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Relationship Between Land Use Changes and the Production of Dust Sources in Kermanshah Province, Iran

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Abstract: Recognizing land use changes (LUC) and evaluating their relationship with producing dust sources are considered effective to manage the environment. Taking Kermanshah Province, Iran as study area, dusty days from 2008 to 2015 were selected and dust sources were identified applying thermal-infrared dust index (TDI), hybrid single-particle lagrangian integrated trajectory (HYSPLIT), false color composite (FCC) and true color composite (TCC) of MODerate resolution Imaging Spectroradiometer (MODIS) images. Afterwards, the land use change map was produced using Landsat images in 2000 and 2015. Then, the distribution and frequency of the sources in each land-use change class and important dust production areas were specified. Eventually, two non-parametric tests including Chi-square and Kruskal-Wallis were applied to examine the relationship between LUC and dust sources. Results indicated that the distribution of dust sources was not identical in the study area, and the sources were mainly generated in the areas where land-use change had occurred. In fact, different classes of LUC have different contributions to dust production, and the highest contribution refers to the deflation in gentle slope areas and lowlands where the rangeland has been converted into agriculture land. The findings from this study are useful to manage and control dust in the identified sources.

Keywords: dust source; hybrid single-particle lagrangian integrated trajectory (HYSPLIT); land use change (LUC); MODerate resolution imaging spectroradiometer (MODIS); thermal-infrared dust index (TDI); Kermanshah Province, Iran; Iran

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1 Introduction

Dust is an atmospheric phenomenon that causes undesirable environmental impacts. Understanding the nature and origin of dust storms plays a significant role in determining procedures for controlling this phenomenon. Two essential conditions that create this phenomenon include strong long-term wind and loose soil, as well as bare ground and sparse vegetation (Qiu et al., 2001). However, some consider the first factor (Ridley et al., 2014) and others the second factor as more effective (Liu et al., 2016), but the frequency of dust events also depends on the local climate (Wang et al., 2006) as well as the land surface characteristics. For instance, the occurrence of dust storms in shrub lands is 1.3 times more than that of grasslands (Engelstaedter et al., 2003). In fact, in the same climatic environments, land surface changes play a critical role in increasing dust storms (Tegen et al., 2004; Munkhtsetseg et al., 2017; Philip et al., 2017; Wang et al., 2017b), although land-use change (LUC) causes soil degradation and the production of fine soil fractions does not affect the appearance of dust, since vegetation coverage and soil moisture in some of these areas prevent dust increase (Wang et al., 2006).

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Nowadays, areas that undergo vegetation deterioration and desertification due to inappropriate human activities have become the most important areas of dust production (Wang et al., 2017a); moreover, global dust has increased in the 20th century due to anthropogenic activities (Mahowald et al., 2010). As an example, in the regional scale, parts of the Middle East, Saudi Arabia, central and southwest of Asia are major areas in which frequency and intensity of dust activity have been dramatically increased during 2000–2015 (Rashki et al., 2014; Klingmüller et al., 2016). This increase, in addition to natural causes, seems to be affected by land cover and LUC; moreover, the most susceptible areas to desertification have been affected by dust events (Hamidi et al., 2013). For instance, deserts and dust events have increased in countries such as Iraq and Syria due to human activities, including military operations (Moridnejad et al., 2015), land degradation and LUC (Sissakian et al., 2013), as well as water resources management (Al-Ansari, 2013). In these countries, 39% of the dust sources were located in the areas that were converted into deserts due to inappropriate human activities (Moridnejad et al., 2015).

Fourteen important dust sources have been recognized inside Iran located in the southwest of Asia and Middle East (Rashki et al., 2021). These sources often include dry and ephemeral lakes like the Hamoun lakes in Sistan (Miri et al., 2010), Hamoun-e-Mashkel (Ginoux et al., 2012), Hamun-e Jaz Murian (Rashki et al., 2017; Nasab and Rahnama, 2019), Al-Howizeh/Al-Azim marshes (Cao et al., 2015; Javadian et al., 2019), Urmia Lake (Ginoux et al., 2012; Gholampour et al., 2015; 2017), Bakhtegan Lake, Gavkhooni wetland (Khusfi et al., 2017); desert areas like Dasht-e Lut (Ginoux et al., 2012), Dasht-e Kavir (Prospero et al., 2002), Dasht-e Rigan (Abbasi et al., 2019); alluvial plains such as Sarakhs plain (Ziyaee et al., 2018), Khuzestan plain (Heidarian et al., 2018) and coastal plains like Makran (Rezaei et al., 2019), Hormozgan (Alizadeh-Choobari et al., 2016; Beyranvand et al., 2019). Natural factors such as climate change, drought, ephemeral lakes and marshes drying, high-speed winds, *etc*. play important roles in dust emission in most of these sources. However, some human interventions like military operations, dam projects, growing demand for water, agricultural water withdrawal (by groundwater pumping and surface water extraction), degraded rangeland, abandoned rainfed agricultural land, *etc*. have also been effective in dust production in some of these sources. Five regions of frequent dust events have been recognized in Iran which are the Khuzestan Plain, the coastal plain of the Persian Gulf, west of Iran, Tabas and Sistan (Alizadeh-Choobari et al., 2016) in the order of importance. Although Kermanshah Province, as an important affected region by dust, is located in the west of Iran, dust sources have not been recognized. Kermanshah is geographically different from most of recognized dust sources in Iran. Probably, there are other effective factors in dust production in this region.

In recent years, dust storms have significantly increased in the west of Iran, especially in the provinces neighboring Iraq. Some believe that the storms are the most important crisis in Iran. Kermanshah, in the west, is a province that was rarely affected by the dust storms in the past, although it is going to experience dust storms more frequently. The maximum number of dusty days (107 d) in Iran was reported for Kermanshah Province in 2008. Moreover, the frequency of dusty days at Sarpol-e-Zahab Synoptic Station increased from 14 d in 1986 to 152 d in 2009. In local scale, the relationship between frequent dust events and climate factors have been proven in some regions of Iran including Sistan-Baluchestan (Miri et al., 2010), Kurdestan (Ahmadi et al., 2015) and Isfahan (Norouzi, et al., 2017). In addition to climatic factors, the occurrence of dust is strongly affected by vegetation degradation. Within the province of Kermanshah, during the past decade, vast areas of vegetation lands (rangelands and forests) have been destroyed and seized due to unwarranted human activities. Although such changes have occurred in recent years, it is unclear whether or not these changes provide the basis of dust production comparable to other parts of the Middle East, and if these changes have facilitated the conditions for dusty events, which types of change have had the largest contribution. For this reason, Kermanshah Province was chosen as the sample to reveal the effect of LUC on production of dust using meteorological data, satellite data, field observations, and statistical analysis. Therefore, the present study aims to detect dust sources in Kermanshah Province of Iran, to determine the role of LUC that created dust sources, and to identify the most important types of LUC that have contributed to dust production.

2 Data and Methods

2.1 Study area

Kermanshah Province is located in the west of Iran with an area of 24 888 km^2. Most of the region includes Zagros Mountains with a northwest-southeast orientation. It has valleys covered with forest and rangelands (Fig. 1) due to its climatic state and adequate precipitation. The amount of precipitation varies from 250 to more than 700 mm in different regions of the province and the annual average temperaturevaries from 22°C in the warmest western regions to about 5°C in high mountains. This province is significant in terms of climate diversity, vast agricultural land, forest, rangeland, fertile soil and adequate water supply.

Generally, Kermanshah Province can be divided into semitropical and temperate mountainous regions. Qhasr-e-Shirin, Sarpol-e-Zahab, Sumar, Naft shahr, and generally the Iraqi border zone are parts of the semitropical region of the province. In addition, the central and eastern parts of the province which includes the highlands and mountainous areas such as Kermanshah, Eslamabad-e Gharb, Kangavar, Paveh and Javanrud, have a temperate climate. Proximity to Mesopotamia plains, Iraqi deserts and Saudi Arabia on the one hand and the low altitudes of the western part of the province on the other hand has made an uneasy climatic situation for the boundary inhabitants. Other climatic consequences are dense and troublesome dust that sometimes drains into the province and the occrrence of maximum temperature of 50°C, which is a normal phenomenon in Qhasr-e-Shirin and Sarpol-e-Zahab based on their geographical location.

2.2 Data sources

2.2.1 Meteorological data

In this study, daily atmospheric dust records from 2008 to 2015 were collected from 12 stations in Kermanshah Province belonging to Meteorological Organization of Iran (https://www.irimo.ir/far/) in order to extract the dusty days. In addition to Meteorological Organization data, weekly data related to the Global Data Integration System (GDAS) with 1° resolution was also utilized to run Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. These data were downloaded from National Oceanic and Atmospheric Administration (NOAA) website (https://www.noaa.gov/).

2.2.2 Satellite data

In the current study, MODIS satellite images which were downloaded from the atmosphere archive and distribution system (https://ladsweb.modaps.eosdis.nasa.gov/) were used to detect the dust. The land use (LU) map was produced by using Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite images for the year 2000 and Landsat 8 Operational Land Imager (OLI) for 2015. The Landsat images were downloaded from the United States Geological Survey archives website (USGS: https://earthexplorer.usgs.gov).

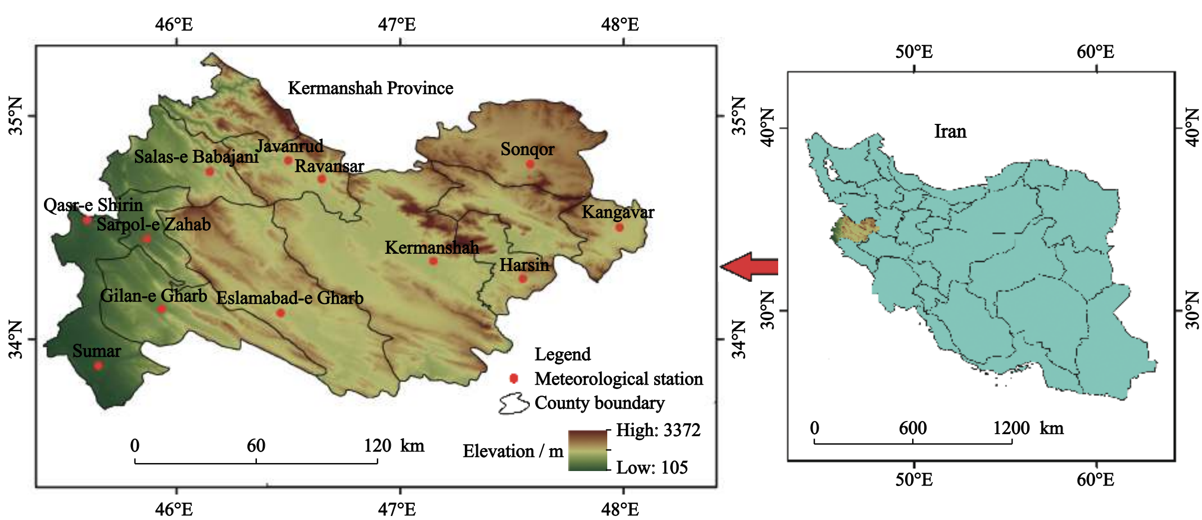

Fig. 1 Geographical location of Kermanshah Province in Iran and the distribution of applied meteorological stations

2.3 Methods

2.3.1 Determining dusty days and selecting MODIS satellite images

We based our research on daily atmospheric dust records from 2008 to 2015, measured by 12 stations belonging to Meteorological Organization of Iran (https://www.irimo.ir/far/). The selection of range of years was already done by satellite images due to significant starting of dust rising from interior of the province (Fig. 1). Atmospheric dust days (ADD) are defined for days in which the visibility is reported less than 1000 m. Accordingly, the study of records showed that 210 samples of dust events were suitable for research.

MODIS satellite images were downloaded from the atmosphere archive and distribution system (https://ladsweb.modaps.eosdis.nasa.gov/) for all of 210 dust days and 19 images (2008–2013) were selected to detect the dust sources in Kermanshah Province after the geometric corrections of the images. The rest of images were set aside for various reasons such as: 1) some images (in 2014 and 2015) had striping noise. 2) Dust detection was not possible on some images due to inactive plumes at the time of satellite overpass and their low concentration. 3) The source of many dust events was located outside the Kermanshah Province and in the neighboring countries, so these images were also removed.

2.3.2 Detection and identification of dust sources

MODIS satellite images have shown that many large dust events around the world consist of dust plumes resulting from point sources (Mahowald et al., 2005). The basis for detecting dust sources in this study is based on the criteria suggested by Bullard et al. (2008), Hahnenberger and Nicoll (2014), and Lee et al. (2009) relating to satellite images. Dust plumes are identified based on several features: opacity of surface feature near the plume, the plume color being brown or tan, cone-shaped plume and the plumes direction (Hahnenberger and Nicoll, 2014). When a dust emission cone is observed in the image, the apex of the cone (the upwind boundary of the plume) indicates the starting point of the plume or the source of the dust event, which is the best way to identify the dust source (Lee et al., 2009). Dust can occur in the form of a single coherent plume or multiple dispersed plumes; therefore, several dust sources can be identified for each dust day (Bullard et al., 2008).

There are several indices to detect and identify dust, among which the thermal-infrared dust index (TDI) algorithm is a better indicator on a regional and local scales in the Middle East (Jafari and Malekian, 2015). This index has been presented by Hao and Qu (2007), which uses MODIS thermal infrared bands (bands 20, 30, 31 and 32) to monitor and detect dust storms using Eq. (1).

$$TDI = C_0 + C_1 \times BT_{20} + C_2 \times BT_{30} + C_3 \times BT_{31} + C_4 \times BT_{32} \quad (1)$$

where, BT_{20}, BT_{30}, BT_{31} and BT_{32} are the brightness temperatures of the bands 20, 30, 31 and 32 for MODIS, respectively, and C_0 (7.9370), C_1 (0.1227), C_2 (0.0260), C_3 (−0.7068) and C_4 (0.5883) are constant coefficients of the equation.

In order to detect dust, the images were first geometrically corrected in ENVI 5.3 software. Afterwards the dust extraction Eq. (1) was written by using extension in the Erdas Imagine 9.1 software. The images of each dusty day were processed by the software, and at the end the output images of the study area were separately acquired from ArcGIS 10.3 software (Fig. 2A).

bIn addition to satellite images, HYSPLIT model was used to identify the dust sources in each dust event (Fig. 2B). This model is one of the most widely used models in calculating directions and particle dispersion, which can be used to trace the transport trajectories of dust material. This model is of significance particularly in areas where the size of the dust sources is very small and tough to identify because of the low concentration of dust plumes in each region.Since HYSPLIT model was applied to identify the wind direction, back trajectories of 12 h with a time step of 3 h at 10 m above ground level were calculated for selected days. Afterwards, MODIS images ch dusty day were matched to the model outputs in order to identify dust movement direction and upwind boundary of the dust plumes; then, the upwind boundary of each plume was recorded as the source of the dust event.

In images which the plumes were difficult to identify, the MODIS image was compared to clear sky imagery in Google Earth^{TM} with greater precision; the dust plumes would not be mistaken for other surface features. In cases where it was difficult to distinguish dust plume from cloud, a false color composite (FCC) of 7-2-1 MODIS was used. In these images, the red, green, and blue (RGB) colors were assigned to bands 7 (2155 nm),

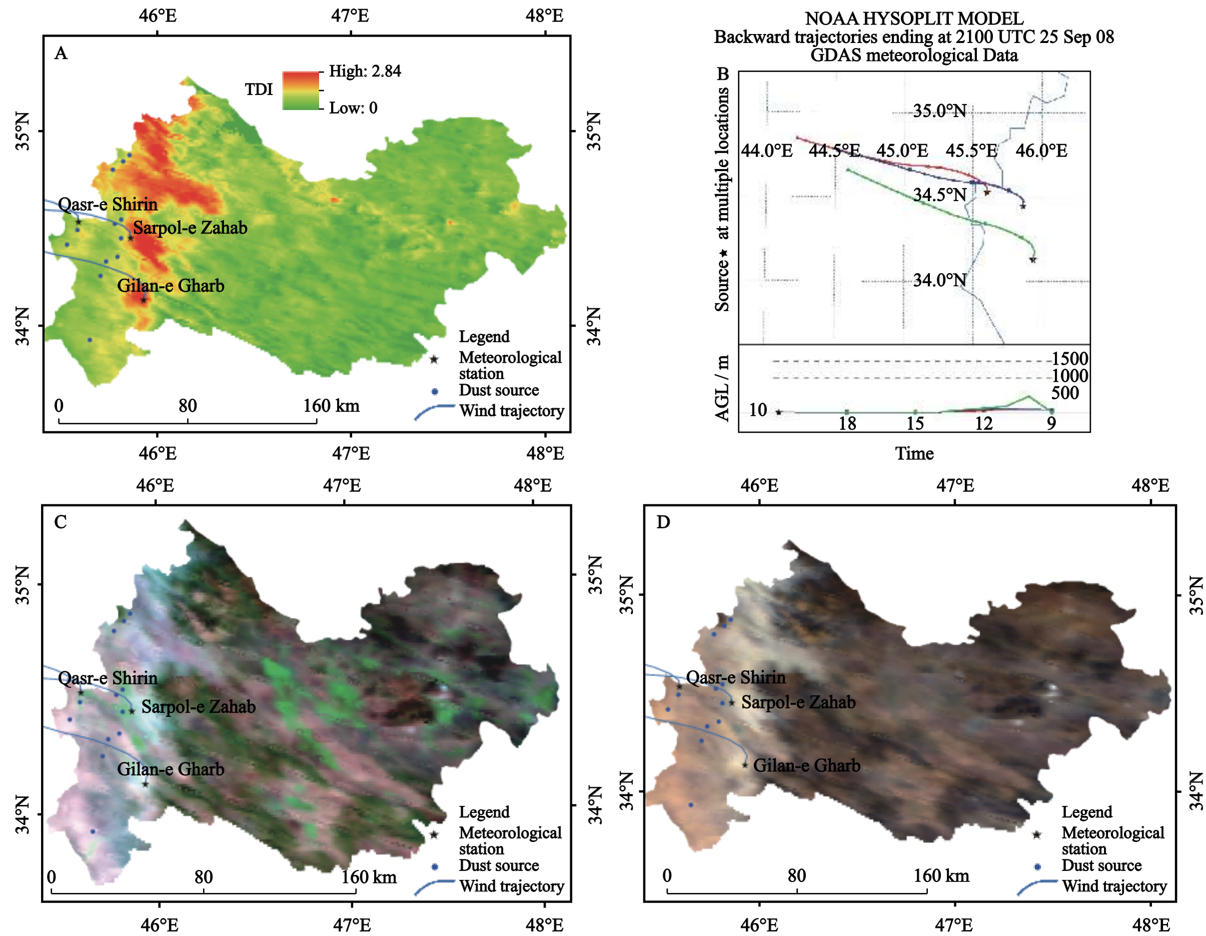

Fig. 2 The method of identifying dust sources on 25/09/2009 using A) TDI =Thermal-infrared dust index, B) HYSPLIT Model = Hybrid single-particle lagrangian integrated trajectory, C) FCC = False color composite, D) TCC = True color composite. The dots and blue lines indicate the dust sources and wind direction, respectively. Source at multiple location in Fig. 2B shows the location of meteorological stations from which dust has been reported. AGL is above-ground-level

2 (876 nm) and (670 nm) respectively. In these false color images, the clouds are bright blue which distinguishes the dust plumes from other surface features (Fig. 2C). In addition, true color composite (TCC) method was also used for the visual interpretation of dust source areas. Although the TCC simplifies detecting earth, cloud, and dust (Miller et al., 2006), it is more useful when the cloud is not observed in the dust sources (Darmenova et al., 2005). The TCC was applied to the visible bands of images in which RGB were assigned to bands 1 (620–670 nm), 4 (545–559 nm) and 3 (459–479 nm), respectively (Fig. 2D).

It should be noted that in order to be more precise in identifying dust sources, the location of the plumes was overlaid to topographic maps, geology, land use and Landsat 8 satellite images. Finally, the identified dust sources from the images were combined in ArcGIS to create a single point map and to transform the resulting point map to dust production areas with different intensities using the point density function.

2.3.3 Extraction of land use change

Since the study aims to investigate the impact of LUC on the production of dust sources, a long-term period (2000−2015) was selected for better analysis of LUC. Moreover, this time period was the selection of cloud-free images that cover the Kermanshah Province entirely. For producing the land use map, Landsat 7 Enhanced Thematic Mapper Plus (ETM $^{+}$) satellite images for the year 2000 and Landsat 8 Operational Land Imager (OLI) for 2015 were downloaded from the United States Geological Survey archives website (USGS: https://earthexplorer.usgs.gov). In order to extract LU classes in the pre-processing stage, the radiometric and atmospheric errors were corrected. It should be noted that geometric correction was not performed on these images, since they have been corrected at the reception station. In the processing stage, the supervised classification method was used. After determining the training samples on Google Earth™, with the maximum likelihood algorithm in ENVI, four LU classes (forest, rangeland, agriculture, and built-up land) in 2000 and 2015 were extracted. Finally, in order to produce the LUC map, two LU maps organized in 2000 and 2015 were compared using the coding method in GIS software. Totally, six types of LUC that affected the emergence of dust events were extracted including forest to rangeland, forest to agriculture, rangeland to agriculture, forests to built-up land, rangeland to built-up land and agriculture to built-up land. Next, dust point sources, which were extracted according to certain criteria from satellite images, were overlaid on the LUC map and their distribution and frequency in each LUC class were determined.

2.3.4 Analysis of the relationship between dust sources and land use change

At this stage, regarding the research objective for the years 2008–2013 (the time when the dust sources could be identified on the images) first, the overall impact of land use changes on the FDSs (Frequency of Dust sources) was examined regardless of the change type. Therefore, in the first step through SPSS 22 software, the difference between the FDSs in two general classes (changed and unchanged areas) was analyzed using the Chi-square test to determine whether LUC (regardless of land use type) had a significant impact on the FDSs. Next, Kruskal-Wallis, a non-parametric test and post-hock Dunn test (Jabbari, 2016), were used in order to specify whether there was a significant difference between the frequencies of dust sources in different types of LUC.

3 Results

3.1 Land use types and their changes from 2000 to 2015

LU was classified into four types in this study: forest, rangeland, agriculture, and built-up lands which include urban and rural settlements, transportation communication and recreational utilities. The LU with largest area was the rangeland, which covered 10 850 km^2 (43.59%) of the total area in 2000 and 10 763 km^2 (43.24%) of the total area in 2015 (Fig. 3). Agricultural, forest and built-up lands covered 34.9%, 20.7%, 1.24% of the region in 2000, and 35.47%, 19.64%, and 1.63% of the region in 2015, respectively. In general, the area of forest and rangeland decreased by 3.1% and 0.8%, respectively in 2015, while agriculture land and built-up lands increased by 1.63% and 31.45%, respectively, compared to those in 2000 (Table 1).

3.2 Spatial distribution and LUC condition in dust sources

A total of 161 dust sources of the study area were detected during 2008–2013. On each image, the number of identified sources varied from 2 to 15 points. The dispersion of the dust sources detected on 19 satellite images shows that the dust sources are not produced in all areas of Kermanshah Province, but most have originated in the areas that are subject to LUC (Fig. 4). The distribution of dust sources in different classes of LUC reveals that from 161 identified dust sources, 26 points (16.15%) fell in the unchanged class, 93 points (57.76%) in the rangeland to agriculture class, 19 points (11.8%) in the forest to rangeland class, and 16 points (9.94%) are located in the rangelands to built-up lands class and 7 points (4.35%) in the forest to agriculture class. However, with regard to the classes of LUC, in the areas of conversion from forest to built-up lands and agriculture to built-up lands no dust sources were observed (Figs. 4). In general, the dust sources in the rangeland to agriculture class had a higher frequency compared to other LUC classes.

As can be seen from the distribution of dust sources, high-density of these points is more obvious in several areas in the west of Kermanshah. These areas, which are the most important dust emission areas, are located in southwest of the rural district from Ezgeleh (region A), southwest of Ghasr-e Shirin (region B), Naft shahr (region C) and southeast of Sumar (region D) (Fig. 5). The densities of the identified sources in the three regions A, B and C are approximately equal, but their density in region D is lower than any of the three areas mentioned. In region A, all four types of LU are observed, and most of the dust sources are due to rangeland change to agriculture and forest to rangeland. Although dry farming is observed sporadically in regions B, C and D, which are parts of the semitropical region, the predominant vegetation covered in those areas is weak rangeland. In re-

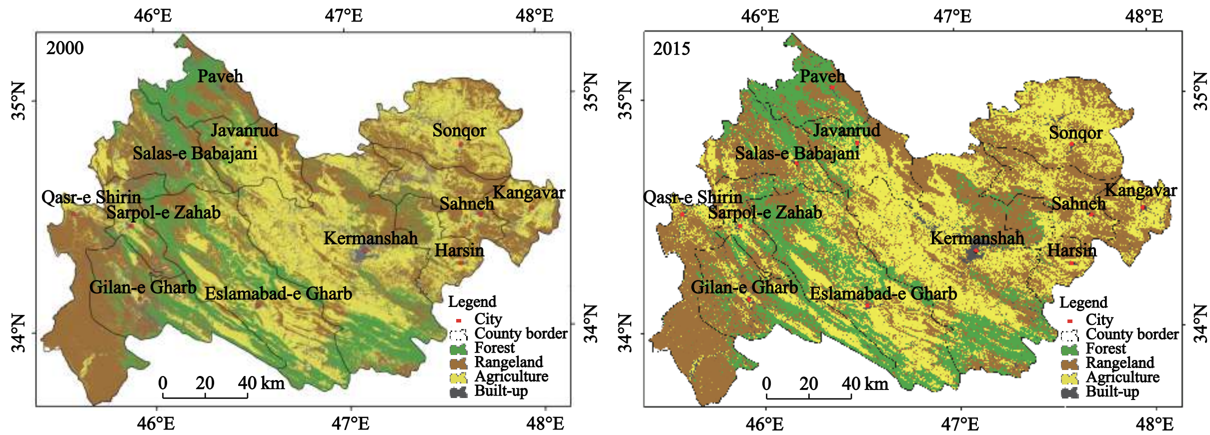

Fig. 3 Land use in Kermanshah Province, Iran in 2000 and 2015

Table 1 Land use change in Kermanshah Province, Iran in 2000 and 2015

Land use types	2000		2015		Relative change of land use / %
	Area / km^2	Percentage / %	Area / km^2	Percentage / %	
Forest	5047	20.27	4890	19.64	–3.1
Rangeland	10850	43.59	10763	43.24	–0.8
Agriculture	8682	34.9	8829	35.47	1.63
Built-up	309	1.24	406	1.63	31.45
Total	24888	100	24888	100	

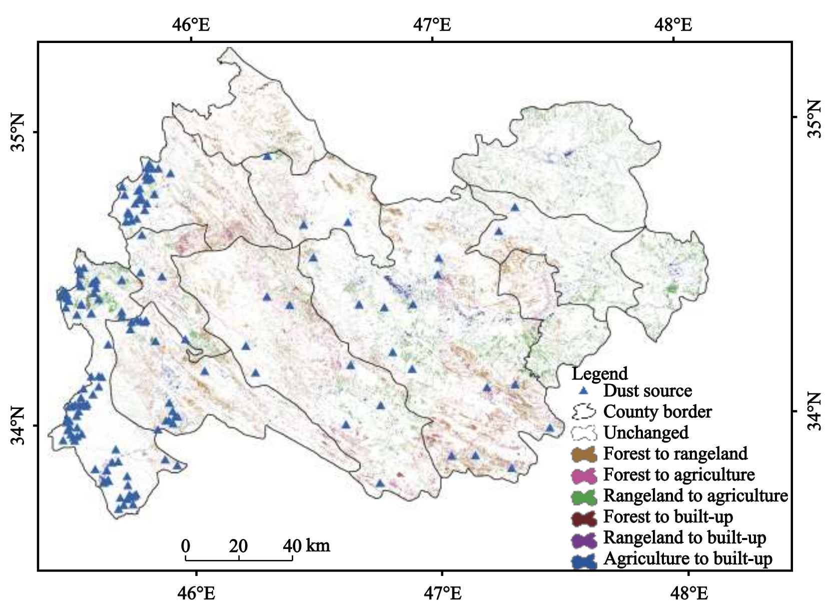

Fig. 4 Land use change and spatial distribution of dust sources that are marked with blue triangles in Kermanshah Province, Iran

gions B and C, dust sources are more observed in areas where the change was from rangeland to agriculture, but in region D, about 40% of the sources occurred in unchanged areas and the rest occurred in classes of rangeland to agriculture and rangeland to built-up lands.

3.3 The relationship between dust sources and LUC

FDSs in areas with LUC were higher than those in unchanged areas significantly ($X2 = 72$, $df = 1$; $P < 0.05$) (Fig. 6).

The comparison of the FDSs in different classes of

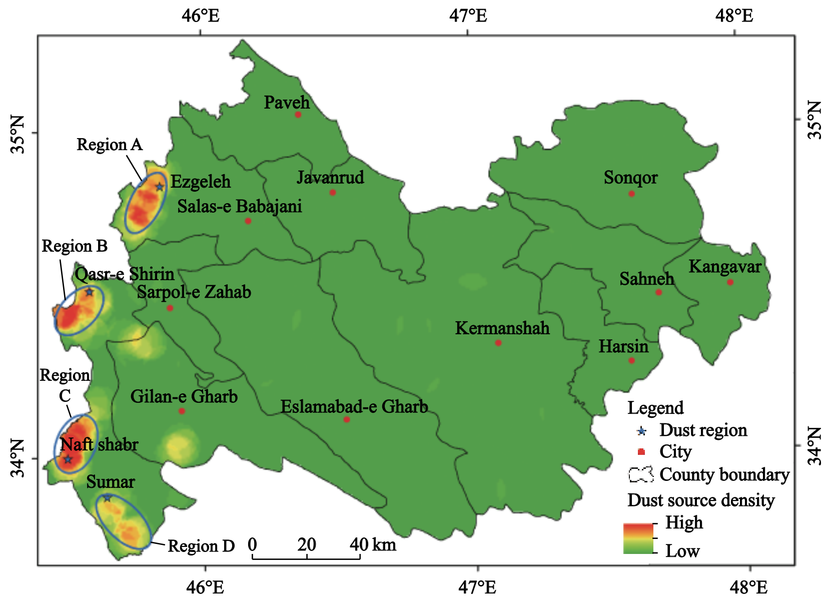

Fig. 5 Density map of dust sources and the four major region of dust production in Kermanshah Province including: Region A: Ezgeleh, Region B: Qasr-e Shirin, Region C: Naft shahr and Region D: Sumar

LUC, conducted by Kruskal-Wallis test, revealed that the distribution of the FDSs in different classes of LUC has a significant difference (H = 20.13, df = 5, P < 0.05); moreover, Dunn's test also showed that among different types of LUC, dust sources are significantly higher in areas where rangeland was converted to agriculture, than those in areas where forest was converted to built-up lands and agriculture to built-up lands (P < 0.05) (Fig. 7).

4 Discussion

The results of this study showed that in Kermanshah Province, areas exposed to LUC are more likely to produce dust. Such an outcome is fully in accordance with scientific principles, since such anthropogenic activities

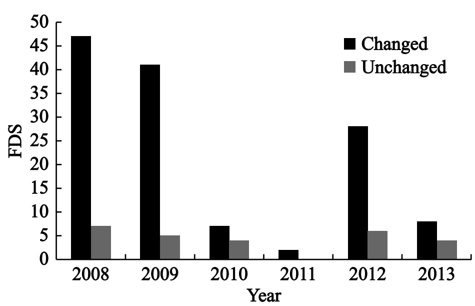

Fig. 6 FDS (Frequency of Dust Source) in changed and unchanged land use areas from 2008 to 2013 in Kermanshah Province, Iran

reduce vegetation and soil degradation which eventually decreases soil sustainability against wind erosion (Wang et al., 2018). In addition, in such areas, not only does the freshly exposed soil to wind erosion contain a lot of fine materials (silt) (Zheng et al., 2016), but it also requires a lower threshold friction velocity to move these particles (Tegen et al., 2004); therefore, these factors cause the soil to be more susceptible to erosion. Unlike these areas, dust production is low in vegetation areas, because in such areas Soil Stability and moisture prevent the production and emission of dust material (Cowie et al., 2013).

The results of this research show that there is a logical connection with regard to the role of LU and dust production, because dust is mainly produced in semi-arid (such as Kermanshah Province), semi-humid and humid regions due to anthropogenic activities (Chen et al., 2018). Dust sources are also subject to LUC, not only in semitropical regions, but also in temperate regions of Kermanshah Province. The plowable dry farming in the semitropical regions of the study area are vulnerable to wind erosion due to lack of soil moisture, weak soil structure, limited vegetation, and LUC; therefore, a large number of dust sources originated in this area (Fig. 8A). Moreover, few dust sources occurred in temperate regions, most in environments where rangeland were converted into agriculture. Such a similar conditions exist in other temperate regions in the world, such

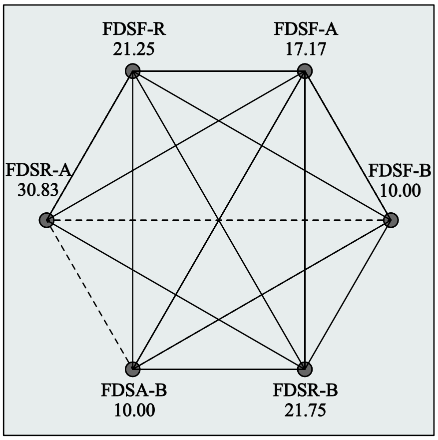

Fig. 7 Dunn Test for comparing the frequency of dust sources in different classes of land use change. FDSR-B = frequency of dust sources in rangeland to built-up, FDSR-A = frequency of dust sources in rangeland to agriculture, FDSF-A = frequency of dust sources in forest to agriculture, FDSF-R = frequency of dust sources in forest to rangeland, FDSA-B = frequency of dust sources agriculture to built-up, FDSF-B = frequency of dust sources in forests to built-up. Dotted lines indicate a significant difference between different classes. Each node shows the sample average rank of land use change

as arable land in Europe (Borrelli et al., 2015) and temperate regions of northern European countries (Riksen et al., 2003). Therefore, it can be said that in semi-arid and temperate regions, anthropogenic activities such as agriculture is the most important factor in dust production.

Out different classes of LUC, rangeland conversion to agriculture had the highest impact on dust production (Fig. 8B). It has been estimated that less than 10% of the dust in the world is released from agriculture land (Tegen et al., 2004), and dust mainly comes from deserts. Kermanshah province is certainly considered as a part of this 10% since a great number of dust sources occur in agriculture lands due to inappropriate human activities. Since in other areas such as West Texas and Eastern New Mexico (Lee et al., 2012), the Southern high plains of the United States and Chihuahuan Desert (Rivera-Rivera et al., 2010), the South of North America (Lee et al., 2009), the eastern South Australia (Cattle et al., 2012), and Southern Iran (Rezaei et al., 2016) had a similar condition, it can be concluded that agriculture land is considered as the most common type of land that causes dust production in Kermanshah Province and other areas in the world.

The relationship between agriculture land and dust emission is expected because certain human activities such as plowing which destroy aggregates (Fig. 8C) and when accompanied by severe winds, produce more dust (Lee et al., 2009); however, these lands in comparison to undisturbed lands, have a lower threshold surface wind speed which is enough for wind erosion (Tegen et al., 2004). In addition, agricultural lands are susceptible to wind erosion during the dry season after harvesting, or during fallow period that lacks vegetation ((Lee et al., 2009; Liu et al., 2016; Shen et al., 2016) (Fig. 8A). Another factor contributing to the increase of dust production in agriculture land is the abandonment of the lands, which provides the basis for the emergence of deflation

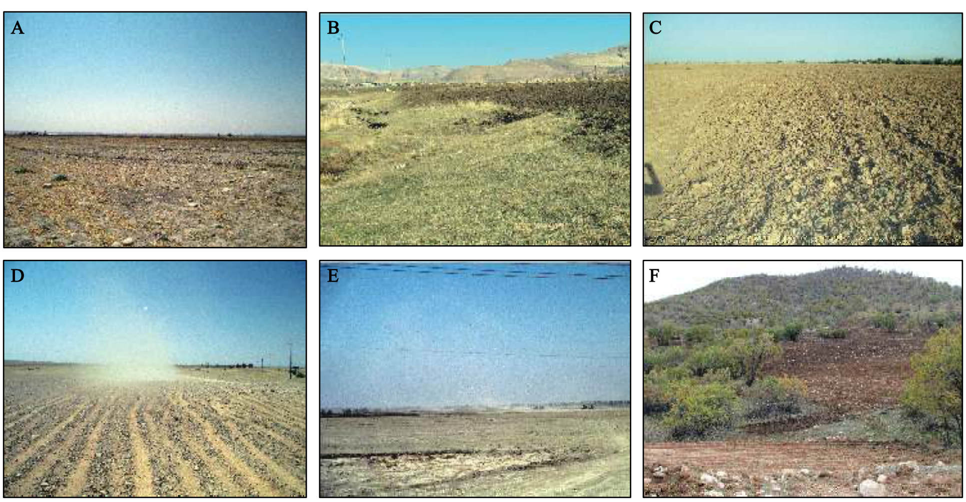

Fig. 8 Some typical images of land use and land use changes of dust sources: (A) Ghasr-e-Shiring agricultural lands without vegetation cover, (B) land-use change from rangeland to agricultural lands in Naft Shahr, (C) Agricultural activities like plowing which have disturbed aggregates in Ezgeleh, (D) Dust emission in weak rangelands in Soumar, (E) Dust emission from disturbed rangelands for road construction in Soumar, (F) land-use change from forest to agricultural lands in Ezgeleh

surfaces (Moridnejad et al., 2015; Rezaei et al., 2016).

Rangelands also had a great impact on dust production. These lands in terms of the number of dust sources are considered as the second type of land that affects dust production. Most of the dust sources in this area were found in weak rangelands, which had bare soil and sparse vegetation, features which are specific to this type of rangeland (Fig. 8D). Such lands like agriculture lands have a high potential in dust production. However, unavailability of detailed information regarding the destructive factors of rangelands such as overgrazing (Fu et al., 2008), livestock trampling (Munkhtsetseg et al., 2017), fire (Lindley et al., 2011), *etc*., which exist in Kermanshah Province, no attempt has been made in this study to examine the characteristics of the dust sources in this regard. However, this kind of land destruction has been observed in the rangelands of Kermanshah province, which like other parts of the world, including Mongolian grasslands (Munkhtsetseg et al., 2017) and the Aral Sea basin (Wiggs et al., 2003) provides favorable conditions for dust emission. Rangelands that are destroyed in this way like agriculture land produce dust; however, such destructions of rangelands cannot result in dust production as much as when rangelands are converted into agriculture land. Hence, it can be concluded that rangelands like agriculture lands are also fragile environments that can facilitate dust production via human intervention.

In this study, few dust sources originated from the areas where rangeland have been converted into built-up lands. Although exposure of such lands to built-up lands, road construction (Fig. 8E) and vehicle traffic development such as the Mongolian rangelands (Munkhtsetseg et al., 2017), and China (Wang et al., 2018) has caused dust emission, this type of change is not widespread and its impact on dust production has not been significant. Another LUC that has not had much contribution in dust production is the change of forest to agriculture land. Although in the last two decades a large part of the forests in the area have been converted into low-yielding dry farming which are susceptible to wind erosion (Rezaei et al., 2016), these changes have taken place in small areas within the forests. As a result, the trees that remain on the margin of these lands act as a barrier which reduce wind speed and prevent dust production (Fig. 8F).

Generally, LUC of any type facilitates the conditions for dust production. Such changes lead to the destruction of forests, rangeland and agriculture lands, and damages their soil and vegetation to a considerable extent which provides conditions for local air pollution. But the frequency of dust production is different in various types of LUC. For example, in residential, industrial, commercial and other construction areas, there is less dust production since most of the land is covered by buildings and roads which do not produce dust. But in other land uses such as forests, rangelands, and especially agriculture lands, more dust is produced because of extensive destruction of vegetation and soil particles. Dust production in agriculture land is more noticeable because every year or even twice a year, human activity such as plowing, directly damages soil particles and produces fine soil fractions. As a result of such activities, which are repeated each year, there are always freshly fine materials that are susceptible to deflation leading to dust production increase.

5 Conclusions

The present study identified the dust sources in Kermanshah Province of Iran, and examined the role of land use change in dust production. The results indicate that most regions are covered by rangelands. The forest and rangeland areas decreased from 2000 to 2015, but meanwhile there was an increase in agriculture and build-up type. Overall, 161 dust sources most of which were originated from areas exposed to land use change were identified in this study. Rangeland to agriculture class from which 57.76% of identified sources were originated played the most significant role in dust emission compared to other various land use change classes. The results from this study prove that these land use types are the main areas of dust production, due to widespread and frequent destruction of agriculture and rangelands. The investigation of the distribution of identified dust sources in Kermanshah Province revealed that these sources do not have a uniform spatial distribution, and in some areas their density is higher. These regions which include southwest of the rural district of Ezgeleh, southwest of Ghasr-e Shirin, Naft shahr and southeast of Sumar are considered as the most important dust emission sources. Recognizing these areas helps controlling and predicting dust events.nclude southwest of the rural district of Ezgeleh, southwest of Ghasr-e Shirin, Naft shahr and southeast of Sumar are considered as the most important dust emission sources.

Overall, the findings of the this study suggest that as long as natural environments are stable, they are resistant to wind erosion. In contrast with desert and arid regions in which natural factors have the most significant role in dust emission, human intervention especially in semi-arid and temperate regions (such as Kermanshah) is recognized as the main reason producing dust events.

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