Impact of Bandwidth on LANDSAT-7 ETM+ Image Quality using Gaussian Filter: Mysore, INDIA

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Abstract— Gaussian filter smoothens digital images during preserving edges, by re-evaluating every pixel. In computing the new pixel value, a window is centered on the pixel of interest with local neighborhood pixels. In this paper, Gaussian filtering technique implemented over LANDSAT-7 ETM+ satellite data product to analyze the impact of bandwidth. The recommendation of window is based on the statistical analysis which best enhances the image while preserving the edges. For satellite image with spatial resolution around 30m, window 3x3 for SD = 3, 3x3 for SD = 1.5, 9x9 for SD = 0.75 and 9x9 for SD = 0.375 are recommended. Resulting in blurred image, the largest window 9x9 was recommended to obtain better results.

Keywords— Gaussian Filter, Enhanced Edges, LANDSAT-7 ETM+

I. INTRODUCTION

In the image processing and computer vision Gaussian filter is extensively used. Signals get distorted when the noise is smoothed out. Gaussian filter is used for edge detection which also gives rise to edge position displacement, vanishing of edges and phantom edges. Authors have explained various techniques for noise removal problems. Gaussian filtering algorithm is later proposed, in which the filter variance is adapted for both noise characteristics and local variance of the signal [1]. In the theory of edge detection analysis proceeds in two parts, First, Changes which occur in a natural image over a wide range of scales are identified distinctly at different scales and intensity changes in images arise from surface discontinuities [2].

In the image, edge detection is the task of determining and focusing changes of light intensity. As discussed by V. Terre and T. Poggio (1984), edge detection is a problem of numerical differentiation. Author shows the regularization techniques, which leads to filtering the image earlier to the suitable differentiation operation. This process is equivalent to convolving the data with the desired derivative of a generalized spline filter [3]. The optimal detector has a simple approximate implementation in which edges are marked at maxima in gradient magnitude of a Gaussian-smoothed image. Author prolonged this finder using operators of several widths to cope with different signal-to-noise ratios in the image. The impulse response of the optimal step edge operator was shown to approximate the first derivative of a Gaussian [4].

Andres Huertas and Gerard Medioni have proposed technique that takes a gray level image as input, locates edges with sub pixel accuracy, and links them into lines. Edges are detected by finding zero-crossings in the convolution of the image with Laplacian-of-Gaussian (LoG) masks. Authors locate zero-crossings with pixel precision that is the edge on the pixel which has the smallest absolute value [5]. Fast calculation of edge and ridge maps were done by anisotropic Gaussian filtering method with high spatial and angular accuracy. Convolution filtering is advantageous when considering locally steered filtering. But, as is the case of tracking applications recursive filtering is more attractive when smoothing or differentiating the whole image array [6].

The various features of Gaussian operator that make it the filter of choice in the area of edge detection are discussed. Despite these desirable features of the Gaussian filter, edge detection algorithms with associated problems are highlighted [7]. Scale-space filter constructs the hierarchic symbolic signal descriptions by converting the signal into a continuum of versions of the original signal convolved with a kernel containing a scale or bandwidth parameter. It is shown that the Gaussian probability density function is the only kernel in a broad class for which first-order maxima and minima respectively, increase and decrease when the bandwidth of the filter is increased [8].

II. STUDY AREA AND DATA PRODUCTS

Mysore is the cleanest city in the Karnataka; India located about 146 km from the state capital. It has an average altitude of 770 meters and spread across an area of 128.42 km^2. During 2001, the land area used in Mysore city was 16.1% roads, 39.9% residential, 13.48% industrial, 13.74% parks and open spaces, 3.02% commercial, 2.02% water, 8.96% public property and 2.27% agriculture.

The description of satellite image used in this testing is depicted in Table 1. The data are of LANDSAT-7 ETM+ obtained from United States Geological Survey (USGS) and Google Earth. The Table 2 shows LANDSAT-7 ETM+ data bands along with ground features.

Fig 1: Google Earth Snapshot of Mysore Rural and Urban Study Area

Table 1: Specifications of Satellite Data Products used

S L . N o	Satellite and Data Type	Date of Acquisi tion	Spectral Resolution	Spatial Resoluti on
1.	Land Sat ETM 7	2010	Blue (0.45-0.515μm) Green (0.525-0.605μm) Red (0.632-0.69μm) Near Infrared (0.75-0.90μm) Short wave IR-1 (1.55-1.75μm) Thermal IR (10.4-12.5μm) Short wave IR-2 (2.09-2.35μm)	30.0m
2.	Google Earth	April 2016	-	-

Table 2: LANDSAT-7 ETM+ Bands along with Ground Features

Ground Feature	Bands Used
Water	1,2,3; 1,2,4; 1,4,5
Urban	1,2,3; 1,4,5
Farmland	1,2,3; 1,4,5
Forest	1,2,3; 1,4,5
Salt scald	1,2,3
Scrub	1,4,5
Vegetation	1,4,7

III. METHODOLOGY
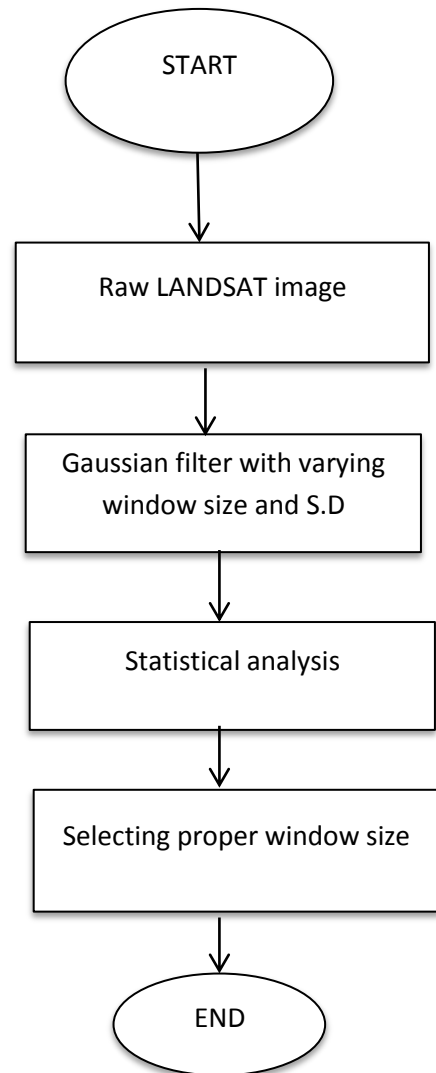
Fig 2: Proposed Methodology for Image Quality using Gaussian Filter

The methodology adapted as shown in Fig 2 to assess the impact of bandwidth on satellite image using Gaussian filter. During the first phase of the experiment, the data was procured and pre-processed. Gaussian filter was applied with varying window sizes 3x3, 5x5, 7x7, 9x9 for standard deviations 3, 1.5, 0.75, 0.375 respectively. Finally, proper window size was selected based on statistical analysis viz Mean, SD and SNR.

IV. EXPERIMENTAL RESULTS

Fig 3 depicts the gray scale image of LANDSAT-7 ETM+ data considered during this experiment. Fig 4 shows the Gaussian filter response for 3x3 size window with standard deviation 0.375 producing mean value of 147.0181 and standard deviation of 57.4985.
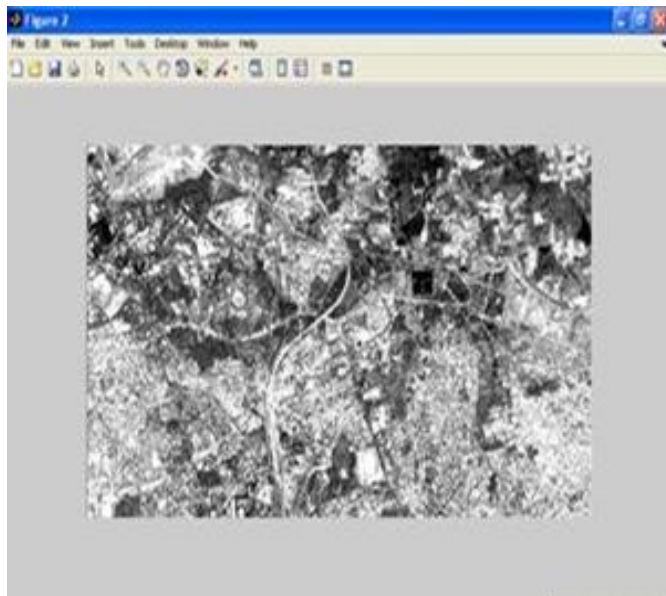
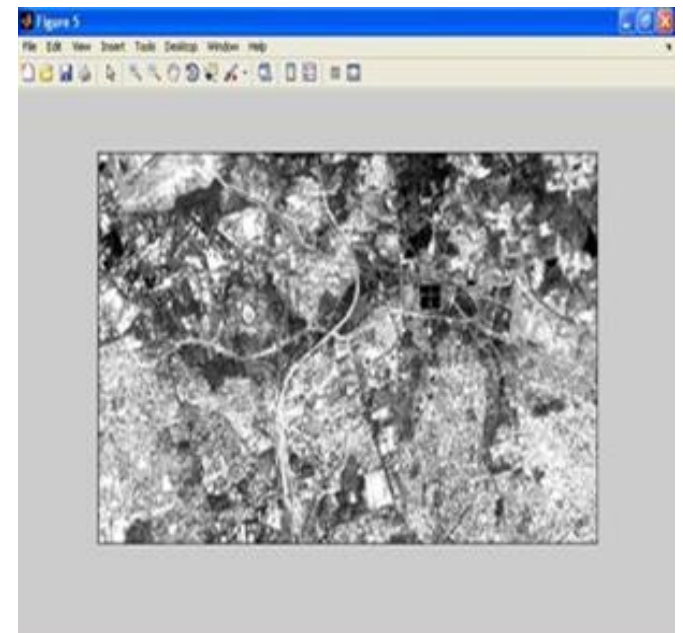Fig 5 shows the Gaussian filter response for 3x3 window size with standard deviation 0.75 producing mean value of 147.0295 and standard deviation of 58.0898. Fig 6 shows the Gaussian filter response for 3x3 window size with standard deviation 1.5 producing mean value of 147.2009 and standard deviation of 59.0779.

Fig 3: Conversion of LANDSAT Image into Gray Scale

Fig 5: 3x3 Size Window with Standard Deviation 0.75
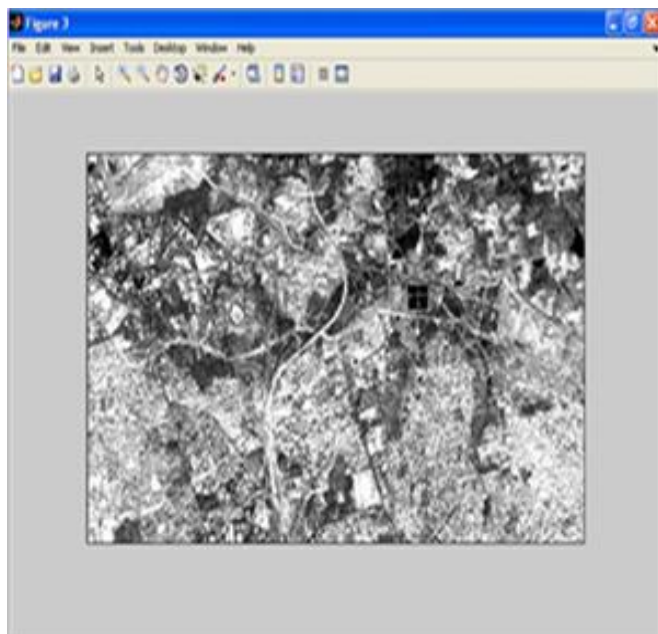
Fig 4: 3x3 Size Windows with Standard Deviation 0.375

Fig 6: 3x3 Size Window with Standard Deviation 1.5

Fig 7 shows the Gaussian filter response for 3x3 window size with standard deviation 3 producing mean value of 147.6440 and standard deviation of 66.8350. Fig 8 shows the Gaussian filter response for 5x5 window size with standard deviation 0.375 producing mean value of 146.2735 and standard deviation of 53.5868.
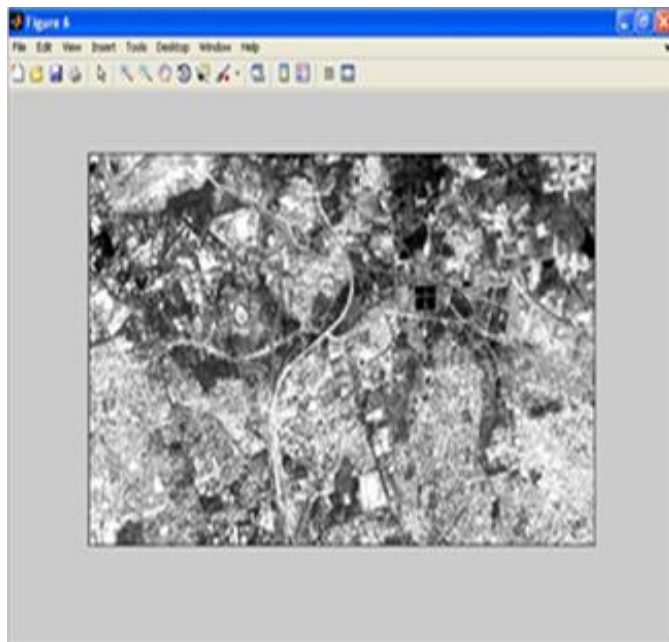
Fig 9 shows the Gaussian filter response for 5x5 window size with standard deviation 0.75 producing mean value of 145.8676 and standard deviation of 55.1626. Fig 10 shows the Gaussian filter response for 5x5 window size with standard deviation 1.5 producing mean value of 145.9870 and standard deviation of 59.4885.
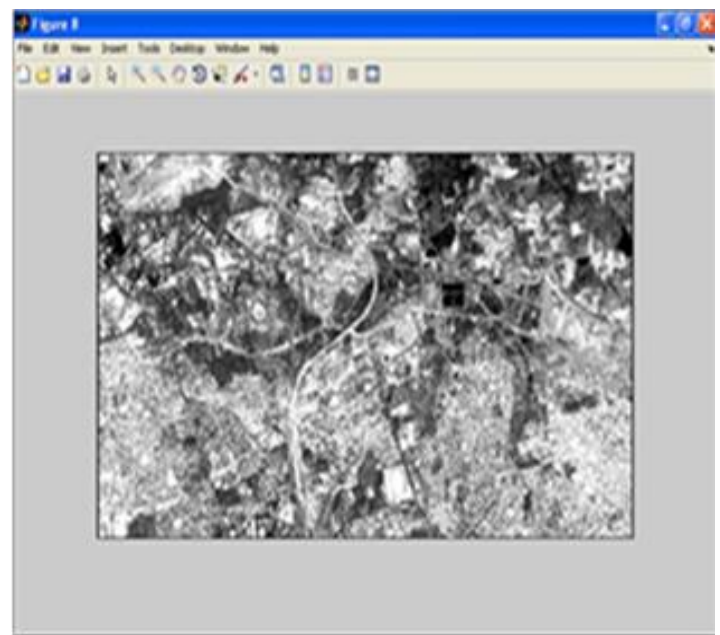

Fig 7: 3x3 Size Window with Standard Deviation 3

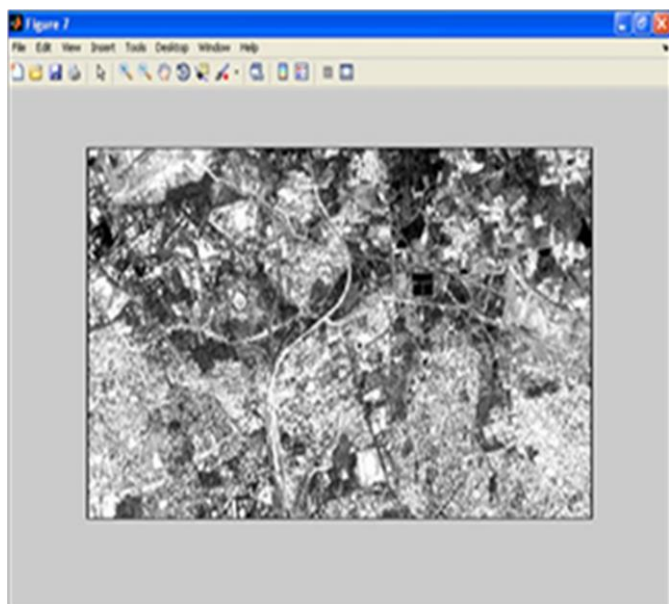**Fig 9: 5x5 Size Window with Standard Deviation 0.75**

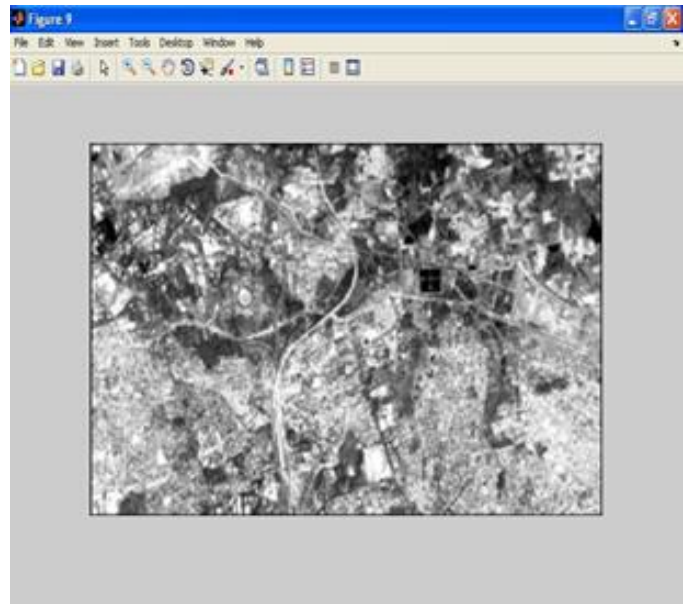**Fig 8: 5x5 Size Window with Standard Deviation 0.375**

Fig 10: 5x5 Size Window with Standard Deviation 1.5

Fig 11 shows the Gaussian filter response for 5x5 window size with standard deviation 3 producing mean value of 146.8167 and standard deviation of 68.4499. Fig 12 shows the Gaussian filter response for 7x7 window size with standard deviation 0.375 producing mean value of 145.2860 and standard deviation of 52.1160.

Fig 13 shows the Gaussian filter response for 7x7 window size with standard deviation 0.75 producing mean value of 144.7191 and standard deviation of 55.0351. Fig 14 shows the Gaussian filter response for 7x7 window size with standard deviation 1.5 producing mean value of 144.7349 and standard deviation of 60.8659.
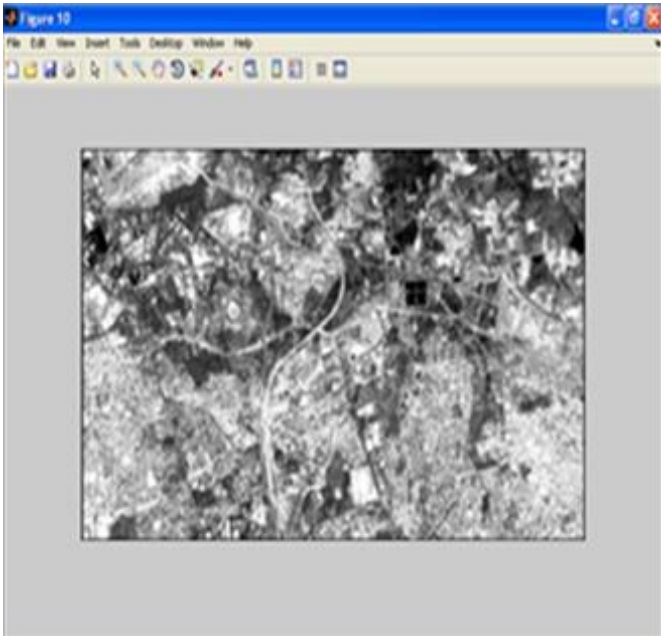

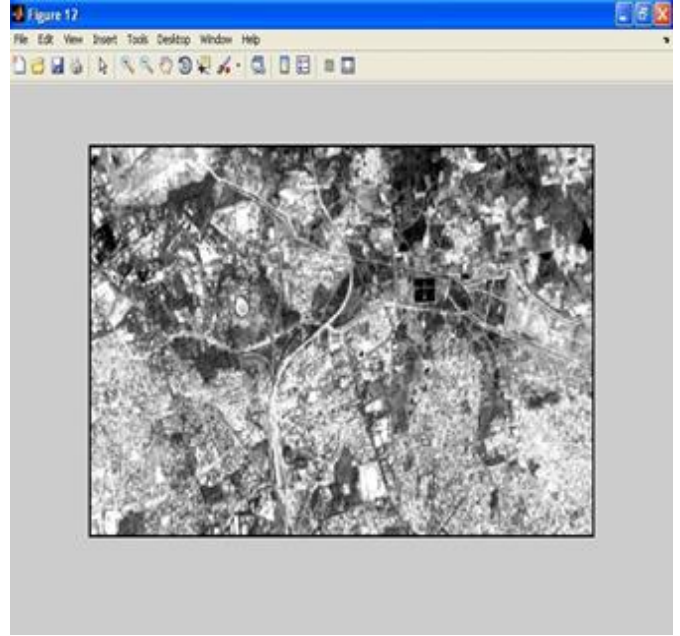**Fig 11: 5x5 Size Window with Standard Deviation 3**

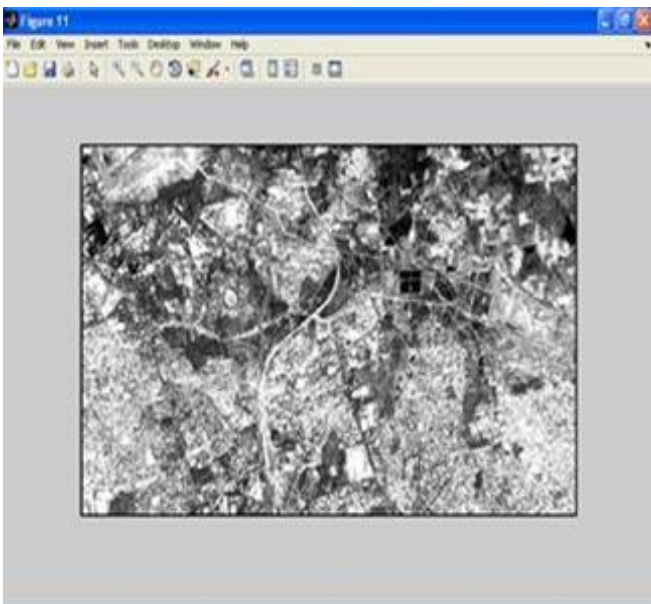**Fig 13: 7x7 Size Window with Standard Deviation 0.75**

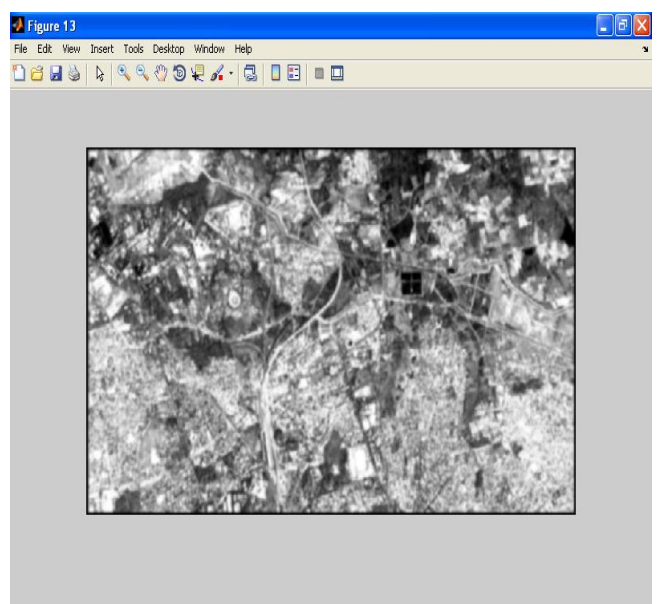**Fig 12: 7x7 Size Window with Standard Deviation 0.375**

Fig 14: 7x7 Size Window with Standard Deviation 1.5

Fig 15 shows the Gaussian filter response for 7x7 window size with standard deviation 3 producing mean value of 146.2569 and standard deviation of 67.3275. Fig 16 shows the Gaussian filter response for 9x9 window size with standard deviation 0.375 producing mean value of 145.0560 and standard deviation of 50.7162.
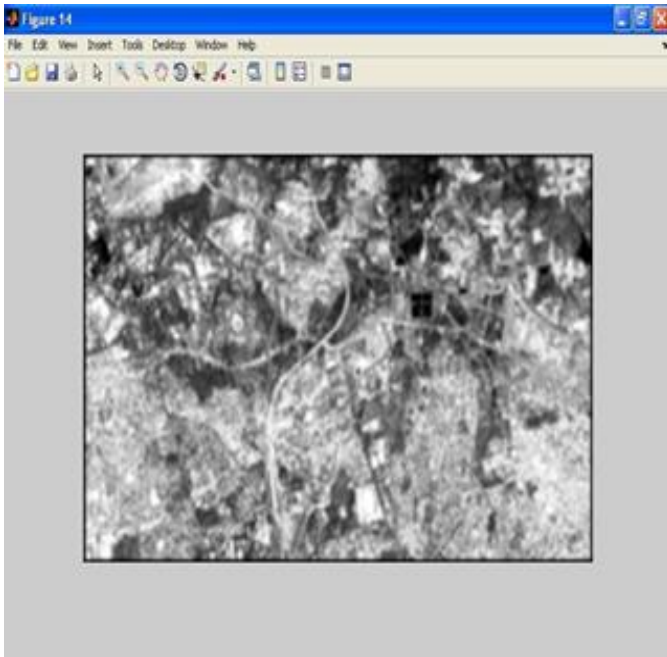
Fig 17 shows the Gaussian filter response for 9x9 window size with standard deviation 0.75 producing mean value of 144.7086 and standard deviation of 54.7057. Fig 18 shows the Gaussian filter response for 9x9 window size with standard deviation 1.5 producing mean value of 144.7788 and standard deviation of 60.5960.
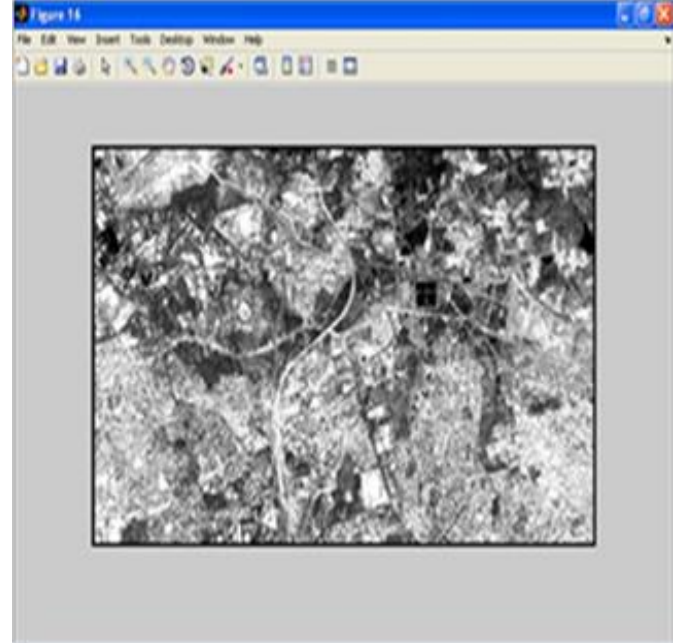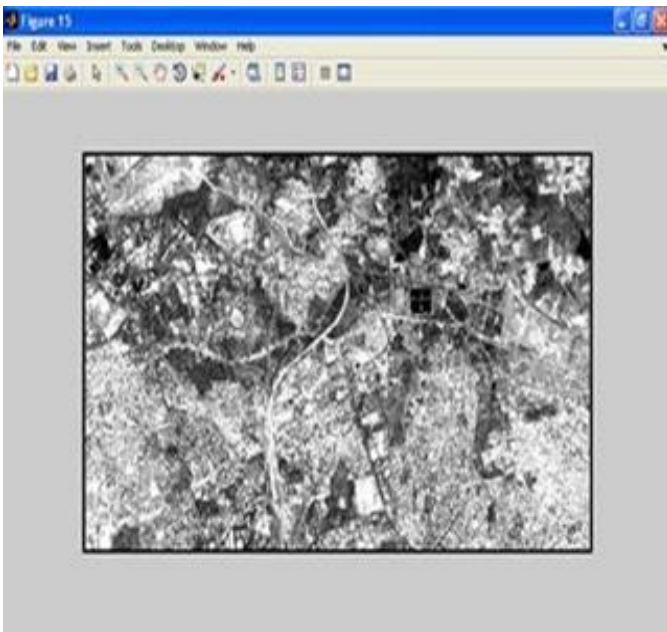

Fig 15: 7x7 Size Window with Standard Deviation 3

Fig 17: 9x9 Size Window with Standard Deviation 0.75

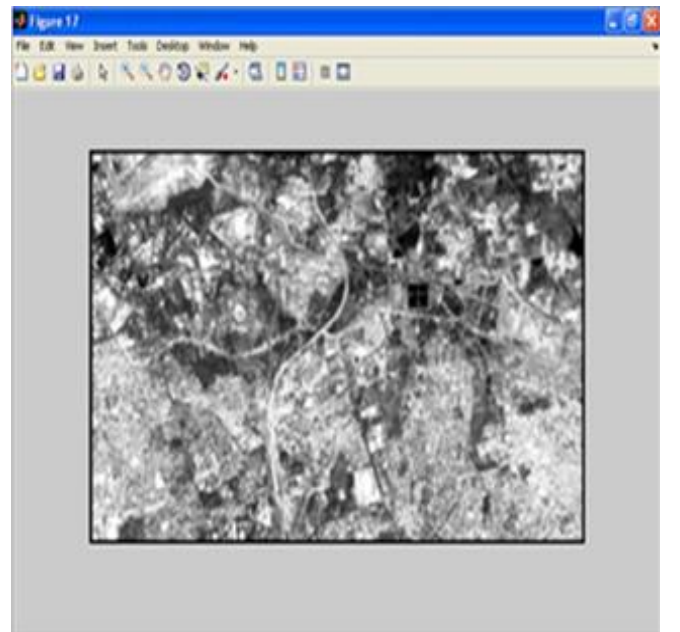**Fig 16: 9x9 Size Window with Standard Deviation 0.375**

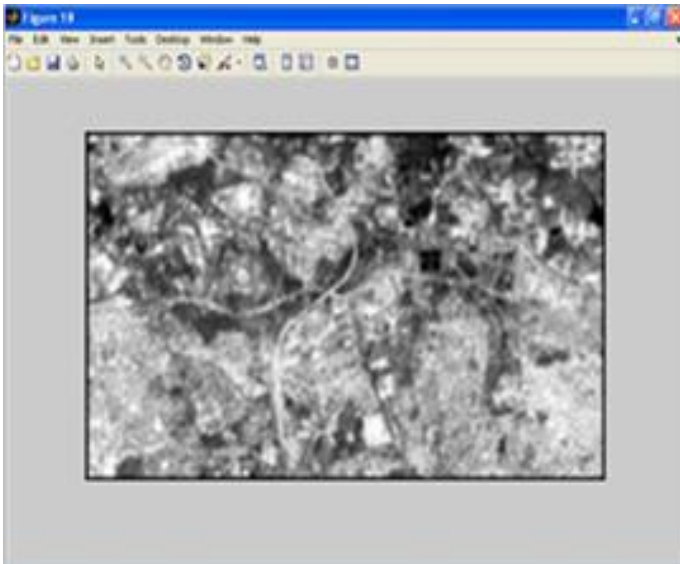**Fig 18: 9x9 Size Window with Standard Deviation 1.5.**

Fig 19: 9x9 Size Window with Standard Deviation 3

Fig 19 shows the Gaussian filter response for 9x9 window size with standard deviation 3 producing mean value of 143.9104 and standard deviation of 69.2592.

Table 3. Statistical Measures of Gaussian Filter for Different Size & SD

Filter Window Standard Deviation	Filter Window Size	Min	Max	Mean	Standard Deviation	SNR
		1	255	147.4123	67.5939	2.1755
3	**3 x 3**	**0**	**255**	**147.6440**	**66.8350**	**2.2090**
3	5 x 5	0	255	146.8167	68.4499	2.1448
3	7 x 7	0	255	146.2569	67.3275	1.5026
3	9 x 9	0	255	143.9104	69.2592	2.0778
1.5	**3 x 3**	**0**	**255**	**147.2009**	**59.0779**	**2.916**
1.5	5 x 5	0	255	145.9870	59.4885	2.4540
1.5	7 x 7	0	255	144.7349	60.8659	2.378
1.5	9 x 9	0	255	144.7788	60.5960	2.3892
0.75	3 x 3	0	255	147.0295	58.0898	2.5312
0.75	5 x 5	0	255	145.8676	55.1626	2.6443
0.75	7 x 7	0	255	144.7191	55.0351	2.6295
0.75	**9 x 9**	**0**	**255**	**144.7086**	**54.7057**	**2.6454**
0.375	3 x 3	0	255	147.0181	57.4985	2.5569
0.375	5 x 5	0	255	146.2735	53.5868	2.7296
0.375	7 x 7	0	255	145.2860	52.1160	2.7877
0.375	**9 x 9**	**0**	**255**	**145.0560**	**50.7162**	**2.8600**

Analyzing the statistical values depicted in Table 3, selection of better window can be made for various standard deviations viz. 3, 1.5, 0.75 and 0.375. From Table 3, for window with standard deviation of 3, the filter window size 3x3 was recommended to enhance the image quality while preserving the edges. Similarly, for window with standard deviation of 1.5, the filter window size 3x3 was recommended. For window with standard deviation of 0.75, the filter window size 9x9 was recommended. For window with standard deviation of 0.375, the filter window size 9x9 was recommended.

V. CONCLUSION

The recommendation of window is performed based on the statistics which best improves the quality of image while retaining the edges. The Gaussian filtering approach to preserve the image quality of satellite image with high resolution around 30 m, window size 3x3 for SD = 3, window size 3x3 for SD = 1.5, window size 9x9 for SD = 0.75 and window size 9x9 for SD = 0.375 are recommended. Resulting in blurred images, the largest window size 9x9 was recommended to obtain better results. The Gaussian filtering technique can be implemented further for different satellite data products of interest. The Gaussian filtering technique can be implemented further for more than 9x9 window sizes to analyze the impact of bandwidth as well.

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