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Article:

A Proposed Simple Ratio Radiometric Conversion Parametric Method for Multi-Temporal Satellite Datasets

Dr. Nermin A. Shoukry
Department of Geography, Faculty of Arts, Cairo University, Giza, Egypt
Email: nerminsh@hotmail.com

Abstract:

The launch of Landsat-8 with its Operational Land Imager sensor (OLI) in 2013, followed by Landsat-9 satellite (OLI-2) in 2021, filled many gaps of handling many remotely sensed analyses and applications due to its superior technical design compared to previous Landsat series of satellites. It collected more images at a substantially higher signal-to-noise ratio (S/N or SNR), higher spectral bands configuration, and higher radiometric resolution in a way that has made some analyses such as Time Series based Change Detection Analysis one of the most significant research topics of remote sensing worldwide. However, some researchers have been misconducted when they applied such analysis and ignored its rightful procedures. When performing bi-temporal or multi-temporal time series change detection comparison algorithms, a prior performance of several processing aspects should be produced such as dealing with radiometric resolution. A conversion process should be applied, if differential radiometric multi-temporal datasets occurred. This research generates a parametrically simple ratio radiometric conversion (SR_{RC}) method that can be applied successfully not only for the research's chosen experimented OLI dataset and for other Landsat satellite series imagery but also for different spatially, spectrally, radiometrically and temporally satellite datasets. Finally, a quantitatively assessing accuracy method is created in two phases: *Standard Deviation-To-Mean Ratio* & *Subtraction Index* (*S.I*). The final results are significantly promising and reached the perfect accuracy with a zero loss of data.

Key words:

Remote Sensing Science, L8-OLI, Simple Ratio Radiometric Conversion Method, SR_{RC} parametric method, "Stdev.-To- Mean" Ratio, Subtraction Index (S.I), SR_{RC} Accuracy Assessment method.

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A Proposed Simple Ratio Radiometric Conversion Parametric Method for Multi-Temporal Satellite Datasets

1. INTRODUCTION

Remote sensing science, with its crucially developed processes and analyses, has become a corner stone for many other disciplines such as geography -physical and settlement- and planning at regional and local level. Time series based change detection analysis is one major analysis to apply in these disciplines to analyze mostly patterns, trends, and mobility types of land change. The "From-To" time series change is considered as the most challenging analysis for both bi-temporal and multi-temporal approaches for imagery datasets. The bi-temporal approach is based on comparing satellite images between two dates only at an "one-time" operation, while the multi-temporal time series approach is considered as the recent evolutionary change methods that based on comparing much more images in the same process providing more comprehensive understanding of the complexity of the land change dynamics, capturing trends, and the capability of revealing both gradual and abrupt changes. These evolutionary potentials have revealed an accelerating usage of intelligent algorithms and nonparametric computation classifiers for change detection analysis in the last decade.

Jungho and Jensen state that methodologically there are three main goals of "*Remote Sensing Change Detection*" are as follows: *i*. detect the geographic location of change found when comparing two -or more- dates of imagery, *ii*. identify the type of change if possible, and *iii*. quantify the amount of change (Jungho & Jensen, 2005).

In 2017, Zhe Zhu categorize Landsat time series change detection algorithms into six main categories that are based on mathematical approach, including thresholding, differencing, segmentation, trajectory, classification, statistical boundary, and regression. Regarding the differencing algorithm, it detects earth's surface change by comparing images acquired at different time, and changes are defined by places that show large differences. This algorithm was subdivided into three subcategories: classification, spectral mixture analysis (SMA), and spectral/index (Zhu, 2017).

Globally, either bi-temporal or multi-temporal image differencing approach have been applied in change detection based time series researches. The post classification change detection analysis is one of the most common technique to be applied due to its advantages of minimizing environmental and atmospheric differences between images and statistical matrix of change detection. Acquiring anniversary date imagery in order to eliminate any seasonal influences is one of the most important consideration or rule to be applied in change detection studies (Lu *et al*., 2003; Jensen, 2005).

Changes "from-to" in land cover classes would be identified and extracted significantly, by differencing the classified land cover results at different anniversary dates, also known as post-classification comparison,. The accuracy of this method is highly dependent on the technique procedures, and on the accuracy of classified land cover (LC) images. Any slight error that presents in each classified image is exaggerated and compounded in the final resultant change map. Prior to performing the chosen algorithm, certain conditioned system, technical procedures, and environmental rules must be accomplished by the analyst to obtain higher accuracies to give a significant impact on the success of the analysis. One main conditioned rule that refers to the dynamic range and quantizing level of an image is "*Radiometric Resolution*" that must be similarly customized and adjusted between all multi-date datasets to have the same radiometric precision for all compared images. The radiometric mismatch between imagery datasets that do not have a common radiometric reference do not enable an effective comparison among images.

Radiometric resolution (RS) has evolved and improved gradually along with the evolution of remote sensing science and its technical support system, while the first generation of remotely sensed satellite multi-spectral system, along with its developed sensors, produced lower radiometry images that have 6-bits depth divisions (64 levels) - *e.g.*, Landsat-MSS -, gradually over fifty years, it was developed and ended with producing high radiometry image datasets up to 16-bits quantization system (65536 levels) such as Landsat-OLI.

Although landsat-8 OLI imagery data still maintains partial spectral and similar spatial data continuity and consistency since the launch of landsat-4 (TM sensor), it revealed higher radiometric resolution data that created a quantization gap between initial and later data which broke the radiometric continuity chain of the time series data. In order to obtain accurate comparable multi-temporal imagery datasets, a radiometric normalization-calibration method should be applied "if needed" and a conversion method (*e.g.*, to convert 16-bit to 8-bit images) must be achieved before preceding any change analysis.

This research offers a simple parametric method to convert dynamic range that is applied to an image of 16-bit to convert it to an image of 8-bit quantization system by using a landsat-8 OLI data. The proposed method maintains and preserves original spectral brightness values without normalizing, calibrating, stretching data, enhancing brightness/contrast, or changing or even losing any spectral data in the studied imagery data set.

1.1 Literature review

In this research, the literature review was directed towards shedding lights on some radiometric methods -especially if generalization of remotely sensed data is needed- that were used when dealing with the bi-temporal or multi-temporal time series satellite images to be carried out a change detection analysis. Moreover, it covers the literature that deals with the radiometric conversion of remotely sensed satellite images, which is the main purpose and objective of this research. Thus, when a generalization process of time series imagery data is not needed, a conversion method is used instead.

Predominantly, change detection analyses are vigorously applied in remote sensing science studies. It involves the conduction of various image analysis techniques to be applied on multi-temporal images in order to quantify variations in the state and the spatial distribution of objects and natural phenomena. Successful change detection studies require careful consideration of all external influences on the reflected electromagnetic radiation (EMR) signal within and between multi-temporal images. Remote sensing sensor systems differ in their temporal, spatial, spectral, and radiometric resolutions and care must be taken to either minimize these differences, when using different systems, or to make use of only one system (Lu *et al*., 2003). There has been a variety of satellite sensors that were used to detect and monitor earth's surface. Several accomplishments should be obtained from the detection of changes, some of which are: *i*. detecting modifications and conversions of land cover, *ii*. monitoring rapid and progressive changes, *iii*. appropriating scaling of the results and *iv*. matching temporal rates of observations with the scale of the processes (Coppin *et al*., 2004). Careful consideration must be given to the characteristics of the area of interest, before implementing a multi-temporal change detection algorithm, the remote sensor system being used, its image pre-processing requirements, as well as the processing/computing abilities of available systems (Coppin & Bauer, 1996; Jensen, 2005).

Additionally, as mentioned above, all possible conditioned rules of change detection analysis in all combined multi-temporal imagery, either from different sensors in same satellite or even from different satellites, must be conducted in any time series studies. However, concerning the imagery radiometric resolution comparison between multi-temporal images, some researchers perform radiometric correction techniques to deal with the imagery data sets. They assume that many definite variations could exist between images which are caused by changes in sensor characteristics and view angle, solar angle, and atmospheric conditions such as scattering that adds brightness or absorption that subtracts brightness from ground target reflectance's (Chen *et al*., 2005; Jensen, 2005). When dealing with radiometric corrections of multi-temporal time series images, consideration is given to two types, namely absolute and relative in the concerned literature review.

On one hand, absolute radiometric correction (ARC) methods attempt to remove all radiometric errors from the image and produce an output image of absolute surface reflectance for each pixel. This type of correction makes use of the satellite calibration parameters as well as atmospheric properties to correct the errors (Chavez, 1996; Song *et al*., 2001; Chen *et al*., 2005). On the other hand, relative radiometric correction -also known as radiometric normalization (RRN)- attempt to reduce radiometric error within and between multiple images by empirically normalizing the radiometry of a single reference image. This other type of correction is used to normalize for variations between multi-temporal images for change detection applications. This type has multi scenes that usually acquired under different sun angle -solar irradiance-, sensor differences, earth-sun distances, solar zenith angles, and different soil moister. These data can be adjusted by converting spectral radiances to top of atmospheric reflectance to minimize or eliminate the effects of any undesirable conditions in time series imagery data (Hall *et al*., 1991; Chander & Markham,2003).

Absolute radiometric calibration requires some computational procedures in order to calculate surface reflectance from at-sensor radiance (Wang & Myint, 2015). Houlès *et al*. (2006) applied absolute radiometric corrections on their twenty three time series satellite images (Spot-4 and Spot-5) with high spatial and temporal resolutions. They studied the effect of calibration coefficient, topography, and atmospheric correction to come up with an evaluation of relative variations of NDVI from one date to another in the time series imagery for agriculture monitoring. As for radiometric normalization, also known as, relative calibration, Jensen (1996; 2005) suggested a multiple-date empirical radiometric normalization method. This method discussed the selection of ground targets that should have constant reflectance values over time. These targets are similar to -have the same concept of- Pseudo-Invariant Features (PIFs) that was named by Schott *et al*. (1988). Some researchers extracted PIFs from the target and reference images to use them to obtain a model transformation between the pair of bi-temporal images (Yang & Lo, 2000; Sadeghi *et al*., 2013). This method evolutes lately to be completely automated and intelligent. Moghimi *et al*. (2022) propose a new automatic RRN technique that efficiently selects the clustered PIFs through a coarse-to-fine strategy and uses them in a fusion-based RRN modeling approach.

Considering radiometric conversion (RC) methods, few systematic literatures were recently conducted concerning detailed techniques for this crucial problem. Although RC approach is related to remotely sensed discipline, it is also dually interested by medical radiology science. Gillespy & Rowberg (1994) generated a dual lookup table algorithm that offers rapid manipulation of image brightness and contrast of radiologic images in a way to enhance and easily display 16-bit gray-scale images on personal computers with standard 8-bits RGB graphic systems without losing any tiniest information. Nelson *et al*. (2005) proposed an ordinal conversion method that neither belongs to ARN nor RRN for radiometric normalization and used for change detection applications. Their method does not require the conversion of digital numbers (DNs) of each image into land-surface reflectivity directly with no need to reference image. Moreover, it converts image values to ordinal ranks (Nelson *et al*., 2005). Although this method deals with multi-temporal high resolution imagery, it is still considered as normalizing method that might change some DNs values in the processed imagery data set.

Furthermore, in remote sensing specialized scientific papers, RC was mainly infused in some research papers that investigated bi/multi-temporal change detection applications. Shoukry (2017) infused the proposed conversion method in her research of artificial neural networks based change detection. She adopted two time series change detection methods and introduced an empirical

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conversion method when dealing with different radiometric resolution imagery data sets. The overall accuracy of her approach exceeds 97% which provides a promising method for change detection analyses. Başeski (2019) proposed an algorithm based on artificial neural network that takes into account the visual content of the image while reducing the color depth to have visually natural looking results. Moreover, it enhanced and optimized brightness and contrast settings that were done by using the generator network by selecting different thresholds. Although this produced method is able to use an existing dataset for image quality evaluation, it is rather complicated and requires extensive training data preparation.

From the aforementioned literatures, it can be noticed that little attention has been given to the necessity of applying radiometrically converting method especially when dealing with comparing higher with lower radiometric resolution imagery data. On the contrary, extensive research studies have been conducted on the radiometric calibration or normalization enhancing processes.

In particular, on one hand, the overall objective of this research is to generate a simple parametric radiometric conversion method to be applied in both bi-temporal and multi-temporal imagery data sets. On the other hand, one specific objective is to justify and purify -in particular the misleading notions of several researchers- the differential imagery radiometric comparison procedures especially when dealing with time series change detection analyses to increase the accuracy and produce the least possible error measurements.

1.2 Experimental Imagery Data Set

Figure 1 displays the experimental 16-bits study area image data set of the Landsat-8 Operational Land Imager (OLI) that covers a scene of the western part of the Egyptian Delta. It has 11 bands divided between reflective and emitted spectral wavelengths which is experienced in examining the research proposed method. These bands are as follows: B1=Coastal/Aerosol, B2=Blue, B3= Green, B4= Red, B5= Near infrared (NIR), B6=Short Wave Infrared-1 (SWIR-1), B7= Short Wave Infrared-2 (SWIR-2), B8 = Panchromatic band, B9 = Cirrus, B10 = Thermal Infrared - 1 (TIR-1), and B11= Thermal Infrared-2 (TIR-2). All bands have spatial resolution (S.R.) of 30×30 meters pixel size except for the PAN band that has S.R of 15 meters, and also for the two thermal bands that have S.R of 100 meters. The acquisition date of the OLI study imagery data is 8 August of the year 2021. Moreover, it has a World Reference System-Path and Row (WRS-P/R) of 177/39.

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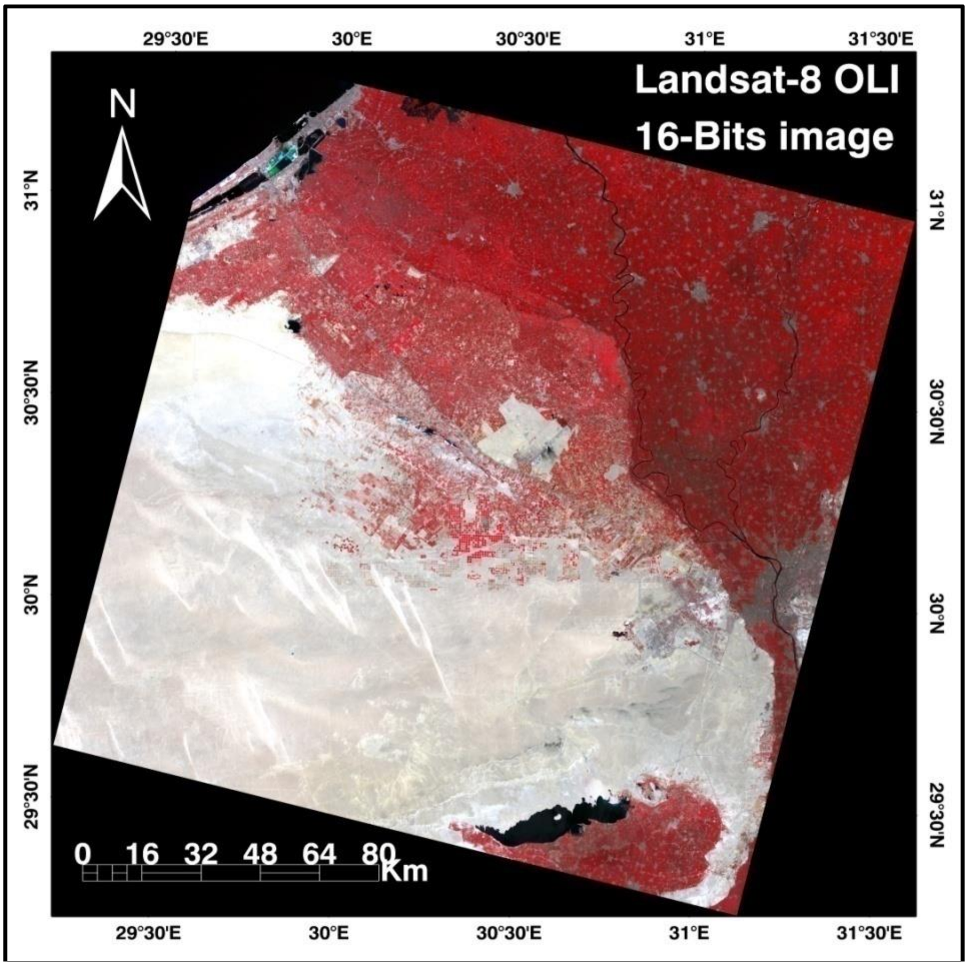

Figure 1. False color composite (5,4,3) of Landsat-8 OLI scene of the experimental 16-bits imagery dataset in August 16, 2021

Table 1 shows on details the geometrical and radiometrical status of the examined image. The data source is obtained from the image courtesy of the U.S. Geological Survey (USGS) with level-1/GeoTIFF data format type and has a zero value of cloud cover and cloud cover land, respectively. Excluded from this study the OLI Shortwave Infrared (SWIRs), Panchromatic (PAN), Cirrus, and the Thermal Infrared (TIRs) bands.

Table 1. Geometrical and Radiometrical Characteristics of Landsat-8 OLI Experimental Study Image

Image Characteristics	Status	Image Characteristics	Status
Sensor Altitude	705 Km	Map Projection	UTM-Zone 36N
Nadir-off/Nadir	Nadir	Projection Units	Meters
Sun Azimuth	122.99°	Datum	WGS-84
Sun Elevation	62.94°	Spectral Bands	11
Central Lat.	30º 24′ 53.93″	Radiometric R.L.	65536 (16-bits)
Central Long.	30º 33′ 23.14″	Img. Center-Time	08:30:11

Lat. = Latitude, Long. = Longitude, and R.L. = Resolution Level.

2. PROPOSED SIMPLE RATIO METHOD

This study produces a simple ratio radiometric conversion (SR_{RC}) parametric equation that could be easily applied when dealing with different bi-or-multi temporal satellite data sets especially when used in change detection analyses. Although the suggested approach is mathematically simple and does not need neither sophisticated nor intelligent procedures to be applied, it needs to achieve several conditions prior processing procedures. These conditions are mainly followed the same conditions as change detection analysis procedures.

2.1. Method's Conditions and Preparing Procedures

To achieve the least error and obtain the highest possible accuracy results, several conditions must be followed to produce a high-quality time series based change detection analysis. Shoukry (2017) specifies 12 main remote sensing system (RSS) conditions that should be accomplished by the analyst as well as another four major environmental considerations. Additionally, six other conditions should be specified concerning the suggested radiometric conversion method (Table 2). These conditions are as follows: (*i*) in case of (Bi / Multi-Temporal) time series based change detection analysis, all 16 conditions that were mentioned above in Shoukry's research in 2017 must be achieved , (*ii*) the quantization level conversion must be transformed from higher to lower level (from higher to lower dynamic range), (*iii*) it is preferable to analyze the conversion method on a series of satellite images that have the same satellite family with different generation and different sensors (multi-temporal / multi-sensor) that have different radiometric quantization levels (*i.e.* the Landsat system with its own series of satellites "Landsat-1,2,3,4,5,7,8, and lately Landsat-9 that launched in the year of 2021" with different sensors such as MSS, TM, ETM+, OLI, and OLI-2 with its enhanced radiometric resolution and higher sensitivity over water bodies), (*iv*) comparing statistics analysis between the target and resultant image - same image before and after applying SR_{RC} P.M., (*v*) comparing to match the spectrum "spectral" profile of a selection of random samples of different land cover features between both target and resultant images and finally (*vi*) after accomplishing the conversion processing analysis, the resultant radiometrically converted image should be co-registered with a chosen base image in the time series imagery datasets.

Table 2. Time series based change detection & SR_{RC} parametric method conditions

Time series based change Detection Conditions (Shoukry, 2017)		
RSS conditions		***Env. Conditions***
1. Temporal Resolution	7. Storage Format	13. Atmospherical
2. Anniversary Date	8. Algorithm	14. Soil moisture
3. Spectral Resolution	9. Decision Rules	15. Vegetation phenology
4. Spatial Resolution	10. LC classes	16. Tidal stage (coastal)
5. Radiometric Res.(RR)	11. Parameterization	
6. Classification Analysis	12. Image Dims.	
Conditions of SR_{RC} parametric method (Shoukry, 2023)		
1. Fulfill all Conditions of bi/multi-temporal based change detection analysis		
2. From higher to lower Quantization level		
3. Same satellite family/different generations/different sensors/different RR.		
4. Comparing statistics (Target versus Resultant conversion image)		
5. Comparing spectrum (Target versus Resultant conversion image)		
6. Co-registration with base image (in time series analysis)		

2.2 Proposed SR_{RC} Parametric Method

In order to compare time series multi-temporal/multi-sensor satellite images radiometrically, the data have to be transformed from higher to lower dynamic range quantization level. In this research, a simple ratio radiometric conversion parametric (SR_{RC}) equation is produced to solve this methodological problem. The proposed method is described in Equation (a) as follows:

$$\boxed{SR_{RC} \text{ of } (i)_{BDR}^{(m)bits} = \left[\frac{(i)_{BDR}^{(n+m)bits}}{(i)_{BDR}^{(n)bits}}\right]} \quad (a)$$

with the letter (i) refers to a satellite image substituted with binary system value of two, and $(i)_{BDR}^{(m)bits}$ is the complete equation form of specified resultant satellite image that should be acquired after applying the conversion equation - the "*BDR*" subscript is stands for "the image binary system of its dynamic range which is always equal to the value of "2", and the *"(m)bits*" superscript is stands for the radiometric resolution (RR) of the required converted resultant image in bits. Moreover, the nominator in the simple ratio equation $(i)_{BDR}^{(n+m)bits}$ refers to the target satellite image that needs to be converted (always have the highest quantization level "QL"), while the denominator $(i)_{BDR}^{(n)bits}$ refers to the division value of the binary quantization level (radiometric resolution in bits) that is needed to divide all brightness values (BVs) of the target image by it (it should be noticed that it is not a constant value, but a changeable one depending on the images' quantization level input values in the equation - differs from one case to another -).

For example: to apply the proposed "radiometric conversion simple ratio (SR_{RC}) equation" to convert an image of 15 bits RR (32768 QL) to an image of 8 bits RR (256 QL). Illustratively, this example is described in Equation (b) as follows:

Example: Converting from (15bits) - to - (8bits)

$$SR_{RC} \text{ of } (2)^{(8)bits}_{\boldsymbol{BDR}} = \left[\frac{(i)^{(15)bits}_{\boldsymbol{BDR}}}{(i)^{(7)bits}_{\boldsymbol{BDR}}}\right]$$

$$SR_{RC} \text{ of } (2)^{(8)bits}_{\boldsymbol{BDR}} = \left[\frac{32768\ QL}{128\ QL}\right] \quad (b)$$

When substituting our research radiometric conversion case study numerical values for the equation variables {in other words, converting from 16-bits (65536 QL) to 8-bits (256 QL) image}, it should be illustrated as follows in Equation (c):

Converting from (16bits) - to - (8bits)

$$SR_{RC} \text{ of } (2)^{(8)bits}_{\boldsymbol{BDR}} = \left[\frac{(i)^{(16)bits}_{\boldsymbol{BDR}}}{(i)^{(8)bits}_{\boldsymbol{BDR}}}\right]$$

$$SR_{RC} \text{ of } (2)^{(8)bits}_{\boldsymbol{BDR}} = \left[\frac{65536\ QL}{256\ QL}\right] \quad (c)$$

3. METHODOLOGICAL PROCEDURES & EXPERIMENTS

The research experimental analysis is conducted by using the commercial remote sensing software ENVI® "Environment for Visualizing Images". Concerning the proposed approach, Figure 2 depicts on details the methodological procedures that are applied on the experimental Landsat 8-OLI (16 bits or 65536 QL) target image that covers the western part of the Egyptian Delta in this research. The analysis starts with checking the basic statistics of target image such as: the mean , standard deviation, min. BV, max. BV. In addition, an image histogram, spectral profile, and scatter plot should be examined to assure the data normality. In case of dealing with time series based change detection analysis, all conditions must be fulfilled. To apply the SR_{RC} P.M. in ENVI software, a band math subroutine should be processed for each separate chosen band of the target image, one at a time. This process resulted the existence of new five separate gray level images. It is preferable that a new statistics comparison check procedures would be achieved between target bands and resultant bands especially comparing the histogram, spectral profile, and scatter plot between each pair (target versus resultant) bands. This step is crucial to be processed to ensure the credibility of the proposed method, the accuracy

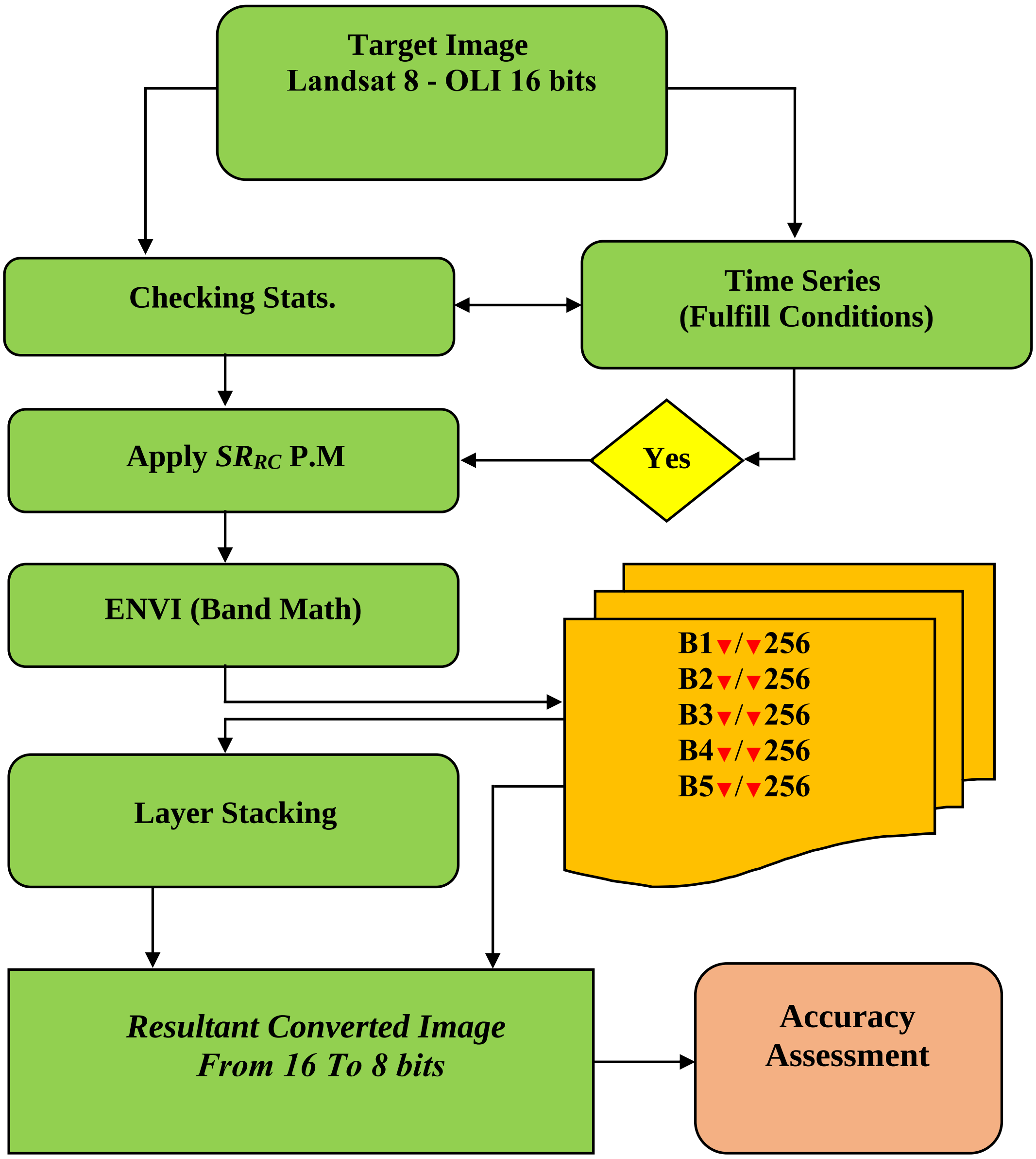

Figure 2. The methodological procedures to apply the proposed SR_{RC} parametric method in the research experiment Data

and degree of precision, and to be certain that no brightness values (BVs) per pixels are radially changed or lost during the conversion process. Finally, a layer stacking process is applied to combine and gather all resultant gray level images into only one multi-spectral resultant converted image.

4. RESULTS & ACCURACY ASSESSMENTS

Figures 3 & 4 and Table 3 depict and illustrate a comparison results of a specified common part of both experimented target input (16-bits) and converted output (8-bits) image as follows:

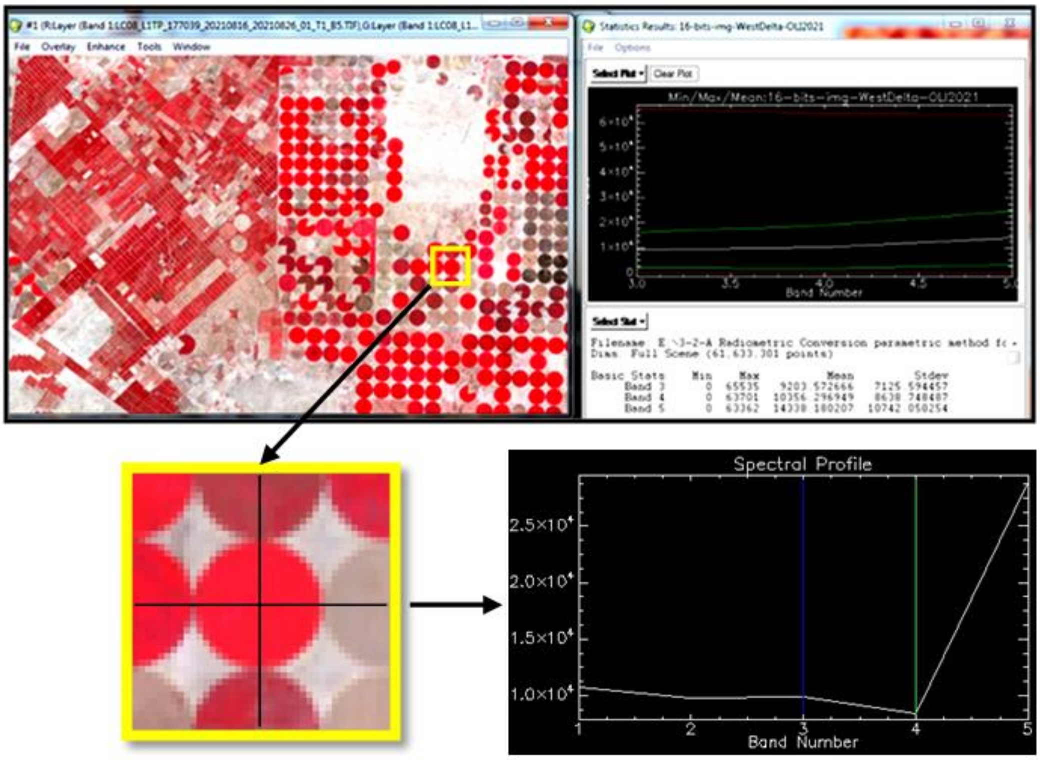

Figure 3. The 16-bits experimental target image showing a part of reclaimed agricultural land by using pivot irrigation system accompanied by a histogram and spectrum curve profile for the specified location.

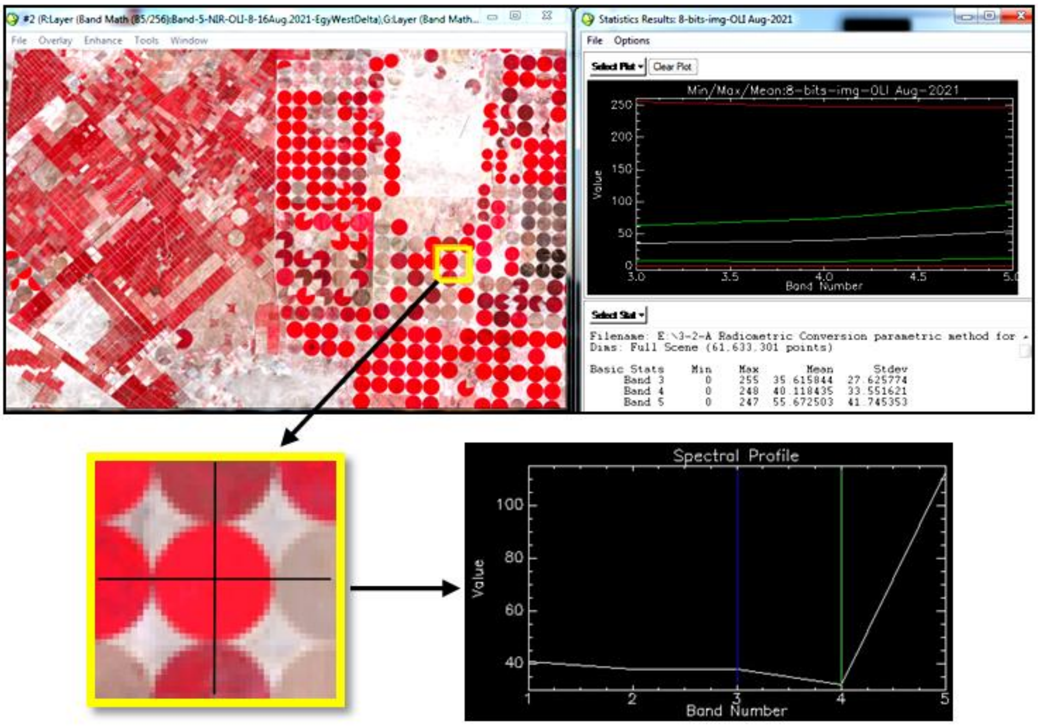

Figure 4. Part of the 8-bits converted image showing the same coordinates of the same selected area as figure.3 accompanied by a histogram and spectrum curve profile after the conversion process

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Table 3. Comparison of basic statistics & measuring accuracy assessments (Standard Deviation-To-Mean Ratio & Subtraction Index) between input (16-bits) and resultant output (8-bits) images .

Display Bands	TARGET INPUT 16-BITS IMAGE					CONVERTED RESULTANT 8-BITS IMAGE					S.I
	Min. BV	***Max. BV***	***Mean*** $(\dot{M})$	***Stdev.*** (σ)	$\frac{\sigma}{\dot{M}} \times 100$	***Min. BV***	***Max. BV***	***Mean*** $(\dot{M})$	***Stdev.*** (σ)	$\frac{\sigma}{\dot{M}} \times 100$	
Band-3	0	65535	9204	7126	77.4%	0	255	35.62	27.60	77.4%	zero
Band-4	0	63701	10356	8639	83.4%	0	248	40.12	33.50	83.4%	zero
Band-5	0	63362	14338	10742	74.9%	0	247	55.67	41.70	74.9%	zero

Min./Max.BV=Minimum/Maximum Brightness value, *Stdev.*{*Sigma or* σ}=Standard Deviation, $\{\frac{\sigma}{\dot{M}} \times 100\}$=Standard Deviation-To-Mean Ratio, S.I=Subtraction Index.

By comparing the target input image (16-bits) with the converted resultant output one (8-bits) statistically, it is noticed that both displayed false color composite images have $(RGB=5,4,3)_{bands}$. All minimum brightness values (BVs) in both images are equal to zero, while band 3 in both images (the target and converted) reached the maximum level of dynamic range quantization of 65535 and 255, respectively. In this regard, the standard deviation and the mean are measured for each band separately in both images.

To ensure the credibility of the proposed method on one hand and to provide the highest possible precision measurement on the other hand, accuracy assessment procedure for the SR_{RC} parametric method is produced. It is created and developed in two phases, the first is measuring the "*Standard Deviation-To-Mean*" Ratio (sometimes "*Stdev.-To-Mean*" or *"σ-to-$\dot{M}$" Ratio*) while the second is called the "*Subtraction Index*" - sometimes "S.I" -. It is measured by subtracting the two opponent resultant ratios (i.e. 16-bits versus 8-bits) of a similar band (i.e. B5) to produce a "S.I" measure for each band in both images (Figure 5).

The equation of the first phase depends on two main variables that are statistically always related and connected to each other such as "the Standard Deviation" and the "Mean". This equation is examined for each band separately in both input and converted images. It can be demonstrated and

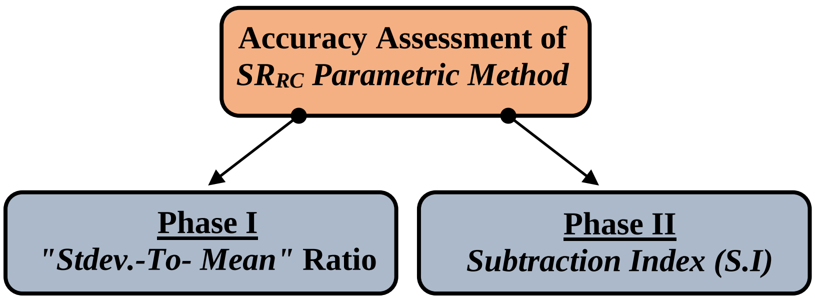

Figure 5. The proposed accuracy assessment methodological procedures of the SR_{RC} parametric method

"Standard Deviation-To- Mean" **Ratio**

$$(\sigma\text{-to-}\dot{M})\ Ratio = \{(Stdev. \div Mean) \times 100\} \qquad (d)$$

mentioned above in Equation (*d*). In this research, when comparing the (σ-to-$\dot{M}$) between the 16-bits and the 8- bits image, it is shown that it has similar results for both images. However, the displayed bands of B5 (NIR), B4 (R), and B3 (G) have registered three different values of Standard Deviation-To-Mean (σ-to-$\dot{M}$) Ratio measurement that are equal to 74.9%, 83.4% and 77.4%, respectively.

Moreover, the second phase of accuracy assessment is to apply the Subtraction Index equation (Equation *e*) as follows:

Subtraction Index (S.I)

$$S.I = (\{\frac{\sigma}{\dot{M}} \times 100\}_{16\text{-bits img.}} - \{\frac{\sigma}{\dot{M}} \times 100\}_{8\text{-bits}} \qquad (e)$$

The range of the ratio function result should be passing through the value of zero and ending at the value of one - in other words, the result should be ranged "from-zero-to-one" or (0-1). The value of 0 indicates that there is a zero loss of data during the converting process between the two images which give the perfect and the highest possible accuracy. Thus, the closer index value to zero the higher captured accuracy. Conversely, the closer index value to one the less obtained accuracy. If the Subtraction Index value exceed the value of one, this means that the image need to be radiometrically enhanced -normalized or calibrated- and corrected prior to the conversion process.

In this research and back to table 3 that was illustrated above, identical accuracy ratios of similar bands between the two opponent images - "input target and output resultant" - are existed which gives an excellent result that assure that all original data have been maintained and preserved very well with a zero data loss.

Finally, a chosen post-processing NDVI analysis is applied in both input and output image for an analytical comparison purpose. Figure 6 displays a comparison between a NDVI analysis of both target and converted image. When geometrically link the two displayed images by matching same pixels in same location in both images, it is noticeable that it has the same NDVI value when checking the spatial pixel editor subroutine in ENVI software. A visual interpretation pixel-based comparison between the resultant NDVI (16-bits Vs 8-bits) images is examined. The result shows that both images have identical values of NDVI. For example, as it is shown in figure 6, the equivalent pixel of a selected location in the software zoom display window has the same NDVI value of (0.76) in both target and converted images.

Figure 6. A post-processing NDVI analysis that is applied for both target input 16-bits & resultant converted output 8-bits images

5. DISCUSSION AND CONCLUSION

This research paper suggests a new contribution to the field of Remote Sensing Science (RSS) studies from both conceptual methodological and technical application perceptions, especially.

when dealing with bi/multi-temporal/sensor Time Series based comparison analysis such as Change Detection. The proposed SR_{RC} parametric conversion method has demonstrated its effectiveness on an experimental landsat-8 OLI satellite image data of the western part of the Egyptian Delta. This method required to radiometrically transform the data from higher (16-bits) to lower (8-bits) dynamic range quantization level. Additionally, to achieve the least error and obtain the highest possible accuracy results, 22 obligatory conditions were proposed when dealing with time series based change detection analyses.

Significantly, this paper has fulfilled its first objective of producing a new radiometric conversion method and followed by creating a new method for assessing accuracy quantitatively. Technologically, the proposed method maintains and preserves original spectral brightness values without normalizing, calibrating, stretching data linearly/non linearly, enhancing brightness/contrast, or changing or even losing any spectral data from the input target image to the output converted one in the studied experimental imagery data set during the conversion processing procedures. Moreover, it has succeeded in achieving its second objective of justifying and correcting several misleading conceptual notions and severe technological errors that usually practiced by several unknowledgeable researchers and analysts especially in the field of Geography-Remote Sensing community.

Regarding the methodological processing procedures of the suggested method, they were divided into three main practical phases. The first dealt with assuring the existence of the required systematical and environmental conditions, checking the basic statistics of each band in the 16-bits target input image, examining the image histogram with a spectral profile and scatter plot to assure the data normality, and then applying the proposed SR_{RC} parametric method. As a cornerstone, the second phase is to measure the proposed accuracy assessment method that was based on two sequentially applied equations. The first equation is "*Standard Deviation-To-Mean*" Ratio which followed by and ended with the measurement of the second equation of "*Subtraction Index*" (*S.I*). The accuracy assessment results shows that the resultant (S.I) value is equal to zero for all specified opponent bands which is considered as the perfect result that can be obtained. It indicates that there is a zero loss of data during the converting process between the two images. Additionally on one hand, it maintained and preserved the original spectral brightness values and achieved the highest possible accuracy on the other hand . Whereas, the third and final phase is to simultaneously apply a post-processing analysis to both target input (16-bits) and converted output (resultant 8-bits) images. This procedure is processed for an analytical comparison purpose between the two resultant opponent images. Thus, a NDVI analysis was chosen to proceed such comparison. The pixel-based comparison processing was applied and it shows that both images have identical values of NDVI in same pixel location.

Finally, the proposed radiometric conversion method along with the proposed accuracy assessment method show promising results that can effectively help many researchers and analysts to eliminate radiometrical differences between bi/multi- temporal/sensor images to justify and improve comparability between these images. This will result in more accurate information being used in several Geographical-Remote Sensing applications and specifically in local or regional planning, or even in environmental decision-making process. Therefore, it is recommended to expand the use of the proposed SR_{RC} parametric conversion method by using different data source and different case studies for further verifications especially in change detection analysis studies.

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بنك المعرفة المصري

ملخص البحث:

أسلوب مقترح للتحويل البارامترى الإشعاعي بطريقة النسبة البسيطة لمجموعات بيانات الأقمار الصناعية متعددة الأزمنة.

د. نرمين أحمد شكري
مدرس بقسم الجغرافيا – كلية الآداب – جامعة القاهرة

أدى إطلاق القمر الصناعي Landsat-8 بمستشعر تصوير الأرض التشغيلي (OLI) في عام ٢٠١٣ و الذي أعقبه إطلاق Landsat-9 بمستشعر (OLI-2) إلى سد العديد من الثغرات في التعامل مع العديد من تحليلات و تطبيقات الاستشعار عن بُعد نظرًا لتصميمه التقني الفائق مقارنة بسلسلة أقمار لاندسات السابقة، حيث يجمع مستشعر OLI المزيد من الصور بشكل أكبر يفوق المستشعرات السابقة بمعدل مرتفع جدا من قياس "الإشارة–إلى–الضوضاء" (S/N أو SNR) ، و كذلك يعمل على تكوين نطاقات طيفية أعلى ، و أيضا دقة إشعاعية راديومترية أعلى بطريقة جعلت بعض التحليلات مثل تحليل رصد التغير المعتمد على السلاسل الزمنية أحد أهم مواضيع الأبحاث في الاستشعار عن بعد في جميع أنحاء العالم. وعلى الرغم من ذلك قد تجاهل وغفل بعض الباحثين تطبيق الإجراءات البحثية الصحيحة عند تطبيق مثل هذا التحليل، وأساء البعض منهم أداء الخطوات الإجرائية المنهجية الصحيحة له. فنجد أنه يجب إجراء العديد من عمليات معالجات الصور الفضائية السابقة للتحليلات، وبالتحديد التعامل مع اختلافات درجة الدقة الراديومترية بين الصور الفضائية و الناتجة عن اختلاف المستشعر و خاصة عند إجراء خوارزميات رصد التغير القائمة على مقارنة السلاسل الزمنية سواء ثنائية الزمن أو متعددة الأزمنة. لذا فمن الضروري تطبيق وإجراء عملية تحويل إشعاعى خاصة عند تضارب وإختلاف مجموعات بيانات الصور متعددة الأزمنة من الناحية الراديومترية. ويقترح هذا البحث أسلوبا ومنهجا جديدا للتحويل البارامترى الإشعاعي و الذي تم تسميته بأسلوب "التحويل الإشعاعي/الراديومترى بطريقة النسبة البسيطة". هذا الأسلوب المقترح يمكن تطبيقه بنجاح ليس فقط لمجموعة بيانات صور OLI التي تم اختيارها في هذه الدراسة أو لأي مستشعر آخر في سلسلة القمر الصناعي لاندسات نفسها، ولكن أيضًا لمجموعات بيانات الأقمار الصناعية المختلفة مكانيا وطيفيا وإشعاعيا و كذلك زمنيا. أخيرًا ، تم إنشاء أسلوبا كميا جديدا أيضا لتقييم الدقة الراديومترية يتم تطبيقه على مرحلتين هما: معادلة "معدل الانحراف المعياري–الى–المتوسط الحسابي" ثم معادلة مؤشر الطرح. كانت النتائج النهائية للبحث واعدة بشكل كبير ووصلت إلى درجة الدقة المثالية مع عدم فقدان أي من بيانات الصورة الفضائية بعد عملية التحويل الراديومترى المقترحة.

الكلمات المفتاحية: علم الاستشعار عن بعد، لاندسات OLI-8، أسلوب التحويل الراديومترى بطريقة النسبة البسيطة ، التحويل البارامترى، معدل "Stdev.-To- Mean"، مؤشر الطرح (S.I)، أسلوب تقييم دقة SR_{RC}.