THE USE OF MODIS DATA TO EXTRACT A DUST STORM PRODUCT

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Abstract. Iraq in the summer is affected by low pressure centered in the area of Arabian Sea and the Indian Ocean, and the high pressure region in the plateau of Anatolia. This climate system causes that the Shamal wind blows from the plateau of Anatolia in the north and northwest with relatively cold temperature. From mid-June to mid-September, the wind is accompanied with intensive heating of the earth surface causing dust storms rising up to thousand meters in the atmosphere above Iraq region. In recent years, the frequency of dust storm events was increased in Iraq and its surrounding regions due to the long drought seasons. Unsupervised classification method was used to determine the intensity of the dust storm and to identify the area of dust cloud. In this study, we were able to map dust storm over Iraq region using MODIS Terra and Aqua satellite data within thermal bands (band 31 and 32), and visible band VIS (band 1). Other thermal band (band 21) was used to produce RGB composite image specifying the dust storm. A spectral subtraction between two bands was also used to produce another RGB composite image to obtain better detection for the dust storm over Iraq region.

Keywords: *Dust storms, identification, composite image, change detection, MODIS*

1 INTRODUCTION

A dust storm event can occur when two basic conditions are met i.e., the existence of dry and loose soils with scarce vegetation, and the presence of high speed winds. Dust storm events in Iraq occurred when cold winds blew from the north or northwest with sufficient speed to lift soil particles, accompanied with a rise in the temperature of the soil surface on the front wind leading to the occurrence of convection currents helping to raise the mass of the dust into the atmosphere. The relatively cold wind from the north or northwest Iraq during summer season could transport dust particles to large areas within Iraq region and over long distance outside Iraq region (Jacquelyn, 2009).

Dust concentration and its particle distribution affect the scattering and absorption values in the atmosphere. Scattering and absorption values of dust and its particle are significantly different than the scattering and absorption values of water vapour or cloud. Therefore, dust storms can be detected by satellite sensors utilizing the visible and thermal bands (Bian *et al*., 2011; Miller, 2003).

The reflected and scattered radiation values from dust and its particles varied in different wave lengths. The dust and its particles absorbed energy in visible wavelength and scatter more in red than in green and blue wavelength. Meanwhile, in the case of clouds, the incident solar radiations were reflected in almost equall proportions in visible wavelength causing the clouds appered in white color (Figure 1).

Many studies have been conducted on dust storm detection using different methods to distinguish between dust storms and other objects like clouds, smoke, and aerosols. Hao *et al.* (2007) investigated the Saharan dust storm detection with the MODIS thermal infrared bands and presented an index called "thermal-infrared dust index", through quantitative analysis of MODIS data for major dust events over the Atlantic Ocean during years 2004-2006. It was found that aerosol optical thickness (AOT) at 550nm had close relationships with the brightness temperature of MODIS in bands 20, 30, 31, and 32. Li (2008) used two different algorithms to separate the dust from other objects such as cloud, ground surface, and desert surface. The results

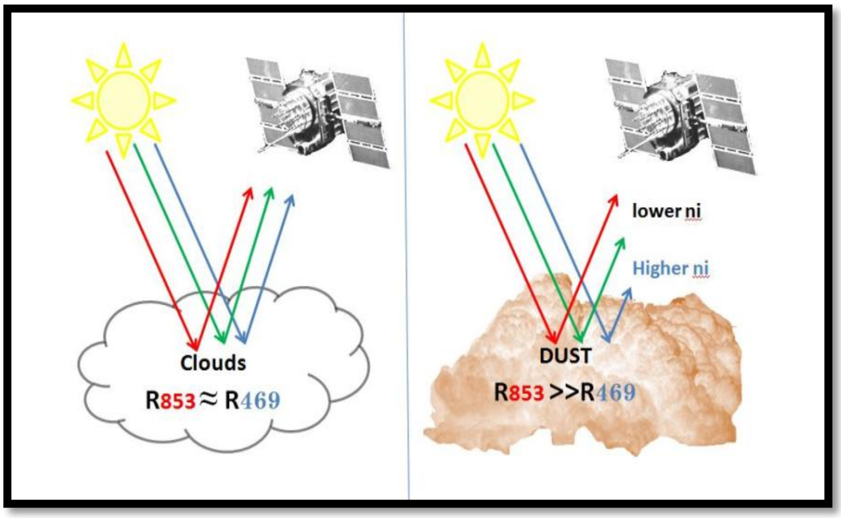


Figure 1. A comparison of the interaction of the electromagnetic (visible wavelength) and the suspended dust in the air and clouds and its impact on the amounts of reflected radiation received by the satellite sensor. The scattered radiations in red and blue wavelength nearly equal in clouds (left), while scattered radiations in red greater than in blue within the dust components (right) (Miller, 2003).

showed a macro-scope view of the dust storm, and it was accorded to the report of weather information services. Seven bands were used to build algorithms for dust information extraction. Ochirkhuyag and Tsolmon (2008) used brightness temperature channels 4 and 5 of AVHRR/NOAA satellite data, emissive bands of MODIS/TERRA satellite data, and meteorological station measurement data to map dust and sandstorm. The differences between thermal bands in combination with GIS layers were used for mapping dust and sandstorm in the study. Miller (2003) developed an algorithm combining color information from multiple visible channels with near and far infrared measurements, provided an improved ability to distinguish areas of dust from water/ice clouds and bright desert backgrounds in enhanced false color imagery. Miller (2003) also described a new satellite-based dust enhancement that combines previous methods with newly available color information to improve visual detection of significant dust outbreaks over water and land during daylight hours.

The purpose of this research was to isolate or identify the dust storm from other objects like clouds, smoke, etc using thermal band 31, 32, and thermal band 21 to produce an RGB composite image.

2 MATERIALS AND METHOD

2.1 Study area and its climate

The study area was located within 29^{o}5'-38^{o}15' E and 38^{o}45'-48^{o}45' N, where Iraq was in the middle of the region (Figure 2).

The weather of Iraq is hot dry in summer and cold rainy in winter. Iraq in the summer is affected by area of low pressure centered in the Arabian Sea and the Indian Ocean, and high presure on the northern side. Therefore, winds blew from high pressure region in the plateau of Anatolia known as the north (Shamal) during the period from mid-June to mid-September, accompanied with intensive heating of to the soil surface easing soil particles release into the amosphere. The Shamal winds helped to mitigate the surface temperature because it was coming from cold regions. This climatic phenomenon was sometimes accompanied with dust storms with more than thousand meters height in the atmosphere. In recent years, severe dust storm events occurred in Iraq and neighboring regions due to long droughts.

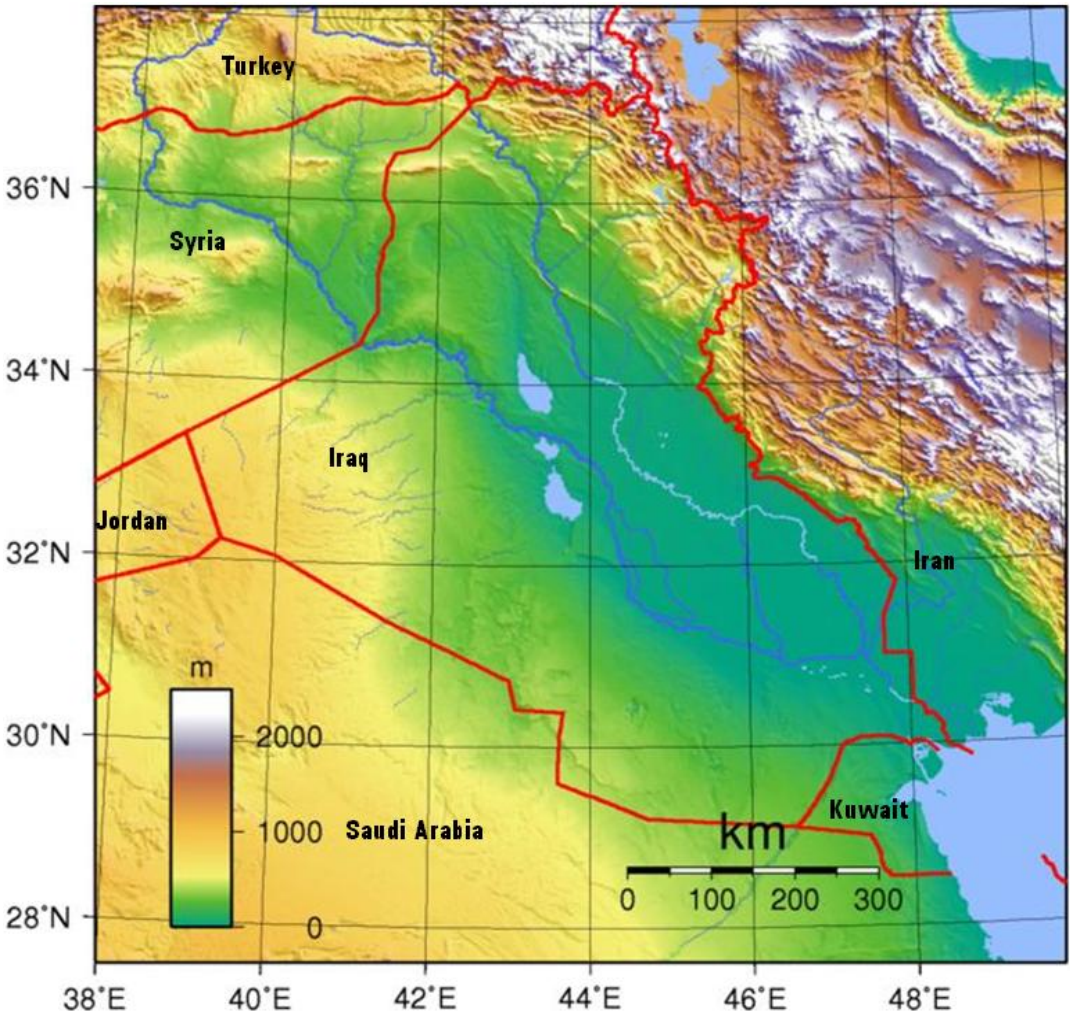


Figure 2. Research areas with Iraq region in the central and other countries in its sourroundings created with GMT from SRTM data (Sadalmelik, 2007).

2.2 Data analyses

Data used in this research were MODIS/TERRA images for clear and dusty days at the dates of 4/7/2008 and 30/6/2008. MODIS sensor provided data from 36 bands in visible, near infrared, and infrared bands with three spatial resolution 250,500, and 1000m. The MODIS products can facilitate the interpretation of data from multiple bands by displaying information in a single RGB composite image.

2.2.1 Image composite

RGB composite imagery assigned individual wavelengths or channel differences of the red, green, and blue components of a pixel color. Each red, green, and blue color intensity was related to physical properties within the final composite image.

Final color functions, therefore, were related to the characteristics of image pixels. A multispectral image consisted of several bands of data. For visual display, each band of the image might displayed in one band at a time as a grey scale image, or in combination of three bands at a time as a color composite image (Andrew, 2012)

Interpretation of a multispectral color composite RGB image would require the knowledge of the spectral reflectance signature of the targets in the scene. In this work, the spectral information content of the image was used in the interpretation. Red color was assigned from the subtracted thermal bands 32 (11.770-12.270) μm and band 31(10.780-11.280) µm since the reflectance temperature of the dust was very effective in these bands. Green color was assigned from subtraction thermal bands 31 (10.780-11.280) µm and band 21 (3.929-3.989) µm. Blue color was represented by band 31.

2.2.2 Change detection

Change detection was the measure of change in two different images in the same periods. It was used to distinguish the changes or phenomena or monitoring the land surface. Therefore, change detection was conducted by subtraction of two bands for the same date to identify the dust storm boundary movement and the intensities of the dust storms. This technique could be applied by taking two georeferenced images of different channels for making the substraction image from MODIS aqua at the same day. This could also provide good informative results about the dust storm expansion and movement. The Brightness temperature difference (BTD) of two bands could distinguish dust storms and the density of dust and sand. In this research dust and sand storm images were determined by method developed by Ochirkhuyag (2008) as follows:

BTDI = ch32-ch31 of MODIS/TERRA sensor

where: Ch31=MODIS channel31, Ch32= MODIS channel32. The BTD for the dust storm was about (149-213) K. The dust storm appeared in red color as shown in Figure 3.

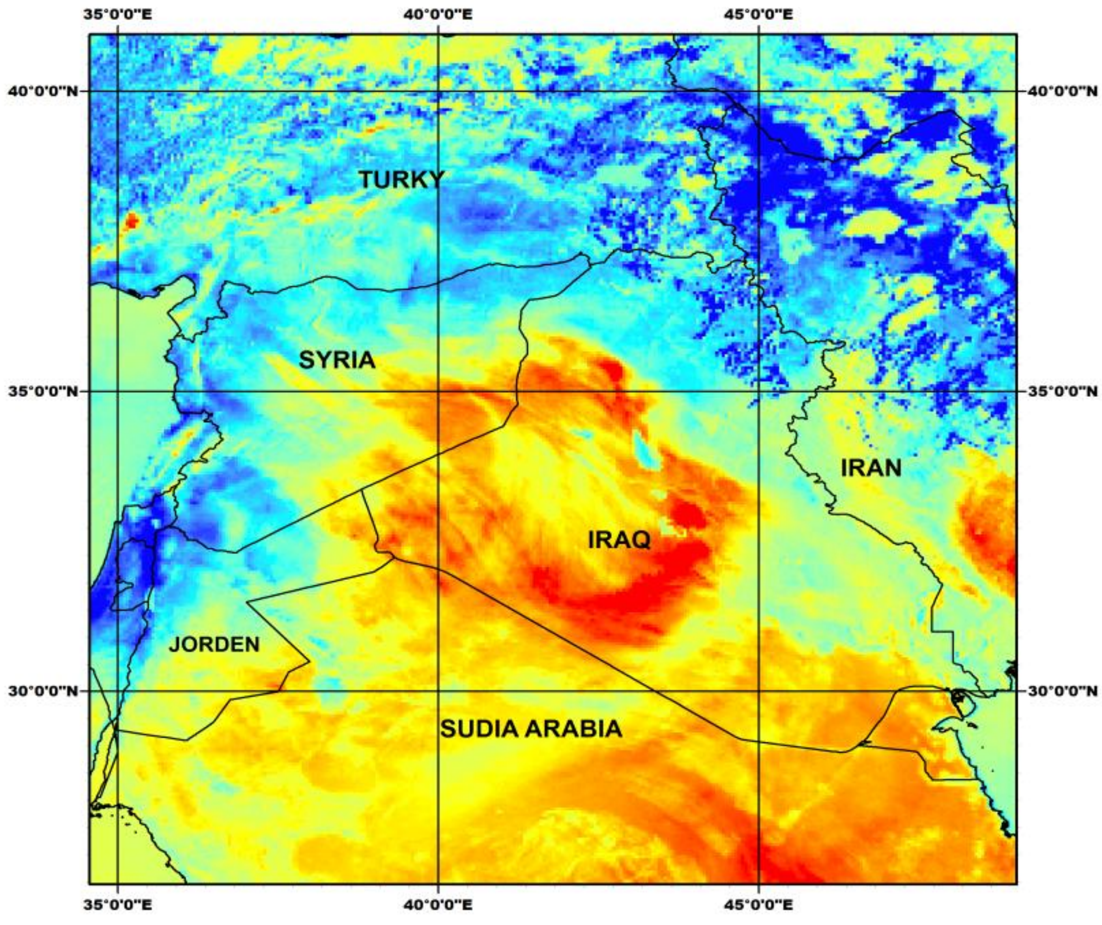


Figure 3. Dust storm images in red false color composite resulted from the subtracting band 32 and band 31.

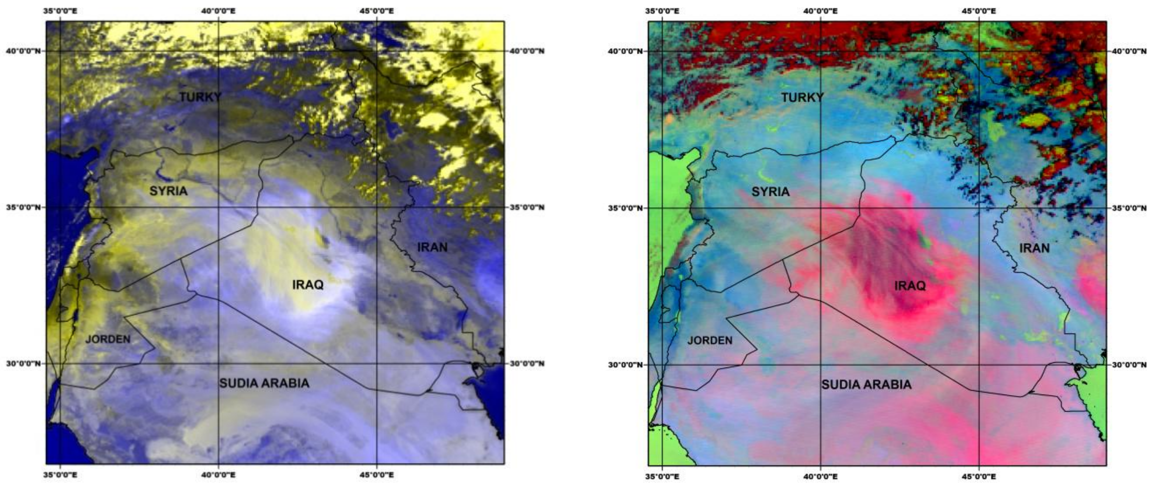
3 RESULTS AND DISCUSSION

Using different bands of MODIS data, an RGB composite image was produced as shown in Figure 4. Figure 4a showed a composite image RGB, (Red represent the subtraction between band32 and band31), (Green and Blue represent band1). The composite image illustrated that the dust storm appeared in white-violet color, while clouds illustrated in yellow color. In Figure 4b, the red color was assigned from the subtraction result between the thermal bands32 and band31, the green color was assigned from the subtraction result between the thermal band31 and band21, the blue color was assigned from band 31. Combining these bands in RGB composite image illustrated the dust storm appeared in pink color.

For clear weather, RGB true color and false color composite images were produced as shown in Figure 5. In this image, red color was the subtraction of band32 and band31, green color was the subtraction of band31 and band21, and blue color represented by band31.

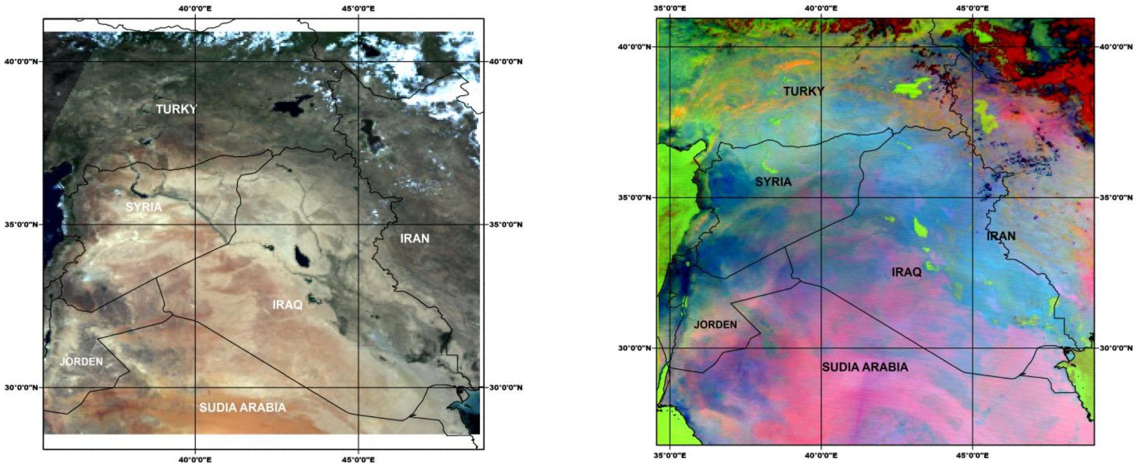
After creating the composite images for dust storm and clear weather cases, the vertical cross sections were applied in both images across the dust storm and in clear weather image (Figure 6 and 7). The results for the pixel values of the selected cross section lines for dust storm were higher than in clear weather case. This explained that the decline and increase in the digital values was an indication of the severity of the storm. The negative values were caused by the subtraction between the thermal bands (Figure 8).

Eight classes extracted using unsupervised classification for the composite image RGB of the dust storm at 30/6/2008, the covered area for the dust storm appeared in orange color equal to about 1097 km^2 of the total area (Figure 9).



(A) (B)

Figure 4. RGB composite image (red substraction of band32 and band31, green (band1), blue (band1)) illustrated dust storm in white-violet color (A). RGB composite image (red substraction of band32 and band31, green substraction of band31 and band21, blue (band31)) illustrated dust storm in pink color (B).



(A) (B)

Figure 5. True color image composite for clear weather (red (band1), green (band4), blue (band 3)) (A). Composite image for clear waether (red (band32-band31), green (band31-band 21), and blue (band 31)) (B).

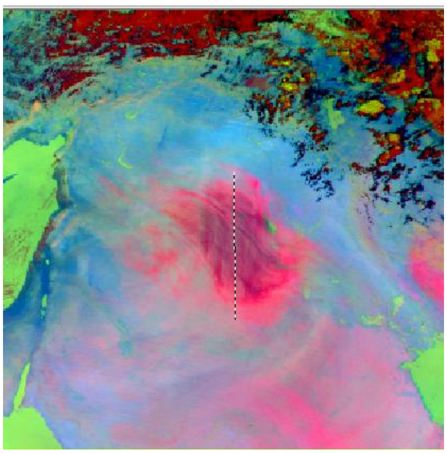


Figure 6. A line of pixels crossed the dust storm for the day 30/6/2008 applied on red composite image (band32-band31), green (band31-band21), and blue (band 31).

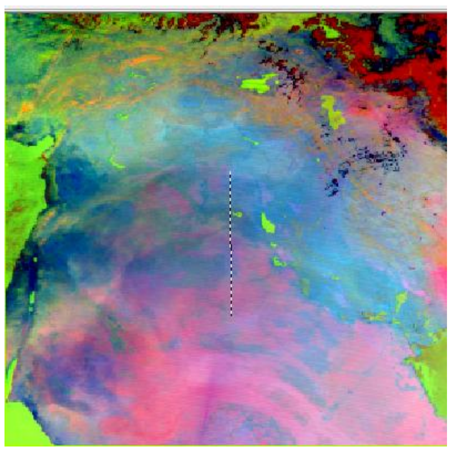


Figure 7. A line of same pixels chosen in Figure 6 for the clear weather day 4/7/2008 on red composite image (band32-band31), green (band31-band21), and blue (band 31).

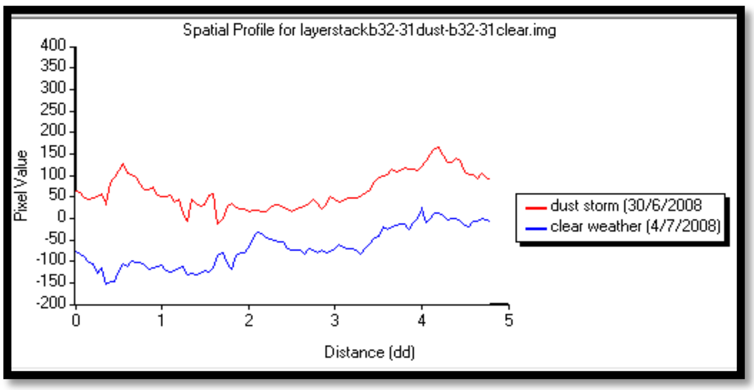


Figure 8. Vertical cross section profile between the subtraction of thermal band (b32-b31) for dust storm day at 30/6/2008 and clear weather day at 4/7/2008.

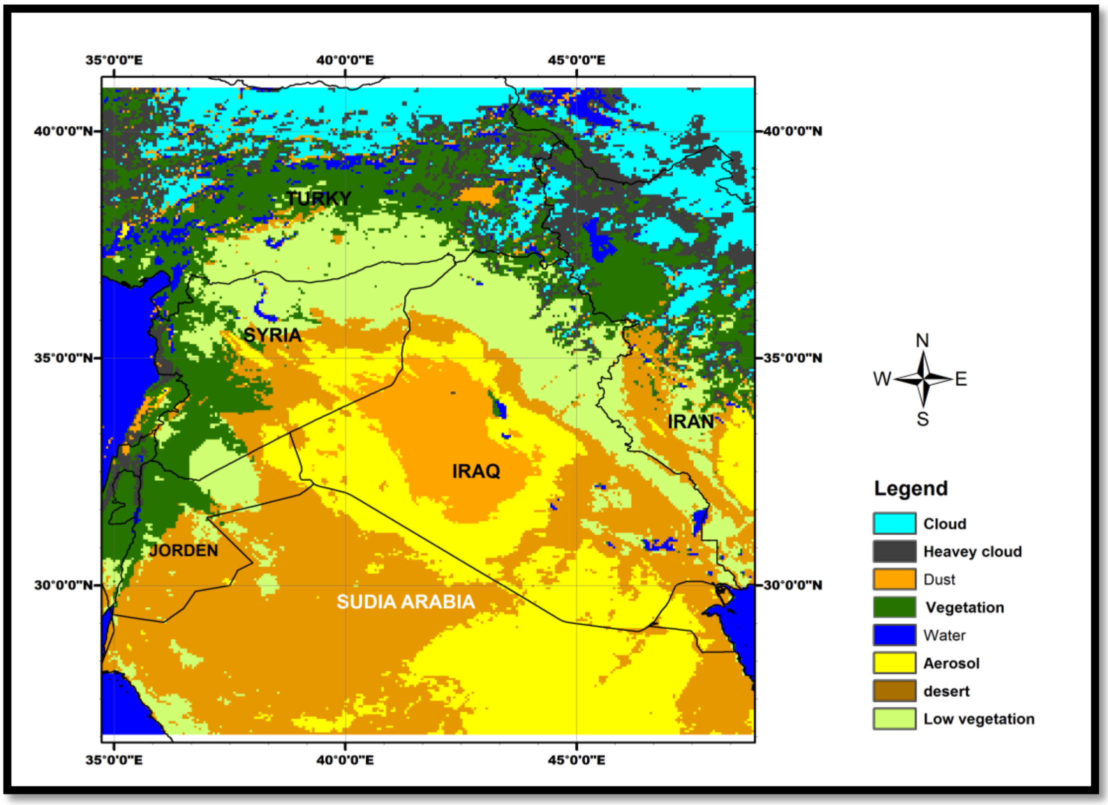


Figure 9. Unsupervised classification image for composite image RGB in Figure 4b using eight classes.

4 CONCLUSION

The spectral data from band1, band21, band31, band32 of MODIS data were very useful to discriminate the dust storm. The thermal spectral channels were used to characterize the temperature of the surface and to distinguish the earth's surface from the area of dust storm coverage. The thermal spectrals were also able to detect dust storms during night or day time. The visible channel (band1) was used to distinguish land areas and to identify the boundaries of the dust storm.

The use of subtraction technique to produce composite image in the process of detecting dust storms produced a good discrimination in the image from the rest of the elements (clouds smoke).

The overlay process for spectral bands (visible or thermal) depend on bands used to compose the red, green, and blue colors. The process also depends on the characteristics of the usage of the combination sensor bands illustrating the border of a dust storm, as well as its relationship with the background and the overlap of dust storm with the background, and dust storm intensity.

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