Effect of image compression and resampling methods on accuracy of land-cover classification

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Abstract
High-resolution digital images that are used in remote sensing technologies tend to be of large sizes, especially with satellite imageries that provide better than 5 m spatial resolution such as (QuickBird, IKONOS, etc). These images consume larger storage space, larger transmission bandwidth, and longer transmission times. In order to minimize the storage space and transmission time, the archived images should be compressed before storage and transmission. Most publications generally investigate the quality of reconstructed (compressed) image, only few studies address the influence of the image compression on processing results, i.e. image classification. This paper investigates the effects of the most commonly used compression wavelet-based formats (JPEG2000 and MrSID) on the classification results of the two high-resolution QuickBird and IKONOS images. It is important to mention that the two high-resolution images cover two completely different study areas; therefore the study methodology was divided accordingly into two main cases. Both cases to the end that the impact of previously mentioned two wavelet-based formats was assessed on the classification results. Furthermore, only for the first data set, another effect was investigated. This other effect is the influence of the traditional resampling methods on the classification results. It is important to mention that typically, in the geo-referencing or geometric correction operations, resampling process is the second step following rectification. Moreover, the influence of resampling methods over compressed images was investigated. This paper shows that classification accuracy which derived from MrSID compressed images is better than that accuracy of JPEG2000 compressed images, especially at the high compression ratios of the two data sets. The first data set illustrate that the NN resampling method is the best method, in which the classification accuracy that was obtained was significantly closer to the classification accuracy of original image than any other traditional methods. Moreover, we concluded that CC method is the best in case of JPEG2000 compressed images while BI method is the best in case of MrSID, especially at high compression ratios. Meanwhile, the second data sets revealed that the ANNs classification method introduce classification accuracy higher than MLC method in case of MrSID compressed image, at higher compression ratios, while it was the higher in case of JPEG2000 at all compression ratios.

Keywords - Image compression; Image classification; MrSID; JPEG2000

1. Introduction & Objectives

In the recent years, many applications, including land-cover mapping and analysis, climate modeling, agricultural and forest management, and disaster management, use Remote-sensing (RS) images. These applications demand images with high spatial, spectral and temporal resolution in order to achieve optimal results however; the characteristics of these data tend to be of large sizes. Even though the commercial providers have a large structure to store all this information, users do not often have access to this structure, and thus data management problems such as (large storage space, large transmission bandwidth, and long transmission times) arise [Shrestha, B. et al, 2005; Marsetic, A. et al, 2011; Zabala, A. et al, 2012b; Ramesh, et al, 2013].

This required a compression method performance on the archived images, prior to storage and transmission [Shrestha, B. et al, 2005].
Conceptually, file size of a digital image significantly depends on real actual dimensions of the imaged area on the ground, also the image spatial, spectral, and radiometric resolutions. This can be quantified by the following equation:

Image file size = total no. of pixels in image * no. of bands * no. of bits per pixels

Where

- ✓ Total no. of pixels in image = image width (no. of pixels) * image height (no. of pixels)
- ✓ Image width or height (no. of pixels) = image width or height (m) / spatial resolution
- ✓ No. of bands = spectral resolution
- ✓ No. of bits per pixels = radiometric resolution

Therefore

Image file size (bits) = [Image width (no. of pixels) * Image height (no. of pixels)] * spectral resolution * radiometric resolution (bpp)

The number of bits available is pre-determined by the design of the system; this highly depends on the sensitivity of the sensor. It is important to mention that adding too many extra bits would simply record system noise rather than provide additional information about scene brightness.
Moreover, each added bit increases transmission requirements. Increasing the transmission requirement depends on the capabilities for recording and transmitting data. If we assume that transmission and storage resources are fixed, increasing the number of bits for each pixel means that we will have fewer pixels per image and that pixel sizes must be larger. Thus, design of remote sensing systems requires trade-offs between image coverage and radiometric, spectral, and spatial resolutions [Campbell J.B, 1996].
JPEG2000 format is the up-to-date image compression standard. JPEG2000 provides superior compression performance compared with other formats. JPEG2000 compresses and decompresses the images using discrete wavelet transformation and allowing image information to be retained without significant distortion or loss. In the other hand wavelet transform-based compression format designed by LizardTech is Multi-resolution Seamless Image Database (MrSID) that is widely supported across GIS. Generally, the compression techniques used by MrSID technology provide both high quality imagery and high performance while still meeting our industry’s challenging workflows.
Compression in JPEG2000 or MrSID can be performed in both lossy and lossless style. Lossy compression is preferred because of its higher compression ratio. When lossy compression is performed, some amount of data is lost during the compression. Such loss of data may lead to wrong results when analysis is performed using computer based image applications. Thus, there is a need for image quality assessment of compressed and reconstructed images using JPEG2000 or MrSID formats at various compression ratios. Using image compression techniques can no doubt reduce the physical size of image but the image quality is unavoidable to degrade. Most of these lossy compression techniques are mainly designed to exploit human vision system limitations. The degraded quality of the compressed image may not be visible or obvious when examines by human eyes. As computer-based image analysis tools are very sensitive to image quality, small changes in the image content may affect the analysed results [Lam, K. W. et al, 2000; LizardTech, 2010].
Intensity interpolation or resampling techniques form an integral part of different processing stages of the images and hence is important in many fields such as medical imaging, consumer electronics, military applications etc. Registration or geometric correction of images usually

requires the resetting of image framework which in turn results in variation in source and target pixel sizes. When the output pixel size is not the same as the original, quality of the resampling technique determines the quality of output. This is not only true in the visual appearance of the images, but also in the numerically interpolated values when used in multi-temporal or multi-sensor studies. In particular, rectification, registration, and geo-referencing require that an image be resampled onto a new coordinate grid because, the planimetric measurements of the imagery by assignment of geographical co-ordinates are accomplished by geo-referencing of images [Katiyar, S.K. and Arun, P.V., 2014].

Image classification, either supervised or unsupervised approach, is an image analysis tool to categorise the unidentified pixels in an image to the designed thematic or spectral separable classes respectively in satellite-based remote sensing discipline. Usually image classification used to create maps such as Land-use Map, Forest Map, Crop Map, etc. or to carry out quantitative interpretation using mathematical /statistical modeling. Moreover, it helps to assign corresponding class to groups with homogeneous characteristics, with the aim of discriminating multiple objects from each other within the image.

There are few studies that address the impact of lossy compression on image classification. They mostly deal with low resolution data or very small images, non-standard compression algorithms, and analyze pixel-based classifications only. The results from these studies are frequently conflicting – some encourage lossy compression, others advise against its use. When classifying urban areas, [Kiema, J. B. K., 2000b] found that compression ratios of up to 20:1 can be used without deteriorating the results of classification. [Lam, K. W. et al, 2000] achieved acceptable classification with JPEG compression of SPOT multispectral imagery with compression ratios of up to 20:1. [Zabala, A. and Pons, X., 2011] came up with interesting conclusions when compressing Landsat ETM+ and TM images with JPEG and JPEG 2000 techniques. They showed that homogeneous areas can be compressed to a ratio of 20:1, while the fragmented areas only to 5:1. Better results were obtained with the classification of compressed images than original images.

The impact of resampling methods on the image classification results was studied also at very few studies. The first study that had been investigated about the impact of image resampling on the supervised classification was for [Dikshit, O. and Roy, D.P., 1996]. In this research [Dikshit, O. and Roy, D.P., 1996] used high spatial resolution multispectral image (Airborne Thematic Mapper ATM) to investigate the effect of Cubic Convolution and Bilinear Interpolation resampling methods on image classification where it was used (MLC) to classify the two resampled images and by comparing the result of classification of the resampled images with the original images. Finally, [Dikshit, O. and Roy, D.P., 1996] concluded that The Bilinear resampled images had significantly higher overall classification accuracies than the cubic-convolution resampled images. Moreover, Bilinear and cubic-convolution resamplers can be expected to smooth the image and therefore reduce the image noise and the spectral variability of the image classes. Consequently, the separability of spectral class training data can be expected to increase after resampling, giving improvements in spectrally based classification accuracies. This effect will be counteracted, however, by smoothing of the boundaries between spectrally distinct classes. This will increase the likelihood of mixed boundary pixels and, therefore, increase the likelihood of their misclassification.

[Arun, P. V., 2013] have used a strategy to investigate the effects of resampling techniques on classification accuracy by using LISS-IV image that was investigated by conducting the three resampling methods (NN, BI, and CC) and classified using the decision trees classifier. Finally, the results of this research have shown that resampling processes change the pixel value and classification statistics considerably. Furthermore, [Arun, P. V., 2013] suggested that it is not suitable to perform the image geo-coding operations before classification. However BI resampling technique can be adopted where prior geo-coding is critical.

[Pillai, R. B. and Tueller, P. T., 2003] compared between the Nearest Neighbor (NN) and Bilinear Interpolation (BI) resampling methods in their effects on the classification accuracy and noticed that there was not much difference in the classification accuracies obtained by the two resampling methods, since they yield similar classification results. Also, [Rodríguez, J. R. et al., 2006] compared between the (NN) and (CC) by using two Landsat (TM and ETM+) images and selected the (MLC) to classify them. The conclusion of his research was that the cubic convolution resampling method improves the accuracy of the maximum likelihood classification. As well as the results obtained for both images suggest that the cubic convolution approach is more appropriate than the nearest neighbor approach.

Nevertheless, [Fahim Arif, 2009] could by comparison of surface plots of different interpolation (resampling) methods to detect that the Cubic Convolution (CC) method produces smoother peaks than Nearest Neighbor (NN) and Bilinear Interpolation (BI) methods and finally He concluded that the image obtained with Cubic Convolution (CC) resampling method is closer to the original image as contrast to (NN) and (BI) methods.

The main objective of this paper is to assess the impact of image compression on the land-cover classification results for the high resolution satellite images (such as QuickBird and IKONOS) in two different study areas which differ in characteristics, homogeneity, and the area of each zone in addition to evaluate the performance of the two most commonly used compression wavelet-based formats (ISO-standard JPEG2000 format and Industry-standard MrSID format) on final processing results (such as image classification). The selection of different natures of zones and images was to provide the analysis space for the compression in different spectral response from various land covers. Other objective for this research is the investigation of the effect of traditional resamling methods (such as Nearest Neighbor NN, Bilinear Interpolation BI, and Cubic Convolution CC) on the classification of original geo-coded images for purpose of determination which method gives the best classification accuracy. Finally, this research will also discuss the influence of resampling methods over compressed images. The goal of this investigation is to find proper suggestion for selection of a suitable resampling method in case of compressed images depending on its file format.

2. Materials and methods

2.1. Study areas and data sets

2.1.1. Description of first study area (Alexandria) and their reference maps

The West of Alexandria, Egypt, was selected for this study, with an approximate area of 25.027 km^2. Part of Mediterranean coast, the Alexandria harbor, Canal Al Mahmoudeya Al Bahri and Mariout Lake at the south part of study area, appear in this zone. Different urban land uses, such as industrial and commercial uses serving the harbor, high intensity of residential use, road networks, some sandy areas, bare soil and small proportion of grass and trees zones can be found in this area. This zone satisfies the degree of variability and heterogeneity required if it is compared to the second study area (Yanbu).

The study area is totally covered by 4 cadastral maps of scale 1:5000 their sheet numbers are (6h), (7h), (6d) and (7d) as shown in Fig. [1] .Those maps are published by the Egyptian General Survey Authority (EGSA), in 2006.Those maps were used in collecting the ground control points (GCPs) and check points (CPs). Then they were used in Geo-referencing process as it will be explained later.

The map (6h)

The map (7h)

The map (6d)

The map (7d)

Figure [1] The maps (6h), (7h), (6d), and (7d) of study area (Alexandria) scale 1:5000

2.1.2. Description of the second study area (Yanbu)

The second study area is located in Yanbu Al-Bahar, province of Al Madinah, Saudi Arabia which is a major Red Sea port in the Al Madinah province of western Saudi Arabia. It is approximately 300 kilometers northwest of Jeddah. It has a huge area (about 288.38 Km^2) if it compared with the first study area which is (25.03 km^2). Fig. [2] shows the location of Yanbu inside Saudi Arabia and Fig. [3] shows the map of Yanbu region. Yanbu is considered as a coastal desert zone has small proportion of residential areas where the downtown area of Yanbu Al-Balad (which is also called Al-Balad) contains most of the population. These characteristics make it to be more homogenous than the first study area which has high degree of heterogeneity.

2.1.3. Characteristics of QuickBird multispectral image

DigitalGlobe offered QuickBird Imagery products in three levels (Basic Imagery, Standard Imagery, and Orthorectified Imagery). The Standard Imagery product has two types (Standard Imagery and Ortho Ready Standard) which are radiometrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection [DigitalGlobe, 2006]. Table [1] shows the most important characteristics of the QuickBird multispectral image that was used in this research and the QuickBird Multispectral image was shown in Fig. [4] which is a false color composite of QuickBird bands 4, 3, and 1 (assigned as red, green, and blue, respectively).

Figure [2] Location of Yanbu Al-Bahar, province of Al Madinah, Saudi Arabia.

Figure [3] The map of second study area (Yanbu)

2.1.4. Characteristics of IKONOS true colour image

The image covering this study area was true colour IKONOS image shows in Fig. [5] that is Geo Product type. The IKONOS Geo Product is a low-accuracy georeferenced product. All Geo products are map projected-rectified to a datum and map projection system. The features of these images are showed in the Table [1]. Data pre-processing consists in a geometrical correction in order to remove the distortions introduced by the acquisition geometry. The re-sampling of the image is carried out imposing a constant ground sample distance, as well as the arrangement in a specific datum and map projection. The circular error (CE90) of this IKONOS product type is about ±15 m [GeoEye, 2006].

Table [1] characteristics of the QuickBird multispectral image and characteristics of the IKONOS True Color image

[a] characteristics of the QuickBird multispectral image		[b] characteristics of the IKONOS True Color image	
Image Type	Ortho Ready Standard	Image Type	GEO (True color)
Acquisition Date	6 May 2007	Cloud Cover	Cloud-free
Cloud Cover	Cloud-free	Number of bits per pixel	8 bits per pixel
Number of bits per pixel	16 bits per pixel	Spatial resolution	1 m
Multispectral bands	Blue (450-520 nm) Green (520-600 nm) Red (630-690 nm) Near IR (760-900 nm)	Image bands	Band 1 (blue) 0.445 – 0.516 micrometers Band 2 (green) 0.506 – 0.595 micrometers Band 3 (red) 0.632 – 0.698 micrometers
Spatial resolution	2.4 m	Cartographic projection	UTM ,Zone 37
Cartographic projection and Datum	UTM ,Zone 35 WGS'84	Spheroid	International 1924
Resampling method	2x2 Bilinear	Datum	Ain el Abd 1970 (Bahrain)

Dimensions	2373 Pixel x 1831 Pixel	Dimensions	24580 Pixel x 22558 Pixel
	5695.2 m x 4394.4 m		24580 m x 22558 m

Figure [4] The FCC of QuickBird Multispectral image

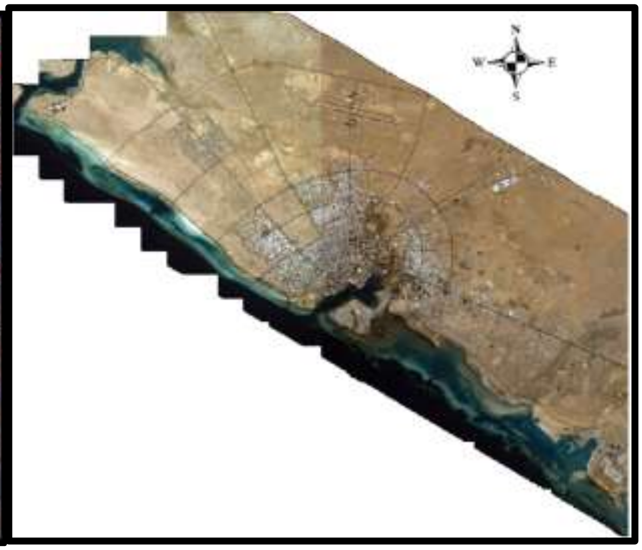


Figure [5] The true colour IKONOS Multispectral image

2.2. Methodology

2.2.1. First data set (QuickBird)

This paper was divided into two main studies that were carried out on two data sets, the first study aims to assess and investigate the influence of different resampling methods as well as the effect of image compression on the classification results. Therefore the methodological process was divided into four phases as follow:

- Phase one: Classification of the original image.
- Phase two: Classification of Geo-coded images.
- Phase three: Classification of the compressed images.
- Phase four: Classification of the compressed images after Geo-referencing process.

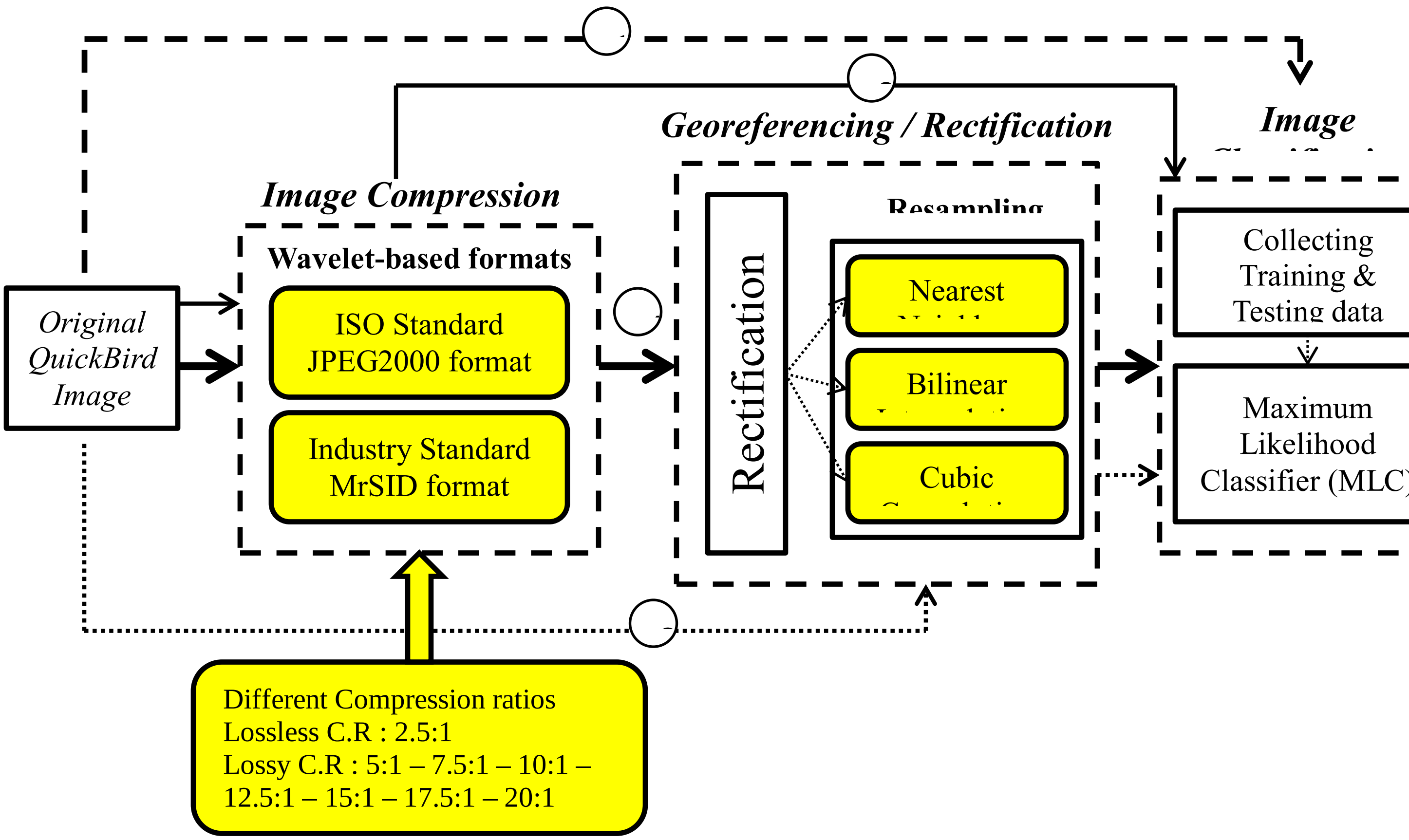


Figure [6] Diagram of the methodology phases for the first data set. The workflows of phases are shown by using the dashed, dotted, continuous, and continuous bold arrows, respectively.

A general overview of all the work phases shows in Fig. [6]. The aim of the first phase was implementation of the supervised classification process that consists of three stages (the training stage, the classification stage, and the output stage) on the original image to use the results of the classification as a benchmark in evaluation of the classification results of the other phases. Therefore, it is important to bear in mind that we are always using the same training samples in the supervised classification process in all following phases.

In the second phase the original QuickBird standard image that was already projected to Universal Transverse Mercator (UTM) projection was rectified in order to conform to a local projection Egyptian Transverse Mercator (ETM) which was used in produce the cadastral maps that are published by the Egyptian General Survey Authority (EGSA) after the rectification step the image was resampled by using the different traditional resampling methods (Nearest neighbor, Bilinear interpolation, and Cubic convolution) after that the three resampled (geo-coded) images were classified by using the same training samples that was used in classification of the original image. The classification results for the three images were compared with the results of the original image to evaluate the effect of the resampling methods.

The effect of image compression was investigated in phase three by applying the compression technique was based on wavelet transformations algorithm on the original image and use different compression ratios (C.R) that is computed as the ratio between the size of the original file and the compressed file. It was begun from lossless compression ratio that was 2.5:1 but when the compression ratio was increased above this ratio the compression became lossy then it was used seven lossy compression ratios that were (5:1, 7.5:1, 10:1, 12.5:1, 15:1, 17.5:1, and 20:1). The compressed images were produced in two wavelet-based formats the first one was the

(JPEG2000) ISO standard format and the second was Multi-resolution Seamless Image Database (MrSID) industry standard format and were classified by using the same training samples that was used in classification of the original image. Finally, the classification results for this phase compared with the results of the original image to assess the influence of the different wavelet-based formats in different compression ratios.

The last phase was involved in investigation of the effect of different resampling methods in addition to the different compression wavelet-based formats on the classification results so we applied the rectification and resampling (geo-coding) process on the set of compressed images that were already compressed in phase three. After this step the classification process was performed and the obtained classification results were compared with the classification results in previous phases.

2.2.2. Second data set (IKONOS)

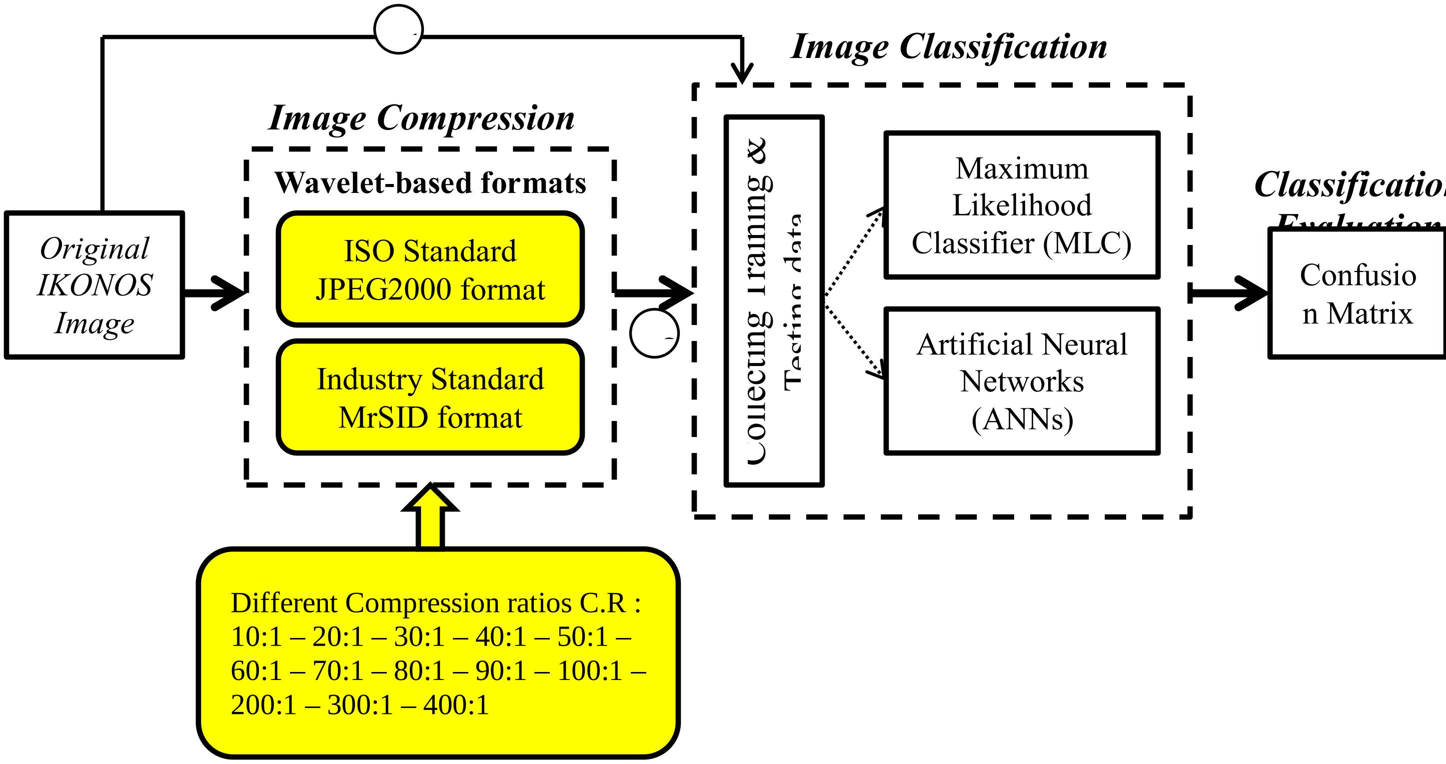


Figure [7] Block diagram for the basic steps for second data set. The workflows of steps are shown by using the continuous and continuous bold arrows, respectively.

The purpose of the second study for the second data set is to investigate the impact of image compression by using the same wavelet-based formats (JPEG2000 and MrSID) on the land-cover classification accuracy of a big size (2.5 GB) IKONOS RGB rectified image. By logic the methodology steps for this data set was divided into two steps. The first step is the classification of the original image and the second one is the classification of the image after compressing process. Fig. [7] shows the diagram of block diagram for the basic steps for the second data set.

Two different supervised classification methods [Maximum Likelihood classifier (MLC) and Artificial Neural Networks (ANNs) using backpropagation] were used in this methodology steps in order to comparing between the classification results by using the parametric (statistic) classification algorithm with non-parametric classification algorithm. This comparison allows us to conclude which classifiers are more affected by compression.

In the first step, the classification process was conducted on the original true colour IKONOS image by using the both classification methods (ANNs and MLC). Subsequently, the second step was implemented where the original image was compressed to either a single JPEG2000 or MrSID file. This compression process was carried out by using LizardTech GeoExpress 8.0 software. Different compression ratios (C.R) were used (10:1, 20:1, 30:1, 40:1, 50:1, 60:1, 70:1, 80:1, 90:1,100:1,200:1, 300:1, and 400:1). The twenty six compressed images (thirteen for each compression format) were then decompressed to feed the classification process which consisted of two different classification methods (MLC) and (ANNs).

Finally, the classification results for both classifiers were compared with the results of the original image to assess the effect of the different wavelet-based formats in different compression ratios and also on both classification method.

3. Results

3.1.The results and discussions for the first data set (QuickBird)

3.1.1. The classification results of the original image

According to the classification system which has been used for the first study area (Alexandria), the original image was classified into nine land-cover classes these classes were: water, shadow, road, grass, tree, sand, concrete, urban, and white urban. The classification stage was carried out by using Maximum Likelihood Classifier (MLC) algorithm and the classified image (Thematic map and its legend) which were derived from the classification process shown in Fig. [8]. A total of 30565 pixels were selected for the testing samples plots which had been previously defined for the classification assessment. The overall accuracy of the classified image which was obtained from the original image was (82.26%), according to the confusion matrix of the original classified image and Overall Kappa statistics of the original classified image was (0.7952).

3.1.2. Overall classification accuracy for phase (two, three and four)

3.1.2.1. Phase two: Classification of the Geo-coded images

In this phase, the original QuickBird standard image was rectified in order to conform to a local projection (ETM) by using GCPs that were collected from the reference cadastral maps of scale 1:5000. The output image was produced in the same spatial resolution (2.4m) but in a new grid which have geographic coordinates belong to the local projection (ETM). There are three method of resampling which use to compute the digital numbers (DN) values to fill that new grid. These resampling methods are (Nearest neighbor NN, Bilinear interpolation BI, and Cubic convolution CC) after that the three resampled (geo-coded) images were classified by using the same training samples that were used in classification of the original image to compare their classification results with the classification result of original image.

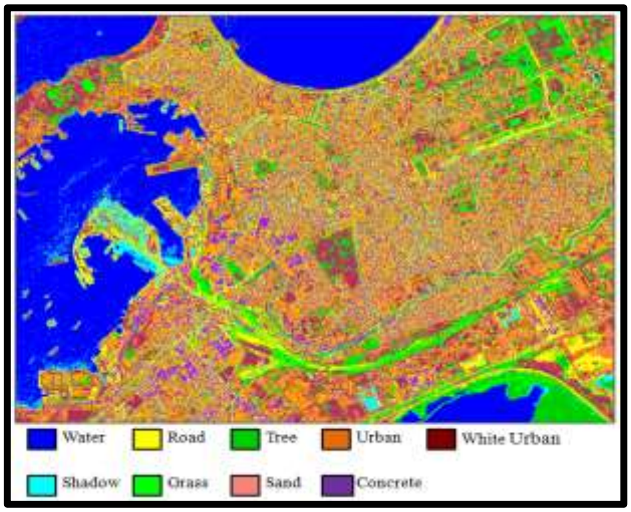


Figure [8] Thematic map derived from the classification of the original image

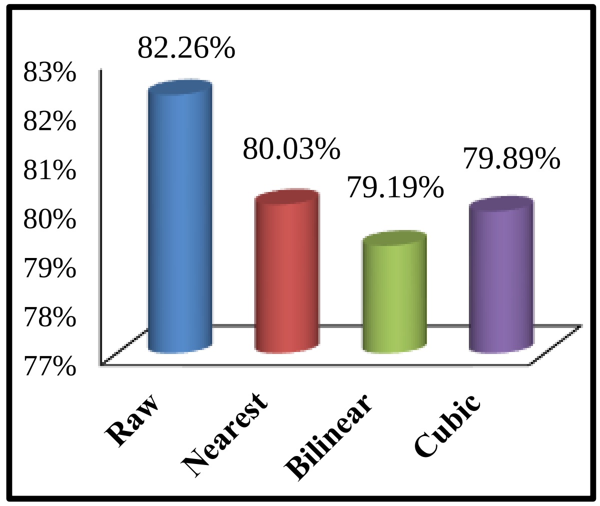


Figure [9] The MLC Overall Accuracy of Raw (original) Image and the Geo-coded images

The overall accuracy for the raw (original) classified image and the overall accuracy for the three resampled images are shown in Fig. [9], these results reveal that the classified image of the original data introduced the highest overall accuracy of (82.26%) among the overall accuracies for other three resampling methods. The nearest neighbor (NN) resampling method given the overall accuracy of (80.03%) which was higher than the accuracies that were obtained with the cubic convolution (CC) and the bilinear interpolation (BI) resampling methods but still lower than the accuracy of the original image by (2.23%).

Summarizing, it can easily imply that all the resampling methods degrade the classification accuracy although some literature were reveled that the resampling processes improve the classification accuracy such as [Dikshit, O. and Roy, D.P., 1996; Arun, P. V., 2013].

3.1.2.2. Phase three: Classification of the compressed images

The original QuickBird image (which consists of 4 bands) was compressed to either a single JPEG2000 or MrSID compressed file in this phase. A total of sixteen compressed images (eight for each compression format) with different compression ratios (C.R) were decompressed to feed the classification process. Finally, the classification results for this phase were compared with the results of the original image to assess the influence of the different wavelet-based formats in different compression ratios. These results are shown in Fig. [9] which introduce the relationship between the overall classification accuracy and compression ratios for each wavelet-based format. According to these results which were obtained from classification of the JPEG2000 compressed images the overall accuracy were slightly increased with growing the compression ratio until the compression ratio reached to (5:1) where the overall accuracy was (82.68%). This accuracy was higher than the overall accuracy for the classified uncompressed (original) image by (0.42%). After this compression ratio the overall accuracy were gradually decreased where the worst overall accuracy was at compression ratio (20:1).

In case of the MrSID compressed images, the overall accuracy were lower than the overall accuracy of uncompressed image by small value at the compression ratio (2.5:1) but it reached to the highest accuracy at the same compression ratio for the JPEG2000 compressed images (5:1) where the MrSID accuracy was improved by (0.07%) if it was compared with the accuracy of

original image. Also, the degradation of accuracy in MrSID case occurred after the compression ratio (5:1) until (20:1) but with small rate.
In general, the overall accuracies of JPEG2000 compressed images were better than the overall accuracies of MrSID compressed images up to compression ratio (10:1) after this compression ratio the overall accuracies of MrSID compressed images became the higher because the degradation in accuracy of JPEG2000 compressed images was worse than the degradation in the overall accuracy of MrSID compressed images.

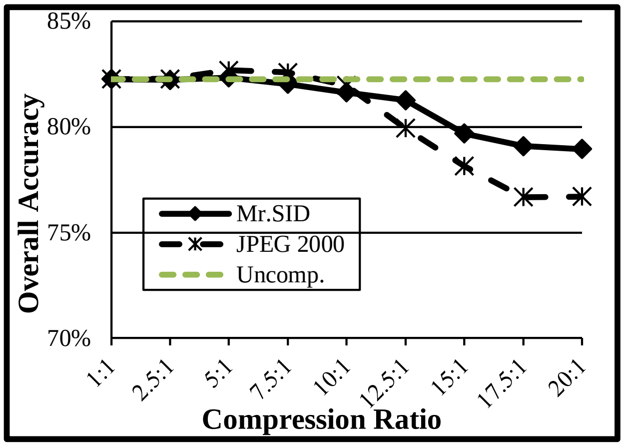


Figure [9] Overall accuracy of compressed images in different CRs.

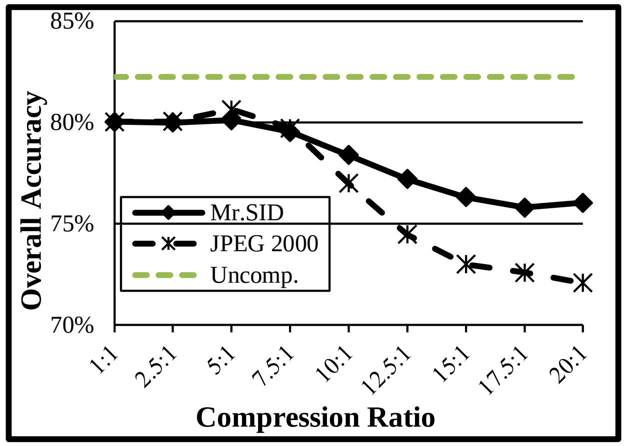


Figure [10] Overall accuracy of compressed Nearest Neighbor resampled images with increasing CRs.

3.1.2.3. Phase four: Classification of the compressed images after Geo-referencing process

The main purpose of this phase is the investigation of the effect of different resampling methods in addition to the influence of the both compression wavelet-based formats on the classification results. Thus, the rectification and resampling processes were applied on the sixteen compressed images that were obtained from the phase three. The results of a total of 48 compressed and resampled images (16 for each resampling method) will be divided into four subsections.

➢ Overall classification accuracy of Nearest Neighbor (NN) compressed images

According to the results of the phase two, it is obvious that the overall accuracy which was obtained from the nearest neighbor classified image was less than the classification accuracy of the original image by (2.23%). Fig. [10] shows the overall classification accuracy of the Nearest Neighbor geo-coded compressed images (in Mr.SID and JPEG2000 compression formats).
As shown in results of the previous section the overall accuracy of the JPEG2000 and MrSID compressed images also raised with increasing the compression ratio up to compression ratio (5:1). But after the compression ratio (7.5:1), the overall accuracy of JPEG2000 was significantly decreased with increasing the compression ratio where the total deterioration of the accuracy at the highest compression ratio was (7.95%) if it was compared with the overall accuracy of the uncompressed Nearest Neighbor resmapled image. The overall accuracy of MrSID compressed images was also decreased but its degradation rate was lower than the degradation rate of the classification accuracy for JPEG2000 images. At the compression ratio (20:1) the difference between accuracy of MrSID compressed image and the overall accuracy for uncompressed NN resampled image was (3.99%).

The overall accuracy of MrSID and JPEG2000 were approximately equal at compression ratio (2.5:1) but the overall accuracy of JPEG2000 was better than the MrSID accuracy at compression ratio (5:1 and 7.5:1) after this compression ratio the overall accuracies of MrSID were higher than the JPEG2000 accuracies.

- Overall classification accuracy of Bilinear Interpolation (BI) compressed images

In case of the Bilinear Interpolation resampled image, the overall classification accuracy was the worst accuracy among the classification accuracies of other resampled images. Increasing of the compression ratio leads to increasing in classification accuracy of the JPEG2000 compressed images until compression ratio (5:1) but this accuracy was dramatically decreased after compression ratio (7.5:1) and was reached to the least accuracy at compression ratio (20:1) as shown in Fig. [11]. On the other hand, the classification accuracy of MrSID compressed images was approximately constant at the compression ratio (2.5:1) but it was increased by (0.05%) at compression ratio (5:1). Then, it began in decreasing by slight rate where the accuracy at compression ratio (20:1) was lower than the accuracy of uncompressed Bilinear Interpolation resampled image by (2.79%). Also, The overall accuracy of MrSID and JPEG2000 were approximately equal at compression ratio (2.5:1) but the overall accuracy of JPEG2000 was better than the MrSID accuracy at compression ratio (5:1 and 7.5:1) after this compression ratio the overall accuracies of MrSID were higher than the JPEG2000 accuracies.

- Overall classification accuracy of Cubic Convolution (CC) compressed images

The classification accuracy was obtained from the Cubic Convolution resampled images was in-between of the Nearest Neighbor and Bilinear Interpolation classification accuracies where it was lower than the accuracy of the original image by (2.37%).
The classification accuracy of the JPEG2000 and MrSID compressed images which resampled by Cubic Convolution method were constant at compression ratio (2.5:1) and simultaneously increased at the (5:1) compression ratio where the best accuracy of the JPEG2000 compressed images was higher than the accuracy of the Cubic Convolution resampled uncompressed image by (0.47%) as illustrated in Fig. [12]. But after (7.5:1) the accuracy of MrSID and JPEG2000 compressed images were dropped down with increasing the compression ratio but the accuracy of MrSID was still better than the accuracy of JPEG2000.

- Comparison for overall classification accuracy of the three resampling methods

  - ✓ *In case of Mr.SID compressed image*

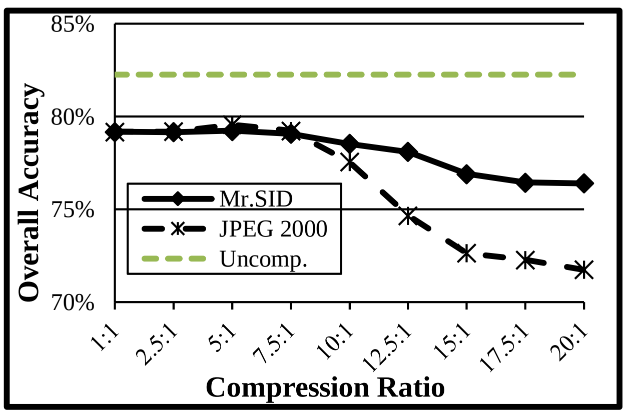
The overall classification accuracies of the compressed images (whether these images were produced from compression process for the original image or the resampled images) had the same behavior with increasing the compression ratios. Where the accuracies of the compressed images were increased at compression ratio (5:1) by small value where the best increasing was (0.21%) in case of CC resampled images. After that the accuracies were decreased with increasing the compression ratios but their deterioration rate differs depending on its case as shown in Fig. [13] that shows the overall accuracies of MrSID compressed images for all cases (Original image, Nearest Neighbor, Bilinear Interpolation, and Cubic Convolution).
Despite the classification accuracy of NN was the best among the accuracies of CC and BI resampled methods in case of the uncompressed images, the deterioration in classification

accuracy was the highest by (3.99% from the accuracy of uncompressed NN image), If it was compared with the degradation in accuracy in case of BI and CC even with the degradation in accuracy of original image. Moreover, although the accuracy of BI method was the worst among the other resampling methods especially at the first compression ratios up to (7.5:1), its degradation rate in accuracy was the least if it was compared with degradation rate in accuracy for CC and NN resampling methods. While the CC and NN were nearly equal at the same compression ratios (also up to 7.5:1). But after compression ratios (10:1), the accuracies of BI became the best and NN was the least while the CC was in-between of them.

✓ *In case of JPEG2000 compressed images*

In case of JPEG2000 compressed image, overall accuracy of compressed resampled images by any resampling methods were behaved by the same way which was identical with the behavior of the overall accuracy of original compressed images where the accuracy was slightly increased up to the compression ratio (5:1). At this compression ratio the NN resampling method was introduced the best overall accuracy among the other resampling methods. But after (5:1) compression ratio, the overall accuracy was dramatically degraded until it reached the highest compression ratio (20:1) where the worst accuracy for all resampling methods was.

From Fig [14], it easy to imply that the best overall accuracies among the resampling methods were the accuracies of NN compressed images at first two compression ratios (2.5:1 and 5:1) while the accuracies of the CC compressed images were less than the NN compressed images which were higher than the BI compressed images. This order differs in medium compression ratios (7.5:1, 10:1 and 12.5:1) but at high compression ratio the accuracies of NN and CC compressed images were approximately identical at all compression ratios (15:1, 17.5:1 and 20:1) and the accuracies of BI compressed images were still the least if they were compared with other methods.



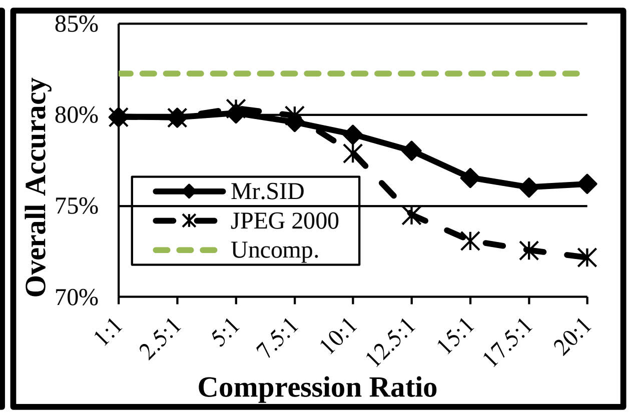


Figure [11] Overall accuracy of compressed Bilinear Interpolation resampled images with increasing CRs.

Figure [12] Overall accuracy of compressed Cubic Convolution resampled images with increasing CRs.

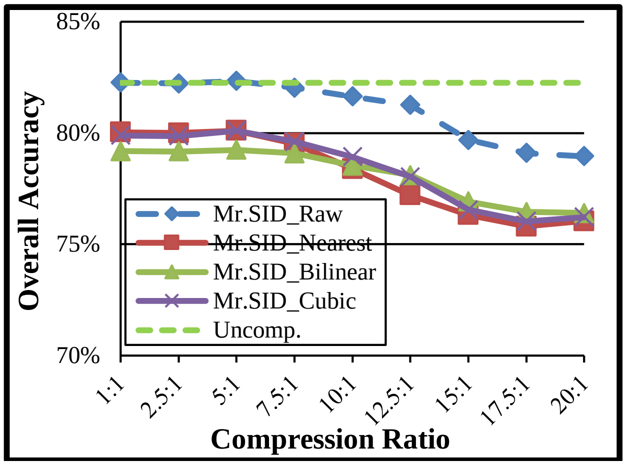


Figure [13] Overall accuracy of Mr.SID compressed (original image) and (NN, BI, and CC resampled images) with increasing CRs.

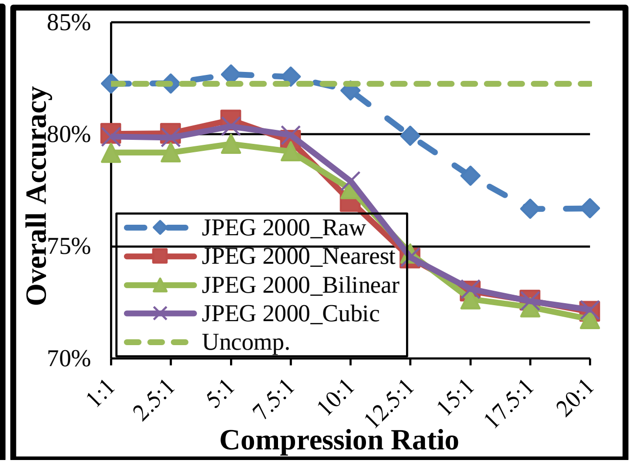


Figure [14] Overall accuracy of JPEG2000 compressed (original image) and (NN, BI, and CC resampled images) with increasing CRs.

3.2.The results and discussion for the second data set (IKONOS)

3.2.1. The classification results of the original IKONOS RGB image

In the beginning, the selection of appropriate classification scheme was carried out depending mainly on the visual interpretation of the image. Eleven land-cover categories were used in the both classification methods which were denoted by; Water 1, Water 2, Water 3, Water 4, Sand 1, Sand 2, Sand 3, Sand 4, Urban 1, Urban 2, and Road & Grass. After this step, the training and testing samples were collecting from the original image to conduct the classification process. Finally, the two classification methods (Maximum Likelihood Classifier [MLC] and Artificial Neural Networks [ANNs]) were applied on the original IKONOS image and their results will be reported this section.

The thematic map and its legend derived from the MLC method is shown in Fig. [15]. Further, overall classification accuracy and Kappa coefficient of the original image by using the MLC method was computed from the confusion matrix was (88.3496% and 0.8682, respectively).

Artiicial Neural Networks (ANNs) using back-propagation classification process is implemented in two steps. Firstly, the training or learning step that requires a set of training samples with inputs and corresponding desired outputs. Basically, the training process is a search for a network interconnected with a suitable set of weights that can minimize the total differences between the network outputs and desired outputs for the training patterns. It can evaluate the performance of the learning step by the RMS error for training samples. After the reaching to the proper RMS error, the second step for (ANNs) classification process uses this network that was trained in the learning step to classify the unclassified pixels of the image to the suitable class.

Finally, the thematic map and its legend of the original image using the (ANNs) classification methods are shown in Fig. [16]. Also the overall classification accuracy and Kappa coefficient of the original image by using the (ANNs) method were (89.115% and 0.8761, respectively).

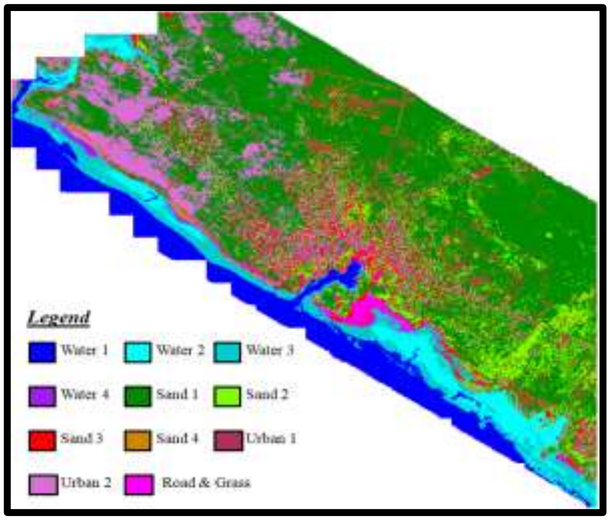


Figure [15] Thematic map derived from the classification of original image using Maximum Likelihood Classifier (MLC)

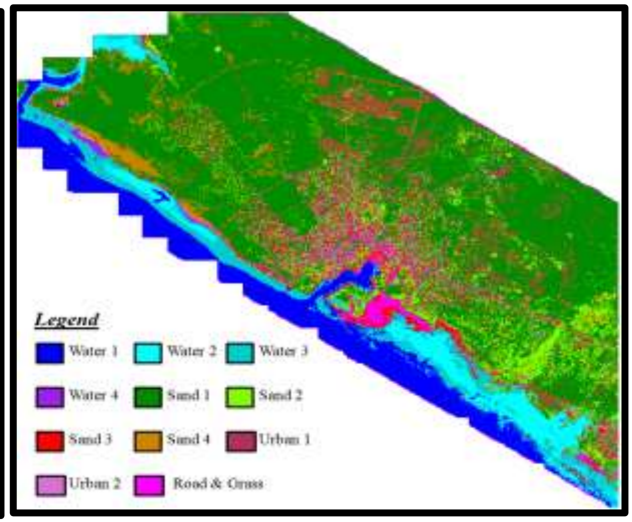


Figure [16] Thematic map derived from the classification of original image using Artificial Neural Networks (ANNs)

3.2.2. Overall classification accuracy of the compressed images

LizardTech GeoExpress 8.0 software was used to compress the original RGB IKONOS image (which consists of 3 visible bands) in either a single JPEG2000 or MrSID compressed file and also in different compression ratios (C.R) for each format. It was used thirteen lossy compression ratios that were (from 10:1 to 100:1, 200:1, 300:1, and 400:1). The twenty six compressed images (thirteen for each compression format) were then decompressed to feed the classification process which consisted of two different classification methods (MLC) and (ANNs). Finally the classification results for both classifiers were compared with the results of the original image to assess the effect of the different wavelet-based formats in different compression ratios and also on both classification method.

Fig. [17] shows the relationship between the overall classification accuracy and compression ratios for each wavelet-based format in case of (MLC). This results show that the accuracy of the JPEG2000 approximately remains constant up to compression ratio (30:1) where the accuracy is higher than the accuracy of the uncompressed image by small value. Then it reduces by small rate between compressions ratios (30:1) to (80:1) after that the decreasing rate become higher up to compression ratio (200:1). Finally, the accuracy sharply diminishes where the difference in accuracy between the compressed image in high compression ratio (400:1) and the accuracy of uncompressed image was (13.82%). But the accuracies of the MrSID compressed images are also constant until it reaches the compression ratio (100:1) after this compression ratio the classification accuracy of the MrSID images decreased by small value (about 4.35% at compression ratio 400:1).

By comparing the accuracy of MrSID and JPEG2000 compressed image, it is obviously that the accuracies of MrSID compressed imaged are approximately equal with the accuracies of JPEG2000 compressed images up to compression ratio (50:1). However, after this compression ratio the accuracy of JPEG2000 decreases in spite of the MrSID compressed image preserve of the classification accuracy of the original image until the compression ratio (100:1). In high compression ratio (after 100:1) MrSID accuracy also degrades but still better than the JPEG2000 accuracy.

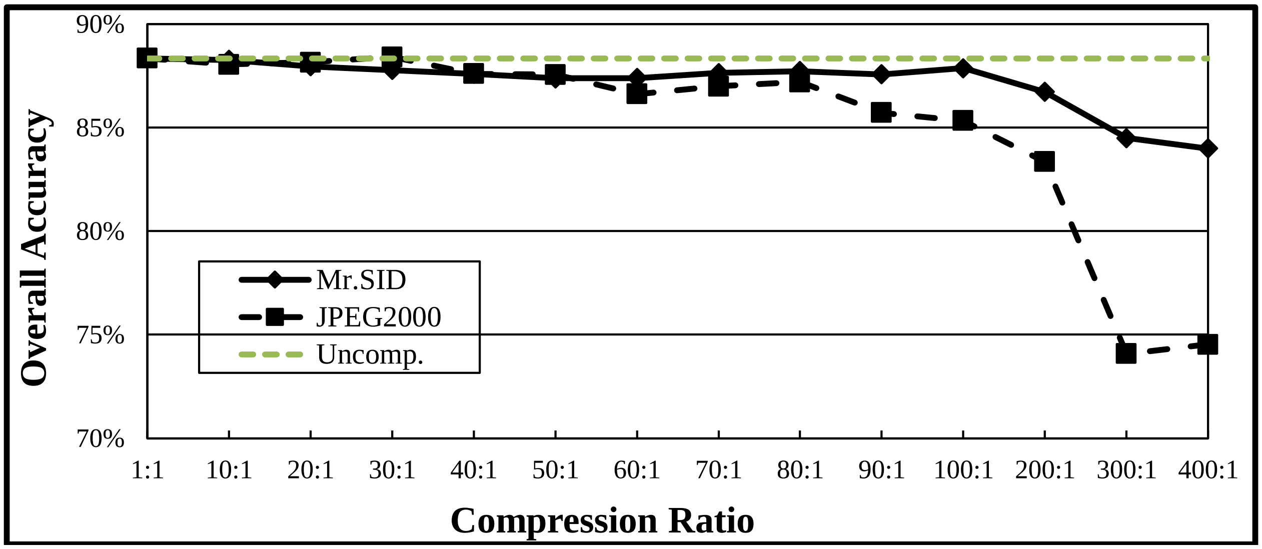


Figure [17] Overall accuracy of compressed images in different CRs in case of (MLC)

In case of (ANNs) classification method, the classification accuracy of JPEG2000 decreases up to (30:1) but surprisingly increases at compression ratio (40:1) after that it returns to deterioration by slightly rate until the compression ratio (100:1) where this deterioration from the original accuracy is (1.58%). After this compression ratio, the accuracy dramatically reduces where the difference in accuracy was (8.73%) at compression ratio (300:1) if it is compared with the original accuracy.
The accuracy of MrSID equals the accuracy of the JPEG2000 at first compression ratio (10:1). Likewise, the MrSID classification accuracies also reduced up to compression ratio (20:1). After this compression ratio, we can easily find that the accuracy of MrSID compressed image is approximately constant in all compression ratios as shown in Fig. [18]. Despite of the accuracy of MrSID compressed images slightly changes at higher compression ratios (after 100:1). Consequently, it can be said that the accuracy of the MrSID compressed image do not change with increasing compression ratio after (20:1). In general, the accuracy of JPEG2000 is higher than the accuracy of MrSID at compression ratios between (10:1) to (100:1). After compression ratio (100:1) the accuracy of MrSID become the higher.

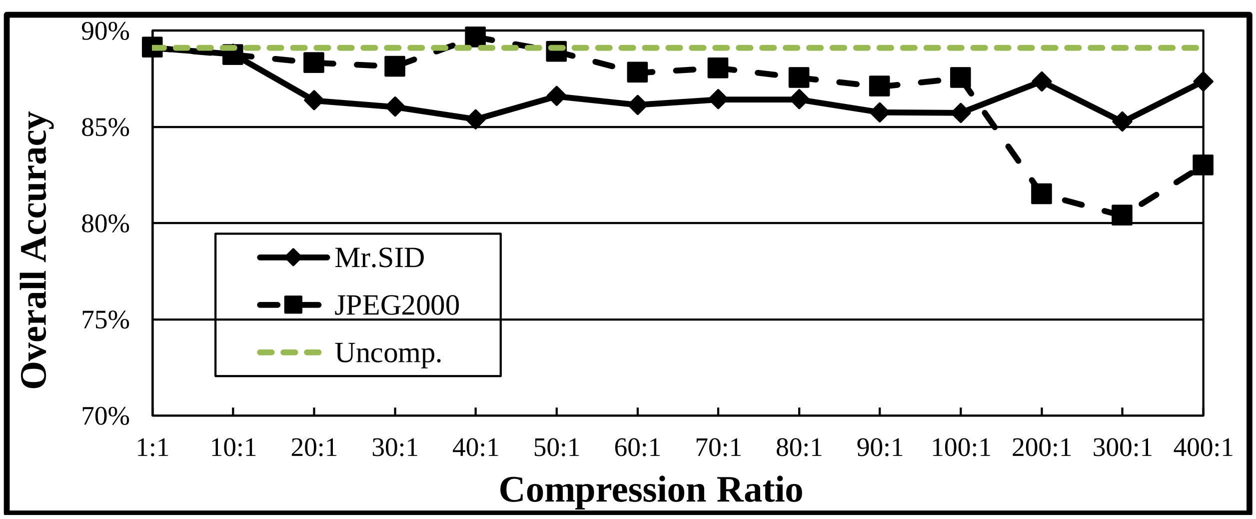


Figure [18] Overall accuracy of compressed images in different CRs in case of (ANNs)

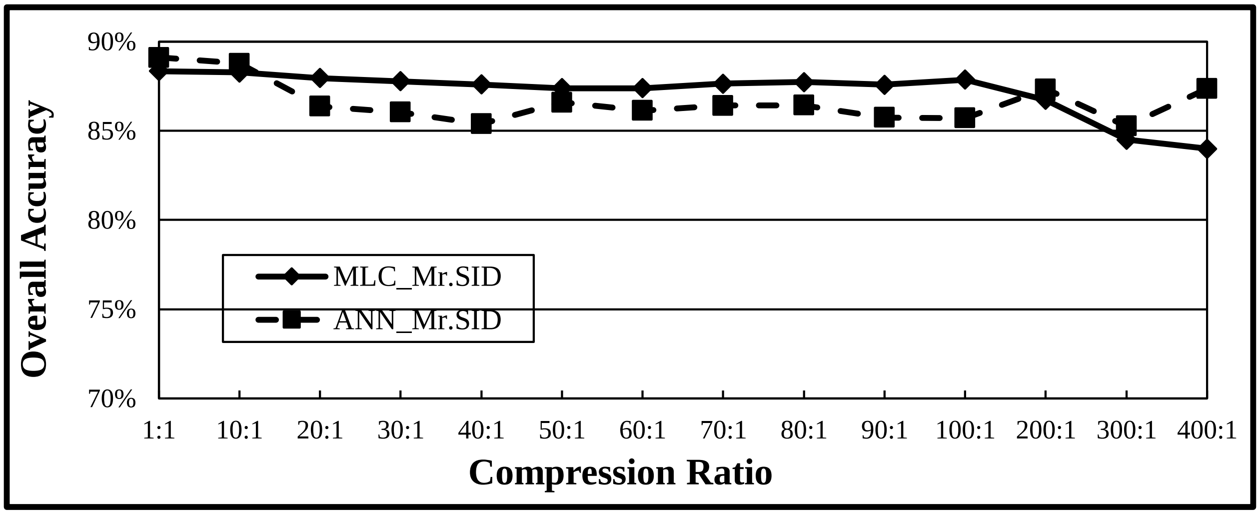


Figure [19] Overall accuracy of MrSID compressed images in different CRs.

Nevertheless, Fig. [19] shows the relationship between the classification overall accuracy and the compression ratio for the MrSID compressed images for the two different classifier (MLC) and (ANNs). It can be deduced that the accuracy of the MrSID compressed images for (MLC) classification method is higher than the classification accuracies that were obtained from the (ANNs) between compression ratios (10:1) to (200:1). However, at the two last compression ratios the accuracy of (ANNs) became higher than the accuracy of (MLC).

The comparison between the classification accuracy of (ANNs) and (MLC) methods for the JPEG2000 compressed image is shown in Fig. [20]. From this comparison, we can derive that the classification accuracy of (ANNs) is approximately better than the accuracy of (MLC) at all compression ratios but by small value except the accuracies at higher compression ratios (300:1) and (400:1) because of the increasing of degradation in accuracy of (MLC) for (ANNs).

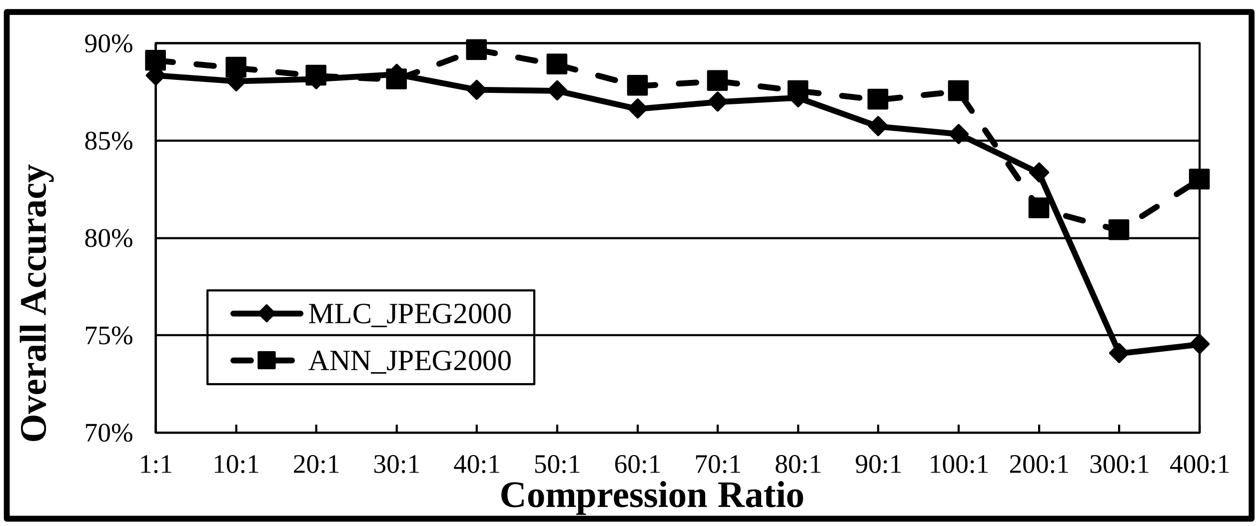


Figure [20] Overall accuracy of JPEG2000 compressed images in different CRs

4. Conclusion & Recommendations

- The overall classification accuracy of Mr.SID compressed images is better than the overall classification accuracy of JPEG2000 compressed images especially at the high compression ratio for two data sets.

- All of resampling methods (NN, BI, and CC) have an adverse effect on the overall classification accuracy. Those, the results suggest that it is not advisable to perform the image resampling operation before the classification for the compressed images. Moreover, the results showed that the overall classification accuracy of NN resampling method was the best accuracy among the accuracies of other resampling methods (BI and CC) where it was the closest to the accuracy of the original image.
- The overall accuracies of JPEG2000 compressed images were slightly better than the overall accuracies of Mr.SID compressed images up to C.R (10:1) in case of original compressed images and C.R (7.5:1) in case of resampled compressed images (whether NN, BI, or CC), after these C.R the overall accuracies of Mr.SID compressed images became the higher.
- Despite the results suggest that it is not advisable to perform the image resampling operation before the classification of the compressed image, the selection of appropriate resampling method for compressed image depends on which wavelet-based format was used and the compression ratio of this image. Where the results explored that if the compressed image was in JPEG2000 format, the suitable resampling method is NN resampler at first two compression ratios (2.5:1 and 5:1) after (5:1) the results recommend CC resampler at any compression ratios. But in case of MrSID format, also the NN is the adopted resampler at first two compression ratios and at medium compression ratios (7.5:1 and 10:1) the CC resampler is, While the BI is the appropriate resampler at higher compression ratios (after 10:1).
- In second data set (IKONOS) and in the case of (MLC) method, the overall accuracies of MrSID and JPEG2000 compressed images were nearly equal until C.R (50:1), But In the case of (ANNs) method; the overall accuracies of JPEG2000 were the best up to C.R (100:1). After these C.R the overall accuracies of Mr.SID compressed images became the higher.

- If it is used the MrSID format, the (MLC) method will give the best overall classification accuracy. But in case of using the JPEG2000 format, the convenient classification method is (ANNs) method.

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