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THE EFFECT OF JPEG2000 COMPRESSION ON REMOTE SENSING DATA OF DIFFERENT SPATIAL RESOLUTIONS

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Abstract. The huge size of remote sensing data implies the information technology infrastructure to store, manage, deliver and process the data itself. To compensate these disadvantages, compressing technique is a possible solution. JPEG2000 compression provide lossless and lossy compression with scalability for lossy compression. As the ratio of lossy compression getshigher, the size of the file reduced but the information loss increased. This paper tries to investigate the JPEG2000 compression effect on remote sensing data of different spatial resolution. Three set of data (Landsat 8, SPOT 6 and Pleiades) processed with five different level of JPEG2000 compression. Each set of data then cropped at a certain area and analyzed using unsupervised classification. To estimate the accuracy, this paper utilized the Mean Square Error (MSE) and the Kappa coefficient agreement. The study shows that compressed scenes using lossless compression have no difference with uncompressed scenes. Furthermore, compressed scenes using lossy compression with the compression ratioless than 1:10 have no significant difference with uncompressed data with Kappa coefficient higher than 0.8.

Keywords: *compression, effect, spatial resolution, remote sensing, JPEG2000*

1 INTRODUCTION

Rapid improvement in satellite technologies encourages providers to produce various spatial, temporal and radiometric resolution imagery. The advent of new remote sensing platforms and sensors would generate an increasing amount data set day by day (Zabala *et al.* 2012b). The huge size of remote sensing data needs a high capacity of storage, computational resource for processing, and bandwidth channel for transmission. Compressing technique is a possible solution to cope the problem with remote sensing data management.

Compression techniques evolved in recent years from discrete cosine transform (such as JPEG) to wavelet-based algorithm (such as JPEG2000). Previous research on image compression concluded that the latter obtain the better result (Zabala *et al.* 2012a; Zabala and Pons 2013). JPEG2000 became ISO standard in 2000 and revised in 2004 (ISO/IEC 2004). JPEG2000 compression can be performed in a lossless (reversible and no information lost) and lossy (irreversible, allows a higher level of compression with information lost as a trade off). JPEG2000 provides advantages in more various and flexible scalability than JPEG, in which compression ratio is adjustable (Taubman and Marcellin 2002).

Studies about the effect of JPEG compression has been performed in many fields such as in medical (Sung *et al.* 2002; McEntee *et al.* 2013). As for remote sensing, Shrestha *et al.* (2005) has been giving assessment on JPEG2000 compression for Quickbird data; Zabala *et al.* (2006) compared JPEG and JPEG2000 lossy compression for crops and forest classification using hybrid classification method; Zabala *et al.* (2012a) compared on-board compression at Sentinel-2 and user-side compression at Landsat 8 using JPEG2000 for image quality and land cover classification; Zabala *et al.* (2012b) investigated JPEG2000 compression at orthophotos with 1m spatial resolution for segmentation-based classifications; while Zabala and Pons (2013) studied JPEG and JPEG2000 compression effect for classification at Landsat 5 using hybrid classifier, maximum likelihood, and minimum distance classifiers method.

While previous papers most likely to focus on one type of data to study the effect of compression, this paper tried to investigate the effect of JPEG2000 compression on remote sensing data with different spatial resolution. Therefore remote sensing data users could examine which ratio is best to be applied to their data.

2 MATERIALS AND METHODOLOGY

2.1 Data and Location

Data used in this experiment were Landsat 8 from path 114 row 064 acquired at September 8, 2015; SPOT 6 acquired at July 27, 2016; and two Pleiades data acquired at September 2, 2013 and May 14, 2014. These data were chosen based on location which cover a part of South Sulawesi area with minimum cloud cover. Spectral bands used were the visible bands and NIR band, namely band 2, band 3, band 4 (visible bands) on Landsat-8 and band 1, band 2, band 3 (visible bands) for SPOT 6 and Pleiades.

Those three types of data were chosen to represent different spatial resolutions. Landsat 8 OLI bands have a spatial resolution of 30 meters, while multispectral bands of SPOT 6 and Pleiades bands have 6 meters and 2 meters of spatial resolutions, respectively.

2.2 Assesment Method

Figure 2-1 shows the flow of the study sequence starting from data collection up to accuracy assessment. All data compressed into JPEG2000 format with five different ratios (lossless, 4:1, 10:1, 20:1, 100:1). This study utilized OpenJPEG version 2.1. to perform the JPEG2000 compression. OpenJPEG is an open-source library, which has officially recognized by ISO/IEC as JPEG2000 reference software (ITU-T 2015).

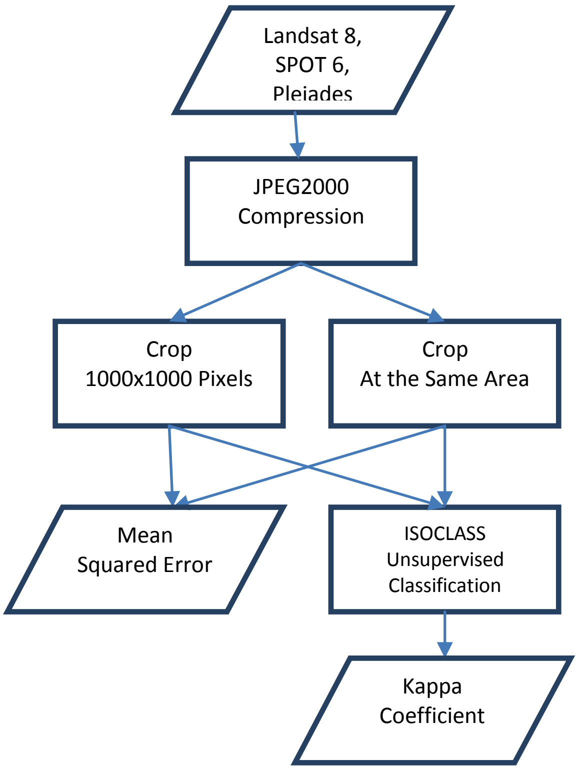


Figure 2-1: Assessment methodology

After compressed, all the data (compressed and uncompressed) were cropped with two different approaches (Figure 2-2). First, these data were cropped into scenes with exactly 1000x1000 pixels-size. Second, all data were cropped into scenes at the exact same area. The scenes were chosen by considering different land cover, which led to different fragmentation.

MSE values were measured using equation (2-1) where *u(m,n)* and *v(m,n)* represent two scenes of size *MxN*, in this case, *u* represent the uncompressed scene and *v* for the compressed scene. Although MSE criticized for heavily weighting outliers (Bermejo 2001), this study tried to see whether there was any relation between different spatial resolution, different standard deviation, and the MSE escalation at every compression ratio level.

$$MSE(u,v) = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}|u(m,n) - v(m,n)|^2 \quad (2\text{-}1)$$

All scenes also processed to ISOCLASS unsupervised classification. Classification results then used to calculate Kappa coefficient using equation (2) where p_o represents the actual observed agreement, and p_e represents chance agreement. Both p_o and p_e were calculated from ISOCLASS unsupervised classification results of uncompressed scenes and compressed scenes.

$$\kappa = \frac{p_o - p_e}{1 - p_e} \quad (2\text{-}2)$$

Kappa coefficient introduced in Cohen (1960). Cohen suggested the Kappa result to be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81– 1.00 as almost perfect agreement. However, this interpretation may be problematic as if 0.61 interpreted as substantial, 40% of the data in dataset represent faulty data (McHugh 2012).

In that way McHugh (2012) suggested interpreting Cohen's Kappa as (Table 2-1).

Landsat 8 SPOT 6 Pleiades

Figure 2-2: Cropped satellite imagery over the study area. at the first row, data cropped into 1000x1000 pixels, at the second row, data cropped in the exact same area

Table 2-1: Interpretation of cohen's Kappa

Value of Kappa	Level of Agreement	% Data that are Reliable
0.00 - 0.20	None	0 – 4%
0.21 - 0.39	Minimal	4 – 15%
0.40 - 0.59	Weak	15 – 35%
0.60 – 0.79	Moderate	35 – 63%
0.80 – 0.90	Strong	64 – 81%
≥ 0.90	Almost Perfect	82 – 100%

Source: McHugh, 2012

3 RESULTS AND DISCUSSION

Figure 3-1 shows that JPEG2000 compression affected the appearance of the data visually. From every tested Landsat 8 scenes, there was no significant visible change up to the ratio 4:1. A notable change was seen at scenes with compression ratio 10:1. Figure 3-1(b) shows compression start to affect at vegetation area, which is more homogenous than other areas (for example city area). Furthermore, SPOT 6 and Pleiades data, which have finer resolution, provided better compression result. Their homogenous area (represented by vegetation) started to blur at compression ratio 20:1 with Pleiades being visibly better than SPOT 6.
This result agrees with Shrestha, *et al* (2005) that suggested 10:1 as a save ratio for JPEG2000 compression to Quickbird data which have spatial resolution 1m.

Mean Square Error

As a tradeoff for smaller file size, a higher compression ratio for lossy compression commonly generates a higher error. Nevertheless, lossless compression JPEG2000 proved to be reversible and provide information as it is.

All scenes, which have been cropped to 1000x1000 pixels, then processed to measure their MSE values. Every scene from every data that was compressed with lossless compression has 0 MSE value, which means that lossless compression has not given any effect. Therefore, scenes that compressed using lossless compression have no difference with uncompressed scenes. While scenes that compressed with lossy compression indicate different MSE increment for every data as shown in Figure 3-2.

The effect of compression to MSE value (at each data which cropped at city area) is shown in Figure 3-2. As expected, Landsat 8 is most affected by higher lossy compression ratio, therefore it has the highest MSE value among other data. Significant differences of MSE value between Landsat 8 and another data started to rise at the compression ratio of 4:1. While significant differences of MSE value between SPOT 6 and Pleiades data started at the compression ratio of 20:1. This trend is also implied to other bands (blue and green) and another area (forest area).

Kappa Coefficient

All cropped scenes were classified using ISOCLASS unsupervised classifier and their Kappa coefficient evaluated. Kappa coefficient results from every scene (that cropped into 1000x1000 pixels) in the same data then calculated to get the average of Kappa coefficient.

Table 3-1 shows the average of Kappa coefficient for every data. It stated that scenes which were compressed using lossless compression have Kappa coefficient of 1, which means perfect agreement. While, the compression ratio up to 10:1 provides Kappa coefficient higher than 0.8 which indicates strong agreement with providing more than 64% reliable data.

As shown in Table 3-1, the average of Kappa coefficient from ISOCLASS unsupervised classification does not seem to have a linear correlation with spatial resolution in this case. There are other factors that give influence on Kappa coefficient than just the difference of spatial resolution.

(a) Landsat 8 uncompressed (b) Landsat 8 compressed 10:1 (c) Landsat 8 compressed 20:1

(d) SPOT 6 uncompressed (e) SPOT 6 compressed 10:1 (f) SPOT 6 compressed 20:1

(g) Pleiades uncompressed (h) Pleiades compressed 10:1 (i) Pleiades compressed 20:1

Figure 3-1: JPEG2000 compression effects on Landsat 8 (a, b, c), SPOT6 (d, e, f), and Pleiades (g, h, i). red circles show homogenous areas that are more affected by compression

For instance, Table 3-2 shows result from classification at different areas of SPOT 6 data. Crop area shown in Table 3-2(c) appeared to be less affected by compression, compared to the less fragmented area shown in Table 3-2(a) (forest area). Therefore, Kappa coefficient for more fragmented area tends to have higher Kappa coefficient larger than those with less fragmented areas. In some cases, lower resolution data, which have more fragmentations, generate better MSE values and Kappa coefficients.

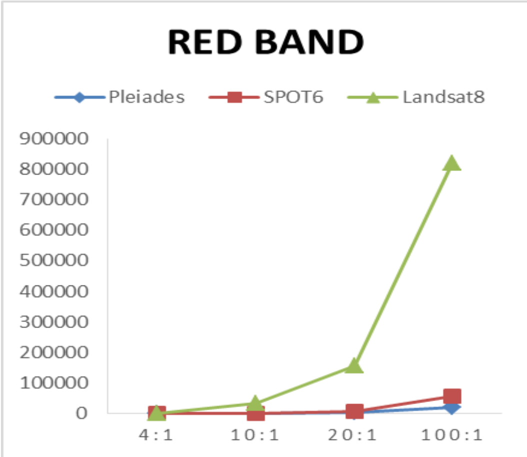
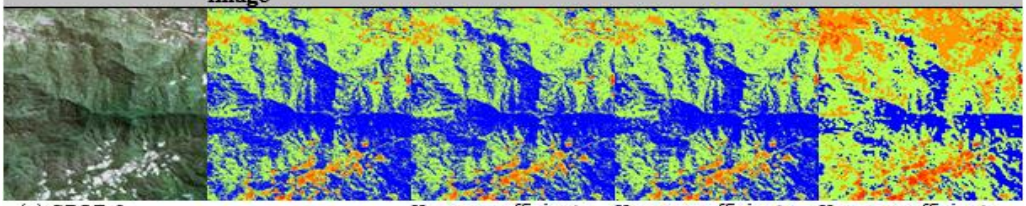
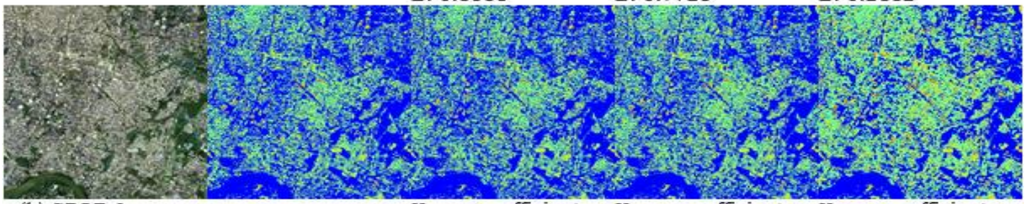
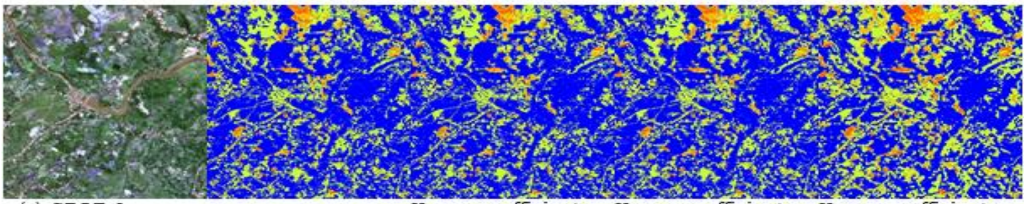


Figure 3-2: Correlation between compression ratio and MSE for Landsat 8, SPOT 6 and Pleiades (red band) data at city area. the x-axis shows compression ratio, while y-axis shows MSE values

Table 3-1: Kappa coefficient measurement

Compression Ratio	**Landsat 8** Blue	Green	Red	**SPOT 6** Blue	Green	Red	**Pleiades** Blue	Green	Red
lossless	1	1	1	1	1	1	1	1	1
4:1	0.9786	0.9820	0.9872	0.9217	0.9416	0.9553	0.9286	0.9556	0.9294
10:1	0.8969	0.8772	0.9179	0.8545	0.8560	0.9083	0.8404	0.9081	0.8941
20:1	0.7729	0.6731	0.8236	0.7595	0.7605	0.8286	0.7540	0.8211	0.8365
100:1	0.3804	0.3536	0.2454	0.1254	0.2280	0.4511	0.2001	0.5144	0.5755

Table 3-2: ISOCLASS unsupervised classification result at three different areas from SPOT 6 data

Uncompressed image	**Classification on uncompressed image**	**Classification on CR 10:1**	**Classification on CR 20:1**	**Classification on CR 100:1**
				
(a) SPOT 6 cropped at forest area		Kappa coefficient: R: 0.7802 G: 0.7936 B: 0.8588	Kappa coefficient: R: 0.7101 G: 0.7073 B: 0.7725	Kappa coefficient: R: -0.0846 G: -0.0708 B: 0.2182
				
(b) SPOT 6 cropped at city area		Kappa coefficient: R: 0.8851 G: 0.8827 B: 0.9160	Kappa coefficient: R: 0.7495 G: 0.7539 B: 0.8160	Kappa coefficient: R: 0.2370 G: 0.3084 B: 0.5178
				
(c) SPOT 6 cropped at crop area		Kappa coefficient: R: 0.8983 G: 0.8917 B: 0.9501	Kappa coefficient: R: 0.8190 G: 0.8203 B: 0.8972	Kappa coefficient: R: 0.2240 G: 0.4465 B: 0.6174

The way fragmented area tends to have higher Kappa coefficient confirmed by Zabala and Pons (2013), which concluded that fragmented images accept less effect from compression. Zabala and Pons (2013) recommended compression ratio 10:1 to 20:1 for more fragmented images and up to 100:1 for less fragmented images depending on the classifier. Zabala and Pons (2013) used Hybrid, Minimum Distance, and Maximum Likelihood classifier.

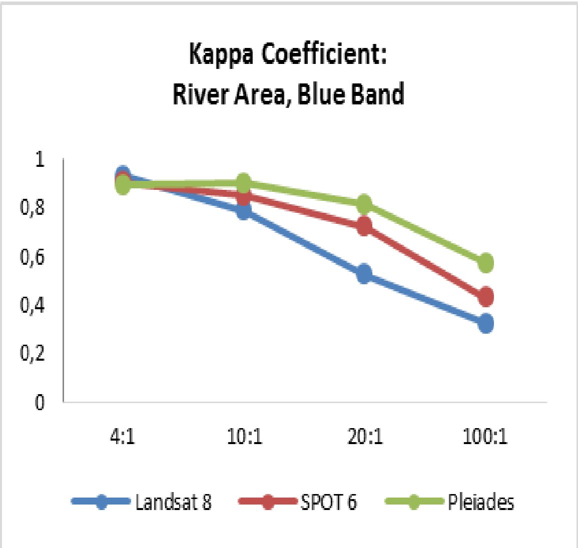


Figure 3-3: Correlation between compression ratio and Kappa coefficient for Landsat 8, SPOT 6 and Pleiades (blue band) data at river area. the x-axis shows compression ratio, while y-axis shows Kappa coefficient

To compare different spatial resolution, scenes that have been cropped at the same area are used. Different with Kappa coefficient result from scenes that cropped with the same size, Kappa coefficient from scenes cropped at the same area indicates a relation with spatial resolution.

Kappa coefficients of the finer spatial resolution generally higher than the coarser spatial resolution. However, at a low compression ratio of 4:1, Kappa coefficient of Landsat 8 was mostly higher than other data (Figure 3-3).

4 CONCLUSION

The study shows that compressed scenes using lossless compression have no difference with uncompressed scenes. Meanwhile, based on visual appearance, sufficient lossy compression ratio for Landsat 8 would be under 10:1 while for the SPOT 6 and Pleiades, the acceptable compression ratios are up to 20:1.

Higher compression ratio generates higher MSE. The MSE value shows a relationship with the spatial resolution where lower spatial resolution tends to have greater MSE than higher resolution.

In accordance with MSE values, higher compression provides lower Kappa coefficient. In general, the compression ratio up to 10:1 are sufficient to be used for ISOCLASS unsupervised classification. Every data (Landsat 8, SPOT 6, and Pleiades) compressed with compression ratio lower than 10:1 presents Kappa coefficient higher than 0.8, which means a strong level of agreement with more than 64% reliable data.

Furthermore, fragmentation of imagery should be considered when choosing lossy compression ratio. Data that have a lower spatial resolution but more fragmented tends to receive better compression result than data that have a higher spatial resolution but less fragmented. However, for a set of data that cropped at the exact same area, higher resolution data get better results, since fragmentation is produced by its resolution.

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