Change Detection of harvested palm areas by using spectral angle mapper algorithm case study Dora in Baghdad

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Abstract. In recent years, the phenomenon of cutting and burning of palm trees in many areas of Iraq has been observed to turn them into residential lands, causing great environmental damage. Hyper spectral image (EO1) for 2003 were used, bands were reduced to 155 bands, after making a subset of the study area in Baghdad with area about 40.88km² and performed the radiometric correction and atmospheric correction. Palm class was then extracted from the image and spectral angle mapper algorithm was applied with spectral angle 0.1 and 0.05 to determine palm areas. Sentinel-2 was used for years 2016 and 2018. After making subset of the same study area and doing the aerial correction and putting the mask on the palm areas extracted from hyper image 2003, permanent palm category was extracted from the images and Spectral Angle Mapper algorithm was applied at different angles to reach the permanent palm areas. The results shows changed from 19% palm area in 2003 to 7% palm area in 2018, meaning that the proportion of harvested date palm accounts for 12% of the total area.

Keywords: hyper spectral images, multi spectral images, QUAC, FLAASH, SAM.

1. Introduction
The aim of the study is to detect the harvested palm areas for Dura area in Baghdad for 2016 and 2018 after comparing them with the old satellite images for 2003 and calculating the percentage change in the palm areas over the years mentioned using remote sensing techniques. The study was based on satellite images of Dora with different dates, The space image of 2003 is a Hyperion type was downloaded from the USGS and belongs to the EO1 with Hyperion sensor. It has 242 bands with spectral accuracy ranges is 10nm and spatial accuracy 30m. The space images of 2016 and 2018 are multi-spectral type belongs to (satellite / EOS) of Sentinal-2 that carries 12 spectral bands with a spatial resolution of 10m, 20m and 60m depending on the type of band. After cutting the study area, number of optical bands were reduced as needed and resampling spatial resolution for all images to 30m, radiometric calibration and atmosphere correction were done depending on image type. The permanent palm category was extracted from the same space image from different locality for the years 2003, 2015 and 2018 to be used in the spectral angle mapper algorithm to obtain the best classification of the permanent palm areas. The results of years 2016 and 2018 were compared with 2003 results for harvested palm areas. Classification accuracy shows good result for image 2003 with spectral angle 0.1 and images 2016 and 2018 with angle 0.05.
2. Study area and dataset
The study area is located in the south of Baghdad (Al-Doura district) at (44°24'27E -44°26'53E) and (33°17N- 33°13N) as shown in figure 1. It covers an area of 40.88km² and contains large areas of permanent palms.

![Figure 1. Study Area](image)

The space image of 2003 is Hyperion image, spectral range is between 0.40 and 2.50 μm with 242 bands which have a spectral resolution of about 10 nm with a spatial resolution 30m. The picture was acquired on 2003-08-24T07:22:27Z) from an altitude of 705 km with coordinate system (D_WGS_1984). Because of the non-calibration of some spectral bands and interference between some bands, they were reduced to 155 optical bands as shown in Table 1 [1].

| Region | Band number | Wavelength(nm) |
|--------|-------------|----------------|
| VNIR   | 10 to 57    | 447.9 to 925.9 |
|        | 81 to 97    | 952.9 to 1114.3|
|        | 101 to 119  | 1154.7 to 1336.2|
|        | 134 to 164  | 1487.6 to 1790.2|
|        | 182 to 221  | 1971.8 to 2365.2|

Table 1. End (155) stable Hyperion bands image

The multispectral satellite images for 2016 and 2018 are from Sentinel-2, and the spectral bands b2 (560nm), b3 (560nm), b5 (705nm), b6 (740nm), b8 (842nm), b11 (1610nm) were used with spatial resolution 20m and coordinate system (WGS_1984_UTM_zone_38N).

3. Methodology
Hyper spectral image and multispectral images were analyzed and processed by the ENVI software, after making spatial subset and spectral subset to all images, where number of rows 352 and number of columns 296 and resampling spatial resolution for multispectral images to 30m. The processing steps to achieve our objective is shown in figure 2.
3.1 Processing for hyper spectral image

The hyper spectral image of 2003 was processed by converting from (DN) (Digital Number) to (Radiance) according to equation [2] [3]:

\[ L = \text{Gain} \times \text{Pixel value} + \text{offset} \]

The formula is used as Band Interleaved by Line (BIL) and the scale factor varies by packet type (VNIR) or (SWIR) as shown in the equations below:

\[ \text{VNIR} \ L = \frac{\text{Digital Number}}{40} \]
\[ \text{SWIR} \ L = \frac{\text{Digital Number}}{80} \]

Then atmosphere correction were done to the image by Appling FLAASH model according to the equation:

\[ L = \left( \frac{A \rho}{1 - \rho S_e} \right) + \left( \frac{B \rho e}{1 - \rho S_e} \right) + L_a \]

Where:

\( \rho \): represents the reflectivity of the pixel surface.
\( e \): represents the surface reflectivity rate for pixels and surrounding area.
\( S \): Surface reflection of the atmosphere.
\( L \): represents the reflected radiation diffused from the atmosphere.
\( A \) & \( B \): represent coefficients based on geometrical coordinates and atmosphere but not on the surface.

Figure 3 shows a high resolution image (2003) after radiometric calibration and atmosphere correction, and Figure 4 shows the spectral profile of a palm pixel before and after applying FLAASH model.
3.2 Processing for multispectral images
The multi-spectral images for 2016 and 2018 were processed by using the QUAC method in ENVI software [4] which based on the empirical finding that the average reflectance of a collection of diverse material spectra, such as the end member spectra in a scene, This allows for a reasonably accurate reflection of the reflection spectra [5], Figure 5 shows the result of QUAC method.

3.3 Extract end member for classification
By ENVI software, ROI (region of Interest) tool was used to select the categories required for each satellite image using visual inspection. The result was three permanent palm categories for each satellite image for years 2003, 2016 and 2018.

3.4 Spectral Angle Mapper Classification
SAM algorithm is based on the assumption that pixels in a space image represent a type of ground surface material in the image and another reference pixel specified by the ROI as a single category for a specific category. The angle between the two spectra is a measure of their similarity by considering each spectrum as a vector in space Dimensional, where n is the number of bands in each spectrum connected to the pixel as shown in Figure 6 [6].
SAM algorithm determines the spectral similarity between two spectra by calculating the angle between the two spectra as in the equation below:

\[
\alpha = \cos^{-1}\left(\frac{\sum_{i=1}^{nb} t_i r_i}{\sqrt{\sum_{i=1}^{nb} t_i^2} \sqrt{\sum_{i=1}^{nb} r_i^2}}\right)
\]

Where nb represents the number of bands, r represents the spectrum of pixels, t represents the reference spectrum, and \(\alpha\) represents the spectral angle [7].

4. Results and Discussion

Following the application of the classification technique (SAM) [8] on the image of the hyper spectral and the identification of the 2003 palm cultivars as reference spectra, the results showed the classification images as shown in Figure 7, the date palm areas represent 16.45% of the study area and 83.55% without palm trees when the spectral angle was determined by 0.1, while the palm areas constituted 6% of the study area and 94% without palm trees when determining a spectral angle of 0.05.

![Figure 7. SAM for hyper image (2003) (a) angle 0.05   (b) angle 0.1.](image)

Figure 7. SAM for hyper image (2003) (a) angle 0.05   (b) angle 0.1.

Figure 8 shows the palm areas defined by the polygon extracted from the SAM image and is applied to the hyper spectral image when selecting the angle value of 0.1.

![Figure 8. Palm area determined by polygon over hyper image (2003).](image)

Figure 8. Palm area determined by polygon over hyper image (2003).

When applying the classification technique (SAM) on the image of 2016 (Sentinal-2) and determining the palm categories for 2016 and determining the spectral angle 0.1 and 0.15, the results showed the classification images as illustrated in figure 9, statistical analysis of the picture showed that palm areas constitute 15.1% of the study area and the area of harvested palm is 1.35% of the total area when selecting the spectral angle 0.1, while the palm areas constitute 9.97% of the study area and harvested palm area constitute 6.48% of the total area when choosing the spectral angle 0.05.
When applying the classification technique (SAM) on the image of 2018 (Sentinal-2) and determining the categories of palm in 2018 and determining the spectral angle 0.1 and 0.05, the results showed the classification images as illustrated in Figure 10, statistical analysis shows that palm areas constitute 11.35% of the study area and palm areas, the harvested area constitutes 5.1% when selecting the spectral angle 0.1. while the palm areas constitute 6.63% of the area of the study area, the harvested palm areas constitute 9.82% of the total area when selecting the spectral angle 0.05.

Calculating overall accuracy and Kappa Coefficient have been done for all images[9]. Table 2 shows overall accuracy for all images is more than 86% except classification image for 2016 with spectral angle 0.1 is 71.5%, kappa coefficient were good for classification images 2003 with spectral angle 0.1 and classification images 2016 and 2018 with spectral angle 0.05.

| Images | Spectral angle for SAM | overall accuracy | Kappa Coefficient |
|--------|------------------------|------------------|-------------------|
| 2003   | 0.1                    | 87.1%            | 0.6               |
| 2003   | 0.05                   | 92.9%            | 0.37              |
| 2016   | 0.1                    | 71.5%            | 0.43              |
| 2016   | 0.05                   | 87.8%            | 0.55              |
| 2018   | 0.1                    | 86.7%            | 0.45              |
| 2018   | 0.05                   | 93.1%            | 0.55              |

Figure 11 shows NDVI images for 2016 and date palm harvested extracted from the SAM method for angles 0.1 and 0.05.
Figure 11. NDVI & SAM for sentinel 2016 with green area represent palm and Red area represent Palm harvested area by using SAM method. (a)NDVI, (b)SAM with angle 0.1, (c)SAM with angle 0.05

Finally, the "Change detection" tool was used by ENVI software to detect the changing of permanent palm areas between 2016 and 2018. The results shows the areas in red has a little change (Permanent palm areas), The areas in blue, yellow, green and pink are the most changed as illustrated in Figure 13. High change represents 3.75% when selecting the spectral angle 0.1 and 3.34% when selecting the spectral angle 0.05.

Table 3 shows the area in square kilometre of palm areas on all the spatial images used in the study and shows the decrease in the permanent palm areas about 2.28 km².

| IMAGE Satellite | θ=0.05  | θ=0.1  |          |
|-----------------|---------|---------|----------|
| HYPER image 2003 | 2.8km²  | 7.38km² |          |
| SENTINEL2 2016 | 4.47km² | 6.77km² |          |
| SENTINEL2 2018 | 2.87km² | 5.091km² |
5- Conclusion

1- Hyperion images are difficult to analyze and process but yield reliable results in classification due to high spectral accuracy.
2- Using SAM classification method as a good and accurate method in the classification. The results showed that the date palm areas for 2003 constitute 19.17% of the study area determining the spectral angle by 0.1
3- The decrease in permanent palm areas for 2016 in the SAM method was 14% of palm area for 2003 when selecting the spectral angle 0.1 and 40% of palm area for 2003 when selecting the spectral angle 0.05
4- The decrease in permanent palm areas for 2018 in the SAM method was 32% of palm area for 2003 when selecting the spectral angle 0.1 and 62% of palm area for 2003 when selecting the spectral angle 0.05
5- Change detection tools in ENVI with SAM rating between 2016 and 2018 resulted in a great change of 20% in the area of the palm area.
6- Classification accuracy shows good result for image 2003 with spectral angle 0.1 and images 2016 and 2018 with angle 0.05.

6- References

[1] Subhashni Taylor, Lalit Kumarm, Nick Reidm & Craig R. G. Lewis, "Optimal band selection from hyperspectral data for Lantana camara discrimination", International Journal of Remote Sensing January 2012.
[2] Prashant Kawishwar, "Atmospheric Correction Models for Retrievals of Calibrated Spectral Profiles from Hyperion EO-1 Data", Thesis for the degree of Master of Geoinformatics, January, 2007.
[3] Marcus Borengasser, William S. Hungate, and Russell Watkins, "Hyperspectral Remote Sensing: Principles and Applications", CRC press, Taylor and Fancie Group, 2008.
[4] "Atmospheric Correction Module: QUAC and FLAASH", User’s Guide, Version 4.7, August, 2009 Edition.
[5] "ENVI® ATMOSPHERIC CORRECTION MODULE (ACM) ", The ENVI ACM is a third party module developed by Spectral Sciences, Inc. A separate license is required for the ENVI ACM, HarrisGeospatial.com.
[6] Sahar A. El_Rahma, "Performance of Spectral Angle Mapper and Parallelepiped Classifiers in Agriculture Hyperspectral Image", (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 7, No. 5, 2016.
[7] Rashmi S., Addamani S., Venkat and Ravikiran S., "Spectral Angle Mapper Algorithm for Remote Sensing Image Classification", IJISSET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 4, June 2014. ISSN 2348 – 7968.
[8] "ENVI Tutorials", ENVI Version 3.4, September, 2000 Edition, Copyright © Research Systems Inc. All Rights Reserved, p94-p101.
[9] Russell G. Congalton, Kass Green, "Assessing the Accuracy of Remotely Sensed Data", International Journal of applied Earth Observation and Geoinformation 11 (2009). ISSN 0303-2434 - p. 448 - 449.