Using Optimum Index Factor and Determinant Covariance Methods and Compare to PCA on Satellite Images to Determine The Earth’s Landmarks (Part of Tar- An Najaf and Its Neighbours)

Dr. Sa’ad R Yousif 1,2, Watheq F Shneen2.
1 Univ. of Kufa/ Faculty of Science/ Dept. of Geology.
2 Univ. of Kufa/ Remote Sensing Center.

Abstract. The research focuses on mixing of Landsat8 ETM+ images for sector of Tar An- Najaf Phenomenon for the sake of gaining the optimum description showing the ground guidelines of the studied area. The optimum Index Factor (OIF) method has ensured that RGB567 represents the preferred mixed bands, where vegetated areas, water and rocks and deposits more obviously distributed. The determinant covariance matrix method stated that RGB457 considered the optimum for spectral resolution. For comparison with Principal Component Analysis, the latter involves PC1,2,3 and shows clear variations that serve the interpreter as a detailed study. Through the study, the best method is the second one.

The Aim of the Study
The study aims to obtain the excellent representation of earth phenomena by composing RGB bands of the colour composite satellite image of Landsat 8 ETM+ using numerical techniques, as well as knowing which of the two methods are the best.

1. Introduction
Images taken by remote sensing satellites in their unprocessed status are often ineffective in detection and accurate perception. Digital processing methods are used to enhance the spectral interpretation; therefore, the interpreter can deduce these concepts so accurately. The intent of image processing approaches is to enhance and focus the spectral utility of terrestrial submissions [1]. The images are stored in a three-dimensional matrix. The three dimensions of the matrix represent the intensities of the red, green, and blue bands. That depiction of image as an arrangement enables to work with the image softly (i.e. calculations and treatments can be performed [2].

The most typical image processing executed on these modes is the composition of the RGB image of the most interpretable bands of the same parameter, for example the method of calculating the optimum index factor (OIF) [3]. Through these two factors, the lowest correlation bands are obtained [4]. OIF is a statistical value that can be used to determine the optimal (best) combination of three bands in the satellite image in which the ability to produce a clear perception can be done [5], whilst the determinant matrix covariance is used to calculate the determinant of a matrix consisting of three dimensional representations of bands. The sensors are sensitive to electromagnetic spectrum resulting images different in their resolutions due to their sensors. So, Landsat8 ETM+ is used for its latest launching and effectiveness.
2. Location of the Studied Area
The research focused on sector of Tar An-Najaf and the surrounding area located in An-Najaf Al-Ashraf Province. Data were taken from Landsat satellite 8 ETM + (LC81680382014130-01014-05-10) from p168-r38, where the area lies within (43 ° 56' 28.88'' E, 32 ° 7' 48.86'' N & 32 ° 2' 8.42''N 44 ° 10' 54.06''E), Figure (1). Tar An-Najaf is a cliff that differs in declination due to various geological factors, and As-Sadeer (Al-Ghazi) River, which is one of the small branches of the Euphrates River runs along the side of the escarpment.

Figure 1. The location of studied area within Iraq Source work researcher.

3. Methodology
The programs used in the research are:

1- ERDAS IMAGINE 2013 for the sake of image processing (by means of which the satellite bands are exported, and the intrinsic value relationship is applied in the way the basic components are converted and read in the resolution of 15m.

2- ENVI 4.7 also for the sake of handling image processing

Enhancement methods aim to make visual information clearer for visual interpretation purposes. Raw visual information is often ill-prepared in a way that is appropriate to the sensitivity of the human eye. In addition, enhancement methods sometimes aim to build a physical link between brightness variance amongst multiple bands of regular features [5]. So, the image processing can emerge the required information efficiently to the interpreters by the following techniques used in the research.

1- Arrangement of the RGB image
   A- Finding the optimum index factor (OIF) from the equation [2] and [6]:


The correlation coefficient that was extracted using ERDAS IMAGINE 8.4 is derived using the Covariance ratio.

B- Obtaining the covariance matrix determinant by the following formula of The Sheffield index (SI), [7]

\[
SI = \text{DET}(B_{xyz})
\]

Where Bxyz is defined as bxy, bxz ............, bzy the two bands discrepancy values of the three bands

Lsi = LOG (SI) (by experiment)

2- Special processing are the mode of conversion of principal component analysis, where the extraction of the intrinsic value (Eigenvalue), which the one of them has three self-vectors (eigenvectors). The first intrinsic values are called the first PC1 and the other values are PC2, PC3 ...... and can be simplified as in equation:

\[
\text{PC}_{123} = \log (\text{pc}_{123})
\]

4. Application

The emergence of vegetative areas near the swamps and ponds is obscured through the viewing of true colour image of the area, Figure (2)

| bands | OIF |
|-------|-----|
| 56 7  | 4751 |
| 46 7  | 4477 |
| 36 7  | 4202 |
| 457   | 4193 |
| 456   | 4119 |
Figure 3. colour composite image RGB567 of Landsat 8 ETM + dated 2014-05-10.

B- Calculating Covariance matrix determinant separately for any RGB bands

Table 2. The values of Covariance matrix determinant of the studied area in a descending order.

| LOG(det) | BANDS | LOG(det) | BANDS |
|----------|-------|----------|-------|
| 19.801   | 457   | 18.013   | 146   |
| 19.572   | 357   | 17.988   | 145   |
| 19.389   | 456   | 17.906   | 345   |
| 19.283   | 257   | 17.898   | 346   |
| 19.268   | 467   | 17.767   | 137   |
| 19.193   | 356   | 17.714   | 237   |
| 19.173   | 567   | 17.643   | 136   |
| 19.099   | 157   | 17.580   | 236   |
| 19.083   | 367   | 17.447   | 135   |
| 18.921   | 256   | 17.367   | 235   |
From Table (2) any RGB band value can be seen distinctly. Of bands 4, 5 and 7, the relation can be illustrated as follows, Table (3)

Table 3. The interrelation of Covariance matrix standards for bands 4, 5 and 7.

| Covariance | Band 4       | Band 5              | Band 7      |
|------------|--------------|---------------------|-------------|
| Band 4     | 8793095.897  | 10400939.22         | 12091176.25 |
| Band 5     | 10400939.22  | 14020351.22         | 15168464.68 |
| Band 7     | 12091176.25  | 15168464.68         | 21253267.65 |

Then the own determinant can be extracted using Equation (3) as follows:

\[
\log(\text{DET}_3) = 19.801
\]

The highest values were for RGB 457 in Figs. 4 and 357 in Fig. 5 without the thermal band, because the amount of variance of bands 3 and 4 with the remaining bands was the highest between the bands.

Figure 4. Determination of covariance matrix determinant of RGB 457 of Landsat 8 dated 2014-05-10 for the study area.
Figure 5. Determination of covariance matrix determinant of RGB 357 of Landsat 8 dated 2014-05-10 for the study area.

Figure 6. Determination of covariance matrix determinant of RGB 456 of Landsat 8 dated 2014-05-10 for the study area.

Figures 4, 5, & 6 are similar in values and logarithms, so the images are very close to the sight.

2- Finding the square root of the multiplication of the intrinsic values corresponding to separate band.
Table 4. Eigenvalues of PCA arranged in a descending order for the higher ten values.

| Mix  | Log(Eigen) |
|------|------------|
| 123  | 20.450     |
| 124  | 19.470     |
| 125  | 19.378     |
| 126  | 19.129     |
| 127  | 18.500     |
| 128  | 17.248     |
| 129  | 16.553     |
| 134  | 19.035     |
| 135  | 18.944     |

Figure 7. Mixing of the principal components 123 which is the best mix using Erdas program.

Table (4) shows the composition of the principal components 123 as in Figure (7) where the green color refers to the extensions of Bahr An-Najaf Depression and the surrounding drainage basin of artesian wells as well as As-Sadeer River and the ponds it consists of. The blue color refers to the wet soil that used as cultivated and agricultural areas, while the light blue color indicates the saturation with water. The variance in the caroty and ruddy colors indicates the soil pattern. That is because the study
area represents a prominent escarpment, and the surroundings are lowlands. The prominent dark pink color that outline Tar An-Najaf represents part of Wadi As-Salam Cemetery. The standards of the covariance array stay unchanged during the conversion. The sum of the variations of the image before and after the conversion leading to the constant data of the image. In the covariance matrix of the pre-conversion, the logarithm of the total sum of the diagonal elements of the matrix (Table 5) equals 7.90, and logarithm of the sum of the intrinsic values of all bands in the covariance matrix after conversion (Table 6) is 7.90 indicating that the standards of the covariance stay the same.

### Table 5. Covariance standards of the image denoting to the studied area before conversion.

| Covariance | Band 1 | Band 2 | Band 3 | Band 4 | Band 5 | Band 6 | Band 7 | Band 8 | Band 9 |
|------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Band 1     | 890873.363 | 1158115.8 | 1513305.8 | 226078.024 | 359776.8 | 4153404.213 | 5429347.49 | 4543546.02 | 43564428 |
| Band 2     | 1158115.849 | 1513305.8 | 226078.024 | 359776.8 | 4153404.213 | 5429347.49 | 4543546.02 | 43564428 |
| Band 3     | 1720309.877 | 226078.024 | 346949.23 | 5475452.7 | 6373286.128 | 8467043.154 | 720575.53 | 4148149.58 | 7171.2093 |
| Band 4     | 2694155.952 | 359776.8 | 5475452.685 | 8793095.9 | 1040939.22 | 1399706.51 | 1209176.3 | 6004373.33 | 13165.442 |
| Band 5     | 3145136.973 | 4153404.213 | 6373286.128 | 1040939.22 | 14202351.22 | 17821759.78 | 15166464.7 | 7752403.15 | 18328.839 |
| Band 6     | 406591.527 | 5429347.49 | 8467043.154 | 1399706.51 | 17821759.78 | 24938379.79 | 22362385.7 | 10358365.3 | 26614.171 |
| Band 7     | 3364019.689 | 4543546.02 | 720575.53 | 1209176.3 | 15166464.7 | 23262385.73 | 21232877.78 | 8888046.82 | 25125.105 |
| Band 8     | 2054174.496 | 2708953.2 | 4148149.58 | 6004373.33 | 10358365.26 | 8888046.82 | 5140094.59 | 9263.8066 |
| Band 9     | 3170.983976 | 43564428 | 7171.230299 | 13165.442 | 18328.8391 | 26614.17094 | 25125.1048 | 9263.8066 |

### Table 6. Covariance standards of the image denoting to the studied area after conversion.

| Covariance | Band 1 | Band 2 | Band 3 | Band 4 | Band 5 | Band 6 | Band 7 | Band 8 | Band 9 |
|------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Band 1     | 890873.363 | 1158115.8 | 1513305.8 | 226078.024 | 359776.8 | 4153404.213 | 5429347.49 | 4543546.02 | 43564428 |
| Band 2     | 1158115.849 | 1513305.8 | 226078.024 | 359776.8 | 4153404.213 | 5429347.49 | 4543546.02 | 43564428 |
| Band 3     | 1720309.877 | 226078.024 | 346949.23 | 5475452.7 | 6373286.128 | 8467043.154 | 720575.53 | 4148149.58 | 7171.2093 |
| Band 4     | 2694155.952 | 359776.8 | 5475452.685 | 8793095.9 | 1040939.22 | 1399706.51 | 1209176.3 | 6004373.33 | 13165.442 |
| Band 5     | 3145136.973 | 4153404.213 | 6373286.128 | 1040939.22 | 14202351.22 | 17821759.78 | 15166464.7 | 7752403.15 | 18328.839 |
| Band 6     | 406591.527 | 5429347.49 | 8467043.154 | 1399706.51 | 17821759.78 | 24938379.79 | 22362385.7 | 10358365.3 | 26614.171 |
| Band 7     | 3364019.689 | 4543546.02 | 720575.53 | 1209176.3 | 15166464.7 | 23262385.73 | 21232877.78 | 8888046.82 | 25125.105 |
| Band 8     | 2054174.496 | 2708953.2 | 4148149.58 | 6004373.33 | 10358365.26 | 8888046.82 | 5140094.59 | 9263.8066 |
| Band 9     | 3170.983976 | 43564428 | 7171.230299 | 13165.442 | 18328.8391 | 26614.17094 | 25125.1048 | 9263.8066 |

The distribution of the band before conversion is unevenly, while the information are largely concentrated in the first component after conversion, and the rest is distributed on the second and third and so on, Table (7).

### Table 7. Percentage of covariance before and after conversion

| Post conversion | component | Pre-conversion | Band |
|-----------------|-----------|----------------|------|
| 94.17402%       | PC1       | 10.54%         | B1   |
| 3.99280%        | PC2       | 10.94%         | B2   |
| 1.46723%        | PC3       | 11.58%         | B3   |
| 0.15384%        | PC4       | 12.30%         | B4   |
| 0.12454%        | PC5       | 12.68%         | B5   |
| 0.07019%        | PC6       | 13.10%         | B6   |
| 0.01647%        | PC7       | 12.98%         | B7   |
| 0.00092%        | PC8       | 11.88%         | B8   |
| 0.00019%        | PC9       | 4.03%          | B9   |
| 100%            |           | 100%           | sum  |
5. Discussion and Conclusion
The research clarifies that the OIF and Variance Matrix Determinant techniques depend on a numerical process without adjustments in the unique data of the image. The second method is more suitable than the first one. While the method of conversion of the principal components are computational calculations, and introduce conversions to modify the original values without any effect on the variance standards before the conversion.

The latter shows pseudocolors to clarify extra features in the processed image, and enables interpreters to get better the output and decision making, and thus it considers the optimum method than the the first two ones.

References
[1] Al-Anqari, K.M., 1986, "Remote Sensing and its Applications in Spatial Studies", Dar Al-Marikh Publishing, Riyadh, 179p.
[2] Al-Juaidi, F., Millington, C.A., & McLaren, J.S., 2003, "Merged remotely sensed data for geomorphological investigations in deserts: examples from central Saudi Arabia", The Geographical Journal, pp (117–130).
[3] Chavez, P.S., Berlin, G.L. & Sowers, L. B., 1982, " Statistical method for selecting Landsat MSS ratios", Journal of applied photographic engineering, 8(1), pp (23-30).
[4] Richards, A.J. and Jia, X., 2006, "Remote Sensing Digital Image Analysis an Introduction",4th Edition, Canberra, Australia, 453p.
[5] Haque, M., 2011, " Selecting optimum band combinations for the visualisation of eight-band Worldview 2 data", PhD Researcher, Monash University, Australia, Pp(3-4), Email: Mahfuzul.Haque2@monash.edu.
[6] Patel, N. and Kaushal, B., 2011," Classification of features selected through Optimum Index Factor (OIF) for improving classification accuracy", Journal of Forestry Research 22(1): pp (99–105).
[7] Sheffield, C., 1985, "Selecting band combinations from multispectral data", Photogrammetric engineering and remote sensing, pp (51, 681-687).