Journal of Research in Biology

ISSN No: Print: 2231 –6280; Online: 2231- 6299

An International Scientific Research Journal

Original Research

Identification of dust storm sources area using Ackerman index in Kermanshah province, Iran

Authors:
Mahsa Karimi[1], Jafar Oladi Ghadikolaei[2] and Jahangir Mohammadi[3]

Institution:
1. Ph.D. Student of Forestry, Department of Forest Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran.

2. Associate Professor, Department of Forest Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran.

3. Associate Professor, Department of Forest Sciences, Gorgan Agricultural Sciences and Natural Resources University, Gorgan, Iran.

Corresponding author:
Mahsa Karimi

ABSTRACT:

Dust storms are one of the most important environmental challenges in the last decade at Kermanshah province, which greatly endangers the health of all living things, especially humans. The first step in controlling this destructive environmental phenomenon is to identify the dust storm sources, which is the main purpose of this research. For this purpose, horizontal visibility data were obtained from the meteorological organization of Kermanshah during the various periods (2005-2015), and the years of 2008 and 2009 The months of May, June and July were selected due to the most frequent occurrence of dusty days. In the next step, the most important dust events were selected in the years and months based on the two criteria: The minimum horizontal visibility and the maximum duration of continuity. MODIS Satellite Images were prepared (MOD 02) for these courses of dusty storms. Ackerman dust index and Gaussian plum diffusion model were used to reveal the center of the dust storm in the images. Total of 67 dust storm sources were identified in the MODIS images, which are located in Iraq (29 points), Syria (17 points), Syria and Iraq border (15 points), and Kermanshah province (6 points), respectively. The important point in the results of this study is the increase of the number of dust storm source area at the Iran in Kermanshah province during 2008 (1 point) and 2009 (5 points), which should be followed by appropriate strategies to prevent their occurrence.

Keywords:

Dust source area, MODIS sensor, Gaussian plum diffusion model.

Article Citation:
Mahsa Karimi, Jafar Oladi Ghadikolaei and Jahangir Mohammadi
Identification of dust storm sources area using Ackerman index in Kermanshah province, Iran
Journal of Research in Biology (2018) 8(6): 2534-2543

Dates:
Received: 06 June 2018 **Accepted:** 02 July 2018 **Published:** 19 Aug 2018

Web Address:
http://jresearchbiology.com/documents/RA0642.pdf

INTRODUCTION

Air pollution is one of the most important environmental problems that is defined as the presence of one or more pollutants in open air with a concentration that compromises the health of living organisms (Jafari *et al*., 2014). Particulate matter is one of the most dangerous airborne contaminants based on the United Nations Environment Program report (WHO, 1992). The dust is a tiny particle with a diameter of 0.05 to 0.1 mm, that can transmit long distances by the wind and can easily surround a country or even a continent (Mehrabi *et al*., 2015). The destruction of forests, reduced agricultural production, soil erosion, water pollution and the spread of respiratory and cardiovascular diseases are the disadvantages of this phenomenon (Pope *et al*., 2002; Takemi and Seino, 2005). The causes of dust storm are vegetation destruction, the occurrence of severe and prolonged droughts followed by increasing temperatures and reducing rainfall, severe winds, dam construction and water transfer projects (Sivakumar, 2005; Di *et al*., 2008).

Although the dust phenomenon has encountered some problems in some part of Iran from the past four decades, in recent decades spatial distribution, dusty days and the reduction of visibility of the ratio have increased (Shamshiri *et al*., 2014). There is a necessity of more research to control this phenomenon. The first step in controlling the dust storm crisis is to identify areas that are capable of producing dust (Karimi *et al*., 2011; Griffin, 2007). Remote sensing technique is one of the most effective methods for identifying these areas (Ackerman, 1997; Miller, 2003; Baddock *et al*., 2009; Hu and Sokhi, 2009). The advantage of this technique include less time, low cost, very precise and extensive, multi-spectrum, high spatial and temporal resolution, and the ability to replicate and update the collected information (Hua *et al*., 2007; Scheer and Sitko, 2007). In general, using this method helps natural resource managers and planners to accurately identify the source areas and eventually plan to solve the problem. Several studies have been carried out using various remote sensing methods around the world, and some of them are referred in our study.

For example, in order to determine the source point of the dust storm in the Middle East, Karimi *et al*. (2011) used a satellite data analysis (28 images of the MODIS image in 2008-2009) and false colour combination method. Based on their results, 420 sources of zone of dust storm were identified in the Middle East countries such as Iraq, Syria, north of Saudi Arabia, west and southwest of Iran, Jordan and Turkey with the percent of 39.2, 23, 14.5, 13.8, 5.7 and 3.8 respectively. Also, in other studies in the Middle East, the existence of the sources of dust storm in the countries of Iraq and Syria was confirmed using methods such as the brightness temperature difference and MEDI index with MODIS images (Shamsipour and Safarrad, 2012; Salahi *et al*., 2015; Moridnejad *et al*., 2015).

Raygani *et al*. (2017) In order to investigate the dust events of the Alborz province during the period 2013-2015, used OLI Landsat-8 images and data of the ASTER digital elevation model, as well as vegetation indicators, soil moisture, roughness and images classifications. According to their results, the main sources of dust events were located in the Alborz province at the abandoned agricultural land in the south and southwest region.

In other study, Baddock *et al*. (2009) identified the origin of the dust storm in Australia using the MODIS images, the false colour combinations method and dust indicators. Their results showed that dust indicators have a better performance than the colour combination method in identifying the sources of dust production.

Cao *et al*. (2015a) also conducted a study to establish the source region of the dust storm in Western Asia. For this purpose, 50 MODIS images were

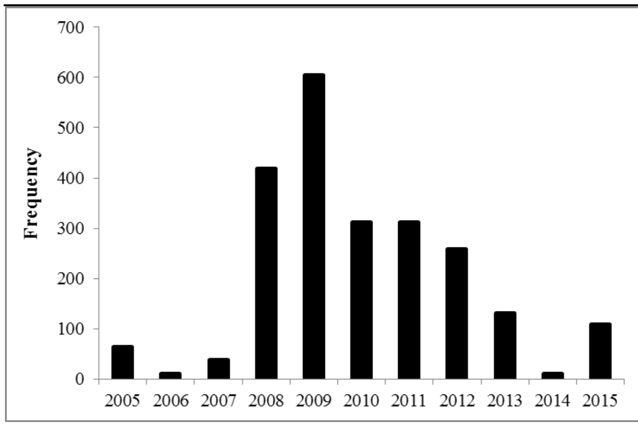

Figure 1. Yearly distribution of frequency of occurrence of dusty days in Kermanshah province during 2005 to 2015

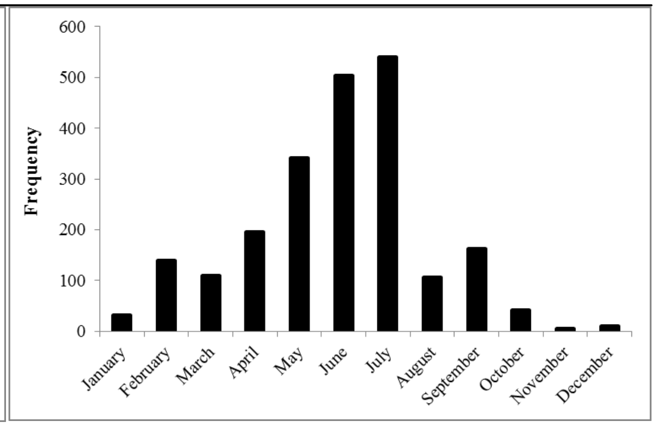

Figure 2. Monthly distribution of frequency of occurrence of dusty days in Kermanshah province during 2005 to 2015

prepared for dust events during 2000-2013. In addition, Landsat images were used as additional databases, climatological maps and geospatial maps as well as hyppolite models. The results showed that 70% of sources region zone of the dust storm is located in the three marginal regions of the Tigris–Euphrates rivers. Yue *et al*. (2017) investigated the sources of dust storm zone of the northeast Asian in the period of 2011-2000. In this research, MODIS images and Ackerman index were used and the result indicated that there are dust storm zone in the northeast of China, eastern Mongolia and some parts of Russia.

The intensive use of Zagros vegetation in recent decades have led to the degradation of vegetation and in many areas the severity of destruction is too high that the lands are completely empty in the vegetation cover (Mohadjer, 2007). Vegetation in the Zagros area played an important role in soil conservation, so the destruction of vegetation in these areas has caused a dust storm sources area. In addition, to the destruction of vegetation (Pourreza *et al*., 2008), the occurrence of long-term droughts and the construction of large dams have exacerbated dust storms event in Tigris–Euphrates watershed (Karimi, 2015). Recent research concluded that new sources of Iranian dust storms in some provinces originated at Zagros mountain (Azizi, 2012; Cao *et al*., 2015b). Kermanshah province is located in the Zagros region, which has been encountered by the degradation of vegetation due to factors such as war, population increase, deforestation and over-grazing (Azizi *et al*., 2012), as well as the destructive phenomenon of drought for many years (Karimi *et al*., 2015). Because of the common border, a huge amount of Iraqi dust storm arrives in Kermanshah province (Almasi *et al*., 2014). Therefore, Kermanshah province due to its internal and external dust storm sources, it is necessary to carry out various investigations in this regard to prevent the occurrence and severity of this phenomenon. The main objective of this study is the application of satellite data to identify the source zone of sand storm in Kermanshah province in order to prevent the development of source areas.

MATERIALS AND METHODS

Study area

Kermanshah province is situated between the latitude 33° 40' to 35° 18' N and the longitude 45° 24' to 48° 07' E and with an average height of 1212 m above sea level. The average of annual rainfall and temperature are 450 mm and 15.9°C respectively. The province is divided into four climatic condition such as dry, semi-arid, Mediterranean and wet based on the Domarton method (Karimi *et al*., 2015).

Table 1. The most important events of the of dusty days based on horizontal visibility and frequency of occurrences

S. No	Date	Horizontal visibility (m)	Frequency of occurrences
1	18/05/2008	800	2
2	16/06/2008	100	4
3	08/07/2008	200	6
4	02/05/2009	900	3
5	19/06/2009	800	8
6	14/07/2009	300	8

Methodology

Horizontal visibility data was obtained from the Meteorological Organization during the various periods (2005-2015) in order to identify the source zone of the dust storm in the Kermanshah province. The annual and monthly distribution of the frequency of dusty days occurrence was plotted from 2005 to 2015. Years and months with the highest incidence of dust were studied (Figure 1 and 2). The most polluted days were identified in the years and months based on the two criteria such as minimum horizontal visibility and maximum duration of continuity. Finally, six dust events were selected in the study period (Table 1). For this purpose, in order to detect dust storm, MODIS B1 images were used for selected events. MODIS sensor have high spectral resolution, wide coverage and high repeatability in dust detection (Zzooli *et al*., 2014; Baddock *et al*., 2009; Yue *et al*., 2017; Ochirkhuyag and Tsolmon, 2008; Madhavan *et al*., 2017) and for this reason, it was used in the present study. In the next step, pre-processing operations of satellite images were performed including atmospheric, geometric and radiometric corrections by ENVI 5.1 software, and finally, the Ackerman index was applied to identify dust storm in satellite images.

Ackerman index

So far, various indicators have been introduced for dust detection with various advantage, but the Ackerman index is a powerful indicator that separates cloud and dust phenomena well. This index is based on the brightness temperature difference between the 31 and 32 MODIS bands. The value of dust brightness temperature in the band 32 is higher than the band 31, so, given the relation (1), the negative values of the Akerman index indicate the presence of dust in the image. The Ackerman indicator is positive for the cloud because of the high brightness temperature of 31 in relation to the band 32 for this phenomenon. In the various studies, the efficiency of the Ackerman index has been confirmed in the detection of dust (Shamsipour and Safarrad, 2012; Zzooli *et al*., 2014; Huang *et al*., 2007; Mie *et al*., 2008; Li *et al*., 2010).

$$BTD = B31-B32 \quad (1)$$

where, BTD = Ackerman index; B31: brightness temperature of band 31 with a wavelength of 11 μm; B32: brightness temperature of band 32 with a wavelength of 12 μm.

The brightness temperature of bands is calculated using equation (2):

$$B_i(T, \lambda) = (2hc)^2/(\lambda^5\times(\exp(hc/\lambda kT)-1)) \quad (2)$$

where, $B_i(T, \lambda)$: The brightness temperature of band (i) at specified wavelength and temperature; h: Planck coefficient (6.626×10^{-34}); k: Boltzmann coefficient (1.3806504×10^{-23}); c: The speed of light ($6.622.9986\times10^{8}$ m/s).

In this research, a Gaussian plum diffusion model was applied to determine the dust source. According to this model, when the cone of diffusion of dust is seen in the image, the head of the cone represents the starting point of pollution or the dust source (Karimi *et al*., 2015; Moghadam and Boroujeni, 2015).

RESULTS AND DISCUSSION

Based on Figures 1 and 2, the annual and monthly distribution of the frequency dusty days in 2005-2015 showed that the years of 2008 and 2009 and the months of May, June and July had experienced the most frequent dusty day occurrences. Azizi *et al*. (2012), Mehrabi *et al*. (2015) and Natsagdorj *et al*. (2002) also showed that the highest dust storms

Table 2. Determination of the number of internal and external dust source area

S. No	Date	The number of internal dust source area	The number of external dust source area			Total
			Iraq	Syria	The border between Syria and Iraq	
1	18/05/2008	-	8	2	-	10
2	16/06/2008	-	1	3	3	7
3	08/07/2008	1	8	6	5	20
4	02/05/2009	-	7	2	2	11
5	19/06/2009	3	-	-	-	3
6	14/07/2009	2	5	4	5	16
7	Total	6	29	17	15	67

occurrence in the spring and summer seasons. When the wind speed reaches to the terminal velocity, the dry soil could easily arise and dust storms occur in summer and spring because in these seasons soil moisture decreases due to the increased temperature and reduced rainfall.

The black parts after the use of the Ackerman index in the MODIS images indicate dust and the red points indicate center area of dust storm. Many studies have identified the center area of dust storm and the distribution of dust by Ackerman index and they confirmed the strength of this indicator to show dust (Shamsipour and Safarrad, 2012; Zzooli *et al*., 2014; Huang *et al*., 2007; Li *et al*., 2010). A total of 67 points source were identified in 6 dust events. The assessment of the distribution of these points source areas showed that Iraq, Syria, the border between them and Kermanshah provinces produced dust with 29, 17, 15 and 6 points, respectively, in the this province (Table 2). The results of Karimi *et al*. (2011), Shamsipour and Safarrud (2012), Azizi *et al*. (2012), Zzooli *et al*. (2014) and Jahanbakhsh *et al*. (2014) also confirmed the results of this study. According to their results, the two countries of Iraq and Syria, and the border between them, have the largest share in creating Middle east dust. Also, based on the results, the number of points source area in July events (36 points) was higher than in May (21 points) and June (10 points) (Table 2). With the arrival of the summer season and the availability of dust conditions, the possibility of soil emissions to air for more region would increase due to the reduced soil moisture and increased wind speed.

The visual interpretation of the dusty day of 18/05/2008 indicated that the main source of the event is in the north-east and east of Iraq (8 points) and the center of Syria (2 points) (Figure 3). In the dust event of 16/06/2008, the main sources of dust storms were located in the north-east of Syria (3 points), north-west of Iraq (1 point), and the border between Syria and Iraq (3 points) (Figure 3). Visual interpretation of the satellite image of the dust storm 08/07/2008 revealed the existence of four major sources of dust in Iraq, Syria and Iran. In this event, Iraq with 8 points, Syria with 6 points as well as the border between the two countries with 5 points were the most important sources of dust storm. An important issue in this event is the identification of a dust source in the southwest of Kermanshah province (Figure 3).

Based on Figure 4, There were 2 point of the dust source on the border between Syria and Iraq. Also, There were 7 points at the northwest and northeast of Iraq and 2 points at north-east of Syria in the event of 02/05/2009. Figure 4 shows that there were three dust source in the north and east of Kermanshah in the event of 19/06/2009. Eventually, the results of the interpretation of satellite images in the event of 14/07/2009 indicated that there were 4 main dust sources. In this event, there were 5 dust sources in the northwest of Iraq, 4 dust sources in the north-east of Syria, 5 points along the border between the two

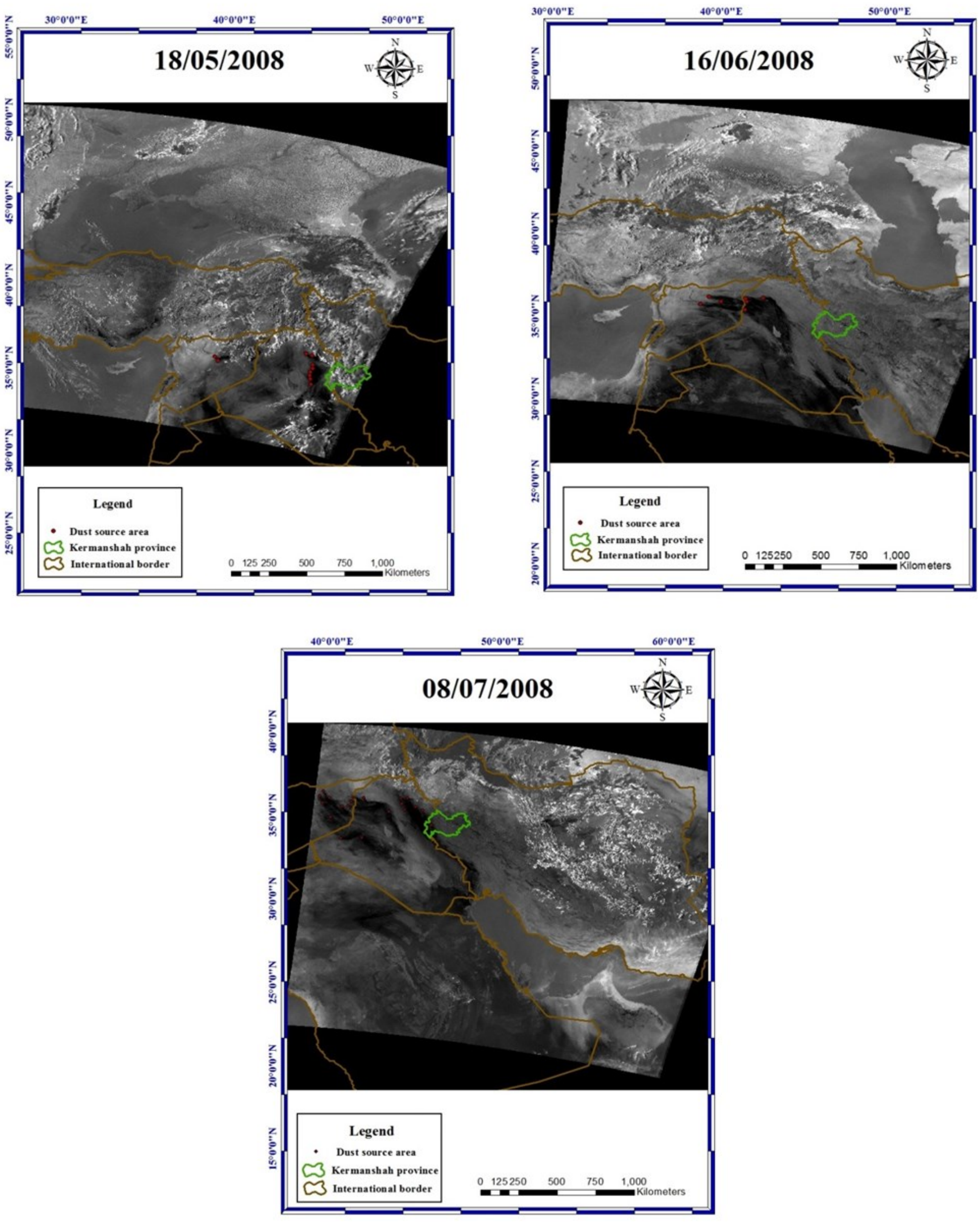

Figure 3. Detecting dust sources area using Ackerman Index with MODIS Image in 2008

countries and 2 points inside Kermanshah province, in the north-west and west (Figure 4).

In general, according to the obtained results of this study in six dusty events, the northern parts of Iraq and the north-east of Syria, as well as the border areas between the two countries, are the main sources of dust storm in the Kermanshah province. This area is a part of the Tigris- Euphrates watershed, with non-integrated

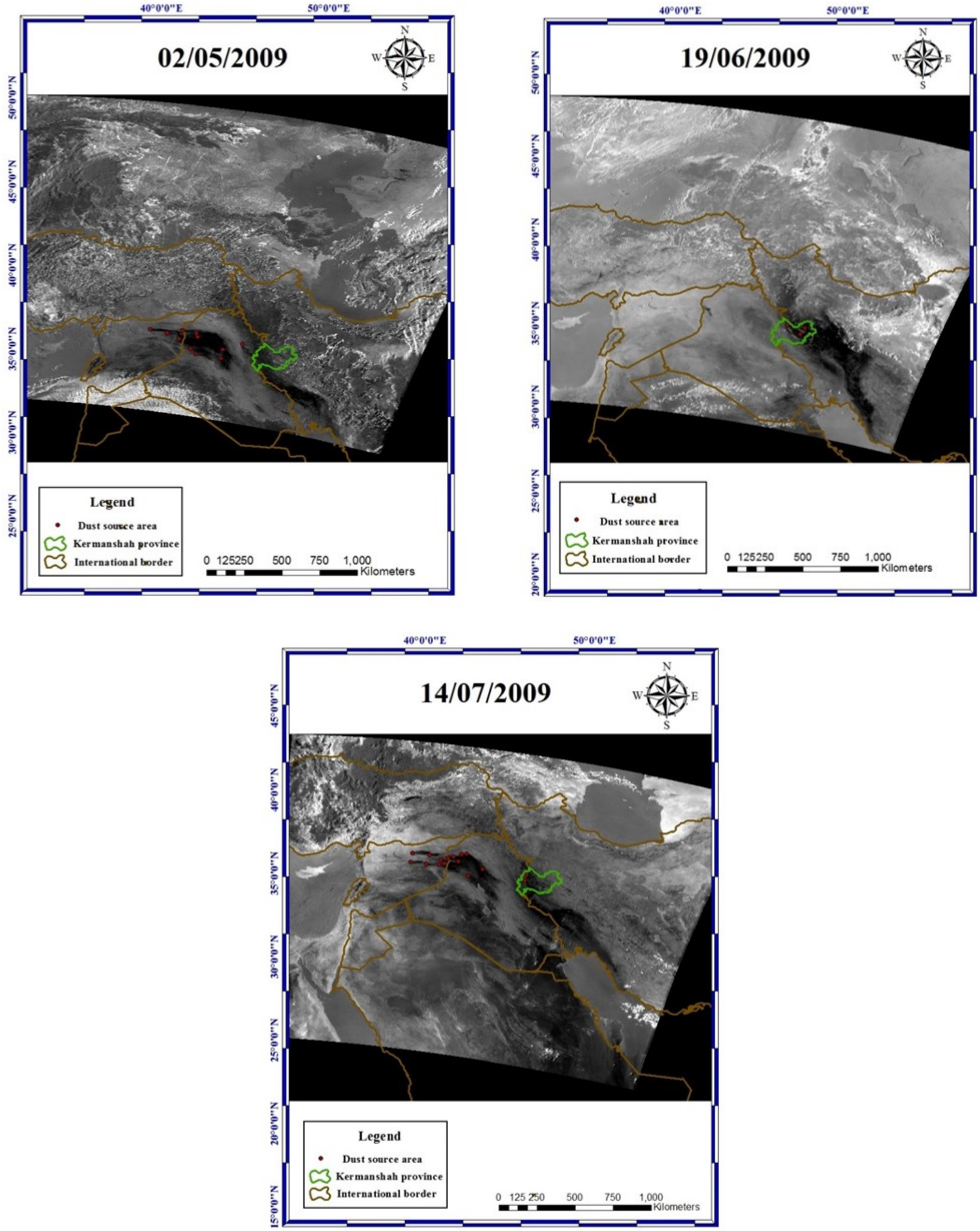

Figure 4. Detecting dust source area using the Ackerman index with MODIS Image in 2009

and young bedrock. On the other hand, the soil in this area has lost its moisture and has become drought because of the intensive use of water in the upstream in the countries of Turkey and Syria. On the other hand, the occurrence of severe droughts and human activities has caused the destruction of vegetation and all these conditions have made the region sustainable for dust source, so that with winds at speeds even below the terminal velocity a lot of soil particle rises to air and dust storms occur. Karimi *et al*. (2011) confirmed the unstable environmental conditions for this area. In half of the dusty days, the existence of internal sources in Kermanshah province is quite evident. Also, based on the results, the number of internal hotspots in 2009 (5 points) have increased from 2008 (1 point) (Table 2). In the Zagros area due to the destruction of vegetation (Pourreza *et al*., 2008), as well as long-term droughts (Karimi, 2011), many areas are susceptible to becoming dust source and this condition is also expected for Kermanshah province. Moghadam and Boroujeni (2015) also confirmed the existence of local areas of dust source in some parts of the Zagros mountain.

CONCLUSION

In this study, 6 dust storm event were selected in May, Jun, and July of 2008 and 2009 for the period of time (2005-2015) in order to identify the dust source zone of Kermanshah province. Then the dust event was revealed using the Ackerman index and the MODIS image. Based on the results, the main sources of dust storm in the Kermanshah province is located in northern Iraq, north-east Syria and the border between the two countries. Also, the results of this study showed that the source zone of internal dust storm in 2009 was higher than 2008 due to the degradation of vegetation in Zagros forests, as well as the occurrence of severe and prolonged droughts in recent years. Due to the reasons mentioned above, in the near future, the number and development of the internal zone for dust storm would increase. For this reason, management practices such as mulching (short-term strategy) and increasing vegetation cover with appropriate species (long-term strategy) are required to control dust storms.

REFERENCES

Ackerman SA. 1997. Remote sensing aerosols using satellite infrared observations. *Journal of Geophysical Research*, 102(D14): 17069-17079.

Almasi A, Moradi M, Sharafi K and Abbasi S. 2014. Seasonal variation in air quality of Kermanshah city in Terms of PM10 concentration over a four-year period (2008-2011). *Journal of Health*, 5(2): 149-158.

Azizi G, Shamsipour AA, Miri M and Safarrad T. 2012. Statistic and synoptic analysis of dust phenomena in west of Iran. *Journal of Environmental Studies*, 38 (63): 31-33.

Baddock MC, Bullard JE and Bryant RG. 2009. Dust source identification using MODIS: A comparison of techniques applied to the Lake Eyre Basin Australia. *Remote Sensing of Environment*, 113(7): 1511-1528.

Cao H, Amiraslani F, Liu J and Zhou N. 2015a. Identification of dust storm source areas in West Asia using multiple environmental datasets. *Science of The Total Environment*, 502: 224-235.

Cao H, Liu J, Wang G, Yang G and Luo L. 2015b. Identification of sand and dust storm source areas in Iran. *Journal of Arid Land*, 7(5): 567-578.

Di M, Lu X, Sun L and Wang P. 2008. A Dust-Storm Process Dynamic Monitoring With Multi-Temporal MODIS Data. 21st congress, International Society for Photogrammetry and Remote Sensing, *Journal of Photogrammetry and Remote Sensing*, 37(3): 965-970.

Fallah Zzooli M, Vafaei Nezhad A, Kheirkhah Zarkesh M.M and Ahmadi Dehkae F. 2014. Synoptic monitoring and analysis of dust phenomena using remote sensing and GIS (Case Study: Dust 18 June 2012). *Geographical Data*, 23(91): 69-80.

Griffin DW. 2007. Atmospheric movement of microorganisms in clouds of desert dust and implications for human health. *Clinical Microbiology Reviews*, 20(3): 459-477.

Hu RM and Sokhi RS. 2009. Light scattering and absorption properties of dust particles retrieved from satellite measurements. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 110(14-16): 1698 -1705.

Hua NP, Kobayashi F, Iwasaka Y, Shi GY and Naganuma T. 2007. Detailed identification of desertoriginated bacteria carried by Asian dust storms to Japan. *Aerobiologia*, 23(4): 291-298.

Huang J, Ge J and Weng F. 2007. Detection of Asian dust storms using multisensor satellite measurements. *Remote Sensing Environment*, 110(2): 186-191.

Jafari H, Hassanpour S, Rahili Khorasani L and Pourahmad A. 2014. Application of Geographic Information System (GIS) in location and spatial analysis of pollution and air pollutants in Kermanshah city. *Ecology*, 40(1): 51-64. [In Persian]

Jahanbakhsh S, Valizadeh K, Khosravi M, Zeinali B and Asghari S. 2014. Identification and detection of 1 July 2008 dust storm with MODIS data. *Journal of Geographical Space*, 14(46): 31-51. [In Persian]

Karimi Kh, Taheri Shahr Aeini H, Habibi Nokhandan M and Hafezi Moghadas N. 2011. Identifying the origins of dust storm production in the Middle East using remote sensing. *Journal of Clinical Research*, 2(7-8): 57-72. [In Persian]

Karimi M, Shahedi K and Byzedi M. 2015. Analysis of hydrological drought using constant threshold level method (case study: Karkheh river basin, Iran). *Journal of Watershed Management Research*, 6(11): 59-72. [In Persian]

Li X, Ge L, Dong Y and Chang HC. 2010. Estimating the greatest dust storm in eastern Australia with MODIS satellite images. [cited 2010 July 25-30] IEEE International Geoscience and Remote Sensing Symposium, Honolulu, HI, USA.

Madhavan S, Qu JJ and Hao X. 2017. Saharan dust detection using multi-sensor satellite measurements. *Heliyon*, 3(2): e00241.

Marvie Mohadjer MR. 2007. Silviculture. 2nd ed., University of Tehran Press, 387 p. [In Persian]

Mehrabi S, Soltani S and Jafari R. 2015. Investigating the relationship between climatic parameters and occurrence of dust. *Journal of Agricultural Science and Technology, Water and Soil Science*, 19(71): 69-80. [In Persian]

Mie D, Xiushan L, Lin S and Ping W. 2008. A dust-storm process dynamic monitoring with multi-temporal MODIS data. *The International Archives of photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVII(B7): 965-969.

Miller SD. 2003. A consolidated technique for enhancing desert dust storms with MODIS. *Geophysical Research Letters*, 30(20): 1-4.

Moridnejad A, Karimi N and Ariya P. 2015. Newly desertified regions in Iraq and its surrounding areas: Significant novel sources of global dust particles. *Journal of Arid Environments*, 116: 1-10. [In Persian]

Natsagdorj L, Jugder D and Chung SY. 2002. Analysis of dust storms observed in Mongolia during 1937–1999. *Atmospheric Environment,* 37(9-10): 1401-1411.

Ochirkhuyag L and Tsolmon R. 2008. Monitoring the source of trans-national dust storms north east Asia. *International Journal of Digital Earth*, 1(1): 119-129.

Pope CA, Brunett RT, Thum MJ, Calle EE, Krewski D, Ito K and Thurston GD. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. The *Journal of American*

Medical Association, 287(9): 1132–1141.

Pourreza M, Shaw JD and Zangeneh H. 2008. Sustainability of wild pistachio (*Pistacia atlantica* Desf.) in Zagros forests, Iran. *Forest Ecology and Management*, 225: 3667-3671.

Raygani B, Kheyrandish Z, Kermani F, Mohammdi Miyab M and Torabinia A. 2017. Identification of active dust sources using remote sensing data and air flow simulation (Case study: Alborz province). *Desert Management,* 4(8): 15-26. (In Persian)

Rezaei Moghadam MH and Mahdian Boroujeni M. 2015. Determination of the dust using NOAA satellite AVHRR (Case Study: South-west of Iran). *Geography and Environmental Sustainability*, 5(17): 1-13. (In Persian)

Salahi B, Moradi M and Alijahan M. 2015. Detecting contemporary conditions -remote sensing in the North-west of Iran (Sep 2013). *Geography*, 13(44): 73-93. (In Persian)

Scheer L and Sitko R. 2007. Assessment of some forest characteristics employing IKONOS satellite data. *Journal of Forest Science*, 53(8): 345-351.

Shamshiri S, Jafari R, Soltani S and Ramazani N. 2014. Detection and zoning of dust of Kermanshah province using MODIS satellite imagery. *Applied Ecology*, 3(8): 29-41. (In Persian)

Shamsipour AA and Safarrad T. 2012. Satellite and Synoptic analysis of dust storm in Western Half of Iran (case study: July 2009). *Physical Geography Research Quearterly*, 44(79): 111-126. (In Persian)

Sivakumar VK. 2005. Impacts of Sand Storms/Dust Storms on Agriculture. *Natural Disasters and Extreme Events in Agriculture*, 7: 159-177.

Takemi T and Seino N. 2005. Dust storms and cyclone tracks over the arid regions in east Asia in spring. *Journal of Geophysical Research*, 110(D18): 11.

[WHO] World Health Organization. 1992. United Nation Environmental Program, Urban Air pollution in Mega Cities of the world. Oxford: Blackwell, 6-14.

Yue H, He Ch, Zhao Y, Ma Q and Zhang Q. 2017. The brightness temperature adjusted dust index: An improved approach to detect dust storms using MODIS imagery. *International Journal of Applied Earth Observation and Geoinformation*, 57: 166-176.