Clouds and shadows detection and removing from remote sensing images

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Clouds and Shadows Detection and Removing from Remote Sensing Images

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Abstract - Clouds and their shadows is common feature in remote sensing images, this causes serious problems for different applications like change detection, classification, crop yield estimation, and environmental monitoring. This means that, for many applications it is very necessary to remove these clouds and their shadows from the required satellite images. National Authority for Remote Sensing and Space Sciences, NARSS, Egypt is using the Thematic Mapper (TM) on-board the Landsat satellite for their remote sensing applications. In this paper, clouds and shadows detection and removing methods are discussed. This discussion includes conventional methods using threshold and subtraction techniques and using image fusion methods. The image fusion method using multi decomposition levels of two-Dimensions Discrete Wavelet Transform (2D-DWT) on thermal band image proved its superiority over other methods.

I. INTRODUCTION

Remote sensing is the acquisition of data about an object or scene by a sensor that is far from the object, Aerial photography, satellite imagery, and radar are all forms of remotely sensed data [1]. This means that the electromagnetic energy emitted or reflected by the surface of the earth is acquired and recorded as an image that represents the features of the earth. Remote sensing technology has made it possible to take detailed measurements over the entire surface of the earth relatively cheaply and efficiently. This technology has made it possible to examine any particular part of the earth's surface and to study earth as a complete system.

In 1972, the National Aeronautics and Space Administration (NASA) initiated the first civilian program specializing in the acquisition of remotely sensed digital satellite data. The first system was called Earth Resources Technology Satellites (ERTS), and later named Landsat. There have been several Landsat satellites launched since 1972, Landsat 1, 2, 3, 4, 5, and 7.

Landsat-7 is a tri-agency joint program of NASA, National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS). Landsat-7 was launched on April 15, 1999. The earth-observing instrument onboard this spacecraft is the Enhanced Thematic Mapper plus (ETM+). ETM+ has a swath width of approximately 185km from a height of approximately 705km.The ETM+ is a multispectral scanning system that records electromagnetic energy from the visible, reflective-infrared, middle-infrared, and thermal-infrared regions of the spectrum. The spectral resolution of ETM+ is 8 bands.

Table I Landsat-7 Spectral Bands.

Band	Wavelength (μm)	Resolution (m)	Nominal Spectral Location
1	0.45-0.52	30	Blue
2	0.52-0.60	30	Green
3	0.63-0.69	30	Red
4	0.76-0.90	30	Near IR
5	1.55-1.75	30	Mid IR
6	10.4-12.5	60	Thermal
7	2.08-2.35	30	Mid IR
8	0.52-0.90	15	Pan

The spatial resolution of ETM+ is 30x30m for all bands except the thermal and panchromatic bands (band6 and band8). The thermal band has a spatial resolution of 60x60m and the panchromatic band has a spatial resolution of 15x15m. The temporal resolution is 16 days. The radiometric resolution is 8-bit, meaning that each pixel has a possible range of data values from 0 to 255. The wavelength and the spatial resolution of each band are shown in table 2.2.

National Authority for Remote Sensing and Space Sciences, NARSS, Egypt is using the Thematic Mapper (TM) on-board the Landsat satellite for their remote sensing applications. The original noisy remote sensing images which composed of combinations of bands 7, 4, and 2 are shown in Figure 1. Roads and some irrigated agriculture regions have brightness values similar to shadows. In the desert there are some types of rocks have brightness values similar to clouds or shadows. This similarity makes the detection process more difficult.

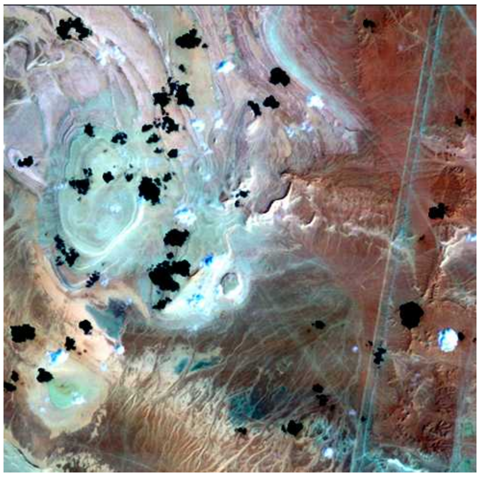


Figure 1 (a)

Figure 1 (b)

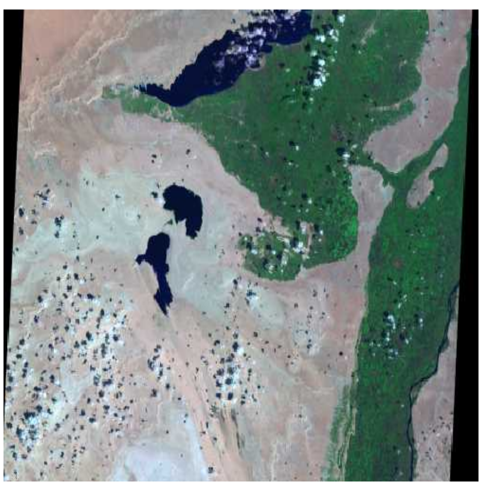


Figure 1 (c)

Figure 1. The original noisy images: (a) image of desert area, (b) image of agriculture area and (c) shows image of both agriculture and desert area in Al-Fayoom-EGYPT.

Some techniques has been developed [2] - [3] to detect and remove clouds and their shadows from the optical satellite images. However, these techniques were designed for the data acquired from low-spatial-resolution systems, such as the Advanced Very High Resolution Radiometer (AVHRR) on-board the NOAA satellite. These techniques are not suitable for data acquired from high resolution systems such as the Thematic Mapper (TM) on-board the Landsat satellite. Clouds free image like Synthetic Aperture Radar (SAR) images are panchromatic and subject to geometric distortion by height variations in the terrain because of the side-looking geometry [4].The aim of image fusion is to integrate complementary data in order to obtain more information than it could be derived from single sensor data alone. The most common conventional methods for image fusion are the Principal Component Analysis (PCA) [5], Laplacian pyramid [6], Intensity-Hue-Saturation (IHS) [7], and Brovey transform [8]. The use of 2D-DWT in image fusion proved its superiority over other mentioned fusion methods[8-15]. The new in this research is using the image fusion method based on 2D-DWT in several determined levels to detect and remove clouds and their shadows form the Landsat TM images.

II. Methodology

The clouds and their shadows will be treated as unwanted noise and the term noise will be used to refer to clouds and shadows. In order to make use of the noisy remote sensing image, two images acquired at different dates are combined using digital image fusion techniques, thereby enabling areas of interest to be monitored at any time of the year. This means that areas of the clouds and their shadows will be removed from the original noisy image and replaced by data from the clear image acquired in previous date. It is preferred to select two images that are acquired in near dates to overcome the problem of environmental changes between the two dates. The two input images are co-registered to each other. This registration ensures that the information from each of the images refers to the same physical structure in the environment. Due to the different solar irradiance and atmospheric effects in the two images, it is required to correct the brightness of the two images. The final step is to detect and remove the areas of noise. Deferent conventional methods and 2D-DWT fusion method [8] have been tested on many samples of images to compare their results.

III. Detection of Clouds and Shadows using Threshold Method

Threshold method is the simplest gray-level segmentation process to detect the areas of clouds and shadows. Two threshold values (*TH1 and TH2*) are proposed for detecting shadows and clouds. In this case of Landsat TM images the pixels of clouds have a brightness values from 230 to 255, and the pixels of shadows have a brightness values from 0 to 40.

Results Evaluation Using Threshold Method

There is false-recognition of clouds where some land areas are detected as clouds because it have the same brightness properties as the clouds. Some areas are detected as shadows such as the roads and some agriculture areas. The final output images of the threshold method are shown in Figure 2. The threshold method failed to detect small clouds and shadows in the images.

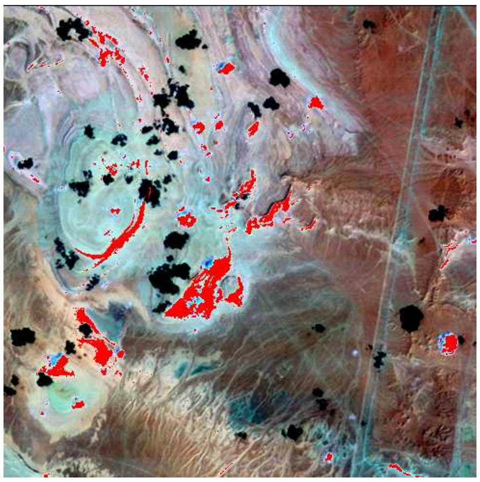


Figure 2 (a): The areas in red color detected as clouds in image of desert area.

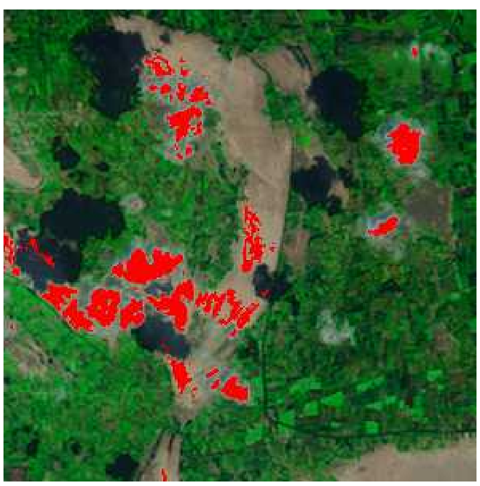


Figure 2 (b): The areas in red color detected as clouds in image of agriculture area.

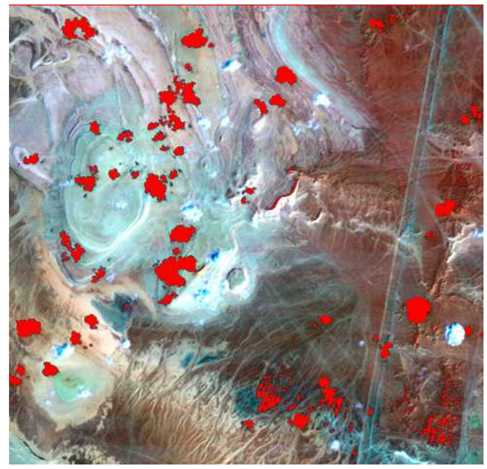


Figure 2 (c): The areas in red color detected as shadows in image of desert area.

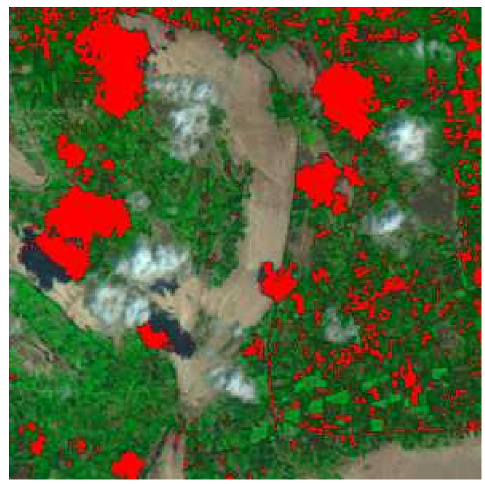


Figure 2 (d): The areas in red color detected as shadows using threshold method.

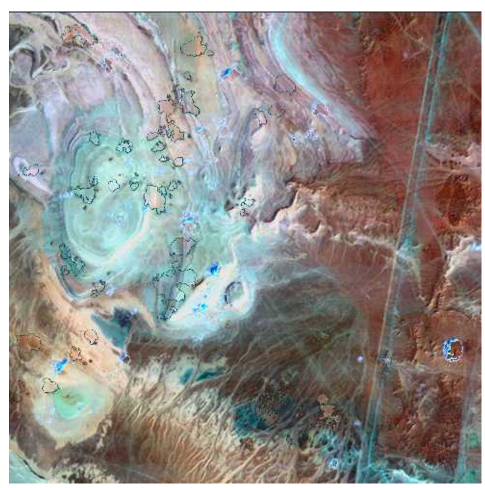


Figure 2 (e): The output image of desert area.

Figure 2 (f): The output image of agriculture area.

Figure 2. The output images of the threshold method, some shadows are not removed, some ground areas are detected as clouds. The small sized clouds are not detected.

Improvements to Threshold Method

Landsat TM band 6 image recorded at wavelength from 10.5 to 12.5 µm to produce Thermal infrared images indicating the radiant temperature of materials. Radiant temperature is determined by a material's kinetic temperature and by its ability to radiate and absorb thermal energy. All matters in the earth surface radiate energy at thermal infrared wavelengths. The thermal band images are shown in Figure3.

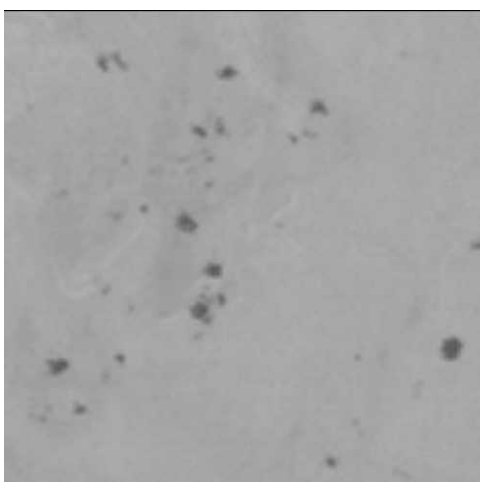
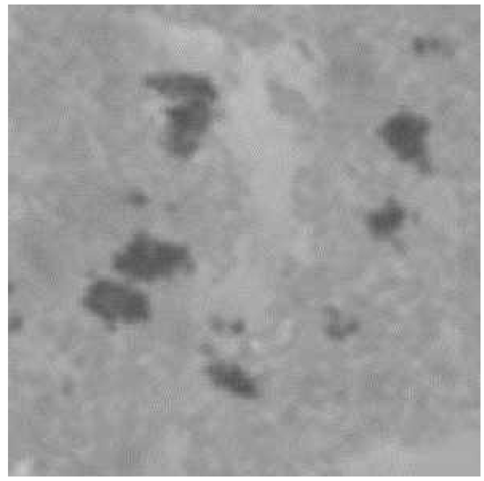


Figure 3 (a) Image of desert area in Al-Fayoom (Band 6).



(b) Image of agriculture area in Al-Fayoom (Band 6).

Figure 3: The thermal images (band 6). (a) Image of desert area in Al-Fayoom. (b) Image of agriculture area in Al-Fayoom.

Clouds consist of tiny particles of ice or water. The clouds are cooler than other features on the earth. Energy of the earth's surface can not penetrate the clouds, so the sensors on the satellite record the energy radiated by the clouds. The pixels belongs to clouds will have smaller brightness values and looks darker. The input images are the original noisy image and the noise free image , and it is required to detect and replace the clouds from thermal image using threshold method. Figure 4 shows the areas in red color that are detected as clouds using threshold method on grey-levels image of bands 742 and thermal image. All the clouds are detected correctly even the small clouds due to using band6 but it is still required to develop an algorithm to detect the shadows correctly.

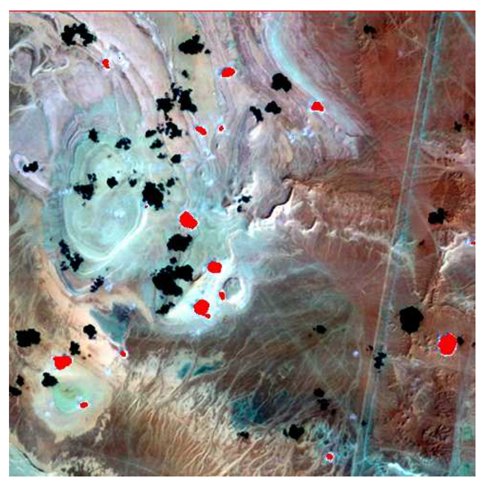
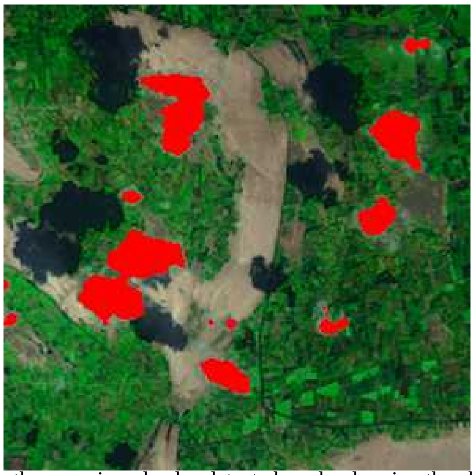


Figure 4 (a) Shows the areas in red color detected as clouds using threshold with band 6.



(b) Shows the areas in red color detected as clouds using threshold with band 6 image of agriculture area.

Figure 4 : This images show the areas in red color detected as clouds using threshold with band 6

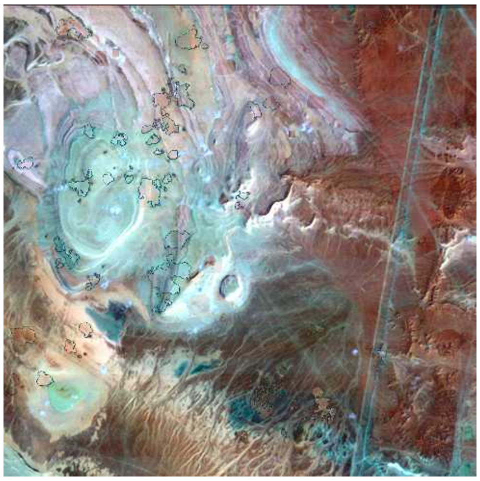


Figure 5 (a): The output image of desert area using threshold with band 6.

Figure 5 (b) : The output image of agriculture area. using threshold with band 6.

IV. Subtraction Method

In subtraction method, the two images (original noisy image and clear image) are subtracted to obtain the difference image. If the original noisy image is subtracted from the clear image, the absolute values of differences of the similar areas will be zero or small value while in the areas of clouds or shadows the differences will be high and the clouds and the shadows areas will be detected.

Results Evaluation using Subtraction Method

Figure 6 shows the areas that are detected as clouds and shadows using the subtraction method. This method failed to detect some shadows especially when some areas have similar brightness and the same position to the shadows in the noisy image.

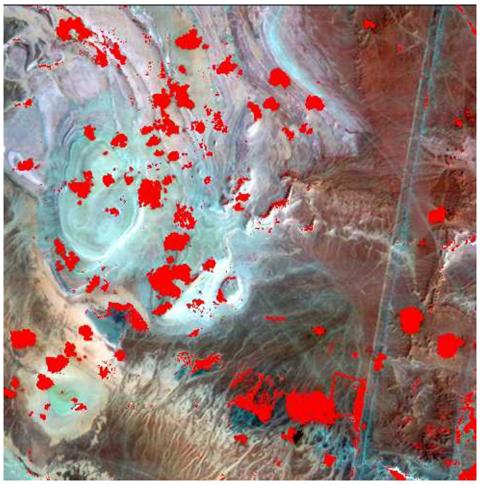


Figure 6 (a): The colored areas in red in images are detected as clouds and shadows of desert area using subtraction method.

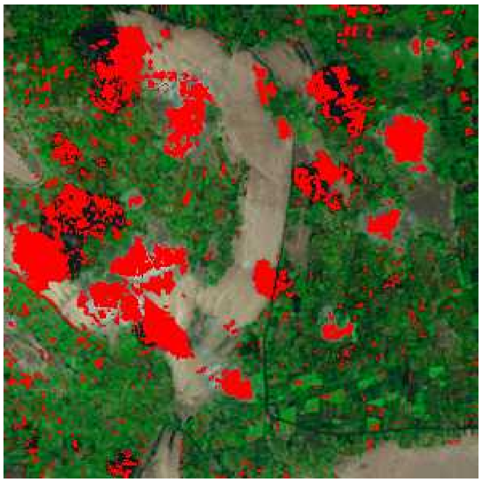


Figure 6: (b) The colored areas in red in images are detected as clouds and shadows of agriculture area using subtraction method.

The results of the threshold and the subtraction methods still have some defects. It is still needed to apply another method that able to detect and remove clouds and shadows efficiently.

V. THE PROPOSED METHOD

The proposed strategy for clouds and shadows detection is based on using the wavelet transforms to obtain the image in the frequency domain. The wavelet transforms cuts up the image into different frequency components. The output from the 2D-DWT is four images of size equal to quarter the size of the original image as shown in Figure 7. These images are called HH (diagonal details), HL (vertical details), LH (horizontal details), and LL (approximation) images. The wavelet transform can be performed for multiple levels, where the next level of decomposition is performed using the LL image only. The first level of decomposition results in the highest frequency components from the image (HH, HL, and LH). The low frequency component is the LL image. In the second level of decomposition the highest frequency components from the LL image is separated. And so on.

The multi-levels of wavelet decomposition produce images at different frequencies. So the proposed method for clouds and shadows detection is based on making threshold at the wavelet coefficients at different levels of decompositions and consequently at different frequencies. A decision map is produced to specify the clouds and shadows pixels. If the pixel is a cloud or shadow, then the wavelet coefficients in the original noisy image are replaced by the wavelet coefficients from the clear image. This means the proposed method based on replacing the wavelet coefficients of the clouds and shadows by the wavelet coefficients of the clear data. Then it is required to obtain the image again in the time domain, so the inverse of two dimensional discrete wavelet transform is performed.

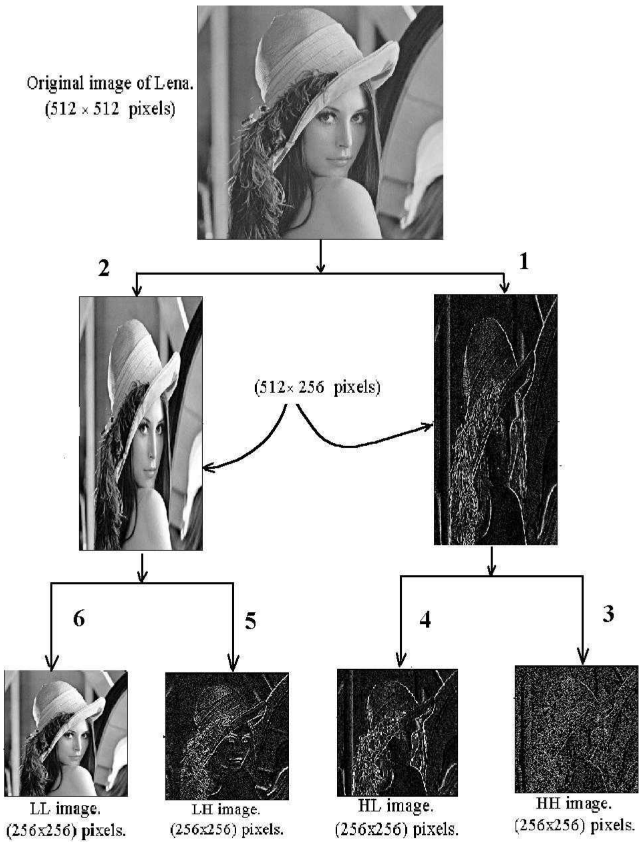


Figure 7: 2-D DWT of Lena. (1) High-pass filter and down sample by 2 along x. (2) Low-pass filter and down sample by 2 along x. (3) High-pass filter and down sample by 2 along y. (4) Low-pass filter and down sample by 2 along y. (5) High-pass filter and down sample by 2 along y. (6) Low-pass filter and down sample by 2 along y

Clouds and Shadows Detection Algorithm using 2D -DWT fusion Method

The steps of shadows detection using multi-levels of 2D-DWT are:

1. The input images are the original noisy image which is the gray-level image of bands 742 and the cloud free image of size $2^N \times 2^N$ are decomposed to their LL, LH, HL, and HH images using 2D-DWT with Daubechies filters with 8 coefficients.
2. For each image (noisy and clear images) perform N/2 levels of 2D-DWT.
3. To detect the shadows, make a threshold in the wavelet coefficients at the all levels of the original noisy image wavelet decompositions (from -0.5 to 0.5). The shadows pixels will set to ones and the other pixels will set to zeros.
4. At each level of wavelet decomposition perform the AND function at HL, LH, and HH images with the opposite component results from wavelet decomposition of clear image to sure that these pixels are shadows. Then a decision map is performed to specify the shadows.

5. Replace the wavelet coefficients at the shadows areas in the original noisy image by the wavelet coefficients from the clear image.

6. Repeat the steps 1-5 to detect the clouds from the original noisy image with using the band 6 image as input instead of the grey-levels image of bands 742 image and replace their wavelet coefficients by the wavelet coefficients from the clear image.

7. The inverse two dimensional discrete wavelet transform (inverse 2D-DWT) is performed to obtain the output image again in the time domain.

Results Evaluation of using 2D -DWT Fusion Method

The output images using multi decomposition levels of 2D-DWT are shown in Figure 8. Note that all the areas of clouds and shadows are detected and removed correctly. The multi decomposition levels of 2D-DWT method succeeded in detecting all the shadows and the clouds. This is due to transforming the images from the time domain to the frequency domain and obtaining the image in multi-levels of frequencies.

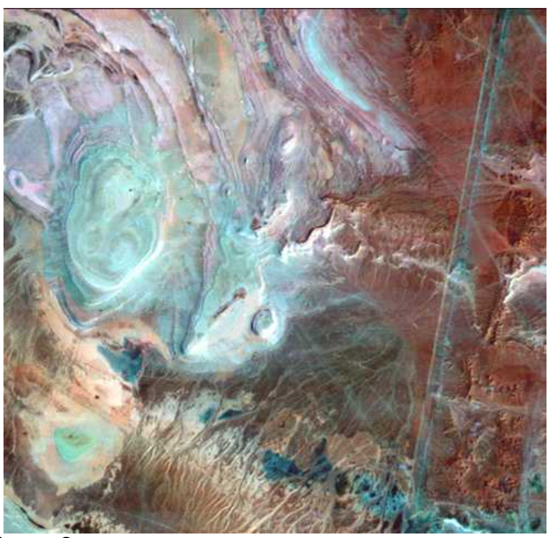


Figure 8: (a) The output image of desert area shown in Figure 1.

Figure 8: (b) The output image of agriculture area shown in Figure1.

Figure 8: The output of two types of images using multi-levels of 2D-DWT.

For more testing, the proposed method was applied on another samples of remote sensing images which composed of combinations of bands 7, 4, and 2 and converted to gray-level image like that shown in Figure 9 which contains both of agriculture area and desert area. The results was encourages to rely on the proposed method in removing the clouds and shadows from remote sensing images.

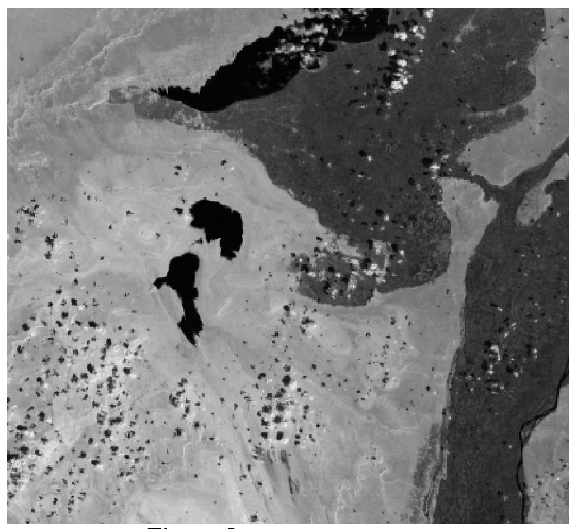


Figure 9: (a) The input image.

Figure 9: (b) The output image of (a) using multi-levels of 2D-DWT.

VI. CONCLUSIONS

In this paper the novel procedure for clouds and shadows detection and removing using multi decomposition levels of 2D-DWT is discussed. This discussion includes the effects of clouds and shadows in remote sensing images on remote sensing applications. Clouds and shadows detection and removing using threshold and subtraction methods are demonstrated. A proposed method for clouds and shadows detection and removing using multi decomposition levels of 2D-DWT fusion method demonstrates efficient detection of more than 98 % of clouds and shadows and overcomes the problem of false-recognition of clouds or shadows.

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