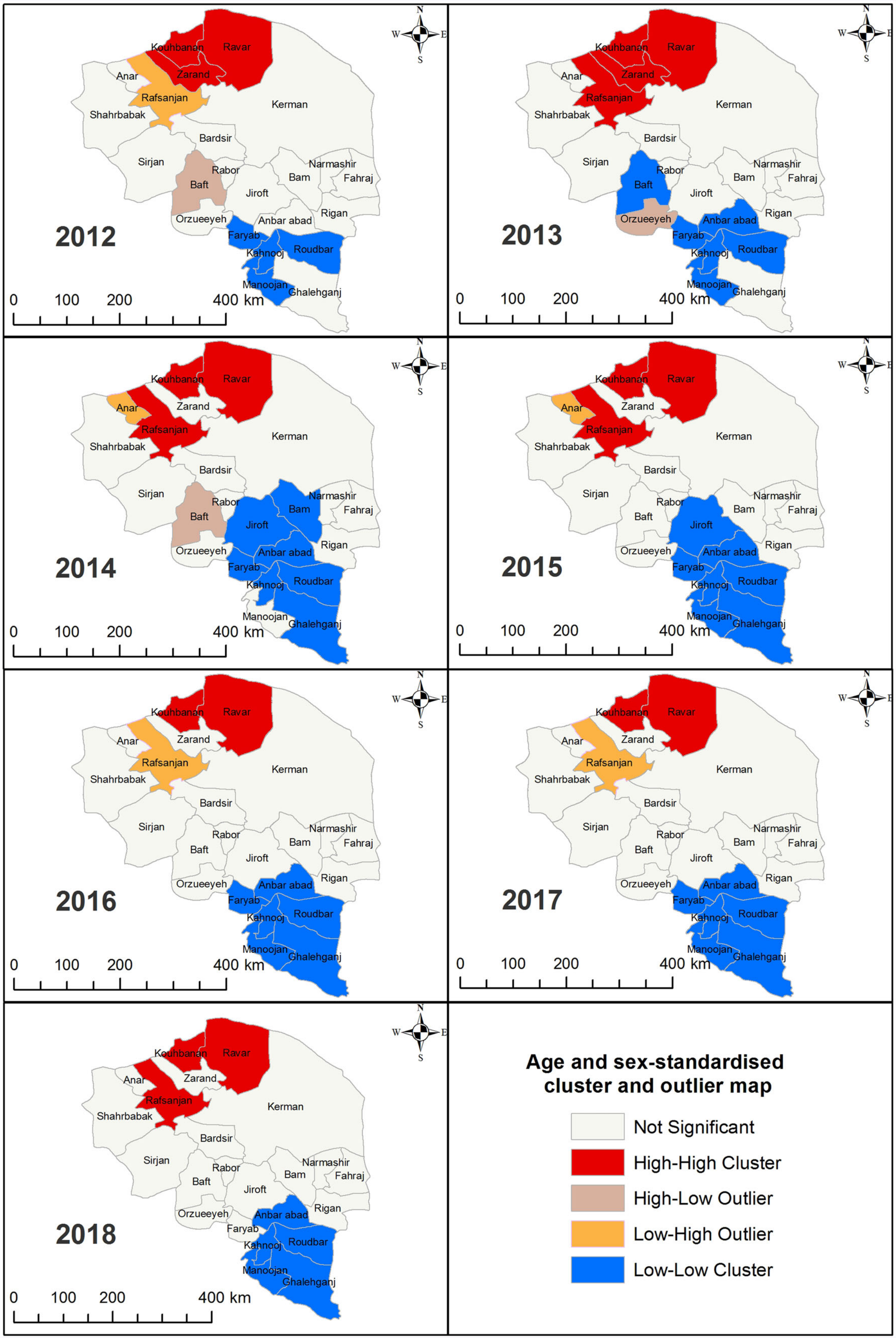

FIGURE 5 Age-adjusted cluster map according to Anselin Local Moran's *I* of mortality rate in Kerman 2012–2018. The authors acknowledge the Kerman Municipality for providing the shapefile of the Kerman districts used to create this map. The shapefile is freely available from https://map.kerman.ir. The image was created by ArcGIS 10.5 (ESRI, Redlands, CA, USA).

seasonal winds play a role in increasing dust in areas close to the desert. Studies have shown that exposure to airborne dust particles can lead to respiratory illness and even death.[54,55] The third reason can be attributed to the Sirjan salt swamp.[56] This swamp is one of the largest salt depots in Iran;[57] due to intense sunlight and evaporation of water, it becomes saline in summer.

Findings show that the mortality rate due to NILRD has almost doubled from 2012 to 2018. Due to the hot and dry climate and desert of Kerman and the occurrence of sand storms in spring and autumn, the concentration of airborne particles goes beyond the allowable amount.[58] Also, having the largest metal mines in Kerman Province has led to an increase in heavy metals in airborne dust particles.[23] In this province, the average concentration of PM2.5, NO_2, and O_3 in recent years has been higher than the WHO guidelines;[59] it was also discovered that there was a significant relationship between monthly PM10 concentration and death from respiratory diseases.[43] Another study reported a link between hospital admissions and SO_2 in Kerman.[40] These results are consistent with the results of other researchers who have stated that the increase in mortality is due to the high number of respiratory diseases in Tehran.[60] This evidence further indicates the need to control air pollution in this province.

The results of seasonal rate pattern analysis showed that the high mortality rate in Kerman and the low mortality rate in Faryab are repeated from year to year during the winter and autumn season changes. Other environmental aspects such as temperature can change the mortality rate. In our study, the mortality rate decreased with increases in temperature. In line with our study, Khanjani and Bahrampour[61] also showed that death in Kerman decreases with increasing temperature. Another study reported the change in behavior patterns in hot weather, such as staying at home and being less exposed to air pollution, as the reason for this decrease.[62]

Based on the research of our research team, this is the first one in Kerman Province, Iran, which identifies the spatial patterns of NILRD incidence. Spatial clustering plays an important role in visualizing and quantifying geographic variation patterns. Global cluster statistics and local spatial statistics are two important types of spatial statistics to identify geographical variations in the NILRD rate. Global methods, including global Moran's *I* that we used in our research, are more sensitive to departures from the null hypothesis. Global methods could identify spatial structures, but do not determine where the clusters are.[49] Local cluster statistics such as Anselin's local Moran's *I* quantify spatial autocorrelation and clustering at the small area level.[63] As this research aimed to detect both spatial variation and spatial clusters, we applied both the global and local methods. Numerous spatial variations have been identified in NILRD incidence in the study area with some significant HH and LL clusters. Also, we identified some outlier regions of NILRD occurrence. These outliers and cluster areas need to be further investigated to identify the drivers associated with the high-risk areas.

5 | CONCLUSION

To conduct this study, mortality registry systems of Kerman Province were used and all the death due to NILRD in Kerman Province during the years 2012–2018 were extracted from these systems. However, people may have migrated or traveled from Kerman Province to other provinces during these years and died there because of this disease and their mortality reports have not been communicated to these systems. However, in Iran, all deaths are recorded in mortality registry systems throughout the country and each city has the possibility of recovering its death from the central system of the country. Due to the ecological nature of this study, we cannot easily extrapolate the results to the individual level.

Our findings showed a significant increase in mortality due to NILRD in Kerman in the last 7 years. The findings of this study also demonstrated that the spatiotemporal distribution of mortality due to NILRD in Kerman followed a heterogeneous pattern. When faced with rising mortality from noncommunicable lower respiratory diseases, environmental pollution control and environmental health policies can help effectively control such diseases. Therefore, due to the special climatic conditions of Kerman Province, it is necessary for health policymakers to have environmental health plans and basic solutions, such as a warning system to reduce commuting on highly air-polluted days, to control pollutants to prevent the promotion of industrial centers in this region.

AUTHOR CONTRIBUTIONS

Parastoo Amiri: Conceptualization; data curation; software; validation; writing – original draft; writing – review and editing. **Soheil Hashtarkhani**: Formal analysis; funding acquisition; investigation; project administration; resources; software; writing – original draft. **Ashraf Yazdizadeh**: Data curation; investigation; resources. **Leila Ahmadian**: Investigation; methodology; project administration; supervision; visualization; writing – original draft.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Raw data on persons deceased due to NILRD from 2012 to 2018 were obtained from the Ministry of Health Organization (Iran). There is no permission to obtain the data sets and they are available from the corresponding author on request.

ETHICS STATEMENT

This article was extracted from an independent research project performed at the Kerman University of Medical Sciences without organizational support (ethical code: IR.KMU.REC.1399.157) and was supported by the Student Research Committee of Kerman University of Medical Sciences (code: 98000974). The manuscript does not contain any individual person's data in any form.

TRANSPARENCY STATEMENT

The lead author Leila Ahmadian affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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