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Effect of Source Areas Anthropogenic Activities on Dust Storm Occurrences in the Western Parts of Iran

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Abstract

Dust storm is one of the main global challenges that is more serious in the Middle- East. This phenomenon causes a lot of environmental and socio-economic problems in Iran and several other Middle-Eastern countries. A Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model was used for trajectory analysis in order to reconstruct the origins of air masses in dust storms over several cities in the Western Parts of Iran. Backward trajectories analysis by HYSPLIT model showed that the main source of two occurrences of dust storms over several Iranian western cities has been originated from Syria passing through Iraq and arriving at the Western part of Iran. The Moderate Resolution Imaging Spectroradiometer (MODIS) images was used to monitor the monthly vegetation changes in the dust storm source areas. The Enhanced Vegetation Index (EVI) was obtained from recent MODIS vegetation data (2002-2009). Results revealed that source areas anthropogenic activities that reduced vegetation cover and activated wind erosion caused EVI numerical value reduction and dust storms occurrence over several Iranian Western cities.

Keywords: Dust storm; HYSPLIT; MODIS; EVI

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1. Introduction

Eco-environmental changes caused by mankind exploitation and regional climate changes have been a severe problem in the world, especially in the arid and semiarid areas because of their ecosystems' vulnerability (Hui *et al.*, 2008; Turner *et al.*, 2000; Gray, 1999; Shahid *et al.*, 1999; Johnson *et al.*, 1997; Johnson and Lewis, 1995). The largest and most persistent dust sources are mainly located in a broad "Dust Belt" that extends from the west coast of North Africa, over the Middle-East, Central and South Asia, to China (Prospero *et al.*, 2002). The Middle-East is well known for its arid and semi-arid environment with frequent and severe dust and sand storms. This annual rainfall in this region is less than 200–250 mm, and it is most affected by dust, in the world, next to Africa (Kutiel and Furman, 2003).

Dust storms are produced by a variety of natural as well as anthropogenic activities, and are distributed in the atmosphere (Meszaros, 1981; Reist, 1984; Eck *et al.*, 2001; Kedia and Ramachandran, 2009). Anthropogenic activities that reduce vegetation cover and activate wind erosion cause dust emission (Iglesias, 1992).

The risk of an dust storm occurrence is increased in areas with minimal vegetation cover, soils that lack snow and/or soil moisture content (NRL, 2009), or soils that are vulnerable to surface disturbance (Wilcox, 2012), thus, the dust storm has the potential to occur. Dust sources are distributed across the landscape according to the vulnerability of landforms to erosion and factors that influence the wind acting upon the surface (Raupach *et al.*, 1993; Gillette, 1999; Okin and Gillette, 2001). Precipitation indirectly influences dust emissions by promoting vegetation (Stockton and Gillette, 1990; Raupach *et al.*, 1993) as biotic crusts (Belnap and Gillette, 1998). Vegetation protects the soil surface and suppresses dust emission (Raupach, 1992). Several months after wet periods, vegetation dries and burns by arson or wild fires or grazing cattle can disturb the land surface, leading to dust emissions at longer time lags. Plants grow rapidly following the onset of the wet season and remain as groundcover for several months until drying, grazing and trampling by livestock, and fires have removed their effectiveness in sheltering and protecting the soil surface (Ehrlich *et al.*, 1997; Herrmann *et al.*, 2005; Linderman *et al.*, 2005).

Normalised Difference Vegetation Index (NDVI) have been related to leaf area index (LAI) (Wiengand and Richardson, 1984; Bouman, 1992). The NDVI has shown consistent correlation with vegetation biomass (Running, 1990; Myneni, *et al.*, 1995). The NDVI provides information about the spatial and temporal distribution of vegetation communities and vegetation biomass (Reed *et al.*, 1994).
Dust storms are found to be substantially increasing and being responsible for severe drought events and significant decrease in the NDVI. A 5.5% decline in NDVI causes an increase in dust loading by 37% (Prasad *et al.*, 2006). According

to Fraser and Kaufman (1985) and Karnieli *et al.* (2001), dust storms apparently reduced the NDVI values.

Another index that has appeared with MODIS is the Enhanced Vegetation Index (EVI) (Huete *et al.*, 2002). This index provides complementary information about the spatial and temporal variations of vegetation, while minimizing many of the contamination problems present in the NDVI, such as those associated with canopy background and residual dust influences. The EVI is more NIR (near infrared) sensitive and responsive to canopy structural variations, including LAI, canopy type and architecture (Pettorelli *et al.*, 2005).

2. Material and methods

Two dust storms occurred in Sar Pol Zohab, Hamedan, and Malayer cities. In order to understand the origins of the air masses arriving in Sar Pol Zohab, Hamedan, and Malayer cities, a day back trajectory analyses based on the NOAA HYSPLIT model was performed (Draxler and Rolph, 2003).

Data for three selected cities in the West of Iran (Figure 1) have been analyzed. The locations of the three selected cities in the West of Iran is shown in Figure 1.

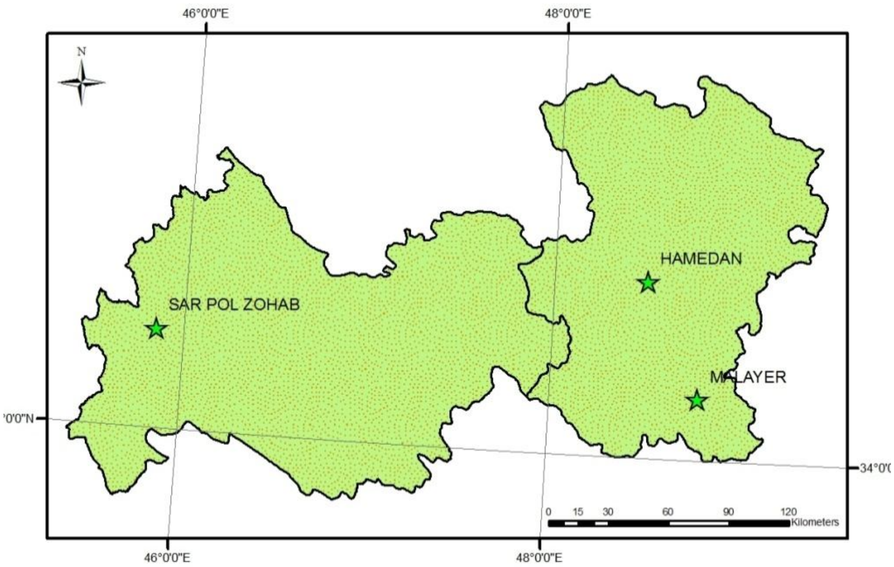

Figure 1. The locations of the three selected cities in the Western Parts of Iran

Southwest Asia between latitudes 33° and 37° N and longitudes 41° and 49° E was the study area for Western Parts of Iran's dust source area detection.

The Lagrangian trajectory HYSPLIT (Hybrid Simple Particle Lagrangian Integrated Trajectory) model isused to generate backward trajectories to trace back the sources of the air masses on June 8th, 2008 and on July 5th, 2009 dust storms.

The Moderate Resolution Imaging Spectroradiometer (MODIS) was used to monitor the monthly vegetation changes in the source areas. The Normalized Difference Vegetation Index (NDVI) is chlorophyll sensitive, while the Enhanced Vegetation Index (EVI) is more responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy, and canopy architecture (Gao *et al.*, 2000). The Enhanced Vegetation Index (EVI) was obtained from the recent MODIS vegetation data (2002-2009).

MODIS acquires data globally at 36 spectral bands, which range from the visible to the thermal infrared wavelengths. The data for each band are acquired in one of the three spatial resolutions (250, 500, and 1000 m). Numerous parameters describing various properties of physical features on land surfaces as well as in the atmosphere are retrieved operationally from MODIS data at different spatial and temporal resolutions. Several dust parameters are retrieved at 10-km spatial resolution from MODIS daytime data. The MODIS dust algorithm employs separate approaches to retrieve parameters over the land (Kaufman *et al.*, 1997). Ninty six MODIS images were obtained for source area. The source area has been divided in 1 square kilometer pixels. The mean values of EVI for each pixel were calculated using the red and NIR reflectance, using Equation 1 (Huete *et al.*, 2002):

$$EVI = G(NIR - RED)/(NIR + C1 \times RED + C2 \times BLUE + L) \quad (1)$$

Where, C1 and C2 are coefficients designed to correct for dust scattering and absorption, which use the blue band to correct for dust influences in the red band. C1 and C2 have been set at 6 and 7.5, while G is a gain factor (set at 2.5) and L is a canopy background adjustment (set at 1.0) (Nagler *et al.*, 2005).

3. Results and discussion

HYSPLIT model showed the dust storm source. Figure 1 reveals that air masses reached Sar Pol Zohab, Hamedan and Malayer cities, started in Syria and passed through the Ninewa Desert in Iraq. The back trajectories for the June 8th, 2008 and the July 5th, 2009 dust storms are shown in Figure 2.

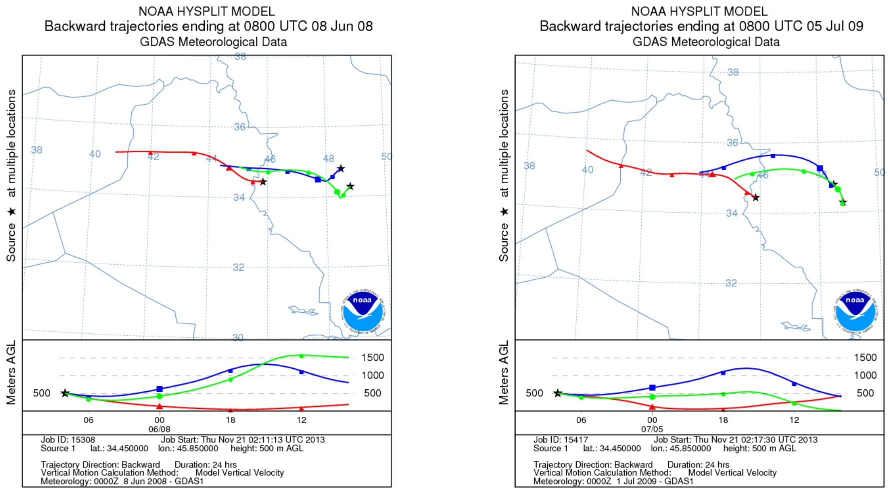

Figure 2. The back trajectories for the June 8th, 2008 and the July 5th, 2009 dust storms.

EVI calculated from MODIS images in the source area of Sar Pol Zohab, Hamedan, and Malayer cities dust storms. The mean values of EVI for each year are shown in Figure 3.

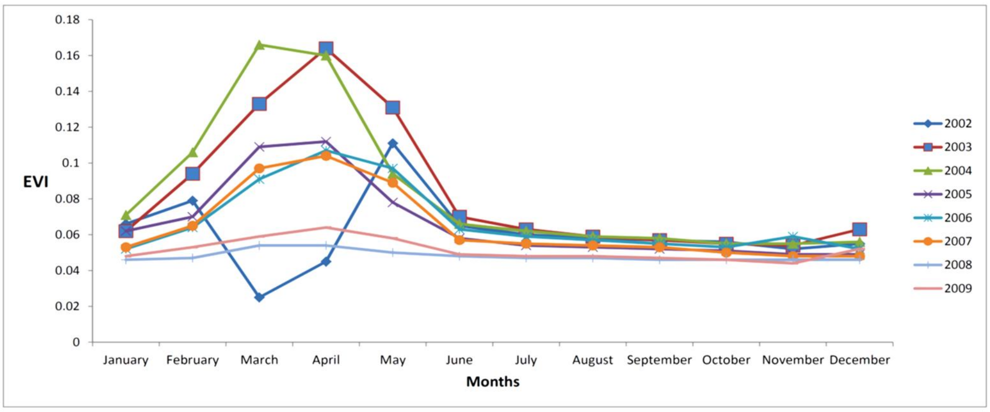

Figure 3. Monthly mean regional EVI of source area for 8-year (2002–2009) period.

Two dust storm events occurred in Sar Pol Zohab, Hamedan and Malayer cities on June 8th, 2008 and on July 5th, 2009. One day back-trajectories (NOAA HYSPLIT model) showed that dust storm on June 8th, 2008 and on July 5th, 2009 originated from Syria, passed through Iraq, and arrived in Western Iran.

Average annual precipitation of Syria and Iraq is 252 and 161 mm, respectively (Bou-Zeid and El-Fadel, 2002; Yaseen *et al.*, 2013) which reflect the characteristic of arid and semi-arid regions (Zhu-Guo *et al.*, 2005). Based on the NOAA

HYSPLIT model (Draxler and Rolph, 2003) output (Figure 2), Eastern Syria, and West and Central parts of Iraq are the sources of Western Iran's dust storms located in the Middle- East with arid and semi-arid climates. Source area detection by HYSPLIT model in this research is in agreement with the previous researches (Kutiel and Furman, 2003; Prospero *et al.*, 2002).

Eastern Syria, West and Central parts of Iraq's all annual precipitation takes place during winter, where summer agricultural activities suffer from water shortages (Zakaria *et al.*, 2012). These regions rainy seasons start in November and nearly ends in May (Al Khalidy, 2004). Summer was mentioned by Kutiel and Furman (2003) to be the time dust storms frequently occurred in Iran, North-east Iraq, Syria, Persian Gulf, South Arabia, Yemen, and Oman. The 2002-2009 EVI monthly changes (Figure 3) indicate increment trend started in November and ended in May.

West and Central parts of Iraq geographical location in a dry area which is characterized by water scarcity and low annual rainfall (Al-Ansari and Knutsson, 2011) with uneven distribution (FAO, 1987) believed to be the major sources of dust storms in the area (Al-Jumaily and Ibrahim, 2013). Given the known physic-geographical, social-political and meteorological conditions prevailing in the region, the low EVI values along the West and the Central parts of Iraq should be associated with anthropogenic dust emissions. The occurrence of dust storms over several Iranian western cities is higher during spring and summer which EVI numerical value shows reductions in the source areas (Figure 3). EVI numerical value has declining trend from 2002 to 2009 (Figure 3). So, recent years' drought conditions caused the source areas vegetation degradations increased and the occurrences of Western Iran dust storms have become more frequent.

Visual inspection of Landsat imagery revealed that the area was barren between 1984 and 1993, thenwidely cultivated between 1998 and 2003, and used less and less between 2004 and 2011 (no imagery is available from 1994 to 1997) (Gibson, 2012). Long-term sanctions against Iraq (1990-2003) forced residents to plant on land that was not suitable for cultivation. The rainfall in this area is not enough for successful agriculture production (Oweis *et al.*, 1999). This process causes this land become barren and saline (Darvishi *et al.*, 2012). Iraq is meeting water shortages and the problem is becoming more serious with the progress of time. The main water resources of Iraq (Tigris and Euphrates Rivers) suffer from severe reduction in their discharges due to construction dams on both banks of the Rivers inside Turkey and Syria (Al-Ansari and Knutsson, 2011; Zakaria *et al.*, 2012). Dams cause major water balance changes and wetlands drying in the South-east parts of Iraq. Dried wetlands are suitable dust sources.

Agricultural lands have been reduced drastically due to water scarcity. There are lots of abandoned farmlands in Iraq. Thousands of hectares of farmlands are abandoned every year (ICARDA, 2013). Several years' cultivation and soil texture changes have caused this area became dust storm source area. On the other hand, overgrazing in Iraq's rangelands has reached the stage of causing soil erosion and has severely reduced the carrying capacity of the rangelands (Kaul and Thalen, 1971). These barred and eroded lands are the main sources of the Western Iran dust storms (Darvishi *et al.*, 2012). The continuous use of unsustainable practices, damage of the infrastructure during the War, and poor maintenance worsened by sanctions, have caused further soil and plant deteriorations (Dougramedji, 1999).

4.Conclusion

Iraq's three war periods [Iraq-Iran war (1980-1988), first Persian Gulf War (1990), and second Persian Gulf war (2003)], long-term sanctions against Iraq (1990-2003), construction dams on both banks of the rivers inside Turkey and Syria, and Iraq's rangelands overgrazing are known as the main source areas anthropogenic activities. These four main reasons cause dust storm occurrences in the West of Iran.

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