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Detection the Dust Storms Using MODIS Reflection Mode

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Abstract

In previous years, most regions of the Middle East suffered from frequent dust storms, Iraq at the top of that where Iraq was classified as the fifth most vulnerable country to climate change according to the Paris Climate Agreement; the frequent dust storms are considered the most prominent effects of climate change, which are a result of lack of rain and drought, and thus desertification and desertification. The storms appear when the winds blow. This research reviews using of space data, MODIS (Moderate Resolution Imaging Spectroradiometer, satellite images), and its two platforms, Terra and Aqua, to monitor storms movement and determine the starting point source using the PCA (Principal Component Analysis algorithm) in ENVI and sub-software MATLAB for (MOD09GA) and (MYD09GA) that represents the reflectivity daily monitoring, the first layer from HDF file of MODIS data red band, 620-670 nm, was used. The period was studied in research in May of 2022 with the kernel of PCA containing five bands represented by the day of the storm and two days before and after the storm for the study area located Coordinates: 35.0468, 43.0305. The results determined that the source of dust storms are cross-border storms that are not local in origin; the estimated area of the storm that covered large regions of Iraq by (351353.45) km^2 for 2022-5-5, (308024.9.km^2) for the day 2022-5-16 and with an estimated area (326933.35 km^2) for the day 2022-5-23.

Keywords: Dust storms, Dust, MODIS, PCA, Remote Sensing

الكشف عن العواصف الترابية باستخدام صيغة الانعكاسية للمتحسس ***MODIS***

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الخلاصة

في السنوات السابقة عانت اغلب مناطق الشرق الاوسط من تكرار العواصف الغبارية وفي مقدمتها العراق , حيث صُنف العراق كخامس أكثر دولة هشاشة للتغييرات المناخية حسب اتفاقية باريس للمناخ حيث تعتبر العواصف الترابية المتكررة أبرز تاثيرات التغيرات المناخية و التي هي نتيجة لقلة الامطار والجفاف و بالتالي التصحر و نشوء هذه العواصف عند هبوب الرياح. يستعرض هذا البحث استخدام البيانات الفضائية المتمثلة بصور القمر الصناعي MODIS و بمنصتيه Terra And Aqua لمراقبة العواصف و تحركها و تحديد مصدر انطلاقها باستخدام خوارزميةPCA في envi و البرمجيات الفرعية باستخدام MATLAB لل MOD09GA و MYD09GA الذي يمثل قيم الانعكاسية بشكل يومي حيث تم استخدام red band

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(620–670 nm) الطبقة الاولى لملف HDF لبيانات ال MODIS لفترة شهر مايو لسنة 2022 و لخمسة باندات متمثلة بيوم العاصفة و يومين قبل و بعد العاصفة لمنطقة الدراسة الواقعة ضمن الاحداثيات 35.0468 , 43.0305 . كانت النتائج متمثلة بتحديد مصدر نشوء هذه العواصف لمعالجة وهي عواصف عابرة للحدود ليست محلية المنشأ و تمثلت ايضاً بتقدير مساحة العواصف التي غطت اجزاء واسعة من العراق و كانت الأشد خلال فترة الدراسة ليوم2022-5-5 ب(351353.489كم^2), (308024.9297كم^2) ليوم 2022-5-16 و بمساحة تقدر (326933.3465كم^2) ليوم 2022-5-23.

1. Introduction

Remote sensing has developed into a fundamental science to answer several problems relating to land, atmosphere, surface phenomena, and natural conditions through the amount of data available for collection, manipulation, and elevated digitization [1]. Dust storms are defined explicitly by the World Meteorological Organization (WMO) as the result of surface winds lifting considerable volumes of material into lowering visibility to less than 1000 m above eye level, 1.8 m. The range of 1-63 microns is relatively similar to the silt particle size (2-63 microns) and clay (2 microns) of soil fractions and sediments; they were utilized as a reference when defining the particle size of mineral dust [2]. Sand and dust storms are atmospheric events that result from the erosion and transport of mineral sediments from the ground surface. They are typically associated with arid and semi-arid (dryland) areas but can occur anywhere with dry unprotected sediments. Iraq dust storms are a natural phenomenon due to their emission from active local dust sources or transit from overseas; dust occurrences in Iraq have grown increasingly regular. The dust emission source, chemical composition characteristics, the dust's physical characteristics, and the wind speed carrier directly affect the dust particles' form and size [3]. Detecting and monitoring storms rely greatly on remote sensing, which could be recognized in various ways, although it can be challenging to identify in semi-arid regions. This study could employ the Principal Component Analysis algorithm (PCA) to differentiate the storm from the yellow lands and clouds, which are difficult to distinguish between these storms and desert areas. The primary scene area represents the Iraqi country and a portion of each neighboring nation, excluding Kuwait, Figure (1). For this objective, space data of MODIS sensors during the May 2022 daily monitoring were used. This research used digital change detection, PCA algorithms, and the K-mean unsupervised classification method, with different kernel parameters to detect with less overly class and extract the dust storms area by the PCA kernel change.

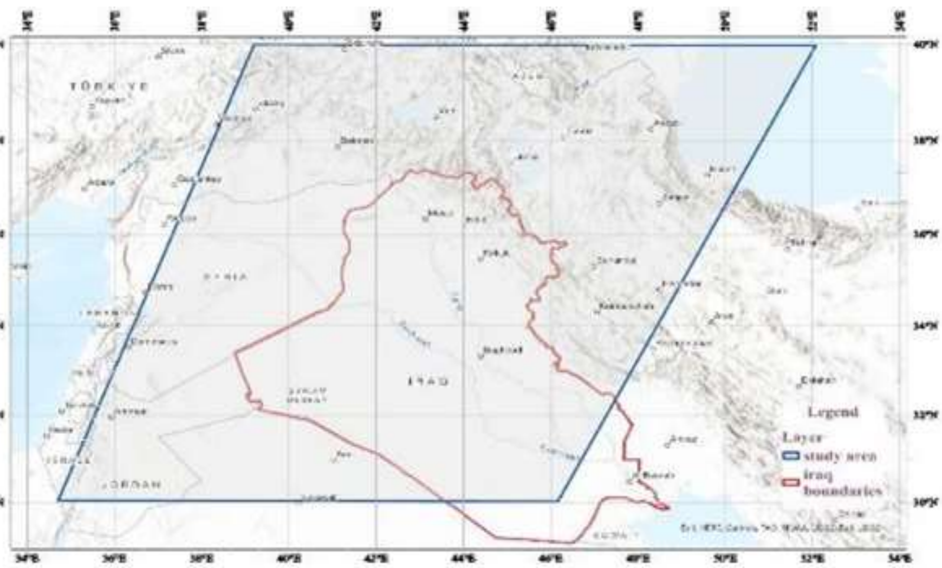

Figure 1: Study area and Iraq boundaries

1.1 Previous Study

- **S. M. Ali et al.(2012)** [4] **In** this work, geographic information systems (GIS) and climatic data were used to analyze and create maps for Iraq; measurements were taken at several climatic stations nationwide to accomplish that. The methodology is based on temperature data from 1990 to 2011 for the minimum, maximum, and mean values. The investigation results included excellent tables and a GIS map showing how temperatures have changed over time for the stations used.
- **EL-OSSTA et al.(2013)** [5] main goals of this work were to create a MODIS dust storm database and improve the automated method for detecting dust storms using data from the Terra and Aqua satellites' Moderate Resolution Imaging Spectroradiometers.
- **Albaqami et al. (2019)** [6] this Ph.D. dissertation examined the suitability of five distinct MODIS-based approaches currently used for identifying airborne dust over the Arabian Peninsula. The Normalized Difference Dust Index (NDDI), Brightness Temperature Difference (BTD) (Band 31-32), Brightness Temperature Difference (BTD) (Band 20-31), Middle East Dust Index (MEDI), and Reflective Sun Band (RSB) were among them.
- **Abbas Ranjbar Saadat Abadi et al.(2022)** [7] looked at the occurrence of dust storms on a monthly and annual basis at a few weather stations around Urmia Lake in northwest (NW) Iran. The monthly variations of AOD550 and AOD532 for the regions 37-39N and 46-59E were compared; it was discovered that the CALIPSO AOD532 and MODIS AOD532 (reconstructed using the ngström exponent) were in excellent accordance. In addition, they investigated the variations in the daily aerosol optical depth (AOD at 550 nm) and the ngström exponent at 412/470 nm.

1.2 Area of Interest and Data Used

Iraq is located in the Middle East, a portion of Asia's western continent, having borders with Syria and Jordan to the west, Turkey to the north, Iran to the east, Saudi Arabia to the south, Kuwait to the east, and the Arabian Gulf to the south. Iraq has a total area of 437 072 km^2, and because of its distance from oceans and seas, it has a continental climate [8]. However, due to the strong (north-westerly) winds that define weather during the winter-spring seasonal transition and the big desert and desert regions, dust and sand storms are most common in Iraq’s spring and summer and other parts of the Middle East [9]. Iraq, the area of interest, is a complete MODIS scene with a 2400×2400 km area assigned to "Coordinates: 35.0468, 43.0305" in the MODIS data index. The daily conditions of the dust storms on a worldwide scale are provided by the EOSDIS (Earth Observing System Data and Information System) [10]. The primary scene area represents the Iraqi country and a portion of each neighboring nation, excluding Kuwait. The scenes chosen can be described as the active local dust producers or travel from outsiders in Iraq (Figure 1). From the raw data, MODIS provides over 40 standard data products. It provides calibrated high radiometric sensitivity (12 bit) in 36 spectral bands covering wavelengths from 0.4-14.4 µm and has three different nadir ground spatial resolutions: 250m, 500m, and 1000m [11]. The available data consists of seven bands for MOD09GA daily reflectance daily monitoring with 463.31m spatial resolution and HDF format without georeferenced. Table 1 shows some of the details of the satellite image, and Figure 2 gives a brief overview of the images [12]. Satellite orbits have the repetitive capability, or temporal resolution, of scanning the same region after a set amount of time [13]

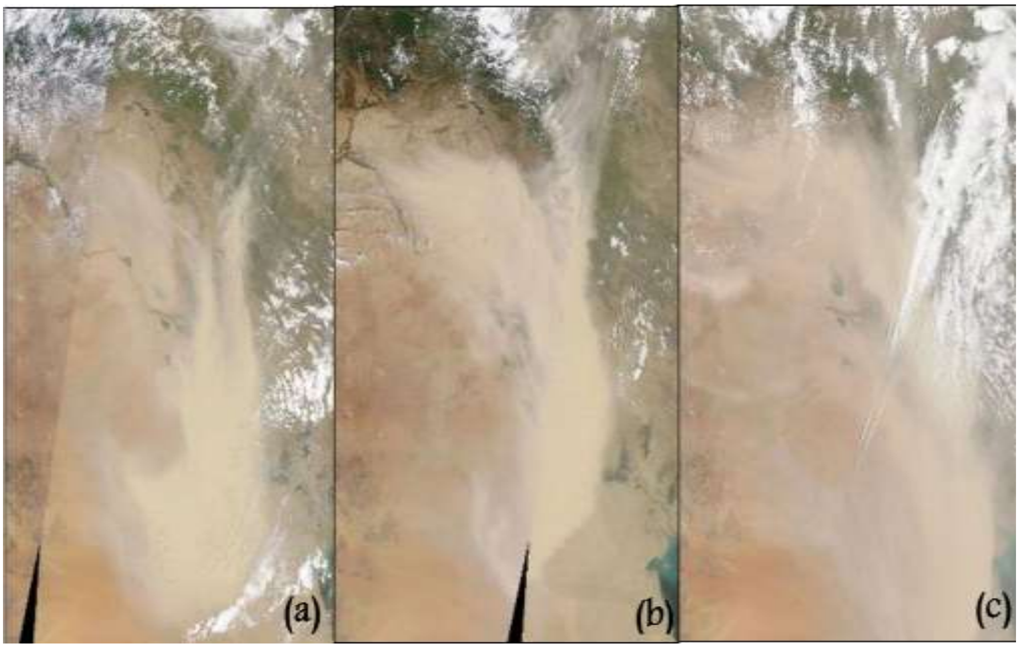

Figure 2: MODIS rapid response system terra true colors (a) 2022-5-5, (b) 2022-5-16, and (c) 2022-5-23

To determine the source of dust and estimate the area and percentage from the full scene cant be depended on the image in Figure (2) because it is unprocessed and also needs geolocation and metadata with a band of reflections to analyze and detect the source and movement.

Table 1 some of the information for data use [14][

Sensor	MODIS/MOD09GA-MYD09GA	Data Type	16-bit signed integer
Data time	Daily	Units	Reflectance
Spatial resolution	463.31*463.31m	Projection	Sinusoidal
Format	HDF	Frequency	2 times a day
Scene dimensions	2400*2400km	Orbit	polar [11]

1.2 MODIS for Monitoring

Asian dust storm monitoring used multi-satellite observations from TOMS, SeaWiFS, AVHRR, and the Chinese FY-1C/D series. However, Remote Sensing of dust storms can only offer almost worldwide horizontal coverage with a small amount of vertical precision. MODIS with characteristics described below in Table (1) could be very useful to determine dust storm properties and monitor movement with terra and aqua images after 3 hrs, Figure 3. However, the current MODIS aerosol optical depth algorithm is limited to dark surfaces [15]. The MODIS instrument was designed to provide improved land, ocean, and atmosphere monitoring twice daily [16]. MODIS data is a collection of scientific and image files in a hierarchical format, not simply a single image file, HDF file type [5].

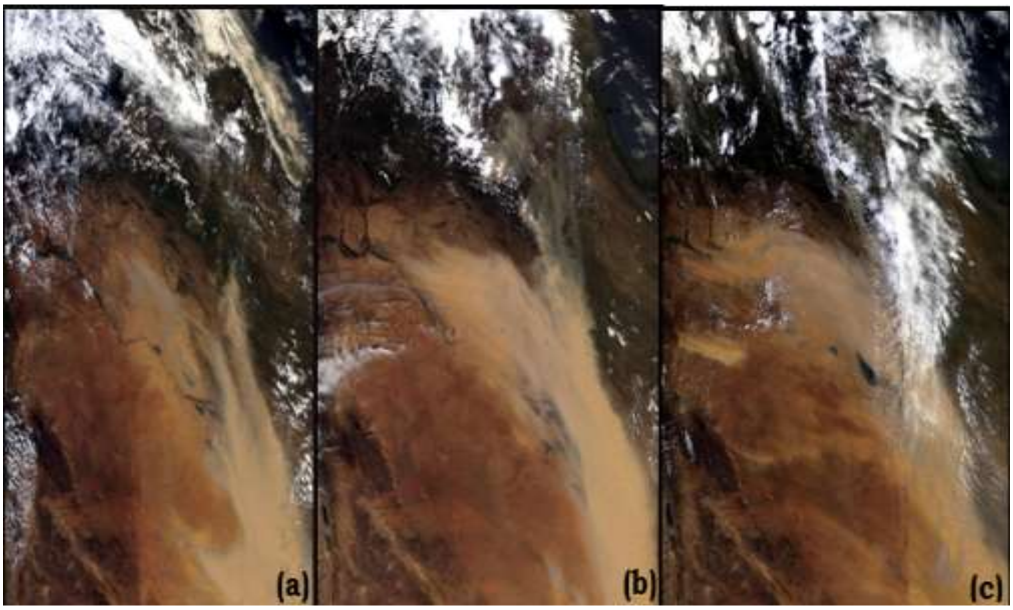

Figure 3: band1,3,4 from Terra platform, (a) 2022-5-5, (b) 2022-5-16, (c) 2022-5-23

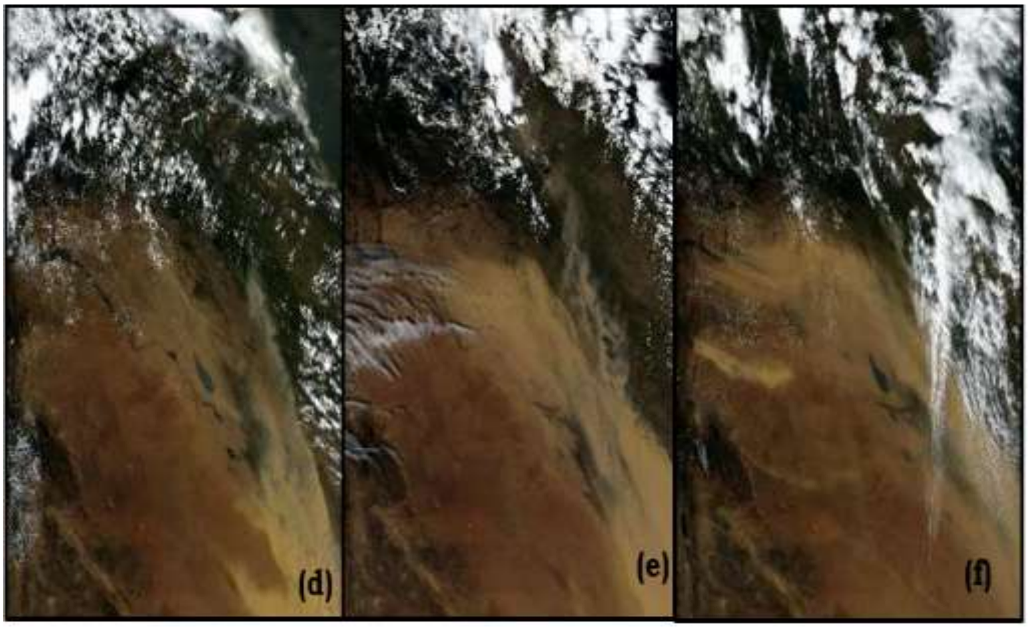

Figure 4: band 1,3,4 from Agua platform, (a) 2022-5-5, (b) 2022-5-16, (c) 2022-5-23

2. Methodology

PCA algorithms in MATLAB and ENVI output were applied to detect the dust area over Iraq for May 2022; the procurer of this work is the following:

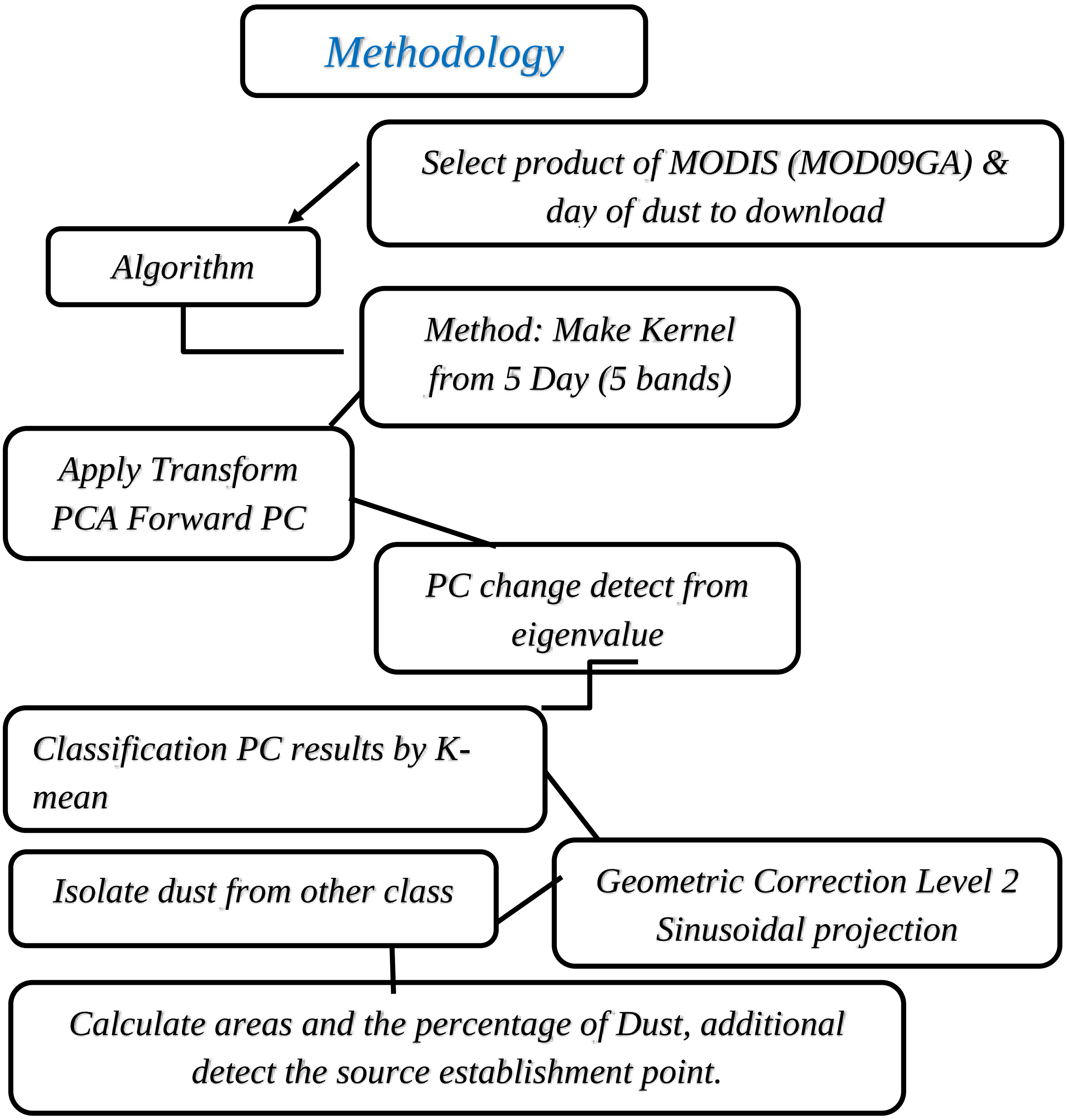

Figure 5: Flowchart presenting the methodology used in this research

2.1 Detection of dust storm sources

To detect and track the sources of dust storms. five days were used for each storm, the five days represented by the day of the storm, which will be X and two days before it and be (2-X) in addition to two days after the storm (X+2) to effectively identify the source. From the same mode (MOD09GA) with spatial resolution equal to 463.31 m, all used for the first layer of dataset red band, saved as envi standard file format.

2.2 principal component analysis

Using PCA rotation tools to perform PCA, known as a PC transform, on multiband datasets. Due to the identical spectral areas that data bands represent, they are frequently highly correlated. PCA is a one-dimensionality reduction type since it eliminates relevant spectral data from multiband datasets [17]; therefore, the first principal component image is expected to include 95% of the data variance. The variance in the last component appears to be relatively little in contrast, and it is to be assumed that this component will nearly entirely manifest as low-amplitude noise [18].

2.3 Classification pc result

One of the essential elements of any remote sensing project is satellite image classification since it is essential to distinguish between different classes based on the value of the digital numbers. There are two primary approaches to classification: supervised and unsupervised [19], with the aid of several digital and statistical algorithms. This research depended on the unsupervised method K-mean to extract dust storms area from the PCA 2 change band using the ENVI program to classify the PCA band 2. It resulted in five classes with different values for maximum standard deviation from mean to each PCA dust; it could be used to distinguish dust from clouds with a threshold value equal to 5, Figure (**6**).

2.4 Geometric correction

There are significant geometric aberrations in the raw digital image data. Therefore, geometric correction aims to adjust the image's pixel locations. Geometric correction is accomplished using well-known ground targets (ground control points collected from a reference map) and linking them to their corresponding places in the image [8]. MODIS data level 2 comes without geolocation [14], so after processing and extracting data, it georeferenced to the sinusoidal projection and got the pixel location from the band 31 and 32 emissivities.

2.5 calculating the area of dust and the percentage

In MATLAB, the PCA algorithm was applied to detect change over five days of the kernel and classify and calculate the estimation percentage of the dust area. The following equations describe it:

$$class = (2400 \times 2400) - No.point \quad (1)$$

$$X = \frac{Class}{5700000} \quad (2)$$

$$Persentage = X \times 100 \quad (3)$$

$$Area(km^{2)} = \frac{(pixelsize)^2}{1x10^6} \quad (4)$$

Pixel size in mode Mod09GA daily monitoring for the red band used in PCA kernel is ≈ 500 m, which is the point it gets from the classification histogram after being isolated from other classes.

3. Result and discussion

Several methods may be used to find dust storms; the application of utilizing space data (MODIS) includes applying the Normalized Difference Snow Index (NDSI) and the Dust Sand Index (DSI), which were used to detect dust storms from clouds and land surfaces. Applying this method to dust storms over sand was less successful [20]. Combining values from the Terra and Aqua MODIS solar reflectance bands (SRB) allows to detect of sand dust storms in the north of China using a technique based on the Normalized Difference Dust Index (NDDI), even when augmented with the BT(Brightness Temperature) estimated from band 31; it does not produce good results over sandy lands, such as the desert, making it helpful in detecting dust storms over non-sandy ground [21]. The result of the research includes selecting establish of dust zone, Figure (5) and calculating the percentage dust area from the whole scene was studied after using the PCA kernel algorithm by the red band for five days for each dust in an accuracy way method below, figure describes it following:

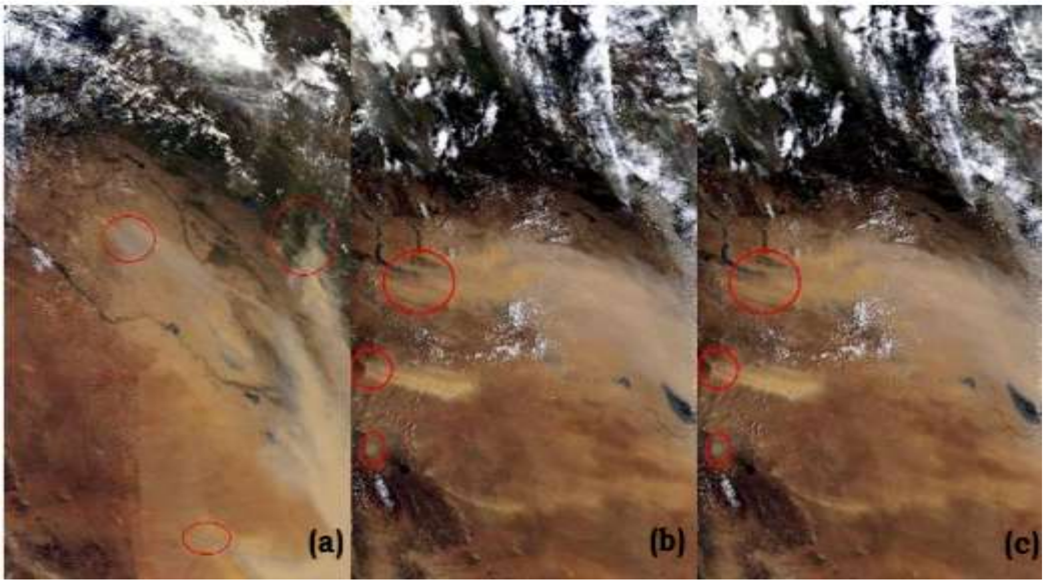

Figure 6: Source of a dust storm with terra for (a) 2022-5-5, (b) 2022-5-16, (c) 2022-5-23

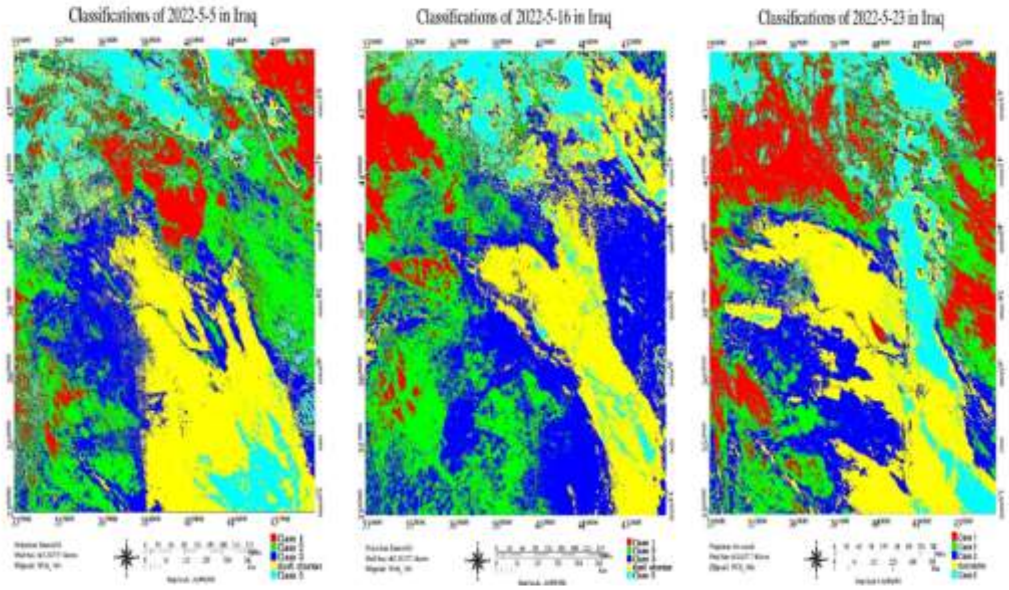

Figure 7: Classification of the scene with Terra for 2022-5-5, 2022-5-16, and 2022-5-23.

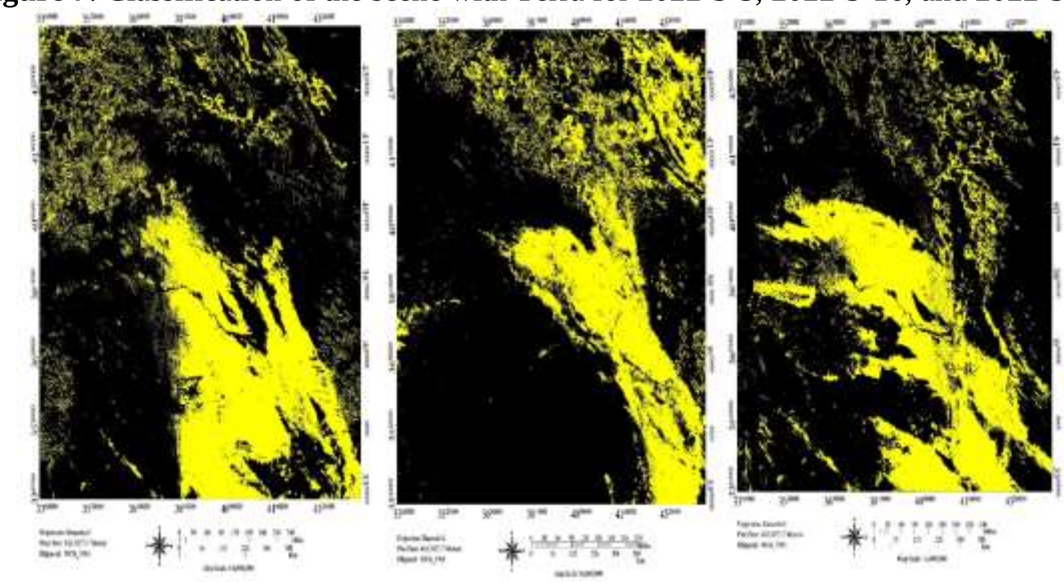

Figure 8: Dust storms 2022-5-5, 2022-5-16, and 2022-5-23

Table 2: The area and percent of dust during the time of the study

Day Of Dust	Percent from All Scene	The area from All Scene
2022-5-5	28%	351353 km^2
2022-5-16	24%	308024 km^2
2022-5-23	26%	326933 km^2

By ENVI band, math isolated the dust from other classes to show the dust source and calculate the area with the percentage of dust from the scene. Computing statistics and histograms of the yellow pixel number can calculate the area and percentage (Figure 7). The area of dust for May 2022 (5-16-23) days was 351353.49 km^2, 308024.93 km^2, and 326933.35 km^2, which means 28%, 24%, and 26%, respectively, from the whole scene shown in Table (2).

4. Consolation

1. Detecting dust storms is an actual application of remote sensing because it cannot be seen from the ground (naked eye) or close elevation; detecting zero point need comprehensive coverage and ensures speed in completing work and accuracy.
2. PCA algorithm can effectively detect dust storms with less overly by clouds and sand and over time movement.
3. The enormous storm reaching Iraq was the most intense on May 5, 2022, with its area equal to 351353.49 km^2, or approximately more than half the size of Iraq.

5. Future Work

Working on other methods to detect dust storms and comparing the accuracy with the results of this research, and studying the impact of these storms on temperatures before and after the storm.

6. Acknowledgment

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