COMPARATIVE STUDY OF DIFFERENT FILTERS OF RADARSAT-2 USING POL-SAR FOR SPECKLE NOISE REDUCTION

Prof. Khirade Prakash Waghji
Assistant Professor, Department of Physics,
Dr. Babasaheb Ambedkar Marathwada University, Aurangabad

Prof. Jagtap Pornima Ramesh
Assistant Professor, Department of Physics,
Milliya Arts, Science & Management Science College, Beed (M.S.), India.

Prof. Sayyad Shafiyoddin Badruddin
Assistant Professor, Department of Physics

Abstract:
The microwave Synthetic Aperture Radar (SAR) is a type of active remote sensing. It has its own energy source for illumination. It receives the radiation reflected from the target on the ground surface. It generates a very high resolution imagery of the Earth. It enables observation in all types of weather condition, day and night capabilities. Image filtering is very important field in SAR image processing. Synthetic Aperture Radar (SAR) data are affected by speckle noise. The speckle appearing in SAR image is due to the interference reflected waves. This noise complicates the problem of interaction of the image by reducing the exactitude of information. That is why speckle reducing is necessary before image analysis because speckle filtering of SAR image has a great impact on the accuracy. This paper proposes comparison between Box-car, Gaussian, Lee, Lopez and Lee sigma filter to remove speckle in RADARSAT-2 image. The results of these filters are analyzed and the implication of statistical parameters is compared. It includes Mean, Median, Standard Deviation, Coefficient Variance and Equivalence Number of Looks (ENL). The overall process is applied on microwave radar Quad Pole RADARSAT-2 Pol-SAR dataset of north of Vancouver, to the flat, agricultural lands of the Fraser River Delta is used.

Keywords: *Synthetic Aperture Radar (SAR), Polarimetric SAR (Pol-SAR), speckle noise filters*.

Introduction:

The microwave SAR is an active remote sensing system (Jensen, 2014), which acquired very high resolution images of the Earth. It has the capacity to penetrate through clouds, fog, smoke etc. though there is change in environmental changes and capable to sense the object on the Earth during the day or night. In the present study Quad Pole RADARSAT-2 Pol-SAR Vancouver dataset is used. The objective of these works is to reducing Speckle noise SAR image using the Box-car filter, Gaussian, Lee, Lopez and Lee sigma filter & analyzed the filtered images on the basis of statistical parameters. The statistical parameters *Viz.*, Mean, Standard Deviation, Coefficient Variance and ENL. This paper will provide comparative simulation model result of these filters using Pol-SAR-Pro Ver. 5.0 and NEST Ver. 5.0.16 software. The both software's are freely available on the internet developed by ESA.

Speckle Noise: Speckle noise is generated during the process of creating the SAR image that cause by coherent radiation. This noise causes the degradation of the image quality [4]. SAR images also have statistical property that mostly evolved from multiplicative noise model. This image can be formed as multiplicative noise models as follows: I (t) = R(t).v(t) Where, *I(t)* is the noise-affected signal, *R(t)* is original image or the radar backscatter property without noise of ground targets and *v(t)* is speckle noise and it is independent with *R(t)*. SAR speckle that generated by a zero-mean random phase of echo signals, causes the mean value of v(t) is one, and its variance is relevant with the equivalent number of SAR images. The speckle noise must be eliminated during the pre-processing of SAR images. This technique becomes an essential procedure in most of the target detection and recognition systems. However, it may lead to the loss of image details such as texture information or edges [1].

Polarimetric SAR Data Speckle Filters:

Filtering is a technique to remove unwanted signal/noise from an image. The main objective of speckle filtering is removing noise in the uniform area, preserve texture and enhance the edge without changing features, as well as providing a good visual appearance. The kernel window moves and applies a mathematical calculation and also

substitutes the value of the window central pixel. As a result, the smoothing effect and visual appearance reduced speckle is achieved [1]. The main objective of the present work is to provide a comparative study of Pol-SAR speckle noise filters with the intention to find the strengths of the different approaches. The objective is not to provide the details of every technique, but just the filtering principle on which the filtering is based on. Here used some (3×3) speckle filters:

Box Filter:

It is a simple averaging filter that replaces the center pixel in a square kernel by the mean value of kernel pixels. This filter has a good performance in reducing speckle in homogeneous area. Because of dealing similarly with all pixels in a kernel it degrades spatial resolution and also destroys the polarimetric properties [5]. Figure 2(a), (b), (c) shows intensity image obtained using a boxcar filter. This image shows enhanced contrast and lower random aspect. As it can be seen, the boxcar filter is characterized by two main limitations:

- Sharp edges are generally blurred.
- Point scatterers are over filtered and transformed to spread targets [8].

Gaussian Filter:

Gaussian filtering is more effective at smoothing images. It is used to blur images and remove noise and detail. In one dimension, the Gaussian function is: $G(x) = (1/\sqrt{\pi\sigma^2})\, e^{(x2/2\sigma2)}$. The Gaussian filter is a non-uniform low pass filter. It might not preserve image brightness. When working with images we need to use the two dimensional Gaussian function. $G(x, y) = (1/2\ ^2)\ e^{(x2+y2/2\sigma2)}$. Where, σ is the standard deviation of the distribution. It is a symmetric function. The Standard deviation of the Gaussian function plays an important role in its behavior. The Gaussian function is used in numerous research areas:

– It defines a probability distribution for noise or data.
– It is a smoothing operator.
– It is used in mathematics [6].

Figure 2 (d), (e), (f) shows intensity image obtained using a Gaussian filter.

Lee Filter:

The Lee filters compute a linear combination of the center pixel intensity in a filter window with an average intensity of the window for removing speckle noise [1]. Lee filtering is a standard deviation based filter that filters data based on statistics calculated within individual filter windows. Unlike a typical low-pass smoothing filter, the Lee filter and other similar sigma filters preserve image sharpness and detail while suppressing noise. The pixel being filtered is replaced by a value calculated using the surrounding pixels [8].

Lopez Filter:

In speckle noise model for the complete covariance matrix in Pol-SAR is proposed. This speckle noise model allows to identifying the noise characteristics for all the covariance matrix elements. The speckle noise characteristics depend on the complex correlation coefficient, causing the speckle noise nature to vary according to it. Two clear noise mechanisms have been identified. The first mechanism has a multiplicative noise mechanism controlled by the real and imaginary parts of the complex correlation coefficient. This mechanism is dominant only when the real or imaginary parts of the complex correlation coefficient are close to one and the second mechanism has an additive nature, being dominant for low-coherence values. As a result, speckle noise for the off-diagonal covariance matrix elements is non-stationary, but also speckle characteristics vary between its real and imaginary parts [2].

Lee-sigma Filter:

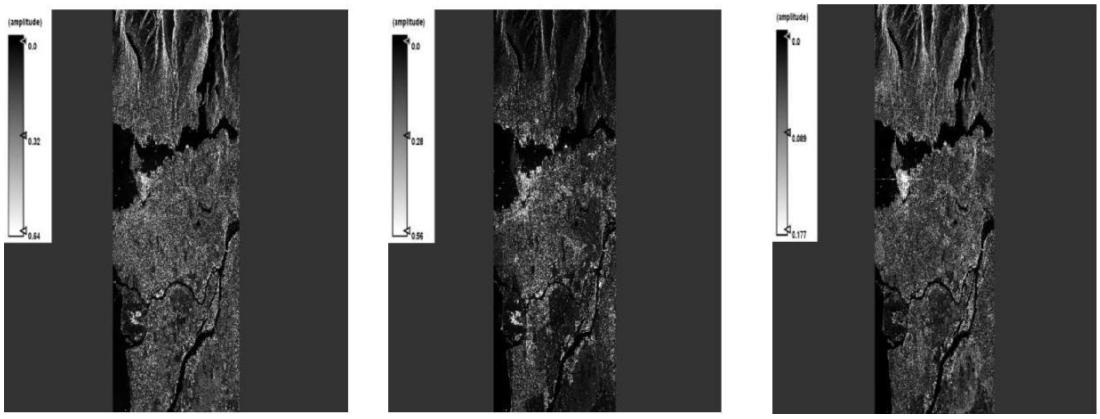
This filter is based on the sigma probability of a Gaussian distribution. It filters the image noise by averaging only those pixels within the two-sigma range of the center pixel within a scanning window. It is well known that the two sigma probability of Gaussian distribution is 0.955. Pixels outside the two sigma range are ignored, because they

are considered as outliers. Consequently, high contrast features are preserved. However, dark spot noise is not removed from the SAR image. This is due to the small sigma range associated with the dark pixels of the multiplicative noise model and a result no filtering action is taken for such pixels [2].

STUDY AREA

The study area is located in dataset of north of Vancouver, to the flat, agricultural lands of the Fraser River Delta with The dataset is quad polarized with HH/HV/VH/VV polarization and date of acquisition is 2008/05/06. RADARSAT-2 Dataset downloads from https://mdacorporation.com>satellite/ . The SAR dataset region of the study area is shown in figure 1.

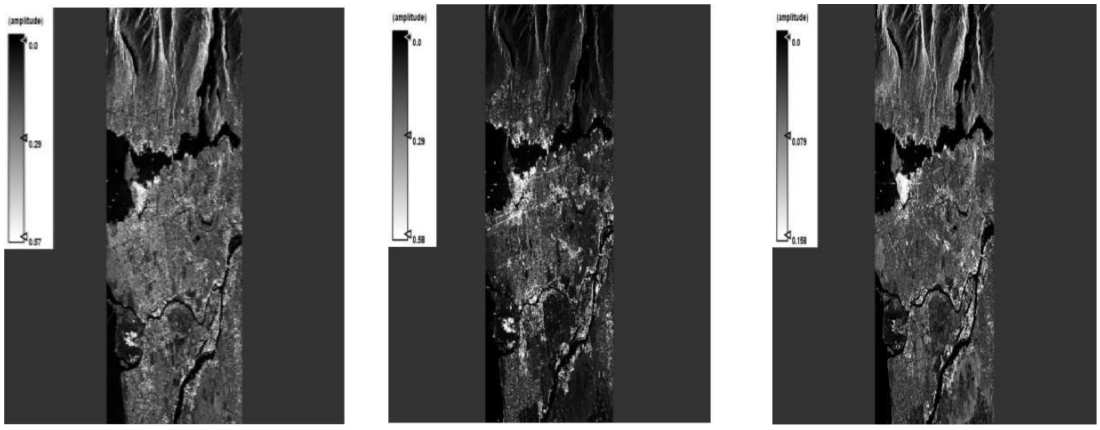
Figure 1: radarsat-2 data image of Band-1, Band-2 and Band-3



Band-1 [T11] Band-2[T22] Band-3[T33]

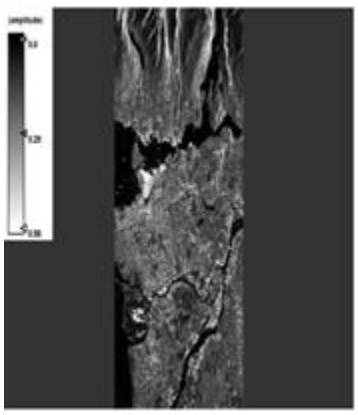
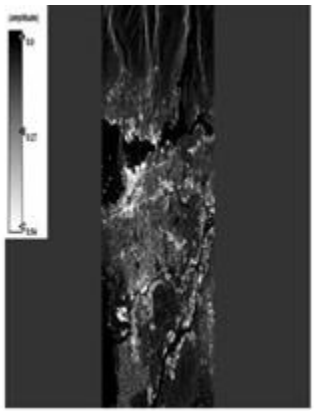
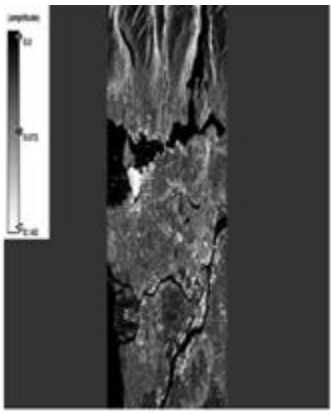
Figure 2: Box-car, Gaussian, Lee, Lopez and Lee sigma filtered images of band-1 for T11, Band-2 for T22 and Band-3 for T33.

Box-car filtered images:



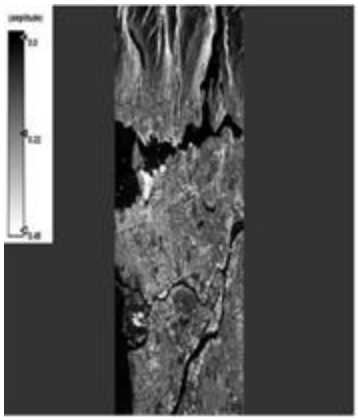
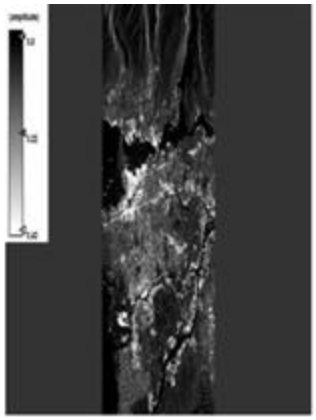
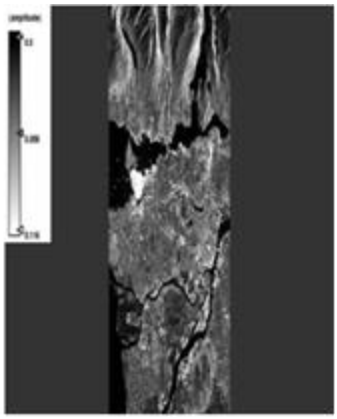
(a) (b) (c)

Gaussian filtered images:

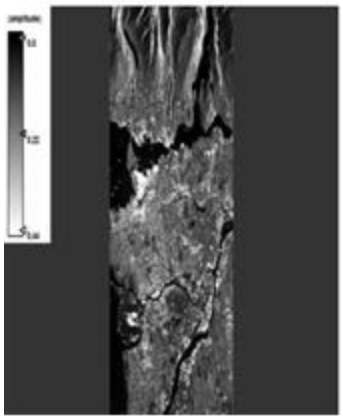
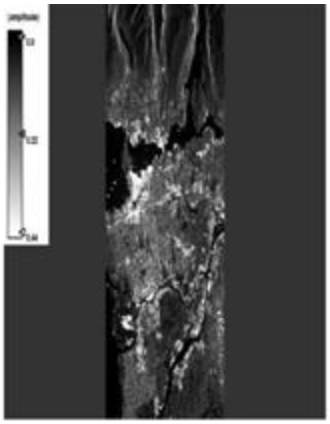
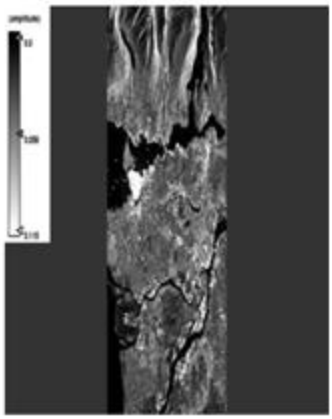
(d) ***(e)*** ***(f)***

Lee filtered images:

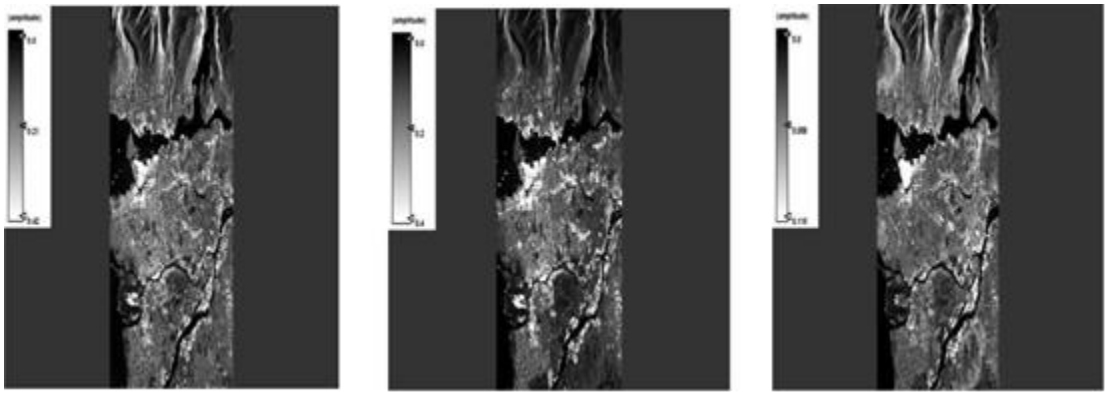
(g) **(h)** **(i)**

***Lopez filtered images*:**

(j) (k) (l)

Lee-sigma filtered images:



(m) (n) (o)

Statistical Parameters

Standard Deviation (SD):

In statistics, the standard deviation (σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. The standard deviation is commonly used to measure confidence in statistical conclusions.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Coefficient of Variation (CV):

This is also called as Standard deviation to mean ratio (SD/M) which is well known quantitative measure for evaluating the level of smoothing in homogenous area. Lower value of CV represents good speckle noise reduction.

CV = √ Var [ˆ] / E [ˆ].

Mean Square Error (MSE):

Mean Square Error is defined as (x, x') = E [(x- x') ^{2}] Where and ˆrepresents original and filtered images respectively, [·] denotes statistical mean. The highest value of MSE represents original and filtered images are dissimilar and lowest value represents better image quality of the filtered image. MSE based measurements are useful to obtain a global performance assessment on the whole image, but usually they yields little information about the preservation of specific features, for which other indexes can be used.

Equivalent Number of Looks (ENL):

The equivalent number of looks (ENL) was applied to measure the degree of suppression, which was defined as the square ratio of the mean to the standard deviation values in a homogeneous region. The larger the ENL was, the

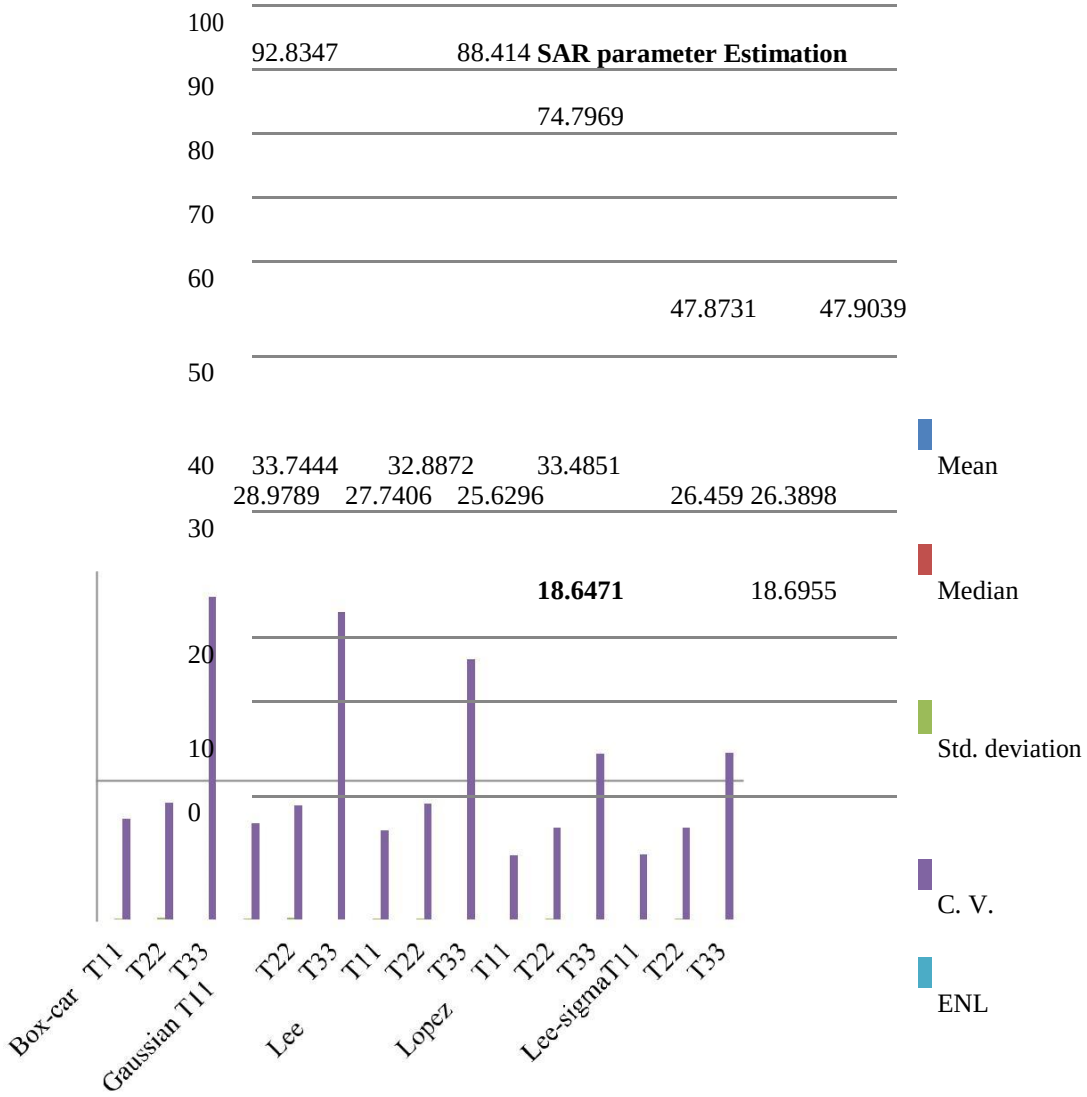
better the quality of the speckle reduction was. The ENL is another good indicator to show speckle noise reduction. The ENL for intensity image is defined as ( ) = 1/ ^{2} and for amplitude image is defined as ( ) = (0.522/) ^{2}

Table:

The accuracy assessment results of the speckle noise reduction using Box-car, Gaussian, Lee, Lopez and Lee-sigma filter for RADARSAT-2 Pol-SAR dataset of north of Vancouver, agricultural lands of the Fraser River Delta image on the basis of statistical parameter.

Filter\statistics	**Mean**	**Median**	**Std. deviation**	**C. V.**	**ENL**
Box-car T11	0.1632	0.0849	0.4063	28.9789	0.0012
T22	0.1010	0.0007	0.6299	33.7444	0.0009
T33	0.0192	0.0003	0.1598	92.8347	0.0001
Gaussian T11	**0.1649**	0.0809	0.3866	27.7406	0.0013
T22	0.1031	0.0007	0.6009	32.8872	0.0009
T33	0.0204	0.0004	0.1516	88.4140	0.0001
Lee T11	0.1428	0.1287	0.2637	25.6296	0.0015
T22	0.0848	0.0004	0.4023	33.4851	0.0009
T33	0.0215	0.0002	0.0987	74.7969	0.0002
Lopez **T11**	0.1389	0.0944	0.2318	**18.6471**	**0.0029**
T22	0.1078	0.0647	0.3306	26.4590	0.0014
T33	0.0306	0.0335	0.0861	47.8731	0.0004
Lee-sigma**T11**	0.1410	0.0948	0.2298	18.6955	**0.0029**
T22	0.1102	0.0650	0.3301	26.3898	0.0014
T33	0.0314	0.0336	**0.0858**	47.9039	0.0004

Figure 4: Graph for SAR statistical parameter of Box-car, Gaussian, Lee, Lopez and Lee-sigma filter for RADARSAT-2 Pol-SAR dataset of north of Vancouver, to the flat, agricultural land of the Fraser River Delta image



Conclusion:

In this paper comparison between Box-car, Gaussian, Lee, Lopez and Lee sigma filter to remove speckle in multi-look SAR image dataset of north of Vancouver, to the flat agricultural land the Fraser River Delta image is used. The results of these filters are analyzed and the implicated of statistical parameters it includes Mean, Median, Standard Deviation, Coefficient Variance and Equivalence Number of Looks (ENL) are compared. Evaluated the performance of statistical parameter of these filters, they are computed and provided comparative simulation model results of both filters using Pol-SAR-Pro Ver. 5.0 and NEST Ver. 5.0.16 software. In figure 1 show the Band-1, Band-2 and Band-3 of RADARSAT-2 input data image and figure 2 shows the result of Box-car[(a),(b),(c)], Gaussian[(d),(e),(f)], Lee[(g),(h)(i)], Lopez[(j),(k),(l)] and Lee sigma[(m),(n),(o)] filtered images of Band-1 for T11, Band-2 for T22 and Band-3 for T33. Ideally, mean should be close to unity and standard deviation should be as low as possible, Lower value of CV represents good speckle noise reduction and the higher value for ENL represents good noise reduction technique for a well performing filter. Here using the table

conclude that Mean close to unity (0.1649) of Gaussian filter of T11 (Figure 2(d)), low Std. deviation (0.0858) of Lee-sigma of T33 (Figure(o)), lower Coefficient Variance (18.6471) Lopez filter of T11(Figure 2 (j)) and higher value ENL(0.0029) of Lopez and Lee-sigma of T11(Figure 2 (j)&(m)) image, then conclude that the Lopez & Lee-sigma then Lee filter are better than Gaussian and Box-car filter.

References:

1. Ardhi Wicaksono Santoso, Luhur Bayuaji, Lim Tien Sze, Habibah Lateh and Jasni Mohamad Zain, "Comparison of Various Speckle Noise Reduction Filters on Synthetic Aperture Radar Image," International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 15 (2016) pp. 8760-8767 © Research India Publications. http://www.ripublication.com
2. Sivasubramanyam Medasani and G. Umamaheswara Reddy, "Analysis and Evaluation of Speckle Filters for Polarimetric Synthetic Aperture Radar (PolSAR) Data," International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 15 (2017) pp. 4916-4927 © Research India Publications. http://www.ripublication.com.
3. RADARSAT-2 Dataset downloads from https://mdacorporation.com>satellite
4. D. Mata-Moya, P. Jarabo-Amores, J. M. Muñoz-Ferreras, J. M. De Nicolás-Presa Ángel, and P.Vázquez, "Speckle filtering for SAR imagery learning through heuristic method," in 2nd International Conference on Space Technology, ICST 2011, 2011, pp. 1–4.
5. Mirmajid Mousav, Jalal Amini, Yaser Maghsoudi and Saeed Arab, "PolSAR Speckle Filtering Techniques and Their Effects On classification,'' ASPRS Annual Conference Tampa, Florida May 4-8 2015 , IGTF 2015.
6. Gaussian Filterring_1up.pdf, University of Auckland, New Zealand, 25/05/2010.
7. J. Zhu, J. Wen, and Y. Zhang, "A new algorithm for SAR image despeckling using an enhanced Lee filter and median filter," in Proceedings of the 6th International Congress on Image and Signal Processing (CISP), 2013, vol. 01, pp. 224–228.
8. Nupur saxena and Neha Rathore, "A Review on Speckle Noise Filtering Techniques for SAR Images," International Journal of Advanced Research in Computer Science and Electronics Engineering (IJARCSEE) Volume 2, Issue 2, February 2013 ISSN: 2277 – 9043.