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USING OPTIMUM INDEX FACTOR TO DETERMINE THE BAND COMBINATION OF LANDSAT IMAGE DATA, A CASE STUDY OF A SITE IN NE IRAQ

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Abstract

An expressive, factual, informative, and concise abstract is required. A single paragraph, no more than 300 words maximum. The abstract should state briefly the main objectives of the research or main points of the manuscript, the materials used, the main findings of the work, and the major conclusions. The abstract should be an objective representation of the article, and it must not contain results that are not presented and substantiated in the main text, and should not exaggerate the main conclusions. The abstract should not contain any undefined abbreviations, but if essential, then they should be defined when first mentioned. References should not be included. The optimum index factor (OIF) is computed for each combination of the three bands. The Band combination that has the bigger value in OIF disposes has more information. The number of band combinations was reduced to four combinations based on (OIF) calculation; therefore, the best of the combination bands were (753), (543), and (743) RGB, respectively. We found that the combination consists of near and middle infrared bands principally (B4, B5, and B7), and B5 and B7 these bands are useful for geological studies. As aforementioned, we use band combination (RGB:432) too. Pixels of these combinations are taken to fill the range (0-255) by equalization stretch. Principal component analysis (PCA) has more advantages in lithological discrimination. This analysis reduced abundance in the data image; the combination bands involved consist of (PC1, 23RGB), which is variance (98.86%) of the whole information in all bands, but the high variance value in (7, 5,3RGB) is (73%), (PC5, 2,3RGB) also used to discriminate ultramafic and mafic rocks clearly.

Keywords: False color composite (FC) and Principal Component (PCA), and spectral enhancements.

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1. Introduction

Use of remote sensing technology in geological studies of regional modern techniques began in the late last century by relying on aerial photos and then satellite imagery. It is considered a major source of derived geological information, such as faults, folds, tectonic phenomena, and drawing geological maps (Talal H. Kadhim 2022). Spectral enhancement involves the manipulation of multiple bands of data, whether from a single multispectral image or from two or more images of the same area acquired at different times (Lillesand, Kiefer, and Chipman 2015). Generating a new image from spectral enhancement processing is better than the original image because the new image highlights particular features or properties of interest. This study uses spectral enhancement images on multiple bands of data ETM+ by False color composite (FCC) and Principal Component (PCA).

The false color composite is defined as the human eye can only distinguish between a certain number of shades of gray in an image (e.g., 16 shades. This false color composite made it easier to identify linear patterns of vegetation, geologic formation boundaries, river channels, and ecological weakness zones (Sarp 2005). The principal component (PCA) spectral enhancement technique is based on the transformation of the original data axis to reduce such redundancy in multispectral data, and compress as much of the information in the original bands into fewer bands. Thus, useful information for the identification of the units that exist within the image can be compressed properly into two or three components(Kadhim 2009). The processing was also relied upon to improve the images resulting from other digital processing, like MNF, PCA, and band ratio (Bety 2022). (Jensen 1996) claims that, generally, the first component of the PCA consists of both near and middle-infrared information (e.g., Bands 4, 5, and 7), and the color composite of the PCA provides a good option for visual interpretation (Sarp 2005). The PC1 gets more information from NIR and MIR (B4, B5, and less from B7). The PC2 gets more information from NIR (B4) and the MIR region (B5 and B7). The PC3 contains more information from the visible region (B1, B2, and B3); therefore, the differences between PC1 and PC2 are an indicator of soil (Dimadi and Tsakiri-Strati 2004).

The studied area is situated at Sulaimaniya governorate, northeastern Iraq, between the Iranian borders on the north and east and Sulaimaniya city in the southwest and bounded by the following coordinates 45°30′, 46°30′ longitude and 35°30′, 36°00′ latitude, as shown in Figure 1. The studied area is a part of the Alpine Orogen represented by the southern part of the Zagros suture zone and Balambo-Tanjero zone (Jassim and Goff 2006); therefore, the area has been considered a complex and important region composed of a wide and extensive range of different rock types(sedimentary, igneous, and metamorphic rocks) and structural features.

This study aims to use the Landsat image data to enhance lithological units discrimination and to evaluate the application of Landsat image data in the differentiation of rock types (sedimentary, igneous, and metamorphic rocks).

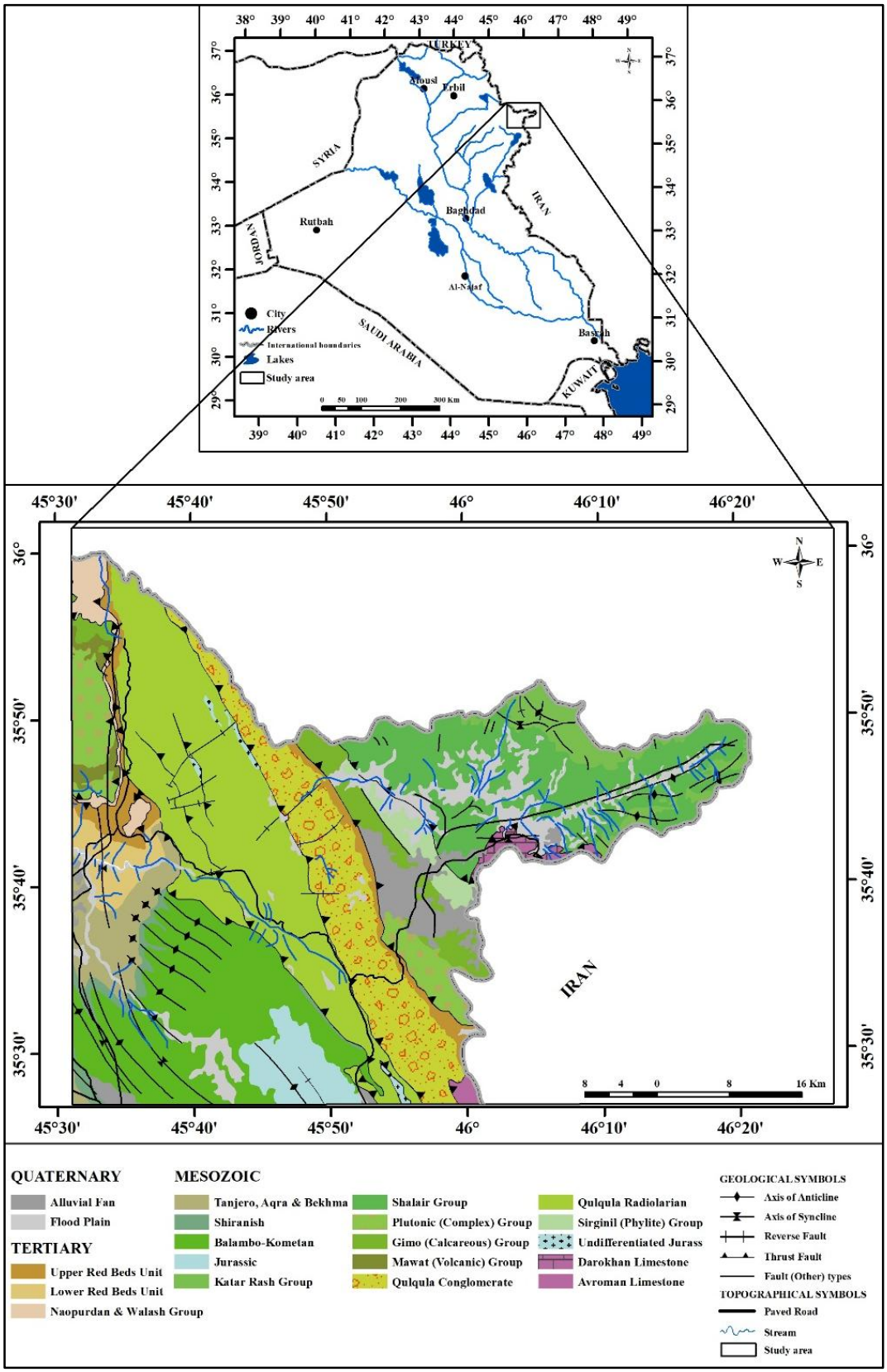

Figure 1. Location and geological maps of the studied area, after (Fouad and Sissakian 2015).

2. Materials and methods

The materials used in this study include topographic and geological maps. The studied area is covered by two map sheets at scale (1:100,000), Penjwin sheet (I-38-D-NE) and Mishav sheet (I-38-E-NW) maps. Topographic maps are published by the Military Surveying, 1990, second edition. Geological maps were used to know the exposed geological units or formations on the surface at a scale of 1:250,000, main tectonic zones, structural elements, and mineral occurrences in the studied area. These were maps published by the State Company Geological Survey and Mining.

Enhanced thematic mapper (ETM+) data is acquired from the Landsat-7 satellite. Landsat-7 was successfully launched from Vandenberg Air Force 41 Base on April 15, 1999. Its weight is about 5,000 5,000-pound-class satellite, designed for a 705 km, sun-synchronous, earth mapping orbit with a 16-day repeat cycle. The payload is a single nadir-pointing instrument, the Enhanced Thematic Mapper Plus (ETM+). Landsat-7 is equipped with Enhanced Thematic Mapper Plus (ETM+), the successor of TM. The observation bands are essentially the same seven bands as TM by resolution (28.5 m), and the newly added panchromatic band 8, with a high resolution (14.25 m). The image data of the studied area is part of scene WRS-S, path 168, and row 035. This image was downloaded from the University website (glcfapp.glcf.umd.edu.8080/esdi/index.jsp). Using ETM+ data characterized by seven bands (1, 2, 3, 4, 5, 7, and 8), which are multispectral wavelengths with spatial resolution (28.5 m), and band 8 is a panchromatic wavelength with spatial resolution (14.25 m). The ERDAS V.9.0 and ArcGIS V9.1 are used in this work.

Input and Registration data: Rectification is the process of superimposing an image over a map or over another already registered dataset. The image registration or "georeferencing" method by selected ground data maps of the Penjwin-Shalair area was rectified with reference to the 1:100 000 scale from screen coordinates to the Universal Transverse Macerator (UTM) Datum, UTM WGS 84, Zone 38, as shown in Table 1. These coordinates are represented by the four corners of each map. Using the UTM WGS84 coordinate system because this coordinate system is the coordinate system of satellite images.

Table 1. Screen and map coordinates of the topographic and geologic map.

	Coordinate point	X-source (screen)	Y-source (screen)	X-map	Ymap
Pinjwin	Point 1	2.354054	28.171975	545064	3984064
	Point 2	20.004024	28.292172	590129	3984411
	Point 3	20.173751	6.462940	590695	3928953
	Point 4	2.414764	6.346064	545347	3928608
Mishav	Point 1	2.354054	28.171975	590129	3984411
	Point 2	20.004024	28.292172	635196	3984989
	Point 3	20.173751	6.462940	636045	3929528
	Point 4	2.414764	6.346064	590695	3928953

The factor of the most optimal index (OIF, optimum index factor) for band combination is computed according to the covariance and correlation of bands. The factor (OIF) is computed for each combination of the three bands. The band combination that has the bigger value in factor (OIF) has more information, and it is calculated according to the equation (Dimadi and Tsakiri-Strati 2004):

$$OIF = \sum\sigma/\sum|rirj| \quad (1)$$

σ: the standard deviation of each band. While rirj is the correlation coefficient of bands I and j.

Tables 1 and 2 show the band characteristics and correlation matrix of all bands ETM+7. Principal component (PCA) spectral enhancement technique is based on the transformation of the original data axis to reduce such redundancy in multispectral data, and compress as much of the information in the original bands into fewer bands. Thus, useful information for the identification of the units that exist within the image can be compressed properly into two or three components. Generally, the first component of the PCA consists of both near and middle-infrared information (e.g., Bands 4, 5, and 7), and the color composite of the PCA provides a good option for visual interpretation (Sarp 2005). The PC1 gets more information from NIR and MIR (B4, B5, and less from B7). The PC2 gets more information from NIR (B4) and the MIR region (B5 and B7). The PC3 contains more information from the visible region (B1, B2, and B3); therefore, the differences between PC1 and PC2 are an indicator of soil (Gonzalez and Wintz 1977).

$$Pe = \sum_{1\Leftarrow 1}^{n} d_k E_{ke} \quad (2)$$

e = number of the PC (first, second), Pe = output PC value for principal component number e, k = a individual input band, n = total bands number, dk = an input data file value in band k and Eke = matrix of eigenvector element at row k, column

3. Results

In Tables (2) and (3), band characteristics and the correlation matrix for each band of the ETM+7 are presented.

Table 2. Characteristics of ETM+7 in each band.

BANDS	MIN.	MAX.	MEAN	STDV.
B1	32	119	64.360	8.019
B2	19	136	64.691	11.139
B3	15	184	83.730	17.962
B4	9	152	77.845	12.992
B5	4	192	90.161	19.709
B7	4	250	70.101	16.675

Table 3. Correlation matrix of ETM+7 in each band.

BANDS	B1	B2	B3	B4	B5	B7
B1	1.000	0.969	0.935	0.686	0.808	0.841
B2	0.969	1.000	0.976	0.766	0.868	0.882
B3	0.935	0.976	1.000	0.783	0.893	0.898
B4	0.686	0.766	0.783	1.000	0.858	0.746
B5	0.808	0.868	0.893	0.858	1.000	0.957
B7	0.841	0.882	0.898	0.746	0.957	1.000

In Table 4, the OIF is presented for all the combinations of bands. In the third column is presented the degree where the smallest corresponds to the biggest OIF and the biggest corresponds to the smallest. Depending on OIF, the better band combinations were RGB (543), (753), and (743) in addition to RGB (432), which can be used in lithological discrimination (Sabins Jr and Ellis 2020), as shown in Figures 2, 3, 4, and 5.

Table 4. The presented OIF for all the combinations.

Band combination (RGB)	OIF	Degree
1,2,3	12.889	20
1,2,4	13.280	19
1,2,5	14.698	17
1,2,7	13.311	18
1,3,4	16.212	15
1,3,5	17.294	9
1,3,7	15.951	16
1,4,5	17.312	8
1,4,7	16.579	14
1,5,7	17.039	11
2,3,4	16.671	12
2,3,5	17.832	5
2,3,7	16.609	13
2,4,5	17.591	6
2,4,7	17.045	10
2,5,7	17.556	7
3,4,5	19.992	1
3,4,7	19.625	3
3,5,7	19.776	2
4,5,7	19.280	4

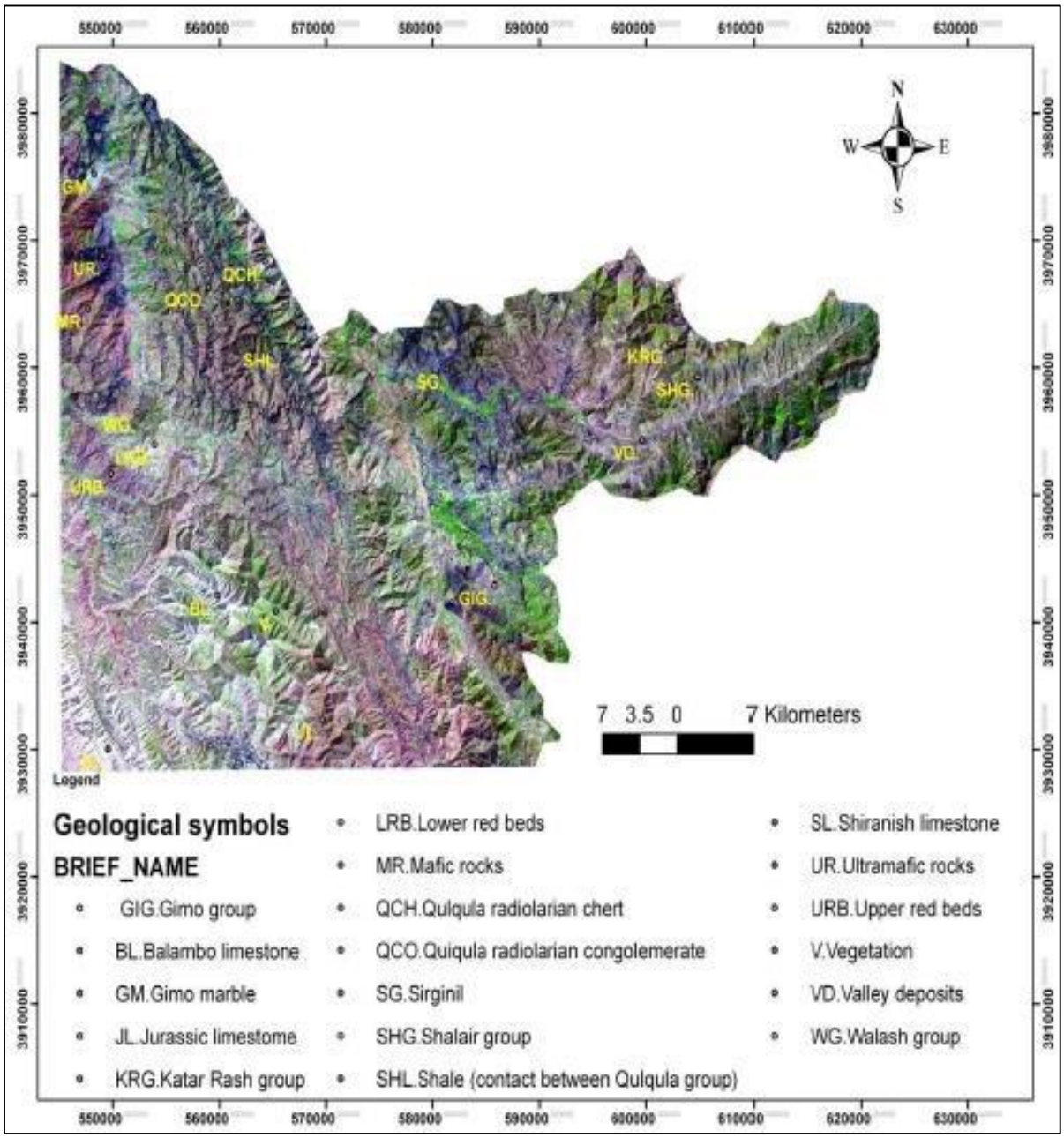

Figure 2. False color composite image (543 RGB).

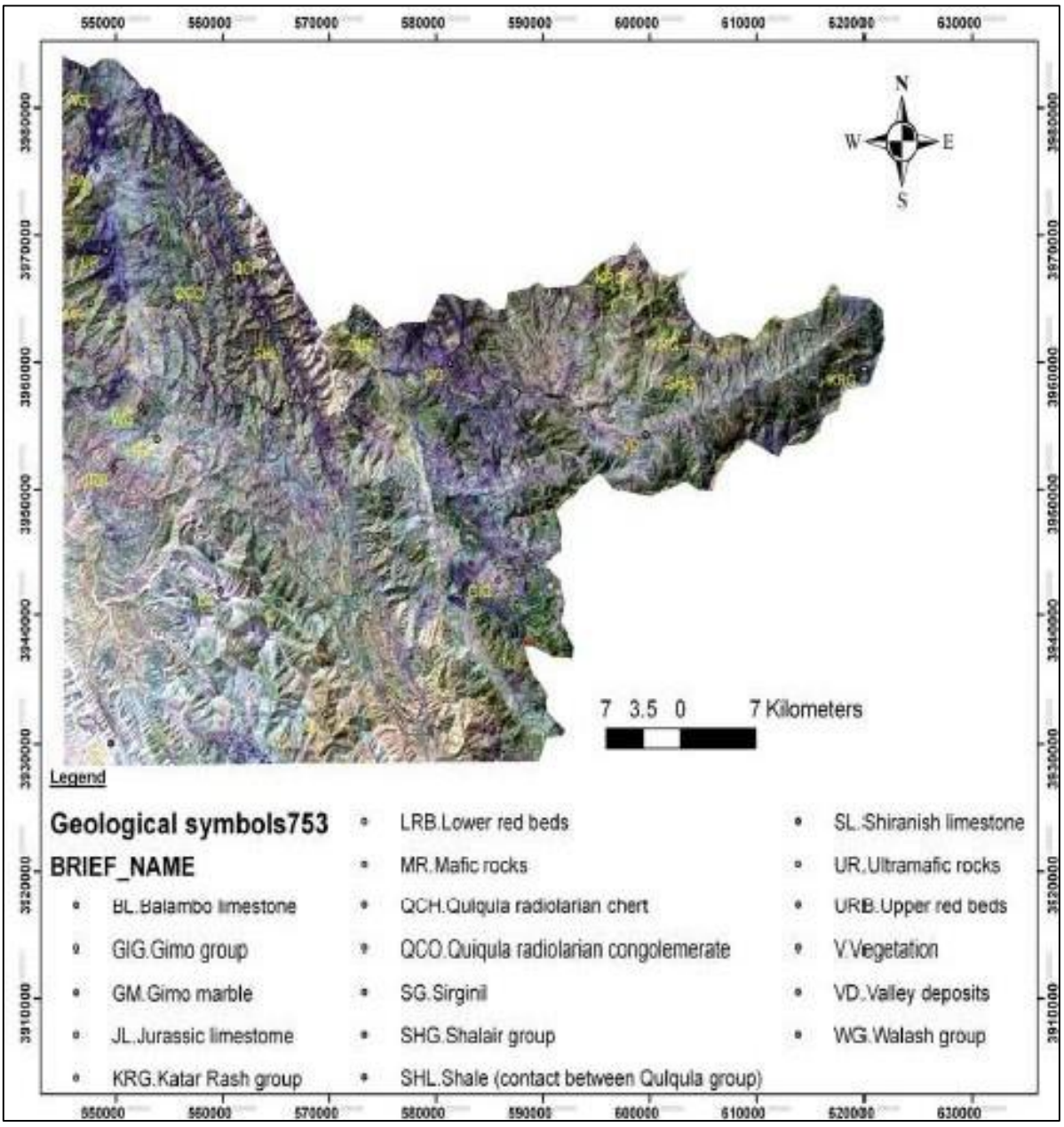

Figure 3. False color composite image (753 RGB).

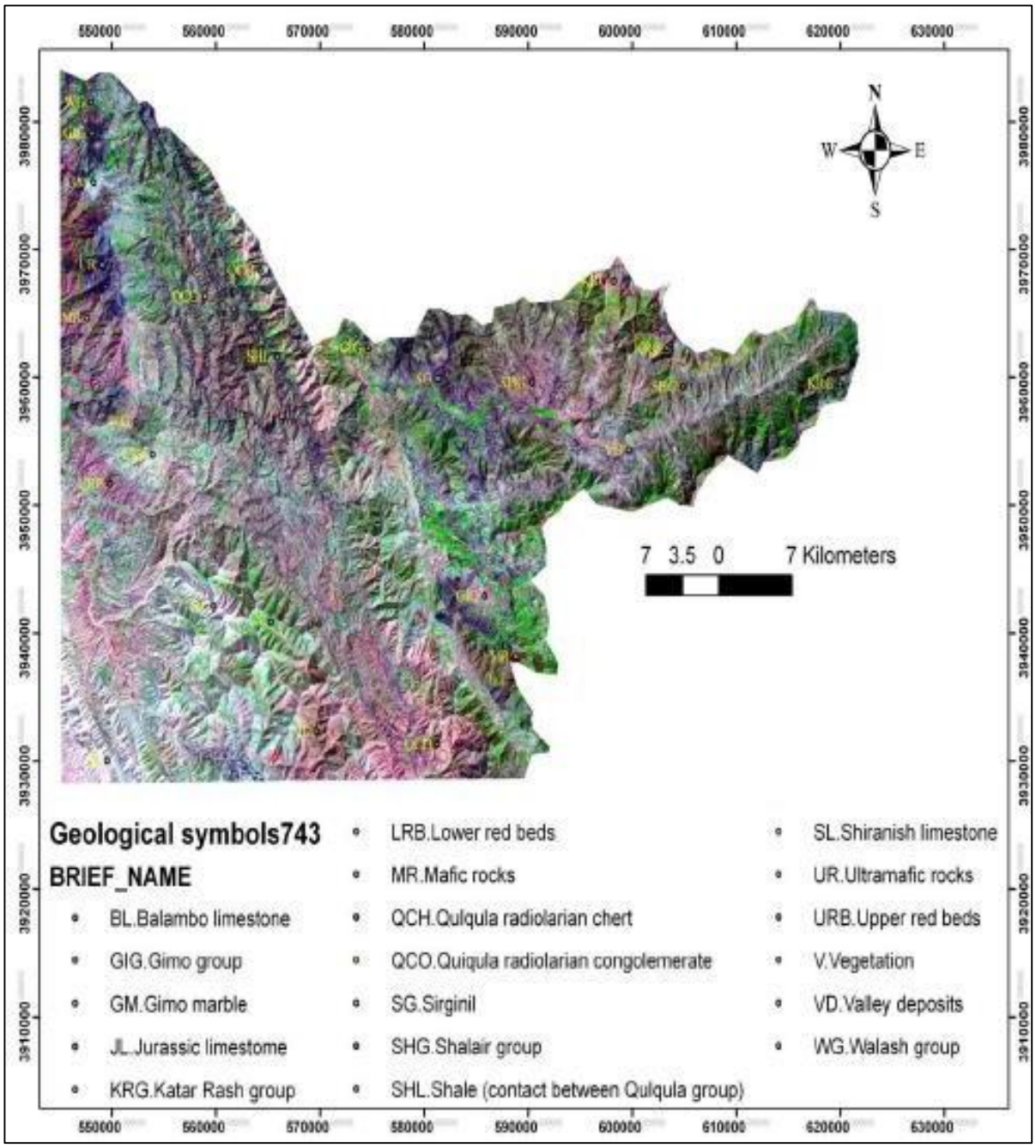

Figure 4. False color composite image (743 RGB).

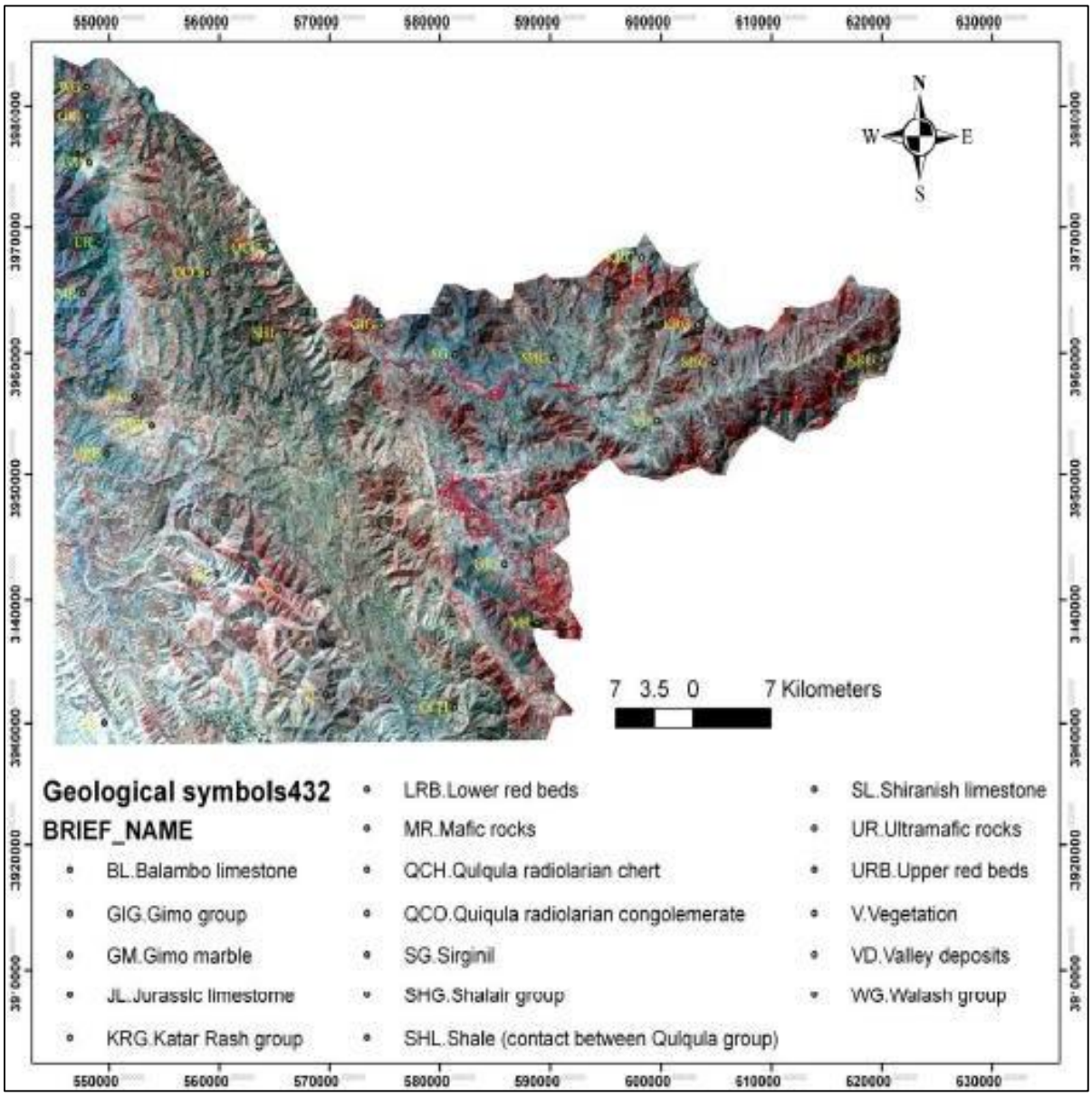

Figure 5. False color composite image (432 RGB).

Then, several combinations are tested by using a new PCA band combination (RGB). Finally, two different combinations are found to be suitable from Table 5. The first combination includes (PC1-PC2-PC3 RGB), as shown in Figure 6, which band combination contains most of the information in the six bands of ETM+. The second includes the (PC5, PC2, PC3 RGB) as shown in Figure 7. During the lithological discrimination process, all the band combinations are spectrally enhanced using linear histogram stretching of the images.

In Figure (6), discriminated among (14) geological units are: limestone of Cretaceous (Balambo and Shiranish formations), limestone of Jurassic, ultramafic, mafic rocks, Gimo marble, Walash group, Mishav complex, Mawat volcanic group, Sirginil group, Qulqula radiolarian chert, Qulqula radiolarian conglomerate, Upper Red beds, Lower Red beds, and Vegetation.

Table 5. The variance and variance percent of landsat ETM+image.

PCA	EIGEN VALUE	EIGEN %
PC1	1216.58	90.36
PC2	65.62	4.87
PC3	48.91	3.63
PC4	7.77	0.58
PC5	5.85	0.44
PC6	1.58	0.12
T0TAL	1346.31	100.00

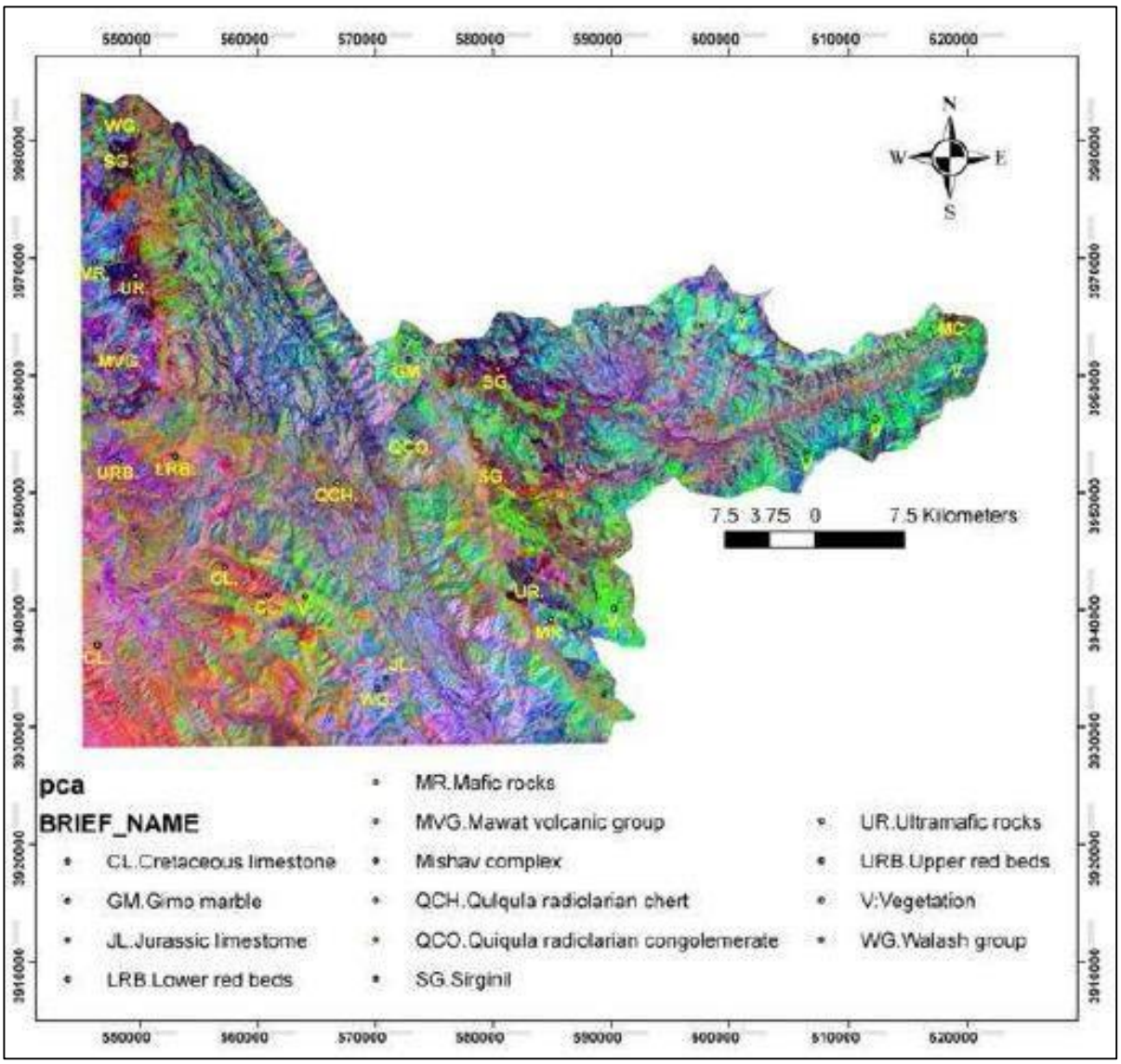

Figure 6. PCA image (1, 2, 3 RGB).

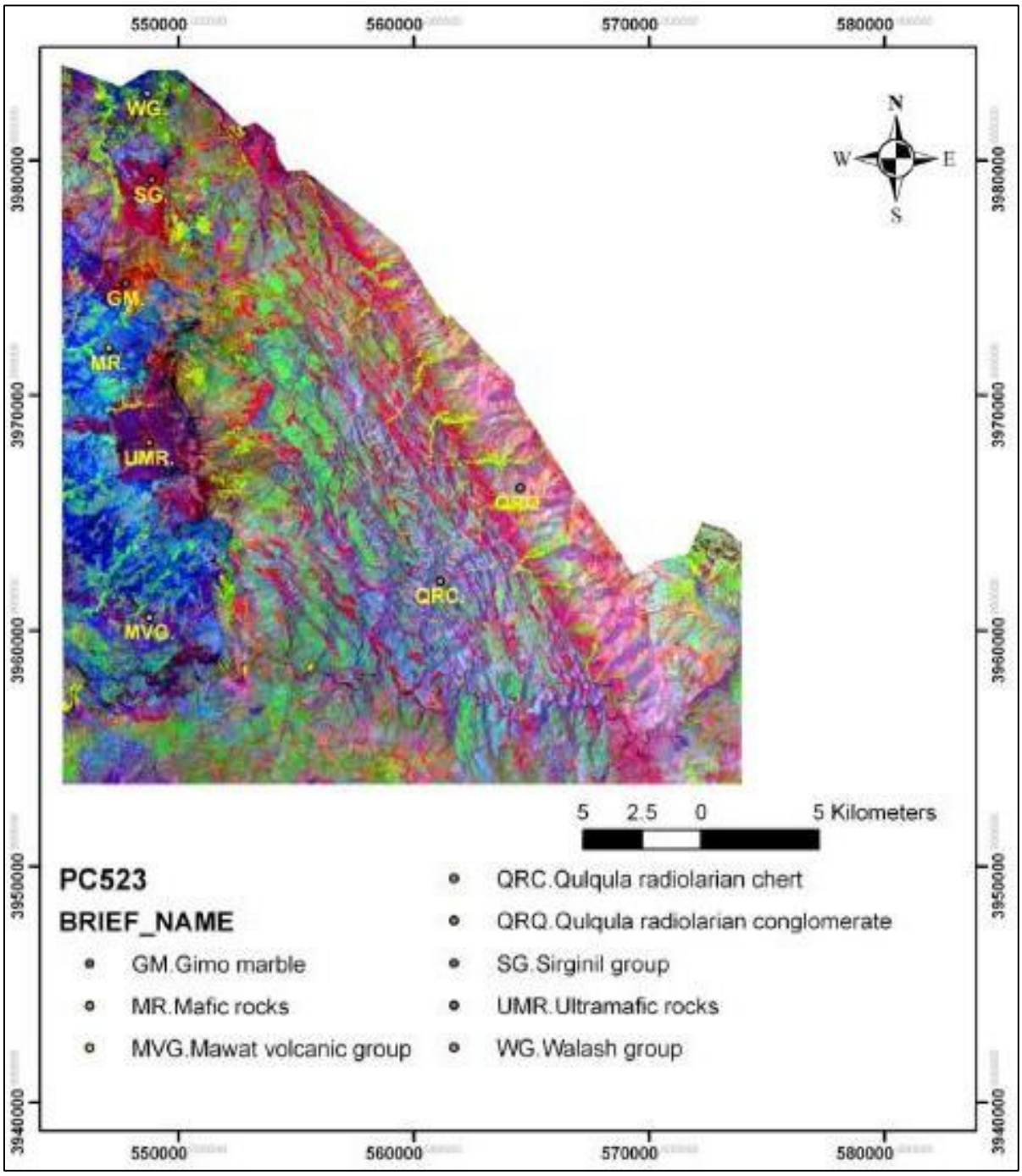

Figure 7. PCA image (5, 2, 3 RGB).

4. Discussion

From observing the results, we note that the high OIF value is very useful to distinguish barren lands, due to its dependence on the 5 and 7 bands of Landsat 7 ETM+, which are designed to study geological discrimination in the Landsat satellite (Lillesand et al. 2015). The OIF helps in distinguishing geological units at the expense of agricultural land and water, especially in the high value of OIF (1 and 2 orders), in Figures 2 and 3, while it can be used in the study of vegetation and agricultural land in the lower value of OIF order 3). While the second order

(Figure 3) of the OIF is more useful than the first order (Figure 2) of geological studies, due to its dependence on three bands specialized in the study of barren lands or soils (Sabins Jr and Ellis 2020), especially the seventh band designed for geological studies as mentioned above. While the first order of the OIF is less useful than the second order of geological studies, due to its reliance on two domains specialized in the study of arid lands or soil only, namely bands 3 and 5, in addition to band 4 specialized in the study of vegetation. While in the FC of 432, it was not possible to distinguish only 6 units because this FC is very useful in the study of vegetation, as the vegetation appeared in red color widely in the study area. Either in figures 6 and 7 of PCA, we note that there is an equal distribution of the main components of the image and according to the information recorded for each image.

Finally, we note that in studies for the purposes of determining geological units, it is better to use the discrimination coefficient because it depends on the packages specialized in studying the earth or geology, especially with high values of the discrimination coefficient. Either for plant purposes, it is better to use the first of the PCA. However, when we observe Figures 6 and 7, Figure 6 is more useful for geological studies than Figure 7 because it relies on key components withmore information, as in Table 5.

5. Recommendation

Spectral enhancements lead to geological units more than from spatial enhancements, but the latter is more commonly used in lineament interpretation, although sometimes using two enhancement processes for lithological and lineament interpretation.

The better of band combinations (RGB) are (543), (753), and (743); these band RGBs involve more information than any other RGB based on OIF values, which are used to lithological units and interpretation. But the RGB (432) used in this study discriminates between vegetation, qulqula radiolarian chert, carbonate, and igneous rocks, so as lineaments interpretation with vegetation corresponding.

In PCA more advantage of lithological discrimination. PCA 123 involved almost all information in bands about (98,68%). In this combination discrimination of three igneous bodies is Mawat, Penjwin, and Mishau, with clastic deposits orange color. In PCA 5, used to clearly discriminate between ultramafic and mafic rocks, therefore, to make a band combination PCA 523 to manifest these rocks in a clear form.

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