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Evaluation of Lossy Compressed Mosaic for SPOT-6/7 Remote Sensing Data in SPACeMAP

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***Abstract*— SPACeMAP is a remote-sensing data portal system owned by LAPAN used to distribute mosaic data of Medium-Resolution to Very-High-Resolution for Provincial Governments. The frequently arising problem is that mosaic images have very large data size, especially for SPOT-6/7 mosaic images. The increasing number of data and users may affect the data loading process on the portal so that mosaic data compression can be considered. SPACeMAP has the Image Compressor feature using the Tile and Line algorithms with a compression ratio (target rate) recommended for optics (15 to 20). This study aims to determine the best algorithm and target rate to get compressed mosaic SPOT-6/7 imagery. The comparison method was done qualitatively through visual comparison and quantitatively by using Compression Ratio (CR), Bit per Pixel (BPP), and Peak Signal to Noise Ratio (PSNR). Results of the experiment show that, quantitatively, both Tile and Line algorithms give a different performance, depends on the zoom level and land cover characteristics. In terms of the qualitative result, the Tile algorithm gives better overall results compare to the Line algorithm. Quantitatively, both algorithms show good performance in the homogenous area. The target rate difference on the testing range does not affect process duration, nevertheless, the Line algorithm has a long process duration compare to the Tile algorithm. However, compression mosaics with lower or higher resolution remote sensing data may provide different results. Hence, this need be addressed on further studies.**

***Keywords*— Compression; tile; line; geoportal; mosaic.**

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I. INTRODUCTION

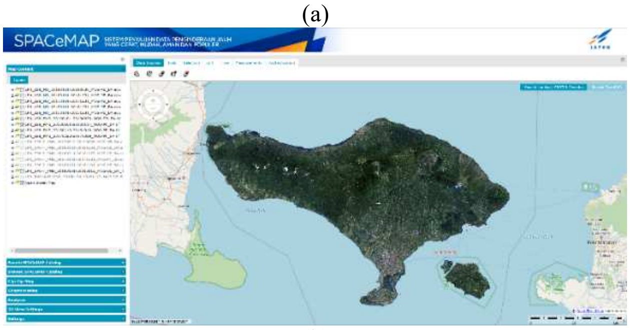
Indonesia is well known for its large area, with nearly two million km2 of total area. Hence, the necessity of remote sensing mosaic data for monitoring is highly relevant. The National Institute of Aeronautics and Space of Indonesia (LAPAN) is appointed as an institution that provides annual remote sensing data with minimal cloud cover and is cloud-free every year for all regions of Indonesia. The remote sensing data provided is data licensed by the Government of Indonesia. Hence, Ministries/Agencies, TNI, POLRI, and Local Governments can obtain this data free of charge following laws and regulations. This data can be used for forestry, agriculture, plantation, disaster, mapping, spatial planning, research, development, etc.

In 2019, LAPAN released a geoportal-based remote sensing data distribution and management platform called the Fast, Easy, Secured, and Popular Remote Sensing Data Portal (SPACeMAP). The SPACeMAP can fulfill local governments' needs for provincial mosaic data with minimal cloud cover. Users can access mosaic data of such various resolutions as Landsat-8, SPOT-6/7, Pleaides, and TerraSAR-X via the SPACeMAP web service. By this portal system, LAPAN can distribute remote sensing data to users online so that the flow of conventional data distribution using such storage media as hard disks can be minimized.

Web service technology provides easy remote sensing data access. SPACeMAP has an Open Geospatial Consortium (OGC) service that allows users to retrieve Web Map Service (WMS) or Web Map Tile Service (WMTS). WMS is an international standard geospatial web service from OGC that produces geographic information on image maps, generally presented as digital image files in PNG, GIF, or JPEG formats on a computer screen [1]. Server-client WMS communication uses the World Wide Web (WWW) standard protocol, which is based on HTTP where the client sends requests in Uniform Resource Locators (URLs) containing standard parameters of the detailed operations requested using POST or GET methods [2]. WMTS is an alternative type of WMS that uses the tiling model that makes it easier to generate images in PNG or JPEG formats using previous requests [3]. WMTS response is faster than WMS because WMTS loads one data and data tiling virtually [4] and minimizes the cost of computing to increase computation performance [5].

The problem that often arises is the size of high–resolution mosaic images. Large mosaic data requires more resources when transferring data from processing buffers into SPACeMAP buffers, crawling/publishing data, setting workspaces on portals, and displaying data on portals. In addition to the time required for the data transfer flow to the portal, the image load time on the portal will also be longer following the data size. Fig. 1(a) shows the homepage of the SPACeMAP portal, and Fig. 1(b) shows the portal for the Bali provincial government. The data displayed is the WMTS mosaic SPOT-6/7 in 2019, which is automatically displayed when the user opens the Bali SPACeMAP portal. The speed of load service data needs to be considered so that the data on SPACeMAP is easily accessible by users, both for WMS and WMTS responses.

(a)



(b)

Fig. 1 Display of SPACeMAP portal: (a) Homepage of the portal; (b) Visualization of SPOT-6/7 mosaic data SPACeMAP portal for the Province of Bali

An image mosaic combines two or more overlapping images to produce a representative image for further analysis according to the required information. Cloud cover is a problem frequently arising on optical images. With multitemporal data, image mosaics with minimum clouds can be obtained by erasing clouds and replacing areas covered by clouds and fog with different pixels free of clouds or haze [6]. Several methods have been developed for mosaicking, including scene-based [7], pixel-based [8], [9], and tile-based mosaics. Scene-based mosaics have long been operationalized and published on SPACeMAP. Selecting the cleanest/cloud-minimum scene as an input in scene-based mosaics is the key to obtaining a mosaic with minimum clouds. The tile-based research that has been developed is the Tile-Based Mosaic (TBM) for Landsat-8 annual mosaics [10], [11], and 8-steps TBM using haze index for SPOT-6/7 data [12]. Scene-based and Tile-based mosaics are outputs of the LAPAN data processing team produced outside of the work scope of SPACeMAP, but it has been operationalized and crawled/published on SPACeMAP.

Compression is commonly used so that mosaics on SPACeMAP are lighter in size. With the rapid growth of technology, data volume, and data transfer over the network, compression may become an option [13]–[16]. Enhanced Compression Wavelet (ECW) is a commonly used lossy compression raster format. ECW compression transforms the image into wavelet space using multi-level Discrete Wavelet Transformation (DWT). Then, it goes through an encoding phase that reduces the information in the image [17]. Mosaics based on compression and wavelet transform can reduce the duration of the mosaic process and reduce irrelevant image matching points [18] and the training time of the classifier [19]. The image that ECW has compressed with the right configuration can maintain visual quality even though the image size has been reduced. The ECW format is recommended as SPACeMAP data input because it can maintain visual quality with a much lighter file size than BigTiff / Tiff files which tend to be large [20].

SPACeMAP is a portal system developed using the Erdas Apollo. In addition to publishing images, SPACeMAP can process tiled data into a compressed mosaic file through the Image Compressor algorithm in the GeoCompressor application. Image Compressor implements two types of algorithms, Tile, and Line. It supports ECW and JPEG2000 file writing, which is determined by the final output file. Different compression options will be adjusted to the format based on the file type, as shown in Table 1 [21].

TABLE I
OUTPUT FORMAT OPTIONS IN IMAGE COMPRESSOR [21]

Capability	ECW	JPEG2000
Line	√	√
Tile	√	x

The target compression level is expressed as a ratio. Image Compressor uses the term target rate as a compression ratio parameter. The quality of compressed images depends on the target rate, although the actual compression ratio becomes higher or lower than the values given. In Image Compressor, the recommended target rate for optical data with ECW output is 15 to 20, where 15 represents "15:1" or, in other words, the size reduction is 94% [21]. The higher the target rate, the higher the compression output, leading to lower image size. This is assumed to have an impact on data access on the portal, which will be faster. The lower the compression value, the better the image's visual quality will be, but it will take a longer processing time and consume more storage memory. Although the target rate beyond the recommended range can still be done, it still requires limitation since an overly low target rate does not optimize the compression function, while a high target rate will damage the image's visual quality.

Proper configuration is required during the compression process to optimize data access speed so that the data is lighter in size but does not drastically reduce visual quality. This research was conducted to compare the compression mosaic algorithms and determine the best target rate between the recommended intervals on the SPACeMAP Image Compressor by considering the compression mosaic processing speed and the qualitative (visual) and quantitative image quality. Secondary level SPOT-6/7 data (ortho bundle of ground stations) was selected as the sample because this data is routinely acquired by the LAPAN ground station and has a sufficiently detailed spatial resolution to simplify visual comparisons.

II. Materials and Methods

LAPAN Ground Station has capacities for receiving, processing, and distributing remote sensing satellite data. All data is collected, processed, and archived by LAPAN. Bali is chosen as Area of Interest (AOI) by filtering SPOT-6/7 archived data. The filtered data is limited to only include data in 2019 with less than 20% cloud cover. Based on these filters, we obtained 24 scene data used for this study.

The mosaic algorithms used in the Image Compressor were Tile and Line. The Compression method was the Lossy ECW. The compressed mosaics would be tested visually and quantitatively using the CR, BPP, and PSNR methods. The study was performed using the GeoCompressor 2018 v16 to compress mosaics on servers with Windows Server 2016 OS specifications, Intel® Xeon® Gold 6126 CPU @ 2.60 GHz and 2.59 GHz (2 processors), 128-GB RAM, and 24 Core. CR, BPP, and PSNR were extracted using MATLAB R2017b, which was run on computers with Windows 10 OS, Intel® Core ™ i7-7700 CPU @ 3.60 GHz, and 8-GB RAM.

A. Mosaicking Methods

1) Line: The Line uses a scanning algorithm that reads each line, compresses, and continues scanning the next line to the end of the file. This approach has been used since ECW was founded. The Line is single-threaded and cannot be compared across multiple CPU cores but is useful for lower memory compression [21].

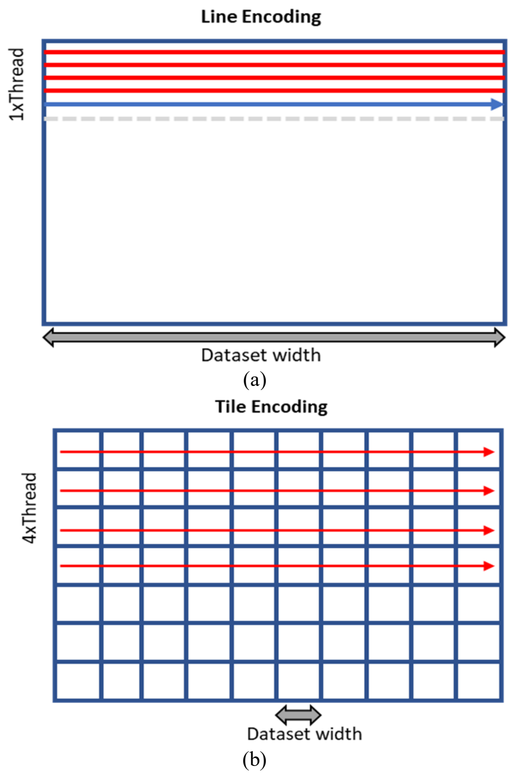


Fig. 2 Image Encoding on Image Compressor: (**a**) Line algorithm; (**b**) Tile algorithm [21]

2) Tile: Tile is a new parallel algorithm that was introduced in ERDAS ECW JP2 SDK v5. This algorithm reads the input data in a different tile which is determined by the threads selected. Each thread processes separately in a collection of series that crosses the width of the dataset and then is repeated by the image [21]. Line and Tile encoding is shown in Fig. 2

B. ECW Compression Wavelet (ECW) Method

Enhanced Compression Wavelet (ECW) is a compression raster format released by Er Mapper products. ECW is lossy or numerically lossless compression based on wavelet transformation by converting images into wavelet spaces using the multi-level Discrete Wavelet Transformation (DWT) [17], [22]. The ECW file format has two versions available. ECW v2 is an old format with the broadest industry support and ensures interoperability with all existing ECW software. ECW v3 was introduced in 2012 with the addition of such new capabilities as zero blocks for improved performance and space savings, improved metadata storage, and support for uint16 cell type [21]. This study selects ECW v3 as the output.

C. Evaluation of Compression Outputs

The parameters used to evaluate compression outputs are as follows [22]–[26]:

1) Compression Ratio (CR): CR is one of the parameters used in compression. CR is formulated as follows:

$$\mathbf{CR} = \frac{\textbf{uncompressed image size}}{\textbf{compressed image size}} \tag{1}$$

2) Bits per Pixel (BPP): BPP shows the number of bits that can be stored in one pixel of the input image. BPP is formulated as follows:

$$\mathbf{BPP} = \frac{\textbf{size of compressed file}}{\textbf{total number of pixel in the image}} \tag{2}$$

3) Peak Signal to Noise Ratio (PSNR): PSNR is used to evaluate the quality of compressed images. PSNR is a statistical parameter derived using Mean Square Error (MSE). MSE is used to measure the extent of the difference between the output image and the input image. MSE is formulated as follows:

$$\boldsymbol{MSE} = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\big(I(x,y) - J(x,y)\big)^2 \tag{3}$$

Where
x, y = Location of the pixel, row x column y
m, n = Image size
I = Input image (before compression)
J = Output image (after compression)

$$\mathrm{PSNR} = 10\,.\log_{10}\left(\frac{\mathrm{MAX}_i^2}{\mathrm{MSE}}\right) \tag{4}$$

MAX_i^2 is the maximum possible value allowed for the image. The higher the PSNR value, the higher is the quality of the compressed image.

D. Data Processing Flowchart

The Data processing flow is shown in Fig. 3. Preliminary data consisted of 24-scene secondary level SPOT-6/7. Data were converted to tiff as input to the Image Compressor. Furthermore, those data were subjected to mosaic compression processing on Image Compressor using the Tile and Line methods, each with the target rate of 15 to 20. Subsequently, the compression output was qualitatively and quantitatively tested.

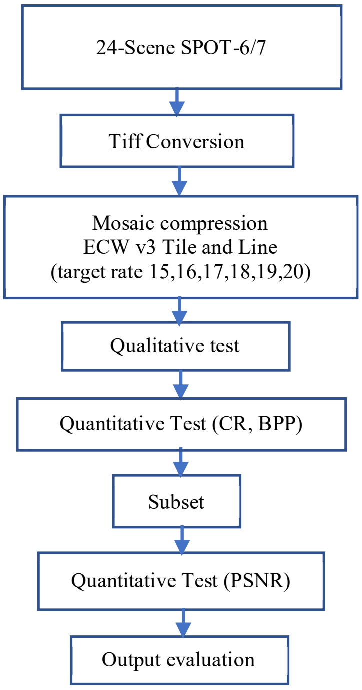


Fig. 3 Data Processing Flowchart

III. Results and Discussion

The purpose of the present study was to determine the best mosaic algorithm (Line or Tile) and target rate (between 15 and 20) capable of maintaining visual quality with low data size. A qualitative evaluation was performed visually by comparing the Tile and Line Mosaic outputs. Fig. 4 shows no compressed image mosaics using GDAL compared to the Line and Tile mosaics. The Line and Tile compressed mosaics are visually quite good, although cloud removal was not performed due to the input data's minimum cloud cover selection (cc <20%). Thus, this mosaic is a scene-based mosaic that is strongly affected by the data scene selection with the minimum cloud as inputs.

Line compression mosaics produce spots on the sides of the mosaics since it does not consider the transparency of 0 value as no data. Although ECW v3 can form a new additional band that helps define the areas of no data, the Line compression skips that stage so that visually there are some areas covered by black spots, especially in the areas at the outer edge of the scene. The black spots are input opacity information automatically formed by the Image Compressor when no region and no opacity value configurations are selected on the Line, and then there are no areas that overwrite this automated translation. Low-zoom visuals show that Tile mosaics are better than those of Line.

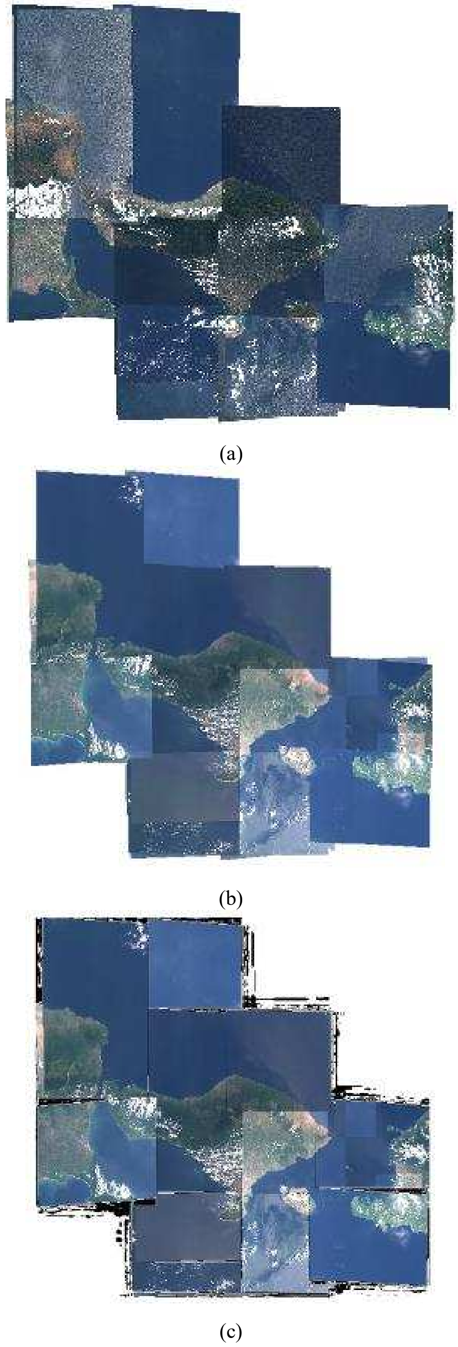
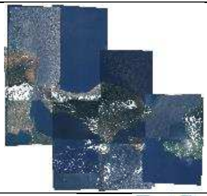
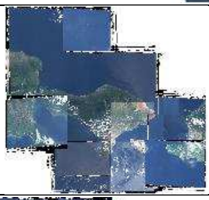
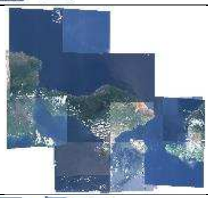
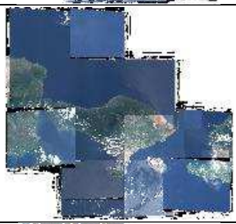
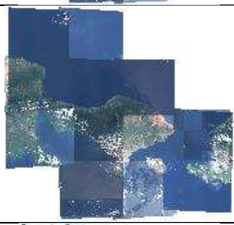
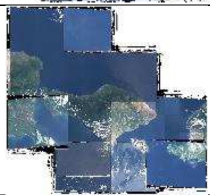
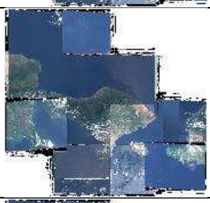
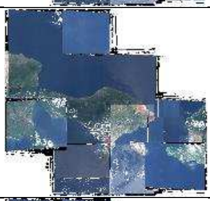
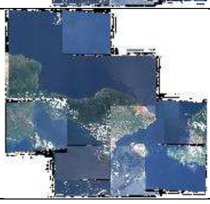


Fig. 4 Comparison of image visualization; (a) no compressed mosaics, (b) tile compressed mosaics; and (c) line compressed mosaics

To corroborate the visual evaluation, the comparison was performed on the zoom levels of 1: 1000 and 1: 5000. Results of the Tile visualization method at the target rate of 15 to 20 on the zoom level of 1:5000 indicate that the higher the target rate value, the more blurred is visual, but not significantly. Likewise, the Line visualization method results at the target rate of 15 to 20 show insignificant visual results. It is expected that with the insignificant visuals, the selection of the target rate of 20 can be considered since the visuals do not considerably differ from those of the target rate of 15. However, the zoom level of 1:1000 at the target rate of 20 shows increasingly blurred visuals.

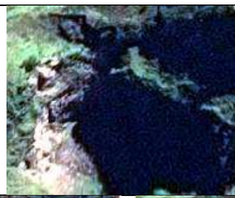
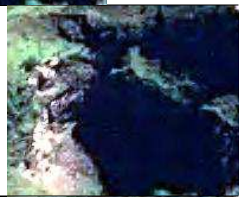
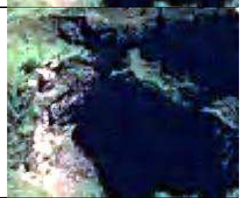
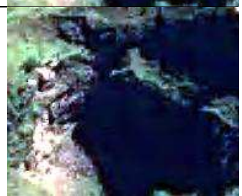
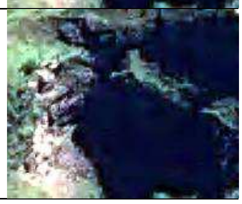
TABLE II
COMPARISON OF MOSAICS WITH NO COMPRESSION AND LINE AND TILE COMPRESSED MOSAICS ON 1:950000 AND 1:5000 SCALES

Compression Information	**1 : 950000**		**1 : 5000**	
	Line	**Tile**	**Line**	**Tile**
No compressed (reference)				
Target rate 15				
Target rate 16				
Target rate 17				
Target rate 18				
Target rate 19				
Target rate 20				

Subsequently, a quantitative evaluation was performed to determine the effect of determining a target rate on the compression outputs. Results of compression mosaics compared to GDAL mosaics with no compression as a reference using the CR and BPP methods are shown in Table 2. The higher the target rate value, the lower the CR and BPP values, which reduces the image size. CR and BPP values for the Tile algorithm tend to be smaller than Line, meaning that Tile reduces an image size more than Line. The Tile compressions obtained the lowest CR and BPP values at a target rate of 20.

TABLE III

COMPARISON OF MOSAICS WITH NO COMPRESSION AND LINE AND TILE COMPRESSED MOSAICS ON 1:5000 AND 1:1000 SCALES

Compression Information	1 : 5000		1 : 1000	
	Line	Tile	Line	Tile
No compressed (reference)				
Target rate 15				
Target rate 16				
Target rate 17				
Target rate 18				
Target rate 19				
Target rate 20				

The next quantitative evaluation used the PSNR method. This method is commonly used to discover image quality. Before PSNR evaluation, 7 subsets of the reference mosaics and compression mosaics were cropped with different land cover and zoom levels. Subset 1 and 6 are settlement areas with a zoom level of 1:1000, subset 2 is the Mount Batur crater with a zoom level of 1:1000, subsets 3 and 5 are settlements with a zoom level of 1:5000, subset 4 is settlements and plantations with a zoom level of 1:5000, while subset 7 is a plantation with a zoom level of 1:5000. The zoom level of 1:1000 was used since visually significant differences began visibly between the compression mosaics and reference mosaics. The zoom level of 1:5000 was used since it is the maximum zoom level set to preview high-resolution image data on SPACeMAP.

PSNR results are shown in Table 3. The higher the PSNR value, the more similar the mosaic image's visual quality to the reference image. Based on the PSNR value in the subsets 1 to 4, the Tile algorithm produces much better compression than the Line algorithm. In the subsets 5 to 7, the Line algorithm produces much better compression than the Tile algorithm. Of the two algorithms, the target rate of 15 is the best parameter to produce mosaics most similar to the reference mosaics. However, on closer observation, the PSNR values between Tile and Line for the target rate of 15 in almost all subsets, except for subsets 1 and 7, have nearly equal values. Thus, Tile or Line parameters have almost the same quality for some subsets.

In terms of the characteristics of the land cover of each subset, on the subset 1 with a settlement land cover tends to be heterogeneous at a zoom level of 1:1000. The difference in the PSNR value between Tile and Line becomes the highest where Tile gives the best result. On subset 8 with a plantation land cover that tends to be homogeneous at a zoom level of 1:5000, the difference in the PSNR value between Tile and Line is the second-highest, where Line gives the best result. Of these seven subsets, the settlement characteristics provide a low PSNR performance relative to the cover land settlement with plantations or simply plantations.

The duration of the mosaicking process was also compared to complement evaluation. The processing speed of the Tile algorithm depends on determining the value of threads, while Line by default ignores the value of threads. Tile reads inputs with multiple thread readers, and each thread processes independently. For core 32, it is recommended to conduct a test to determine the optimum threads between 8 or 16. The speed of I/O depends on the value of threads since it affects CPU usage and makes its performance slower than that of the Line algorithm if the thread's value is not appropriate since Tile needs more memory for compression of the same input as that of Line. If the I/O parameters are appropriate, the Tile method can be 400% faster than the Line method depending on the hardware, and input format used [21]. Both of these algorithms are suitable for different situations. A benchmark is required to determine the ideal method by considering the compression speed. The present study did not specify the threads or allowed the Image Compressor to automatically determine the value of threads.

TABLE IV
RESULTS OF QUANTITATIVE TESTS USING CR AND BPP

Mosaic Algorithm	Target Rate	CR	BPP
Line	**15**	0.025	0.210
	16	0.024	0.198
	17	0.023	0.188
	18	0.021	0.179
	19	0.020	0.171
	20	0.020	0.163
Tile	**15**	0.024	0.202
	16	0.023	0.191
	17	0.022	0.181
	18	0.021	0.172
	19	0.020	0.164
	20	0.019	0.157

TABLE V
RESULTS OF THE QUANTITATIVE TESTS USING PSNR

Mosaic Algorithm	Target Rate	PSNR						
		Subset 1	Subset 2	Subset 3	Subset 4	Subset 5	Subset 6	Subset 7
Line	**15**	59.55	68.08	47.50	50.19	45.41	45.74	73.56
	16	59.52	68.00	47.50	50.19	45.41	45.74	73.22
	17	59.48	67.98	47.50	50.19	45.41	45.74	73.00
	18	59.47	67.91	47.50	50.19	45.41	45.74	72.73
	19	59.44	67.85	47.50	50.19	45.41	45.74	72.51
	20	59.42	67.82	47.50	50.19	45.41	45.74	72.27
Tile	**15**	69.04	68.15	47.92	50.31	45.32	45.70	69.20
	16	68.69	68.11	47.92	50.31	45.32	45.70	69.12
	17	68.39	68.12	47.92	50.31	45.32	45.70	69.07
	18	68.08	68.03	47.91	50.31	45.31	45.70	69.00
	19	67.80	67.96	47.91	50.31	45.31	45.70	68.94
	20	67.54	67.90	47.91	50.31	45.31	45.70	68.87

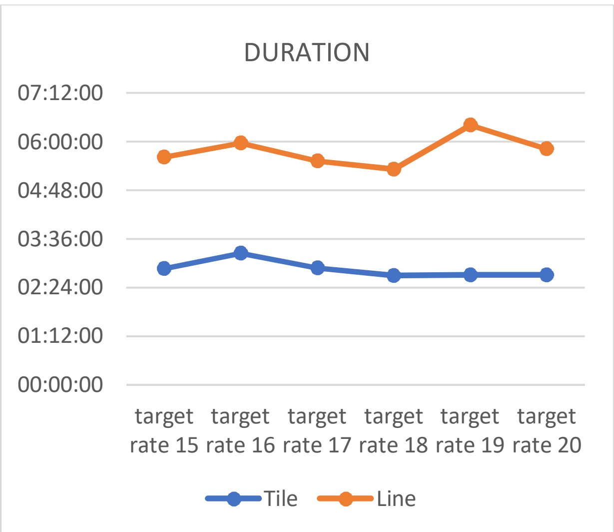
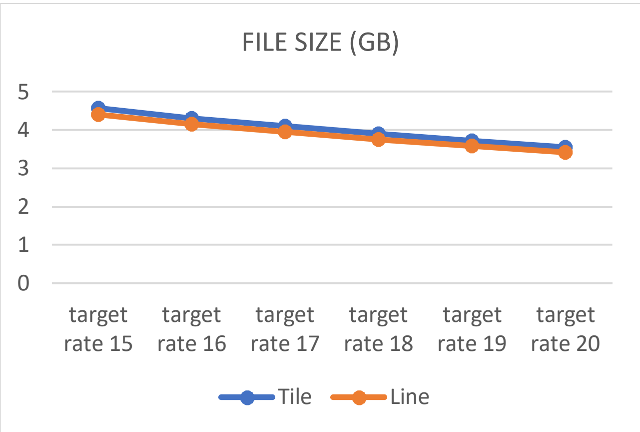


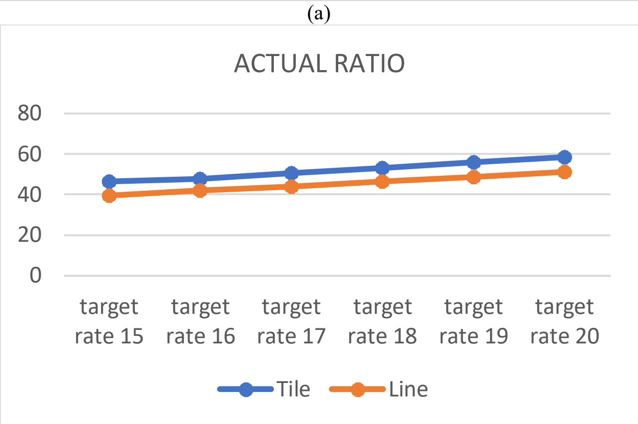
Fig. 5 Comparison of the duration of the Tile and Line mosaic compression process

Overall, Fig. 5 shows the Tile algorithm has a shorter processing duration than Line. The Tile had an average duration of 2h 53m 8s while Line had an average duration of 5h 48m 11s. The lowest duration of the mosaic compression process is at a target rate of 18 with a duration of 2h 41m 58s for Tile and 5h 19m 33s for Line. The highest duration of the mosaicking process is a target rate of 16 with a processing duration of 3h 14m 59s for Tile, while the target rate of 19 with a processing duration of 6h 24m 49s for Line. This comparison shows that the target rate in the range of 15 to 20 does not affect the processing duration, whereas initially, it was assumed that the higher the target rate, the longer the processing duration. Parameters with low process duration can be considered in mosaic compression since a low process duration eases the performance of the SPACeMAP server, thus minimizing server memory-related interruptions when many users access SPACeMAP data. Besides, the low process duration means that the data update on SPACeMAP is increasingly faster; thus, the data can immediately be utilized by users.

The size of compression outputs is also a concern since it can be an indicator of speeding up the display of data on the portal and reducing data transfer traffic when copying data from the processed output buffer to the SPACeMAP buffer server-to-storage traffic. A comparison of compression sizes is shown in Fig. 6(a). The mosaic image with no compression used as a reference has a data size of 182 GB, while the size of the compressed mosaic image is approximately 4 GB. Fig. 6(b) shows that the Image Compressor maintains the compression ratio despite the different mosaic algorithms. Each target rate of Tile and Line has the same size. The higher the target rate, the smaller is the data size. The target rate of 20 produces a mosaic with an average size of 3.6 GB for Tile and Line, while the target rate of 15 produces a mosaic with an average size of 4.7 GB for Tile and Line. Although the mosaic compression at a target rate of 15 and 20 is visually insignificant, the data size differs significantly by 1 GB. Fig. 6 shows that Tile and Line provide compression outputs that are not considerably different, although the compression ratio of Tile is slightly higher than Line.



(a)



(b)

Fig. 6 (a) Comparison of Tile and Line compressed mosaic data size; (b) Comparison of actual rate of Tile and Line compressed mosaics

IV. Conclusions

The evaluation results show that the Image Compressor on SPACeMAP is capable of producing mosaics using the Line and Tile algorithms at a target rate of 15 to 20. Visually, at a low zoom level, mosaics with the Tile algorithm provide the best performance. However, visuals at high zoom levels of up to 1:5000 tend not to make a significant difference between Tile and Line. Thus, it is visually recommended to use the Tile algorithm.

Based on CR and BPP testing results, Tile compressed mosaics at a target rate of 20 perform the best. Tile compressed mosaics at a target rate of 20 are those with the lowest compressed image size. Although the visual is not considerably different, the size of mosaics at the target rate of 15 and 20 differs by up to 1 GB. Based on the results of PSNR tests, both algorithms provide better performance on data with homogeneous land cover characteristics. Tile compressed mosaics at a target rate of 15 are those compressed mosaics with the best performance in general. The determination of the compression ratio at the target rate does not significantly affect the processing duration. Thus, when a mosaic with the lowest size is required, the Tile algorithm at a target rate of 20 can be selected. Meanwhile, when a compressed mosaic most similar to a reference mosaic (with no compression) is required, the Tile algorithm at a target rate of 15 can be selected.

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