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Satellite Image Enhancement Using Histogram Equalization

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ABSTRACT

Image enhancement is an indispensable technique in improving the quality, brightness, contrast and clarity of satellite images. The object that appears in images and variation caused by shadow, occlusion, camouflage in satellite images are the fundamental challenges posed by image enhancement techniques. The aim of this research work was to enhance satellite images of Sambisa using histogram equalization technique. MATLAB 2021 was used to implement the experiment. The results show that histogram equalization method has an excellent processing effect and it improved the brightness, contrast and clarity of the images as compared original images and the enhanced images.

Keywords: Histogram equalization; Image enhancement; Satellite image; Image preprocessing

1. Introduction

Image enhancement is an essential stage in satellite image analysis, improving the quality appearance of every pixel in an image is a prerequisite for getting the accurate results during analysis. However, the pixel appearance and the variation caused by shadow, camouflage and noise caused by mechanical and electronic components of satellite during the process of acquisition are the fundamental challenges

posed by different enhancement techniques in recent years.

Satellite images are collection of images of either the whole earth surface or some part of it (lithosphere, biosphere, and hydrosphere) or other planet captured by an artificial satellite from the space where electromagnetic radiation serves as a carrier of information^[1]. These images have been applied in so many areas of human endeavor such as intelligent military, remote sensing, metrology transportation system and many

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ARTICLE INFO

Received: 4 November 2022 | Revised: 20 March 2023 | Accepted: 21 April 2023 | Published Online: 10 May 2023
DOI: <https://doi.org/10.30564/ese.v5i1.5234>

CITATION

Goni, I., Malgwi, Y.M., Ahmadu, A.S., 2023. Satellite Image Enhancement Using Histogram Equalization. *Electrical Science & Engineering*. 5(1): 9-20. DOI: <https://doi.org/10.30564/ese.v5i1.5234>

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more.

Image enhancement is the process of increasing the quality, brightness sharpness smoothness of an image different techniques and methodologies are applied in the literature to enhance images. Based on this, we are going to review specifically on histogram equalization technique. In the work of Tan T. et al. ^[2], they applied non-linear histogram equalization on background brightness preservation three different histograms were plotted in this work: Low medium and high grey levels. The purpose here was to enhance both the objects as well as the background of the image. This is practically applied in digital and analog satellite image analysis is the ability to contrast, stretch, cropped, filter, degrade image and histogram equalization to enhance low and high frequency component edges and texture of the images ^[3]. Moreover, satellite images can be linearly and non-linearly converted with the real world phenomena using statistical technique called principal component analysis ^[4].

In the work of Shanmugavadivu and Balasubramanian ^[5], the central idea of this technique is initially to segment the input image into two using Otsu's threshold, based on which a set of weighing constraints is formulated. A decision is made whether to apply those constraints to any one of the sub-histograms or to both, with respect to the input image's histogram pattern. Then, those two sub-histograms are equalized independently and their union produces a contrast enhanced output image. While formulating the weighing constraints, Particle Swarm Optimization (PSO) is employed to find the optimal constraints in order to optimize the degree of contrast enhancement. In the work of Shome and Vadali ^[6], contrast limited adoptive histogram equalization technique was applied to normalize the contrast in the retinal image to enable improved the quality of the image and also preserved the sharpness of the image. The number of histogram peaks, spreads, and their degree of asymmetry provide clear information about the class count and their separation, homogeneity, and the structural properties of the image. Moreover, in the research of Purna and

Pratiks ^[7], these algorithms also provide nonlinear contrast enhancement to some extent. They took pre-existed algorithms like SMQT (Successive Mean Quantization Transform), V Transform, histogram equalization algorithms to improve the visual quality of digital pictures with large range scenes and with irregular lighting conditions. These algorithms were performed in two different methods and tested using different images facing low light and color change and succeeded in obtaining the enhanced image. These algorithms help in various enhancements like color, contrast and very accurate results of images with low light. Multidimensional histograms, on the other hand, represent the grey level distribution of multispectral images and are used to find the difference in the band's responses for the same scene, allowing easy and efficient interpretation, analysis and classification of the objects in the image ^[8].

Landsat satellite is an American remote sensing satellite launched on 23rd July 1972, and it was the first satellite that consistently provides earth images with a very excellent at that time. Later the USA launched a series of satellites ranging from Landsat-1 to Landsat-8 as summarized in **Table 1** ^[9]. Landsat satellites are jointly managed by the consortium of the United States of America and National Aeronautic Space Administration (NASA). This category of satellites moves around the earth on a near polar sun-synchronous orbit having an altitude of 705.3 km, covering the entire earth within 16 days and capturing over 400 images within 24 hours.

Landsat-8 was launched on 11th February, 2013 from Vandenberg Air force base California. It was developed by the consortium of National Aeronautics and Space Administration (NASA) and United State Geological Survey (USGS) in which NASA led the mission and spearhead in "system engineering and system design, developing the flight segment, providing support in launch services, flight ground system integration, including testing in the orbit and verification". While USGS spearhead in "ground system development". It is then that the satellite was named Landsat-8 on 30th May, 2013. Finally, USGS became formally responsible for controlling and co-

ordinating operations including collecting archiving, processing and distributing of Landsat data. Landsat-8 consists of two recording sensors: “Operational Land Imager” (OLI) and “Thermal Infrared Remote Sensor” (TIRS) capturing over 500 images in a day^[10]. Satellite images were downloaded from their website.

1.1 Advantages of Landsat satellite image

- i. It is free for US and international users who are going to use it for research and commercial purposes.
- ii. Landsat-8 images are cloud-free.
- iii. Landsat images maintained data continuity by providing data that are consistent in terms of geometry spatial resolutions, calibration, coverage features, and spectral features with the previous images captured by the Landsat satellites.

The Spectral Characteristics Viewer in remote sensing satellite is an interactive tool that can be used to visualize how the bands or channels of different satellite sensors measure the intensity of the many wavelengths (colors) of light. This is also called the relative spectral response. The major characteristics of Landsat satellite are illustrated in **Table 1** below.

Table 1. Operational land image and thermal infrared sensor of Landsat-8.

Landsat-8		Wave length
1. Band 1	Coastal aerosol	0.43-0.45
2. Band 2	Blue	0.45-0.51
3. Band 3	Green	0.53-0.59
4. Band 4	Red	0.64-0.67
5. Band 5	Near infrared	0.85-0.88
6. Band 6	Shortwave infrared	1.57-1.65
7. Band 7	Shortwave infrared	2.11-2.29
8. Band 8	Panchromatic	0.50-0.68
9. Band 9	Cirrus	1.36-1.38
10. Band 10	Thermal Infrared	10.60-11.19
11. Band 11	Thermal Infrared	11.50-12.51

1.2 Methods of image enhancement

Basically, there are different methods available for image enhancement such as power-law transformation and piecewise linear transformation.

The major advantages of piecewise linear transformation are:

- 1) It is mainly used in contrast stretching.
- 2) It is applied to intensity level slicing.
- 3) It is also applied to bit plane slicing.

The disadvantages of piecewise linear transformation:

- 1) Improper illumination occurrence in low contrast value.
- 2) Image sensor there will be a loss of dynamic value and also in the acquisition of the image wrong placement of the lens aperture may happen during the processing of the image.

2. Histogram equalization

The histogram equalization is a plot that illustrates the frequency of occurrence of various grey levels in an image. It presents the probability distribution of intensity values which is the basis for spectral image analysis and classification. It is normally used in transformation functions to equalize. The shape of the histogram indicates the amount of spectral data that fall in each range of intensities as well as the corresponding classes of objects in an image. The statistics derived from the plots such as mean and standard deviation also specify other features of an image such as average brightness and the contrast of the image. The number of histogram peaks, spreads, and their degree of asymmetry provide clear information about the class count and their separation, homogeneity, and the structural properties of the image. Multidimensional histograms, on the other hand, represent the grey level distribution of multispectral images and are used to find the difference in the band's responses for the same scene, allowing easy and efficient interpretation, analysis and classification of the objects in the image^[10].

Histogram equalization is an advanced statistical technique in image processing for improving the construction of either dark image or light image, the final output of the processing image is given by $g(x, y)$. In a direct form let $rk = f(x, y)$ the histogram equalization of the image $g(x, y)$ is given as:

$$g(x, y) = Sk = (l-1)^n = \sum_{j=0}^k p(rj) \quad (1)$$

Theoretically let r represent the grey levels of the image and S on random variables in relation to probability function $Pr(r)$ and $Ps(s)$ respectively then from (5) if we use the cummulative distribution function it become:

$$S = T(r) = (l-1) \int_0^T pr(w)dw \quad (2)$$

Such that $Pr(r) > 0$ on $[0, L-1]$ then T is increasing from $[0, L-1]$ to $[0, l-1]$ but T is invertible.

However, if we differentiate T and use the formula from probability if $T(r)$ then:

$$Ps(s) = Pr(r) \left[\frac{\partial s}{\partial r} \right] \quad (3)$$

Since we refer $s = s(r) = T(r)$ on a formula of r where $r = r(s) = T^{-1}(s)$ as a function S with reference to the diffraction of s then we have:

$$\frac{\partial r}{\partial s} = (l-1) pr(r) = T^{-1}(r) \quad (4)$$

Therefore the equation becomes:

$$\frac{\partial r}{\partial s} = \frac{\partial}{\partial s} (T^{-1}(s)) = \frac{1}{T^{-1}(s)} = \frac{1}{(l-1)pr(r(s))} \quad (5)$$

But,

$$Ps(s) = pr(r) \left[\frac{\partial s}{\partial r} \right] = pr(r) \left[\frac{1}{(l-1)pr(r)} \right] = \frac{1}{l-1} \quad (6)$$

The Equation (10) now becomes the uniform distribution function on the interval $[0, l-1]$ which also correspond to the flat histogram equation of the image in a discrete form.

3. Method

To implement histogram equalization on RGB images each channel of the RGB was concatenated and got a better image. The probability density function (PDF) that was operated, changed to uniform PDF that was spread out from the lower pixel (0) to the highest pixel values and this was achieved since PDF was in continuous function.

Probability density function (PDF) was approximated using probability based on the histogram $p(rk)$ as:

$$pdf(x) = p(rk) = \frac{\text{Total Pixels with intensity values } rk}{\text{Total Pixels values in the image}} \quad (7)$$

From Equation (4) the Commutative Density Function (CDF) is given as:

$$cdf(x) = p(rk) \quad (8)$$

Therefore the histogram is given as:

$$p(sk) = \sum_{k=0}^m p(rk) \quad (9)$$

Since the histogram was interpreted as a probability density function and the images were considered as a discrete function then commutative distribution function was applied so that the histogram can be finally obtained as:

$$f(m) = \frac{255}{NXM} \times \sum_{k=0}^m n[k] \quad (10)$$

The computational Expression of equation (10) was implemented in MATLAB 2021.

Datasets

To prepare a dataset for satellite image analysis in MATLAB the images are supposed to be segmented, Segmented image is a proposed image without noise and sometimes sharp which can be an input f and the output could be an image g or not even an image but would be an attribute set of the point representing the edges of f boundaries of the object but, segmentation is based on certain criteria such as similarity, color texture or region of interest or any set of predefined rules.

If we consider a differentiable function $(x, y) \rightarrow f(x, y)$ in two dimensions to let defined it gradient operator as being the vector of first order partial derivatives.

$$\Delta f(x, y) = \left(\frac{\partial f}{\partial x}(x, y), \frac{\partial f}{\partial y}(x, y) \right) \quad (11)$$

And the gradient magnitude as Euclidean norm of the vector Δf :

$$|\Delta f|(x, y) = \sqrt{\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2} \quad (12)$$

The central finite differences approximation of the gradient are assuming $\Delta f_x = \Delta f_y = 1$.

$$\begin{aligned} \frac{\partial f}{\partial x}(x, y) &\approx \frac{f(x+1, y) - f(x-1, y)}{2}, \quad \frac{\partial f}{\partial y}(x, y) \\ &\approx \frac{f(x, y+1) - f(x, y-1)}{2} \end{aligned} \quad (13)$$

The gradient can be used to detect edges where the image f does not vary the gradient magnitude $|\Delta f|$ is close to zero while in the area where there is a strong variation the gradient magnitude $|\Delta f|$ is larger. Since we have defined the output image as $g(x, y) = |\Delta f|(x, y)$ which would show white edges or black background or a threshold version of $|\Delta f|$.

If we are to represent the discrete version of the output it would become:

$$g(x, y) = |\Delta f|(x, y) \quad (14)$$

Or the threshold gradient of the output can be represented as:

$$g(x, y) = \begin{cases} 255 & |\nabla f|(x, y) \geq \text{tolerance}T \\ 0 & |\nabla f|(x, y) < \text{tolerance}T \end{cases} \quad (15)$$

where the operation $f \rightarrow g$ $|\nabla f|$ is *ono linear*.

4. Results and discussion

Satellite images require enhancement after pre-processing in this research work histogram equalization was used to enhance the quality and visibility of the filtered images, images of the selected years are enhanced and plot their associated histogram equalization as shown in the figures below.

Histogram was applied to the denoised image of the Sambisa forest captured in 2019 using MATLAB by merely looking from the outputs all the intensity values are distributed and enhanced and the brightness of the images is improved. The quality, contrast, brightness of the colors is significantly improved with much better as compared with the original image. Moreover, the histogram equalization of both the original image and the enhanced images are plotted to verify the efficiency of the technique used, this shows that the histogram equalization of the enhanced image was widely spread out, that is, the images are exposed to proper contrasting method. In addition, excellent contrast in the enhanced image can be clearly seen with larger differences between maximum and minimum intensity values in the histogram. By comparing the two histograms it can be concluded that the proposed technique is highly efficient in terms of enhancing the quality of satellite

images which was also implemented by Purna and Pratiks^[7] in their dissertation and is similar to our work as shown in **Figure 1** below.

Histogram was applied to enhance the quality of the denoised satellite image of the Sambisa forest captured in 2021 using MATLAB 2021 as shown in **Figure 2** below. From the output, there is an increase in the contrast, brightness, and adjustment of the intensity values with much better clarity of colors in the enhanced image as compared with the original image. Moreover, histogram equalization of both the original image and enhanced image was plotted to show the efficiency of the applied technique, the plot of the enhanced image is spread widely out which shows that the images are contrasted using a good method. It also shows clarity in terms of larger differences between maximum and minimum intensity values distributed in the histogram.

Satellite images of the Sambisa forest captured in 2013 are enhanced using the histogram equalization technique. It was implemented in MATLAB codes as shown in **Figure 3** below. Based on the output there is a significant increase in the contrast, brightness, and adjustment of the intensity values with so much better clarity of colors in the enhanced image. In addition, histogram equalization of both the original image and enhanced image are plots. The plot of the enhanced image is spread widely out this shows clarity in terms of differences between the smallest and largest intensity values distributed in the histogram.

Histograms are applied to enhance colored satellite images of the Sambisa forest captured in 2014. This was implemented in MATLAB codes as shown in **Figure 4** below. The output of the enhanced images shows a significant improvement in the contrast, brightness of the colors with so much adjustment of the intensity values as compared with the original images. In addition, histogram equalization of both the original image and enhanced image are plots, the plot of the enhanced image is spread widely out this show clarity in terms of differences between the smallest and largest intensity values distributed in the histogram.

Enhancement of colored satellite image of the

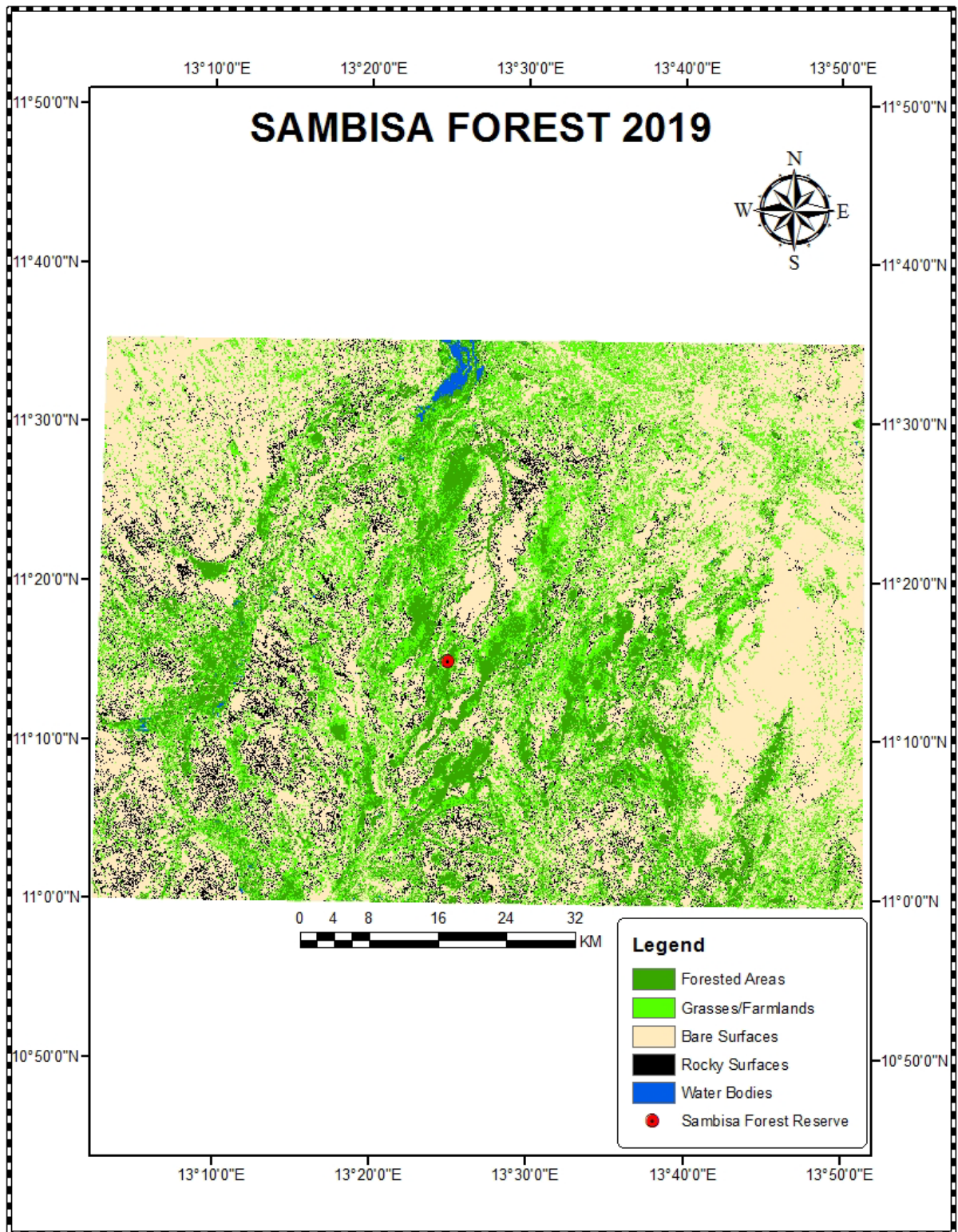


Figure 1. Original and enhanced image of 2019 with their associated histogram equalization.

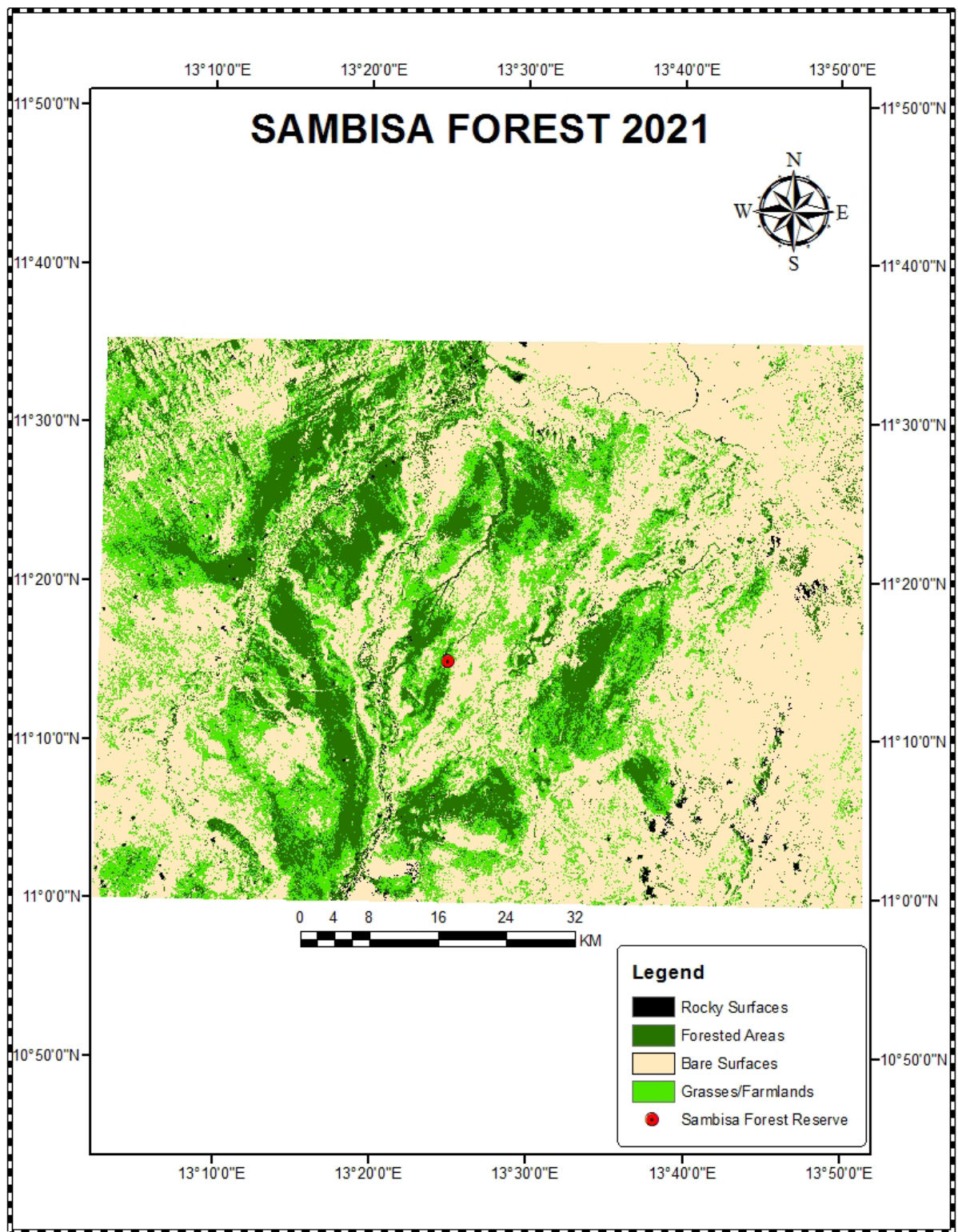


Figure 2. Original and enhanced image of 2021 with their associated histogram equalization.

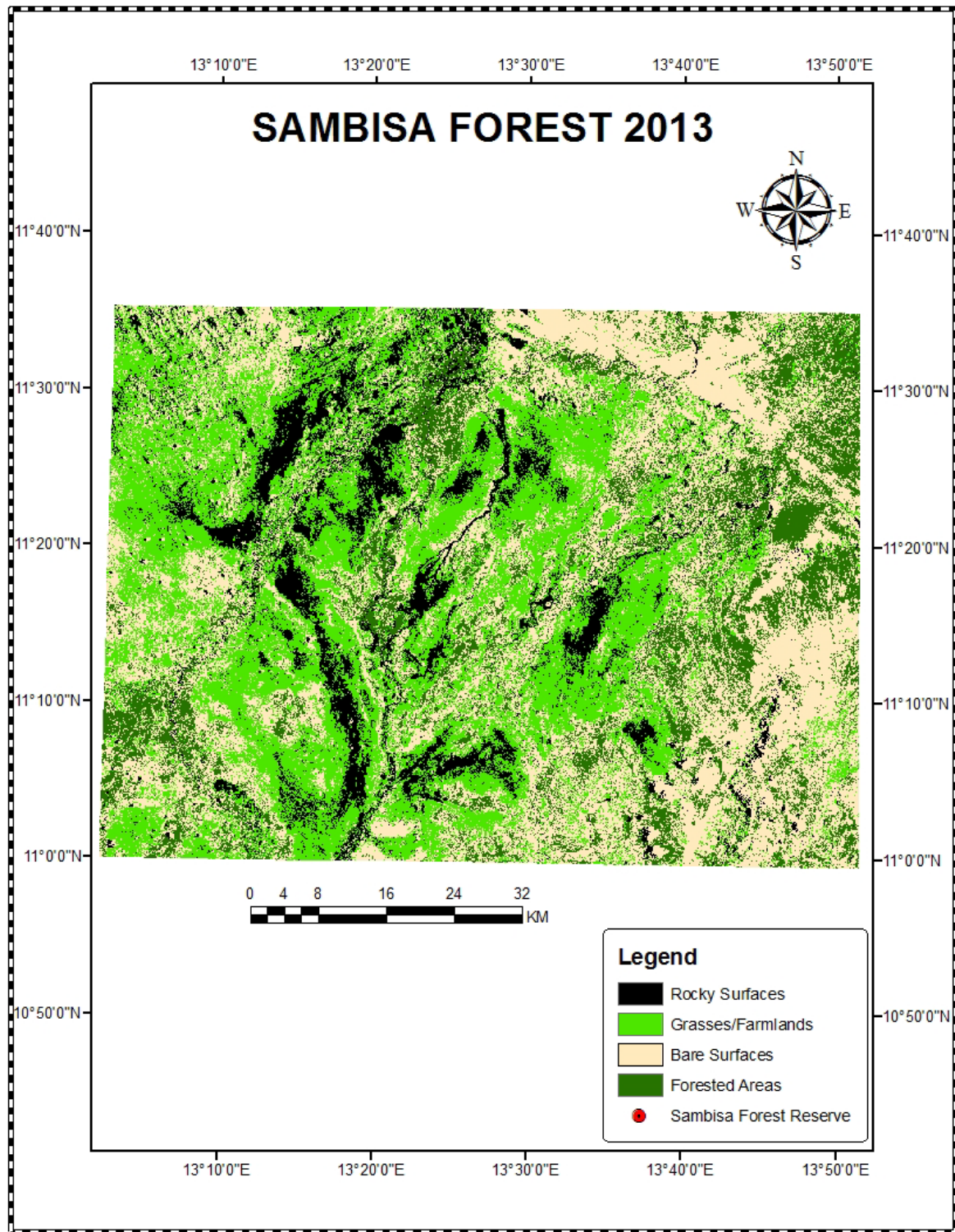


Figure 3. Original and enhanced image of 2013 with their associated histogram equalization.

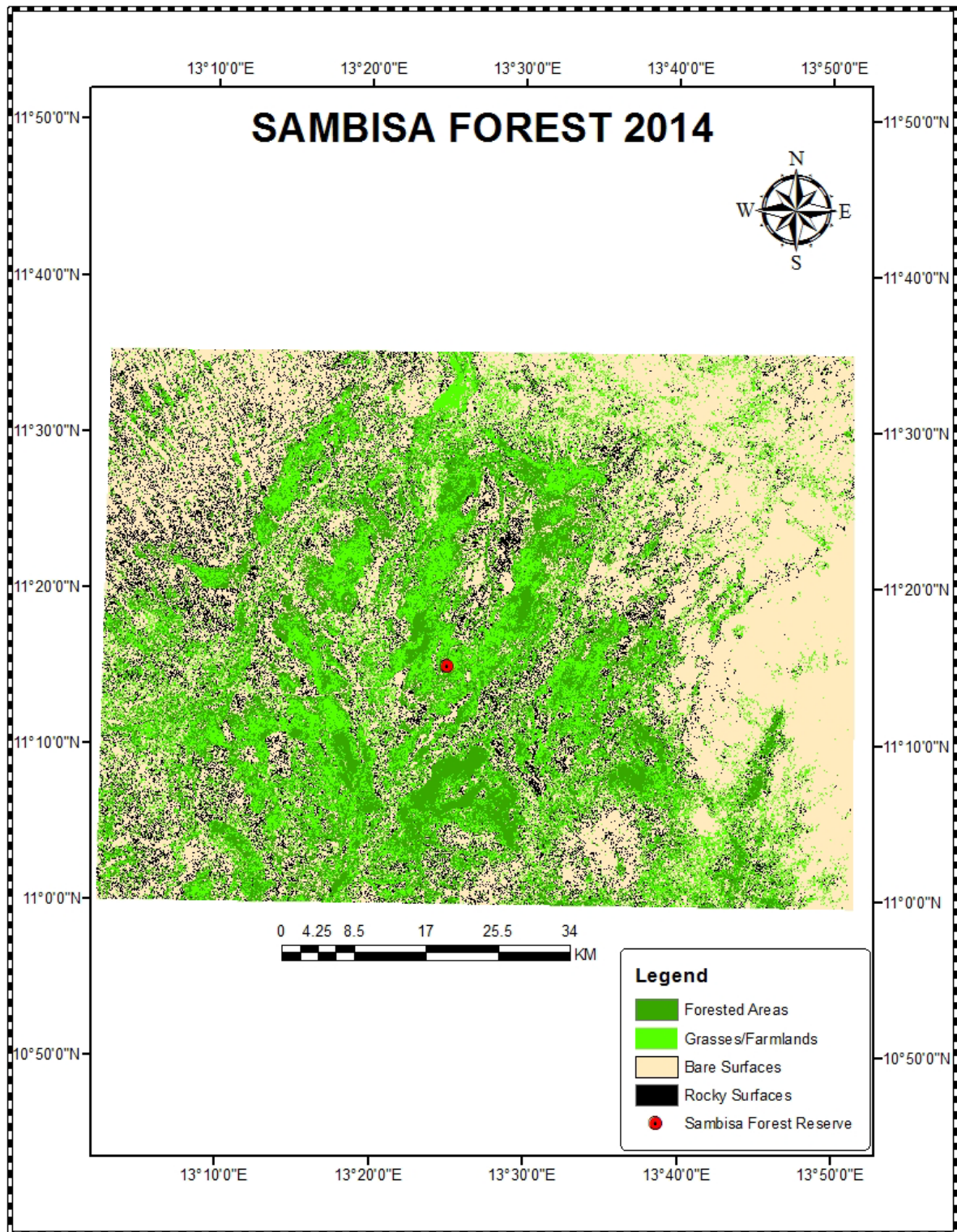


Figure 4. Original and enhanced image of 2014 with their associated histogram equalization.

Sambisa forest captured in 2014 are implemented using histogram equalization in MATLAB codes as shown in **Figure 5** below. The technique improved the contrast, brightness and colors of the enhanced image as compared with the original image. In addition, histogram equalization of both the original

image and enhanced image are plots, the plot of the enhanced image is spread widely out this shows clarity in terms of differences between the smallest and largest intensity values distributed in the histogram.

Colored satellite images of the Sambisa forest captured in 2017 are enhanced using the histogram

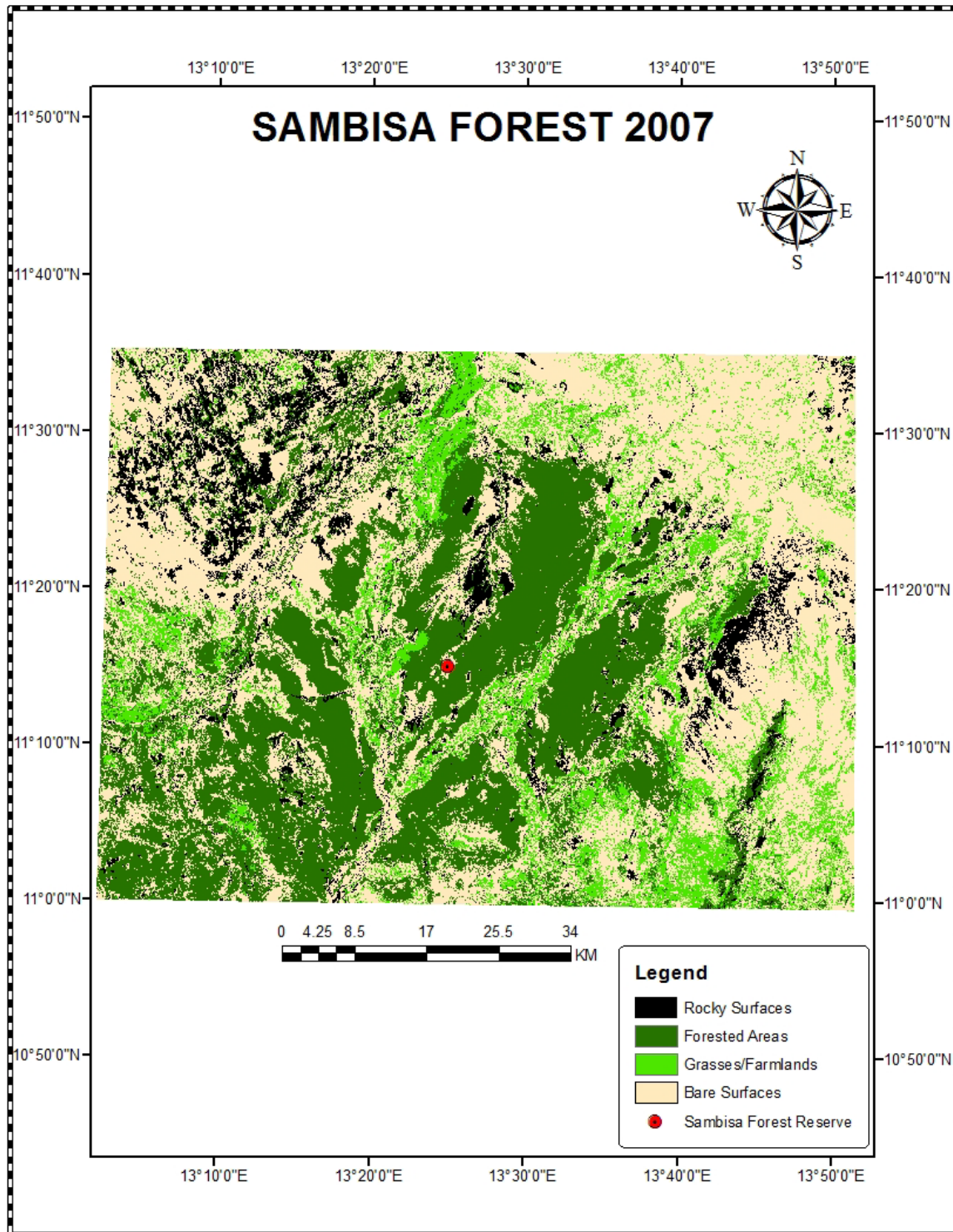


Figure 5. Original and enhanced image of 2007 with their associated histogram equalization.

equalization technique. It is implemented in MATLAB codes as shown in **Figure 6** below. Based on the output there is a significant increase in brightness and colors of the vegetation, water bodies and mountains with so much adjustment of the intensity values this will improve the accuracy of object detection

and classification. In addition, histogram equalization of both the original image and enhanced image are plots, the plot of the enhanced image is spread widely out this show clarity in terms of differences between the smallest and largest intensity values distributed in the histogram.

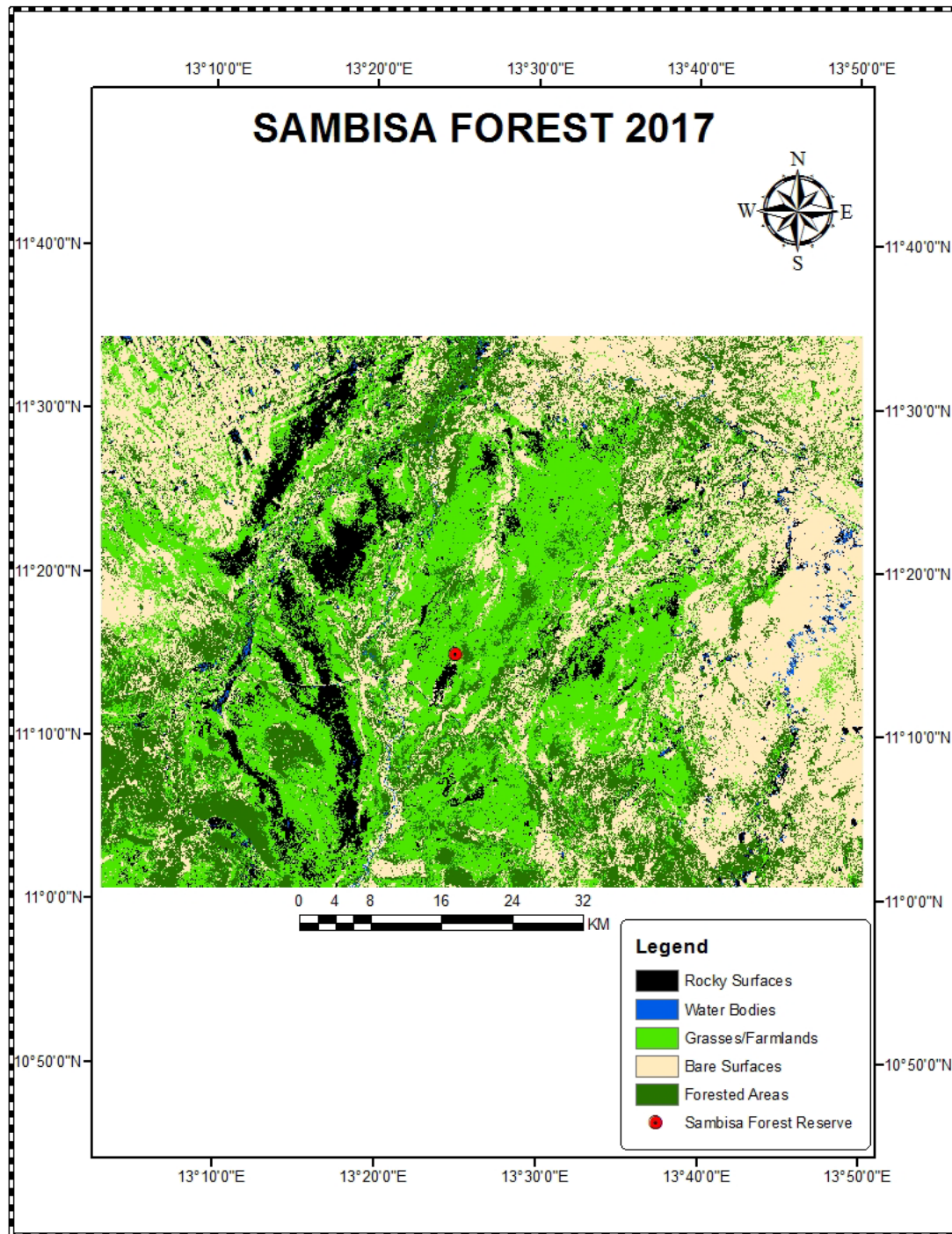


Figure 6. Original and enhanced image of 2017 with their associated histogram equalization.

5. Conclusions

Image enhancement is a significant method in understanding the major characteristics of satellite images in satellite image analysis. In this research work histogram equalization technique was applied to enhance satellite images captured by Landsat satellites in 2007, 2013, 2014, 2019, and 2021, respectively. This method has improved the brightness, contrast and clarity of the images as compared to the original and the enhanced images.

Conflict of Interest

There is no conflict of interest.

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