THE EFFECTIVITY OF DOUBLE FILTER TO REDUCE THE SPECKLE AND DETECT FLOOD INUNDATION AREA ON ALOS/PALSAR IMAGE

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ABSTRACT: Flood is one of the devastating natural disasters. By applying remote sensing technology, we determined the flood inundation areas, using the Synthetic Apertures Radar (SAR) sensor. Removing the speckles due to the phase fluctuations of the electromagnetic return radar signals by filtering 2 times image by using small kernel size to prevent losing information. The kernel size was 3x3. Removing the speckles by single filter and double filters, we applied and combined14 kind of filters (Low Pass filters, Gaussian Low Pass filters, Median filters, Sobel filters, Roberts, User-defined convolution filter, Lee filters, Enhanced Lee filters, Frost filters, Enhanced frost filters, Gamma filters, Kuan filters, Local sigma filters, and Bit error filters). Using a single filter the best filter is Gamma filter and for the double filter, Local Sigma filter combined with Low Pass filter, Enhanced Frost and Enhanced Lee. The Sobel filter, Kuan filter and Robert filter could not be applied for flood inundation analysis because these filters are unable to reduce the speckle and prevent information.

Keywords**:** ALOS/PALSAR, Filter, Flood, Speckle.

1. INTRODUCTION

Remote sensing has an important role in the spatial analysis. Remote sensing has two kinds of sensor, namely, a passive sensor and an active sensor. Passive sensors contain different types of spectrometers and radiometers. This sensor needs other source energy to record the information, such as solar energy. The active sensor is operating in the electromagnetic spectrum of the microwave fraction. Hence, the active sensor is possible to penetrate the atmosphere under most conditions weather (JAXA, 2003).

Synthetic aperture radar (SAR) images are becoming more broadly used in remote sensing applications. During bad weather condition, for example, heavy rain occurs; a clear image is hard to obtain using passive sensor especially optical sensors. Hence, a Synthetic Apertures Radar (SAR) sensor is the best solution to get the information at this time because the SAR sensor can record in all conditions of weather and record all day and all night (JAXA, 2003). However, the SAR image has excellent performance in all weather conditions and recording periods; it also has limitations such as speckle. Speckle is noise on a radar image due to the phase fluctuations of the electromagnetic return signals (Sumantyo & Amini, 2008). Reduction of the speckle would improve the discrimination of land use type, and would make the usual per-pixel classifiers more efficient in radar images. This approach aims to reduce speckle without loss the information.

There are two types of techniques to reduce the speckle. The first technique is multi-look processing, and averages together several images or "looks" of different portions of available azimuth spectral bandwidth (Lillisand, et al., 2004). The second technique involves the use of image processing techniques to smoothen the image. The second technique is divided into two approaches. The first approach is the digital filtering that achieved in the frequency domain by wavelet transformation (Gagnon & Jauan, 1997). The second approach is accomplished in the spatial domain; that noise is reduced by averaging or statically manipulating the values of neighboring pixel (Qiu, et al., 2004). This study applied on reducing speckle by statistically manipulating the pixel value to determine the best filter that can be applied to detect the flood inundation.

In this study, a new method to reduce speckle by filtering is introduced, namely, the double filtering method. A double filtering is an image that filtered two times by using a different combination of the filter. A single filter is an image just filtered one time. During filtering processing, the user will decide the kernel size of filter such as 3x3, 5x5, 7x7, 9x9 and so on. As consideration, the kernel size has an important role in preserving the information. Using a big kernel size, for example, kernel size 7x7 or 9x9, the user will obtain a clean image from speckle but might lose some information because the speckle contains the information. The most common problem when reducing speckle is degradation of pixel image depending on the level of smoothing filter (Sheng & Xia, 1996). Lee et al. (1994) confirmed that, in general, applying small kernel size (such as 3 × 3) is able to preserve better information. In other hands, when utilized the small kernel size, the speckle is still appearing on the surface of the image. Hence, the double filter is proposed in this research as one method to reduce the speckle and preserve the information without the broad changes in pixel value because the objects are smoothed. By using a double filter, we can use a small kernel size but produce a clear image without a significant loss the information. The double filter prevents the degrading of pixel intensively.

Senthilnath *et al.* had investigated Lee, Frost and Gamma MAP using filter sizes 3x3, 5x5 and 7x7 (Senthilnath, et al., 2013). They found that Gamma MAP is the best filter for flood extent extraction analysis and proposed Mean Shift Segmentation (MSS) for detecting inundated flood area. Dellepiane and Angiati had measured the quality of filtered de-speckled SAR Image and introduced a new method to measure the filter performance (Dellepiane & Angiati, 2014). Even though Gamma filter has the best performance comparing to Lee and Frost (Senthilnath, et al., 2013), Gamma generates the homogeneous area (Lopez, et al., 1990). It means a smoothing process conducted to obtain the new images. The filtering purpose is to reduce the noise, but the degradation information on the image depending on the smoothing level of the filter (Sheng & Xia, 1996).

The filter must preserve the edges and preserve the information (Senthilnath, et al., 2013). The convolution filter and adaptive filter are applied to this study. Even though convolution filters purpose for smoothing, it also can preserve the edges. The adaptive filter well-known to use on speckle removal, it calculates the local pixel then observing the mean by normalized standard deviation (Senthilnath, et al., 2013). Hence, we applied 14 kinds of filter to reduce speckle noise on ALOS/PALSAR image. PALSAR has L-band wavelength. It can be easy to detect a water surface because its wavelength is L-band which could penetrate the canopy of vegetation. The filters are (1) Low Pass, (2) Gaussian Low Pass, (3) Median, (4) Sobel, (5) Roberts, (6) User-defined convolution, (7) Lee filter, (8) Enhanced Lee filter, (9) Frost filter, (10) Enhanced Frost filter, (11) Gamma filters, (12) Kuan filters, (13) Local Sigma filters and (14) Bit error filters. When we select only one filter from those 14 filters then filtering the image, it means that we will generate a single filter image, whereas, when we select and combine two kinds of those 14 filters, we will generate the double filters image. We assume, each filter has advantage and disadvantage, by combining the advantage of two filters, we can achieve the best filter for speckle reduction.

This study was divided into four steps. First, we did pre-processing to convert the pixel value to a backscattering value, and then we applied 14 filters by using kernel size 3x3 and 7x7 on ALOS/PALSAR image. We called the result as the single filter. Then the second step, we applied 14 filters with kernel size3x3 for the second time on each single filter image; we called the result as the double filter image. Double filters only utilized the kernel size 3x3 because the kernel size 7x7 is over smoothing. Third, we compared the result single filter kernel size 3x3, single filter kernel size 7x7, and double filter 3x3 by visual evaluation, then statistic performance evaluation for double filter kernel size 3x3and single filter kernel size 3x3. The last step, we evaluate the efficiency filter on flood detection.

2. METHODOLOGY

2.1 Pre-processing of ALOS/PALSAR Image

The purpose of filtering SAR image of this research is evaluation the best filter performance to reduce the speckle and preserve the information. Thus, the adaptive filters and convolution filters provided by ENVI have been applied. Convolution filters produce output images in which the brightness value of a given pixel is a function of some weighted average of the brightness of the surrounding pixels. Convolution selected kernel with the image array returns a new, specially filtered images (ENVI, 2004).

The convolution filters have been applied; (1) Low Pass, which preserves the low-frequency components of an image, which smooth it. Low Pass filter contains the same weight in each kernel element, replacing the center pixel value with an average of the surrounding values; (2) Gaussian Low Pass, used for image smoothing; (3) Median, used for smoothing an image, while preserving edges larger than the kernel dimensions (useful for reducing speckle noise); (4) Sobel, a non-linear edge detector filter, special case filter that uses an approximation of the true Sobel function; (5) Roberts, a non-linear edge detector filter similar to the Sobel. It is a particular case filter that uses a preset 2x2 approximation of the true Roberts function, a simple, 2D differencing method for edge-sharpening and isolation; (6) User-defined convolution, the user can define custom convolution kernels (including rectangular rather that square filters).

Adaptive filter uses the standard deviation filter those pixels within a local box surrounding each pixel to calculate a new pixel value. Typically, the original pixel value is replaced with a new value calculated based on the surrounding valid pixel (i.e., pixels which satisfy the standard deviation criteria) (ENVI, 2004). Unlike a typical Low Pass smoothing filter, the adaptive filters preserve image sharpness and detail while suppressing noise. The following adaptive filters were conducted; (1) Lee filter, which is based on the assumption that the mean and variance of the pixel interests is equal to the local mean and variance of all pixels within the user-selected moving window (Lee, 1980); (2) Enhanced Lee filter, an adaptation of the Lee filter and similarly uses local statistic (coefficient of variation) within individual filter windows. Each pixel is put into one of three classes (homogeneous, heterogeneous and point target) (Lopez, et al., 1990); (3) Frost filter. It replaces the pixels of interest with a weighted sum of the values of the moving windows (Zhenghao & Fung, 1994); (4) Enhanced Frost filter, an adaptation of the Frost filter and similarly uses local statistics (coefficient of variation) within individual filter windows. Each pixel is put into one of three classes (homogeneous, heterogeneous and point target) (Lopez, et al., 1990); (5) Gamma filters, which assumes that the data is gamma distributed. The pixel being filtered is replaced with a value calculated based on the local statistics (Zhenghao & Fung, 1994); (6) Kuan filters, used to reduce speckle while preserving edges in radar images. It transforms the multiplicative noise model into an additive noise model. It is similar to the Lee filter but uses a different weighting function (Zhenghao & Fung, 1994); (7) Local Sigma filters, that uses to preserve fine detail (even in low contrast areas) and to reduce speckle significantly. The Local Sigma filter uses the local standard deviation computed for the filter box to determine valid pixels within the filter window. It replaces the pixel being filtered with the mean calculated using only the valid pixels within the filter box (Eliason & McEwen, 1990); and (8) Bit error filters, that uses to reduce bit error noise, which usually the result of spikes in the data caused by isolated pixel that have extreme values unrelated to the image scene. The noise typically gives the image a speckled appearance (Eliason & McEwen, 1990).

The kernel size 3x3 and 7x7 were used. The kernel size 3x3 size does not change the pixel value drastically comparing to the kernel size 7x7. The starting point for this filtering stage consists of three steps. The first step, Digital Number (DN) image were converted to Backscattering Coefficient (σ^0) by following Equation 1, where the radar backscattering coefficient values are output in decibels (dB). The second step, the dB were filtered by following 14 filters by using kernel size 3x3 and kernel size 7x7. Third, the filtered kernel size 3x3 were filtered for the second time by applying 14 kinds of filter. Hence, we generated 14 images single filter kernel size 3x3, 14 images single filter kernel size 7x7, and 196 images of the double filter kernel.

$$\sigma^0 = 10\, log_{10}(DN^2) + CF \quad (1)$$

where: σ^0 is sigma naught; DN is a digital number; CF for ALOS/PALSAR is -83 (JAXA, 2003).

2.2 Visual Performance Evaluation

Visual performance evaluation is evaluating the image by visual interpretation to observe the speckle on the surface and the ability the filter to preserving the information such as the edge and object detail. All images (single filter kernel size 3x3, single filter kernel size 7x7, and double filters) were selected by visual interpretation to continue to the next analysis. The selected images from the visual evaluation were analyzed by the statistic parameter. From the statistic parameter, we selected 10 of best filter combinations. The selected combination images were compared with the original image to show the difference of pixels numbers. Visual performance evaluation was conducted two times; the first visual performance evaluation is a quick analysis where we selected filter that could preserve the edge. The filter that could not preserve the edge was deleted. The second visual performance evaluation was held after statistics performance evaluation. The selected images from statistically performance evaluation were evaluated in detail by visual performance evaluation.

2.3 Statistic Performance Evaluation

The purpose of filtering SAR data is a reducing the speckle, preservation of edges and object detail. Thus, the statistical analysis examined the selected filter for next analysis. In this paper, we applied the Mean Absolut Error (MAE), Signal to Noise Ratio (SNR), Speckle Suppression Index (SSI) and Speckle Mean Preservation Index (SMPI) for determining the filter performance.

2.3.1. Mean Absolute Error (MAE)

Mean Absolute Error (MAE) helps to assess the feature preservation indirectly. It measures the extent different from the output image to the input image.

$$MAE = \frac{1}{K}\sum_{i=1}^{K}|S_i - S_o| \quad \textbf{(2)}$$

where S_i is the pixel value of input image, in this case, is original image, S_o is the pixel value of the filter output image, K is the number of pixels (size of the image). In this analysis, if the image has high noise content, it could lead to the large value of MAE.

2.3.2. Signal to Noise Ratio (SNR)

Signal to Noise Ratio (SNR) strengthens the comparison of the pure signal or image with the noise present that reduced the filter (Senthilnath, et al., 2013).

$$SNR = 10\, log_{10}\left(\sum_{i=1}^{K}\frac{S_o}{(S_i - S_o)^2}\right) \quad \textbf{(3)}$$

The higher number SNR value of filter indicates that the pixel has better performance comparing to the low SNR value.

2.3.3. Speckle Suppression Index (SSI)

One of technique to measure the speckle strength is a coefficient of variance or the ratio of the standard deviation to mean (Lee *et al*. 1994). *Speckle Suppression Index (SSI)* corresponds to the ratio between normalized standard deviations of the pixel value of an original image and a filtered image (Sheng and Xia, 1996).

$$SSI = \frac{(\frac{std\ S_O}{mean\ S_O})}{(\frac{std\ S_i}{mean\ S_i})} \quad \textbf{(4)}$$

The filtering result has lower variance due to the speckle suppression. When value SSI is smaller than 1.0 means efficient speckle suppression (Sheng and Xia, 1996). *SSI* is reliable only when the filter simultaneously has good mean-preservation properties.

2.3.4. Speckle Mean Preservation Index (SMPI)

When the value is overestimated, SSI is not reliable. Based on the *Speckle Mean Preservation Index (SMPI)*, lower value of SMPI indicates the better performance of filter [Shamsoddini & Trinder, 2010].

$$SMPI = 1 + \ |mean\ S_o - mean\ S_i|)\ x\ \frac{\sqrt{variance\ S_o}}{\sqrt{variance\ S_i}} \quad \textbf{(5)}$$

2.3.5. Mean Preservation Index (MPI)

Mean Preservation Index (MPI) is a normalized measure. It has a good appearance to representative the mean preservation capability of a filter. Thus, MPI allows a filter comparison that is independent of the specific SAR image acquisition mode to be made with various homogeneous regions (Dellepiane & Angiati, 2014). The MPI makes use of the sample mean due to computed from a homogeneous region. The filter will be indicated better performance when its value is low.

$$MPI = \left|1 - \frac{S_i}{S_o}\right| \quad \textbf{(6)}$$

2.3.6. Mean Preservation Speckle Suppression Index (MPSSI)

By using SMPI the mean difference between the speckled and filtered image is not normalized, it has higher values for larger backscattering regions. For solving this problem, the Mean Preservation Speckle Suppression Index (*MPSSI*) can be used, which has better normalized than *SMPI* (Dellepiane, 2014). The equation follows below:

$$MPSSI = \left|1 - \frac{S_i}{S_o}\right| * \frac{Std\ S_o}{Std\ S_i} \quad \textbf{(7)}$$

or we can substitute the Equation 6 to the Equation 7 follows the Equation 8.

$$MPSSI = MPI * \frac{Std\ S_o}{Std\ S_i} \quad \textbf{(8)}$$

The lower values of MPSSI indicate, the better performance in the mean preservation and noise reduction independently of actual mean value.

2.4 Flood detection

In August 2008, the heavy rain occurred in Japan. The most impacted area was Aichi Prefecture. Thus, it caused a flood in Okazaki City and Anjo City and depth flood inundation reached 1.05 m from 28th to 31th August (Japan Meteorology Agency, 2008). ALOS/PALSAR image was used to observe the flood inundation areas, flood extent mapping using SAR images is widely applied because water appears dark with very low backscattering compared to other objects (Smith, 1997). Figure 1 shows the research location.

For detecting the flood, we utilized simple method by using classification namely ISO classification for measure the efficiency of selected filter to delineate the flood inundated area. ISODATA is an unsupervised classification that calculated by the variation in the minimum distance of distribution pixel (ENVI, 2004). ISODATA trains the selected data in order to cluster in multidimensional data space. Each cluster has a centroid; all the unallocated pixels are allocated to the nearest centroid. The allocation process of the pixel are repeated until there is no change or a small change of pixel in class centroid; this is called as iteration. The step of ISODATA follows: 1) selecting the class mean data, 2) recomputed the class mean to reallocate the pixel, 3) repeating the step 2 if any changes of class (Campbell & Wynne, 2011). This classification is not necessary the information as feature classification which must have the information needed to discriminate amongst categories, be oblivious to unrelated variability in the input, and also, be delimited amount, to authorize, effective computation of discriminant utilizes and to limit the amount of training data required (Kumar & Bhatia, 2014). The essential in ISODATA is only the distance, if the distance between the class mean is less than the minimum value, hence it can be merged to be one class. The threshold parameters decide the class splitting, pixel merging and class deleting.

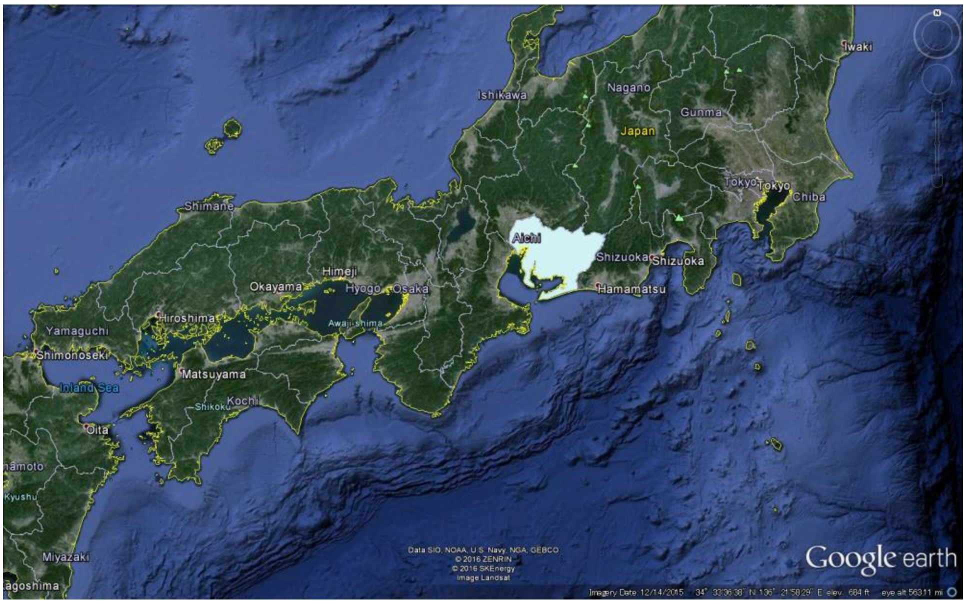

Figure 1 Research Location

2.5 Flow Chart

This research follows a method as shown in Fig. 2. The Digital Number values are converted to backscattering coefficients; then the image is filtered one time and/or two times. The filtered images are selected by quick visual performance, if the image can delineate the object clearly, it will be evaluated by using statistic performance and visual performance. Finally, the selected images are applied to show the effectivity of filter to distinguish the inundated and non-inundated area.

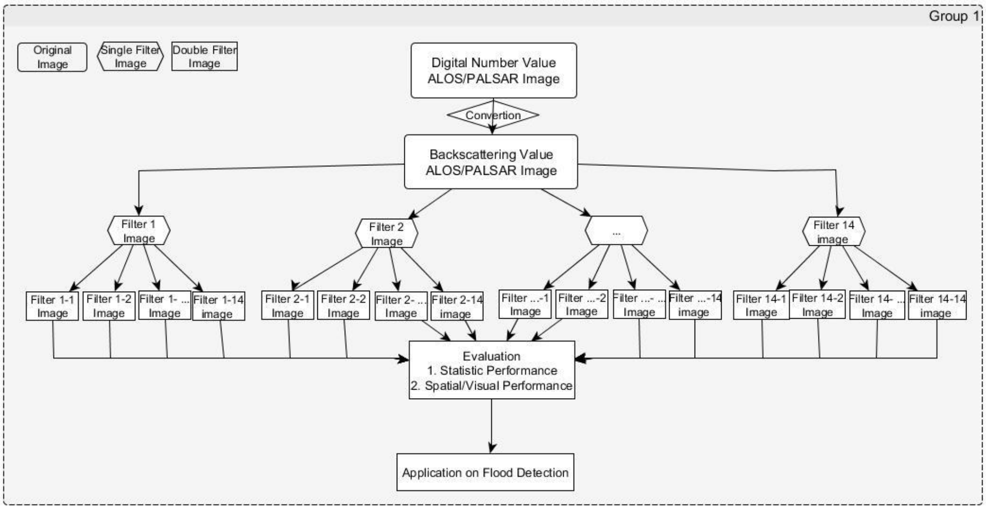

Figure 2 Flowchart

3. RESULT

This study generated four kinds of the result; the first is the spatial performance of 14 images of single filter kernel size 3x3, 14 images single filter kernel size 7x7, and the spatial performance of 196 double filter images for ALOS/PALSAR. Thus, 224 images were generated from ALOS/PALSAR images. Second is the statistical performance of single filter kernel size 3x3 and double filter images. Single filter with kernel size 7x7 shows low performance on the spatial performance evaluation. Hence, we could not continue it for statistical analysis. After evaluating the filtered images by visual and statistical analysis, we evaluated the selected filters performance on detecting flood.

Several of the adaptive filters type and convolution filters type unable to reduce and preserve the edge and object detail. Thus, the filter that powerless to reduce and preserve the edge was reduced from the catalog of images. Hence, the best filter is usually selected based on qualitative evaluations performed through visual analysis (Dellepiane & Angiati, 2014). We reduced some filtering image by seen the image; this is a quick analysis to minimalize the images.

196 double filter images have been classified into two categories, namely unclearly delineation filter and clearly delineation filter. Unclearly delineation filter is a filter that unable distinguish the object. The clear delineation filter is a filter that able distinguish the object. The unclear delineation filters are Sobel filter, Kuan filter, and Robert filter. As a result, we could not utilize these filters for the next analysis. In additional, clearly delineation filter are a User defined filter, Median filter, Low Pass filter, Lee filter, Enhanced Lee filter, Enhanced Frost, Local Sigma filter, Gamma filter, and Frost filter. User defined filter changed the pixel value and removed from this analyses. Thus, Local Sigma, Gaussian Low Pass, Gamma, Frost, Lee, Enhanced Frost, Enhanced Lee, Low Pass and Median continue the process to the next performance evaluation.

3.1 Single Filter Performance

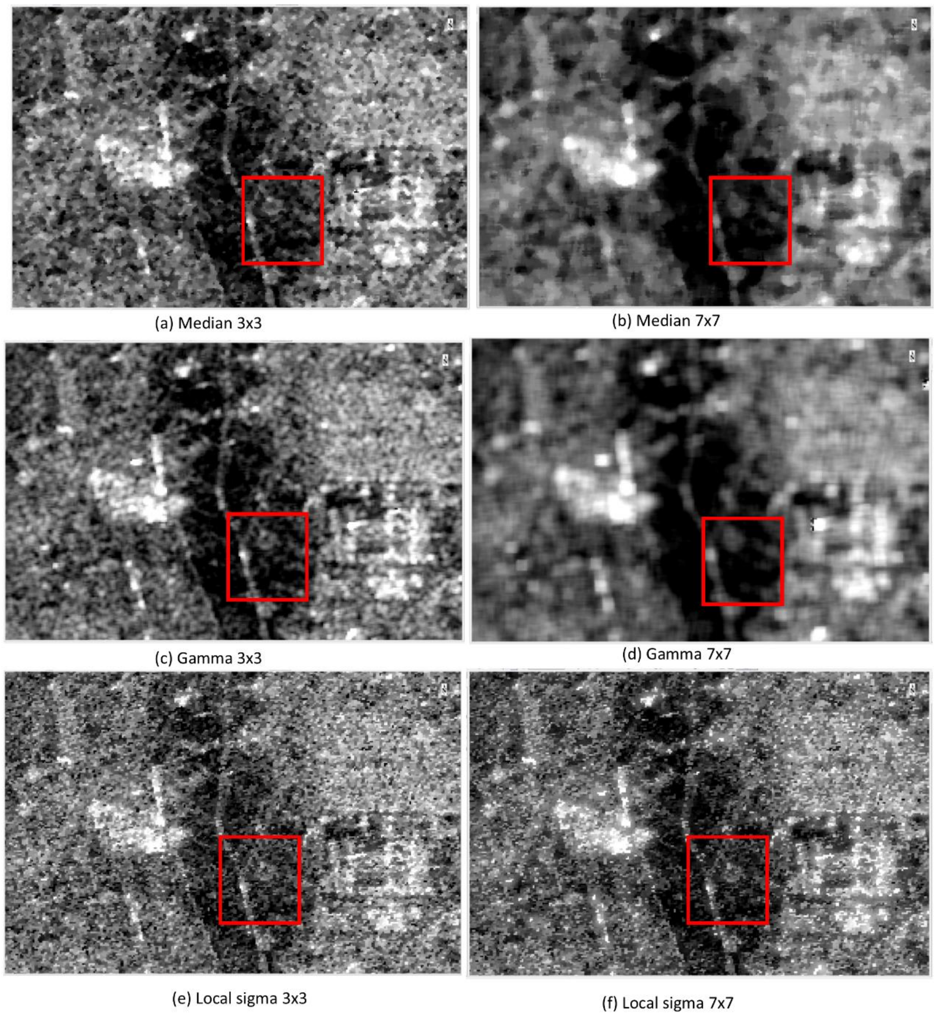

Fig.3 (a) Representative Single filter image; image Median 3x3, (b) Median 7x7, (c) Gamma 3x3, (d) Gamma 7x7 (e) Local Sigma 3x3, (f) Local Sigma 7x7

To comparing Fig.3, we can focus on the red box; it shows the ability of the filter to reduce the speckle and preserve the information. Figure 3a shows blocking object, 3b and 3d show over smoothed for example line object as shown as the white line was over-smoothed. Figure 3e and 3f show the speckle on the surface as shown in the red box. Figure 3c shows the best performance. Hence, Gamma filter shows best performance on single filter event though some speckles are appearing.

There are 14 single filters that applied on the image. By quick visual performance evaluation, the filtered images were selected. The images that show good performance on delineation the objects were selected. Table 1 lists the statistical performance of single filter 3x3. The best statistical performance image when MAE, SSI, SMPI, MPI and MPSSI are low value, then SNR is high; we categorized it as a good performance when the filtered image can fulfill the statistic criteria. Hence, Local Sigma has a good performance in MAE, MPI and MPSSI. Gaussian Low Pass has a good performance in SNR. Low Pass has a good performance in SSI and Median has a good performance in SMPI. Local Sigma shows the best performance due to a low value on MAE, MPI and MPSSI. Gamma, Frost, Lee, Enhanced Lee and Enhanced Frost are not prominent on all statistic performance. Spatial or visual evaluation as the first parameter and statistical performance as the second parameter to select the best filter.

Table 1 Statistically Performance of Single Filter 3x3

Filter Name	MAE	SNR	SSI	SMPI	MPI	MPSSI
Local Sigma	*0.003	1.234	0.951	0.960	*0.001	*0.001
Gaussian Low Pass	0.008	*1.981	0.945	1.053	0.010	0.009
Gamma	0.009	0.064	0.727	0.876	0.017	0.013
Frost	0.012	0.100	0.723	0.872	0.017	0.013
Lee	0.014	0.791	0.835	0.916	0.008	0.007
Enhanced Frost	0.070	0.064	0.691	0.833	0.047	0.032
Enhanced Lee	0.070	0.020	0.691	0.833	0.017	0.012
Low Pass	0.103	0.056	*0.666	0.802	0.017	0.012
Median	0.125	0.023	0.720	*0.750	0.004	0.003

* Best performance

3.2 Double Filter Performance

All combinations almost show the good performance and similar results except combination filter using Sobel filter, and Robert filter. Hence, for to display Figure 4, the double filters images were selected by using statistical analysis and then we selected best 10 of double filter images. Figure 4 shows that combination Median as the first filter or second filter had low performance some pixel over-smoothed and blocked. The combination with Local Sigma as the first filter shows a good performance.

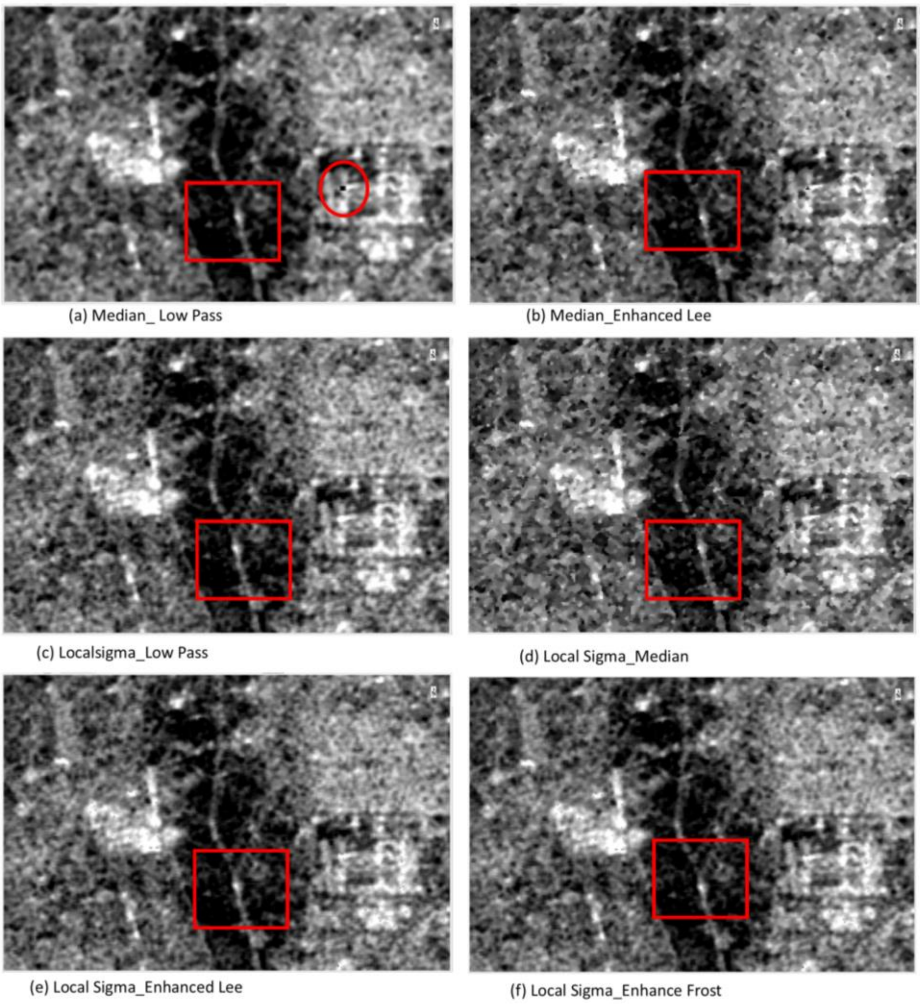

Figure 4 Double filter performance for ALOS/PALSAR (a) Median_Low Pass, (b) Median_Enhanced Lee, (c) Local Sigma_Low Pass, (d) Local Sigma_Median, (e) Local Sigma_ Enhanced Lee, (f) Local Sigma_Enhanced Frost

Table 2 lists the statistical performance of double filter 3x3, combining Local Sigma filter as the first filter shows good statistic performance and combination median filter as the first filter shows the worse combination of 10 selected images. According to Table 2, the combination of Local Sigma and Low Pass shows the best performance on MAE, MPI and MPSSI. The combination of Local Sigma with Enhanced Frost and Enhanced Lee need to consider because those are a good performance in MP and MPSSI. Similar case with combination with Median as a first filter, those shows a good performance in SSI and SMPI. Event though some filters show a good statistically performance, spatial/visual performance maybe is worse for the example combination with the median filter show the image is blocked. Hence for the double filter, we select combination local sigma with lowpass, enhanced lee and enhanced frost.

Table 2 Statistically Performance of Double Filter 3x3

Filter Name	MAE	SNR	SSI	SMPI	MPI	MPSSI
Local Sigma_Low Pass	*0.004	0.046	0.662	0.683	*0.003	*0.002
Local Sigma_Enhanced Frost	0.021	0.050	0.675	0.697	*0.003	*0.002
Local Sigma_Enhanced Lee	0.021	0.050	0.675	0.697	*0.003	*0.002
Local Sigma_Median	0.017	0.030	0.719	0.862	0.017	0.012
Gaussian Low Pass_Enhanced Frost	0.045	*0.061	0.691	0.724	0.004	0.003
Gaussian Low Pass_Enhanced Lee	0.045	*0.061	0.691	0.724	0.004	0.003
Gaussian Low Pass_Frost	0.045	*0.061	0.691	0.724	0.004	0.003
Median_Enhanced Frost	0.046	0.037	*0.626	*0.667	0.006	0.004
Median_Enhanced Lee	0.046	0.042	*0.626	*0.667	0.006	0.004
Median_Low Pass	0.046	0.027	*0.626	*0.667	0.006	0.004

* Best performance

3.3 Flood Detection

Figure 5 displays the flooded area by using the single filter and double, the areas of flooded and non-flooded area were classified. The ISO classification method was applied to determine the flood extent area.

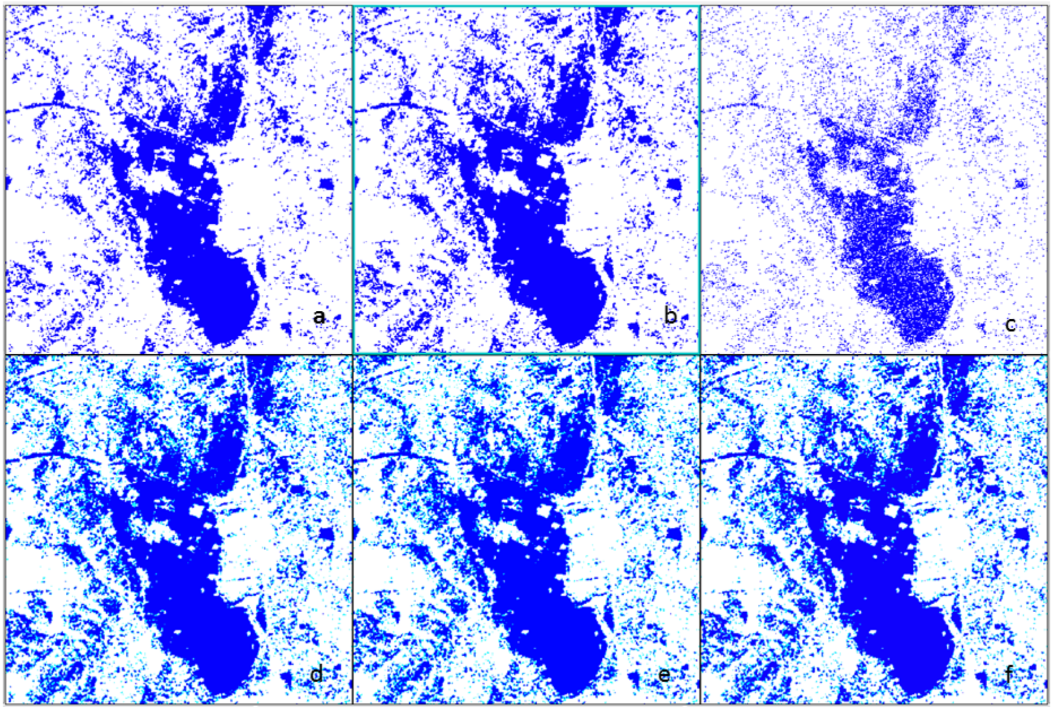

Figure 5 Flood Location 2; a)Frost filter, b) Gamma filter, c) Gaussian Low Pass filter, d) Flood location 1: a) Local Sigma filter and Enhanced Lee filter, e) Local Sigma filter and Enhanced Frost filter, and f) Local Sigma filter and Low Pass filter

We allowed the system classification classify the images automatically to know how much the range classes could be obtained from each filtered image. The double filter images showed the range class shorter and obtained more classes than single filter images. The double filter image could distinguish the object more detail than single filter images. The variation of depth could be obtained from the double filter as shown in Figure 5 (d), (e), (f); the double filters images show the graduation of color.

4. DISCUSSION

Many despeckling filters have been recommended to reduce the speckle. Each filter has its advantage and limitations. Hence, the selecting of which filter to apply is dependent on the need of the particular application and the highlighted features (Lee et al., 1994). The speckle noise usually appears in or near to the brighter pixel area because the higher signal strength means, the higher speckle noise appearing (north & Wu, 2001).

According to the analysis of ALOS/PALSAR image. The best filter for single filter 3x3 is Gamma filter. The Low Pass needs to be considered as the best filter also because it shows a good performance in SSI and similar visual performance with the Gamma even though Low Pass filter is darker than Gamma. Gamma filter has an excellent performance because the pixel being filtered is replaced with a value calculated based on the local statistics where is the local statistic offer better performance within the homogeneous area (Saad, et al., 1996). For the double filter, the combination with Local Sigma and Low Pass, Enhanced Frost and Enhanced Lee show the best performance among double filter image.

Even though as statistical, the Local Sigma shows the best performance on ALOS/PALSAR. But, it has low performance in spatial performance. In the image of Local Sigma filter, some speckles are appearing. The valid pixel intensity is determined by moving the window in local Sigma. Each pixel value in moving window is confirmed by pixel value range. If the pixel value is outside of the pixel value range, definitely, it is called as speckle noise. Otherwise, valid pixel value when it is inside of pixel value range (Qiu, et al., 2004). Due to using a small kernel size, the pixel value in moving window is categorized as a valid pixel value. Hence, some speckle appears on the image. The Local Sigma filter is adaptive to local variance not the variance of the whole image([Eliason & A.S, 1990]. Even though Local Sigma filter has the lowest value as listed on statistical performance but the image of Local Sigma, we could find a bright pixel in the dark area because the Local Sigma filter does not exclude heterogeneous pixel in a homogenous region (Saad, et al., 1996). The limitation of Local Sigma became an advantage when combining with another pixel where Local Sigma as statistical does not change the pixel, but it enhanced in the edges and contrast of the object. Hence, this filter can be used as a preface phase concerning segmentation by gray level.

Gamma filter was developed by (Lopex, et al., 1993) and modified from Kuan Filter (Kuan, et al., 1987). Statistically, the value of Gamma filter is not superior comparing to another filter. However, it is visual performance better than another filter even though the pixel is smoothed. Frost has excellent performance in spatial similar with Gamma. This filter could reduce and keep the edge at the same time for 3x3 kernel size, but for 7x7 the image is over smoother and some black and white appearing on the image.

Median filter shows better performance in statistically, but low performance in spatial performance. Median Filter conserves to edges, linear features, and fine details, even in low-contrast areas (Qiu, et al., 2004). Hence in this study, median shows a strong edge in each pixel. Lee et al. (1994) declared that the 3×3 median filter preserves the texture information very clearly but does not retain the mean value at an acceptable level.

All of these adaptive filters aim to reduce effectively speckle in radar images without eliminating the fine details (Jensen, 2004). Adaptive filters, such as the Lee filter, are based on the assumption that the mean and variance of the pixel of interest are equal to the local mean and variance of all pixels within the user-selected moving window (Lee, 1980).

The double filter as a proposed method in this study tried to combine the filter to preserve edge, the detail of the object and reduce the speckle. Generally speaking, a combination of Local Sigma as the first filter shows better combination compare to others filter. Local Sigma does not change the pixel value but preserves the edge. Hence, combine the filter with the Local Sigma Low Pass, Enhanced Frost and Enhanced Lee generated a clear image and could preserve the edge.

We evaluated the filtered image by applying on flood detection. The flood area was classified by using ISO classification. Although radar does not penetrate inundated water, it can reflect the surface action of oceans, lakes, and other bodies of water and sometimes furnish information about the bottom features of the water body (Jensen, 2000). The speckle reduction in water bodies and preservation of edges were fundamental required. The filter removes the speckle on the homogeneous object. Hence, by filtered image the flood could generate easily because flood area is the homogeneous area. Since the inundated area is covered by water and it has low backscattering which becomes dark in the image. As we show from the result, the double filter has grade color. It might lead due to the depth of inundation.

5. CONCLUSION

Single filter kernel size 3x3 enable to remove the speckle and kernel 7x7 over-smoothed the image. The proposed method that called as the double filter is powerful because combining the advantage of two filters. When the double filter applied to the flood inundated area, the variation of depth possible to be detected. Best performance for a single filter for ALOS/PALSAR is Gamma filter and for the double filter is a combination of Local Sigma combination with Low Pass, Enhanced Frost and Enhanced Lee.

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