COURSE: SATELLITE IMAGE PROCESSING

LECTURE 6 – Introduction to Image Enhancement Techniques

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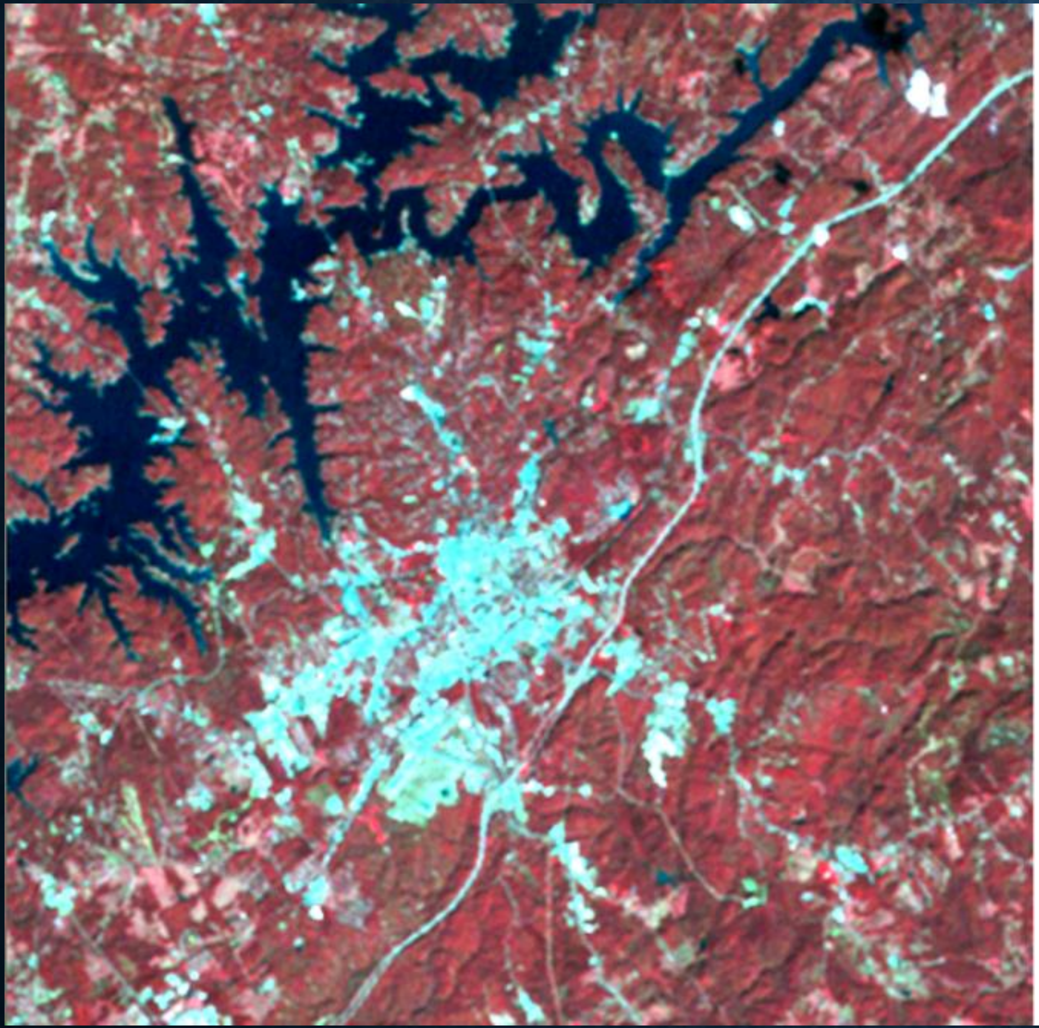
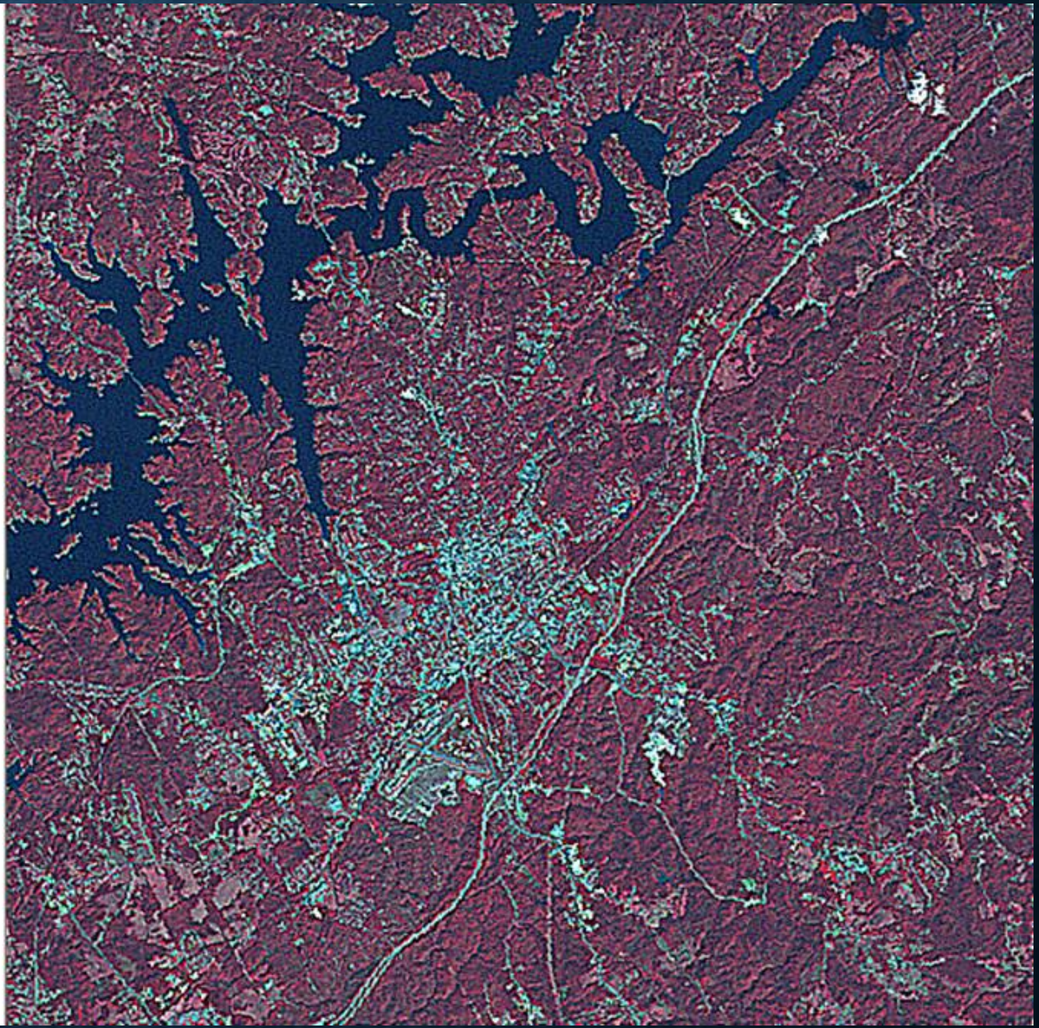
Remote Sensing Image Enhancement

Source: John R. Jesen, 2015, 4th Ed; NASA

Remote Sensing Image Enhancement





Landsat 7 ETM +

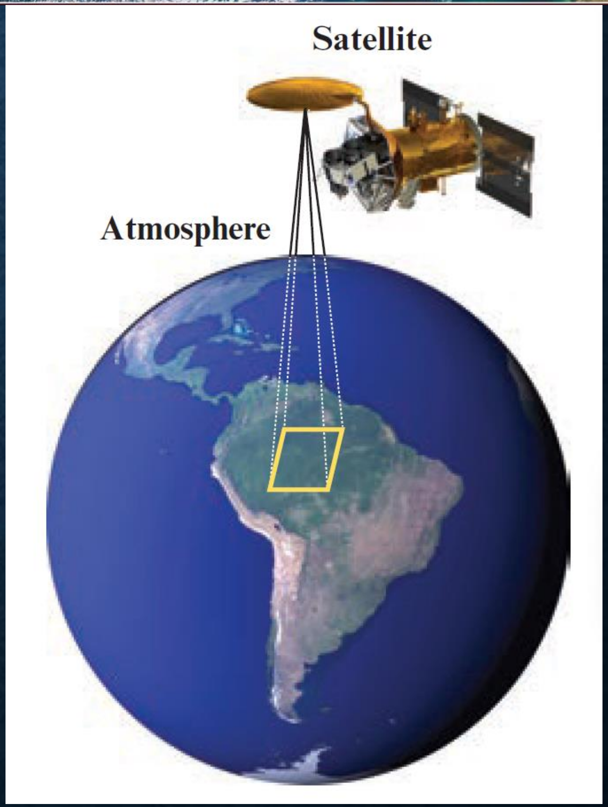
Source: ERDAS Imagine 8.5 sample image

What is Remote Sensing

- ❑ Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.

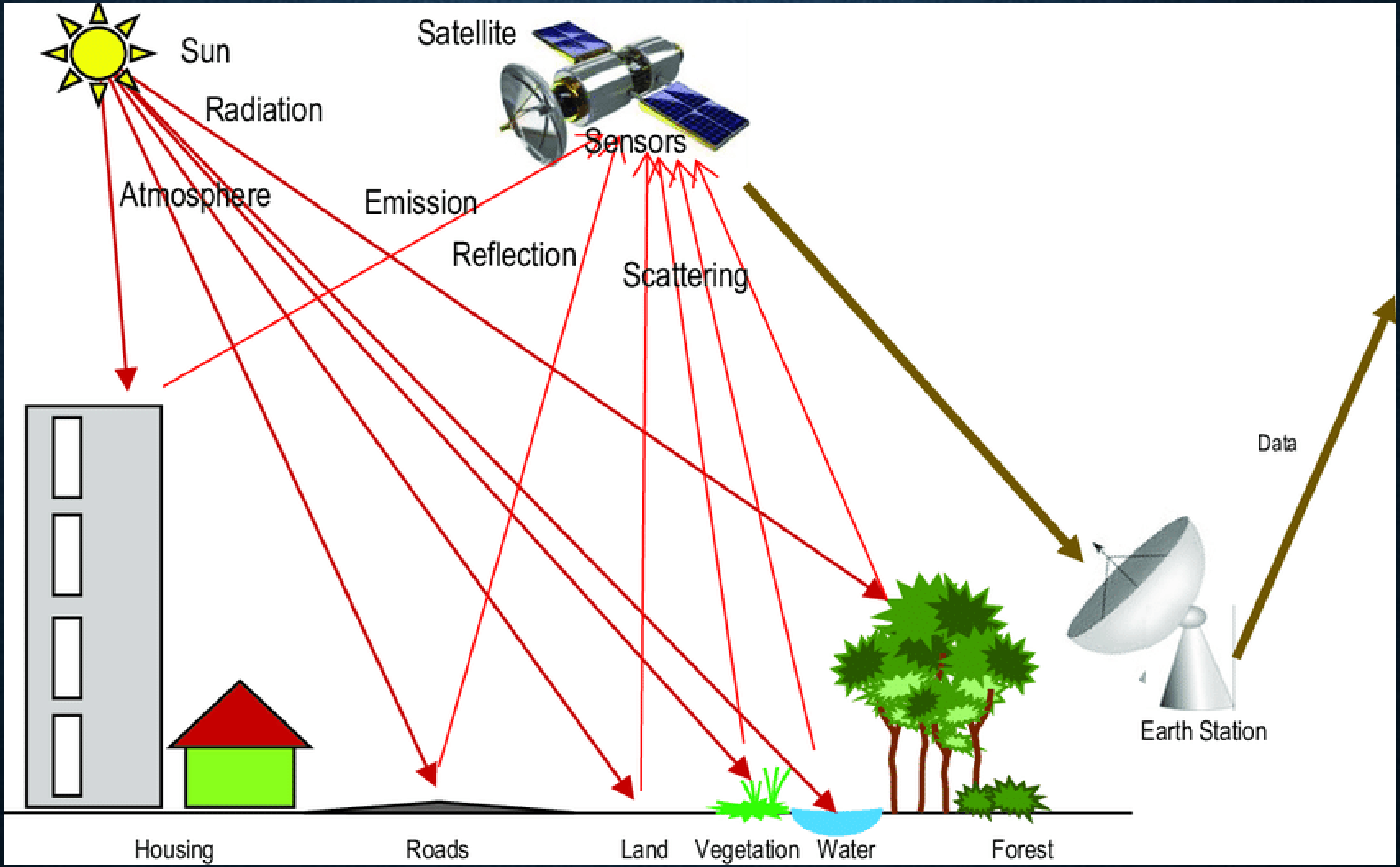
- ❑ Example Applications:

- Environmental monitoring,
- land cover mapping,
- agriculture,
- disaster management.
- other



Source: John R. Jesen, 2015, 4th Ed; Blue Marble image of the Earth courtesy of NASA Earth Observatory.

What is Remote Sensing



Source: Gutta Srinivasa Rao and Atluri Srikrishna, 2021

Why Image Enhancement?

- ❑ Improve Visual Interpretation:

  - Enhance image clarity and detail for better interpretation by human analysts.

- ❑ Facilitate Automated Analysis:

  - Prepare images for computer-based analysis techniques such as classification and feature extraction.

- ❑ Aid Decision Making:

  - Enhance images to extract meaningful information for informed decision-making in various fields.

Image Enhancement Summary

- Image enhancement is the process of making an image more interpretable for a particular application

- Enhancement makes important features more interpretable to the human eye.

- There is no such thing as the ideal or best image enhancement because the results are ultimately evaluated by humans, who make subjective judgments as to whether an enhanced image is useful.

Source: John R. Jesen, 2015, 4th Ed; NASA

Common Type of Remote Sensing Image Enhancement Technique

- Radiometric or Contrast Enhancement
- Spectral Enhancement.
- Spatial Enhancement.
- Pan-sharpen/Resolution Merge

Source: John R. Jesen, 2015, 4th Ed; NASA

Differentiation of Atmospheric correction and Contrast enhancement in Remote Sensing imagery

- Both atmospheric correction and contrast enhancement aim to improve the quality of satellite imagery, however they serve distinct purposes:

- ✓ Atmospheric correction is a preprocessing step aimed at removing or mitigating the effects of the Earth's atmosphere on satellite imagery to obtain accurate surface reflectance values.

- ✓ Contrast enhancement is a post-processing technique used to improve the visual quality and interpretability of remote-sensing imagery aims to enhance the visual appearance of the image for better interpretation by human analysts.

Radiometric/Contrast Enhancement Technique

- Remote sensing systems record reflected and emitted radiant flux exiting from Earth's surface materials.

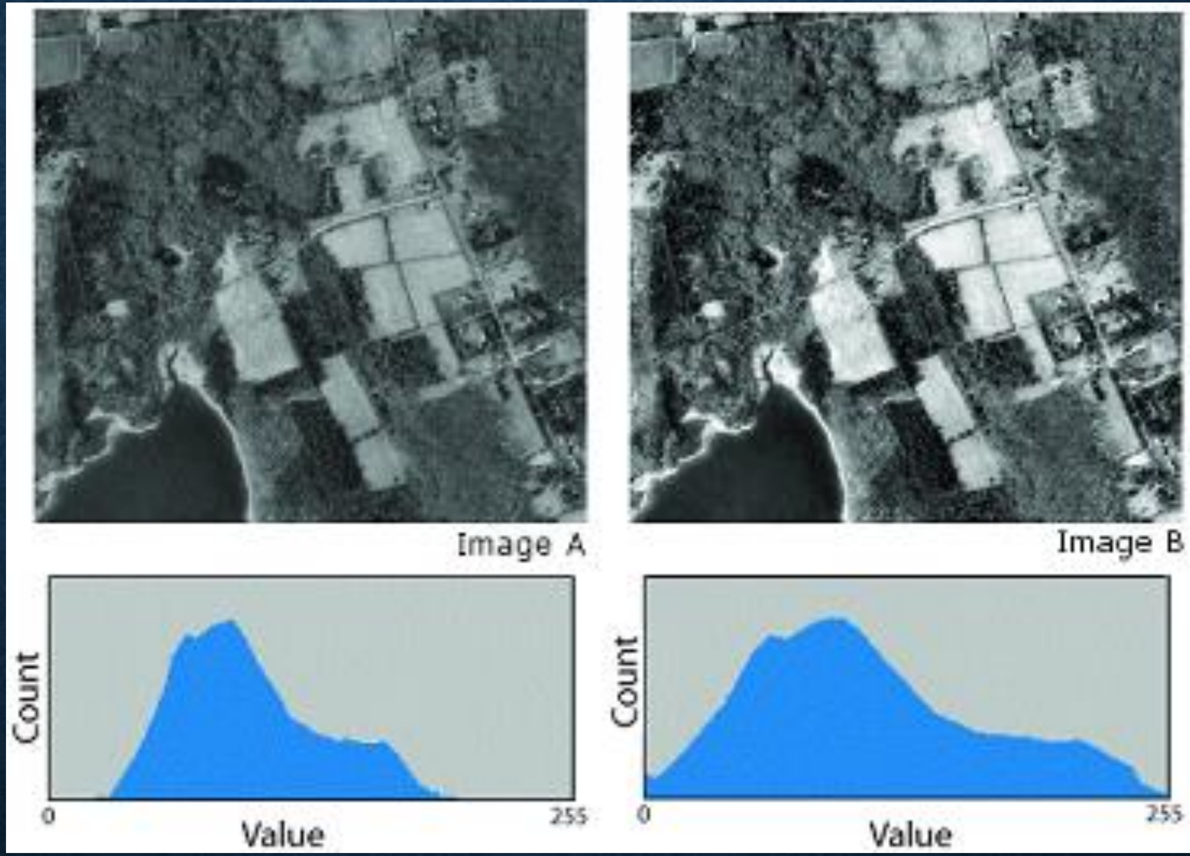
- Ideally, one material would reflect a tremendous amount of energy in a certain wavelength and another material would reflect much less energy in the same wavelength.

- This would result in a *contrast* between the two types of material when recorded by the remote sensing system.

Source: John R. Jesen, 2015, 4th Ed; NASA

Radiometric/Contrast Enhancement Technique

Different materials often reflect similar amounts of radiant flux throughout the visible, near-infrared, and middle-infrared portions of the electromagnetic spectrum, resulting in relatively *low-contrast* imagery.



Source: Gutta Srinivasa Rao and Atluri Srikrishna, 2021

Source: John R. Jesen, 2015, 4th Ed; NASA

Radiometric/Contrast Enhancement Technique

The image pair shows the variation in soil and vegetation brightness due to soil moisture.

The left image is generally wetter whereas significant drying has occurred in the right image, resulting in greater contrast between areas with higher and lower soil moisture.

The contrast here is normal based on feature changes over time

13 February, 2016

19 May 2016

Source: Norman Mueller, Geoscience Australia

Why Low contrast

- ❑ Certainly! Here are the four main reasons for low-contrast imagery in satellite remote sensing:

- ✓ Atmospheric Conditions:

- ✓ Surface Characteristics:

- ✓ Sensor Characteristics:

- ✓ Illumination Conditions:

Why Low contrast

- Atmospheric Conditions:

✓ Atmospheric scattering and absorption reduce the amount of light reaching the sensor, leading to decreased contrast.

✓ Haze, fog, and air pollution scatter light, degrading contrast in the image.

Source: John R. Jesen, 2015, 4th Ed; NASA

Why Low contrast

❑Surface Characteristics:

✓Certain materials and land cover types inherently exhibit low contrast due to their spectral properties.

✓Homogeneous surfaces like water bodies and deserts reflect light uniformly, resulting in low contrast.

Source: John R. Jesen, 2015, 4th Ed; NASA

Why Low contrast

❑Sensor Characteristics:

✓Sensor noise and calibration errors introduce variations in pixel values, obscuring details and features.

✓Limited sensor resolution or dynamic range may hinder the capture of fine-scale contrast variations.

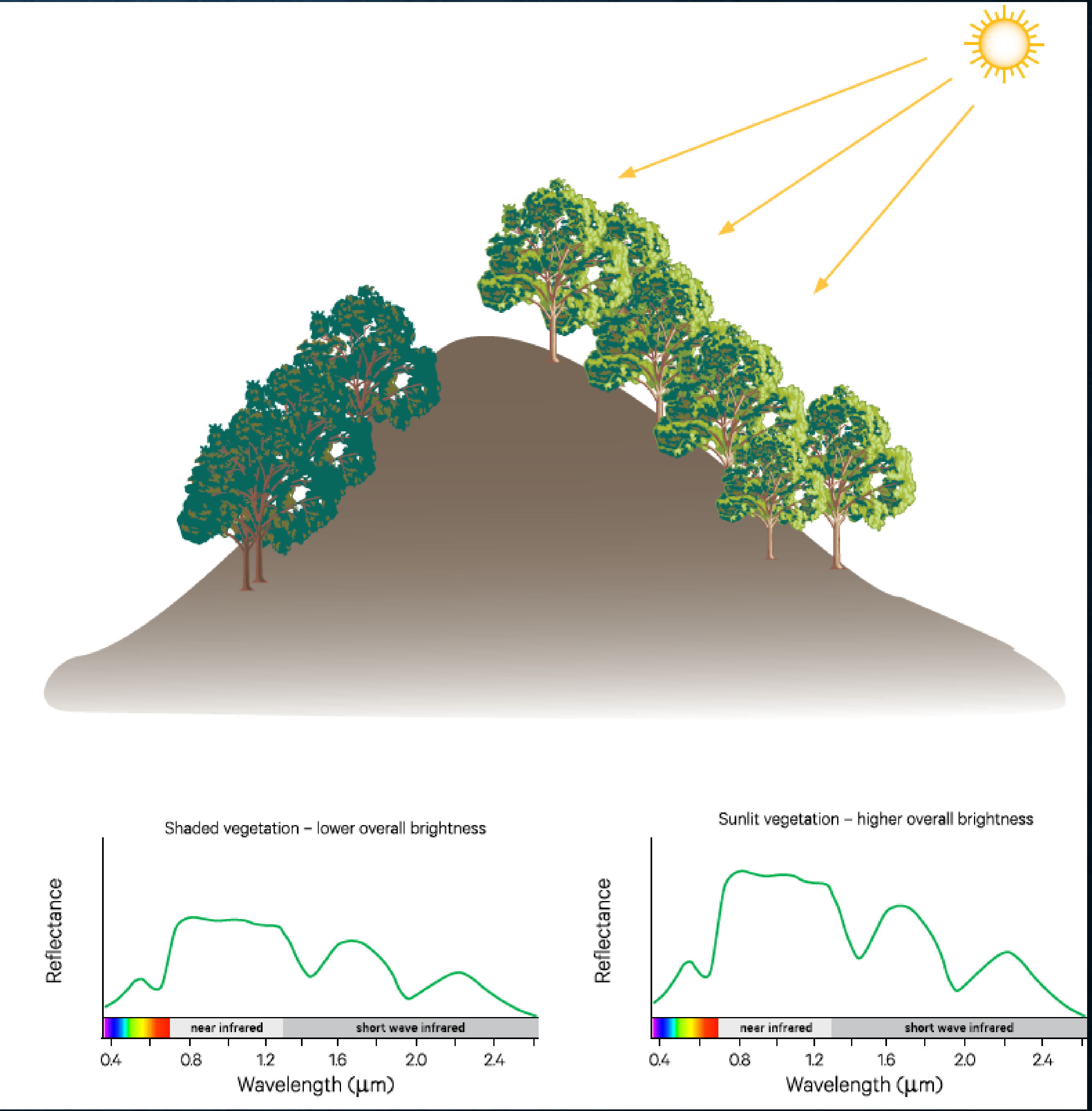
Source: John R. Jesen, 2015, 4th Ed; NASA

Why Low contrast

- ❑ Illumination Conditions:

- ✓ Sun angle, time of day, and seasonal changes influence surface illumination, affecting image contrast.

- ✓ Terrain shadows and topographic variations create areas of darkness, reducing overall contrast.



Source: John R. Jesen, 2015, 4th Ed; NASA

Source: Megan Lewis, University of Adelaide

Types of Radiometric/Contrast Enhancement

Common Radiometric/contrast enhancement techniques

1. Linear Contrast Enhancement:

    - Minimum-Maximum contrast enhancement

    - Piecewise Linear Contrast Enhancement.

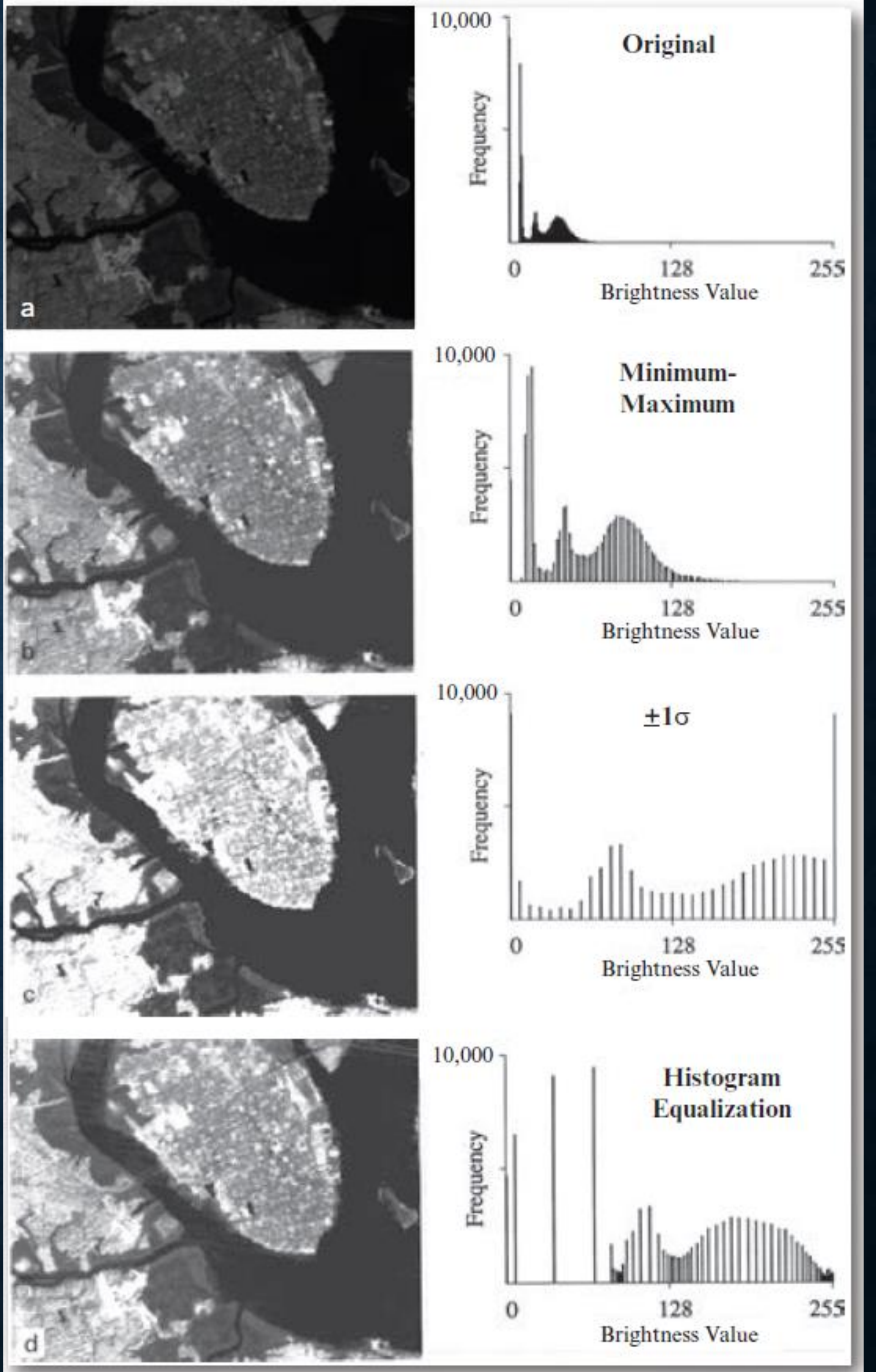
2. Non-linear contrast enhancement – Histogram equalization.

Source: John R. Jesen, 2015, 4th Ed;

Linear Contrast Enhancement- Min-Max contrast enhancement

- Contrast enhancement (also referred to as contrast stretching) expands the original input brightness values to make use of the total dynamic range or sensitivity of the output device.

- Charleston, SC , TM band 4 image produced by a sensor system whose image output levels can vary from 0 to 255.



Source: John R. Jesen, 2015, 4th Ed;

MIN-MAX LINEAR CONTRAST ENHANCEMENT

- To perform the linear contrast enhancement, the following algorithm is used-

$$DN' = \frac{(DN - MIN)}{(MAX - MIN)} \times 255 \text{ (quantk)}$$

where, DN’ = Digital value assigned to pixel in output image

DN = Original digital number of pixel in input image

MIN = Minimum value of input image

MAX = Maximum value of input image

Source: John R. Jesen, 2015, 4th Ed;

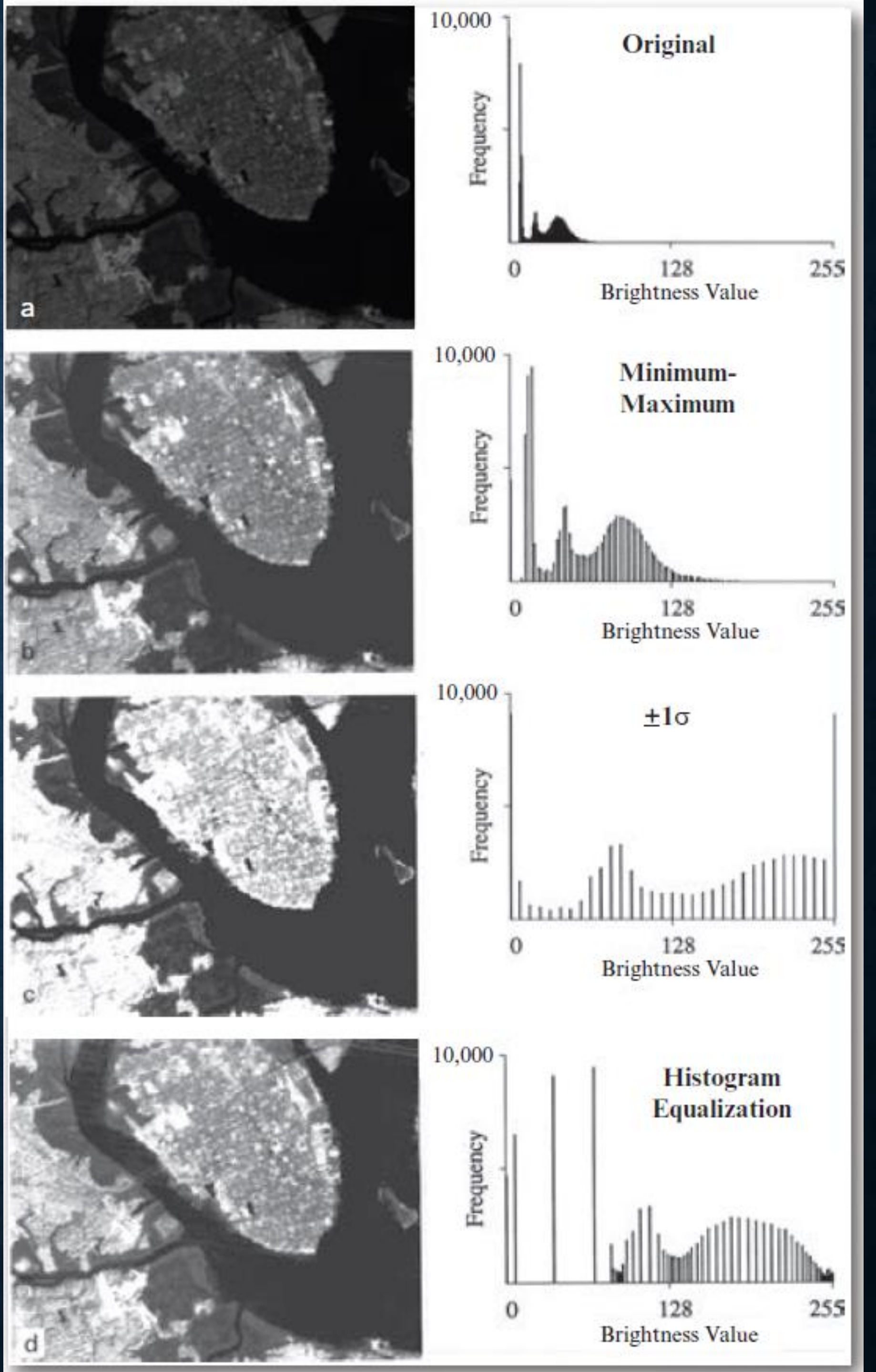
Linear Contrast Enhancement- Min-Max contrast enhancement

a) Original Landsat Thematic Mapper band 4 data, and its histogram. This image has not been contrast stretched.

b) Min-max contrast stretch applied to the data and the resultant histogram.

c) One standard deviation (± 1) linear contrast stretch applied to the data and the resultant histogram.

d) Application of histogram equalization and the resultant histogram.



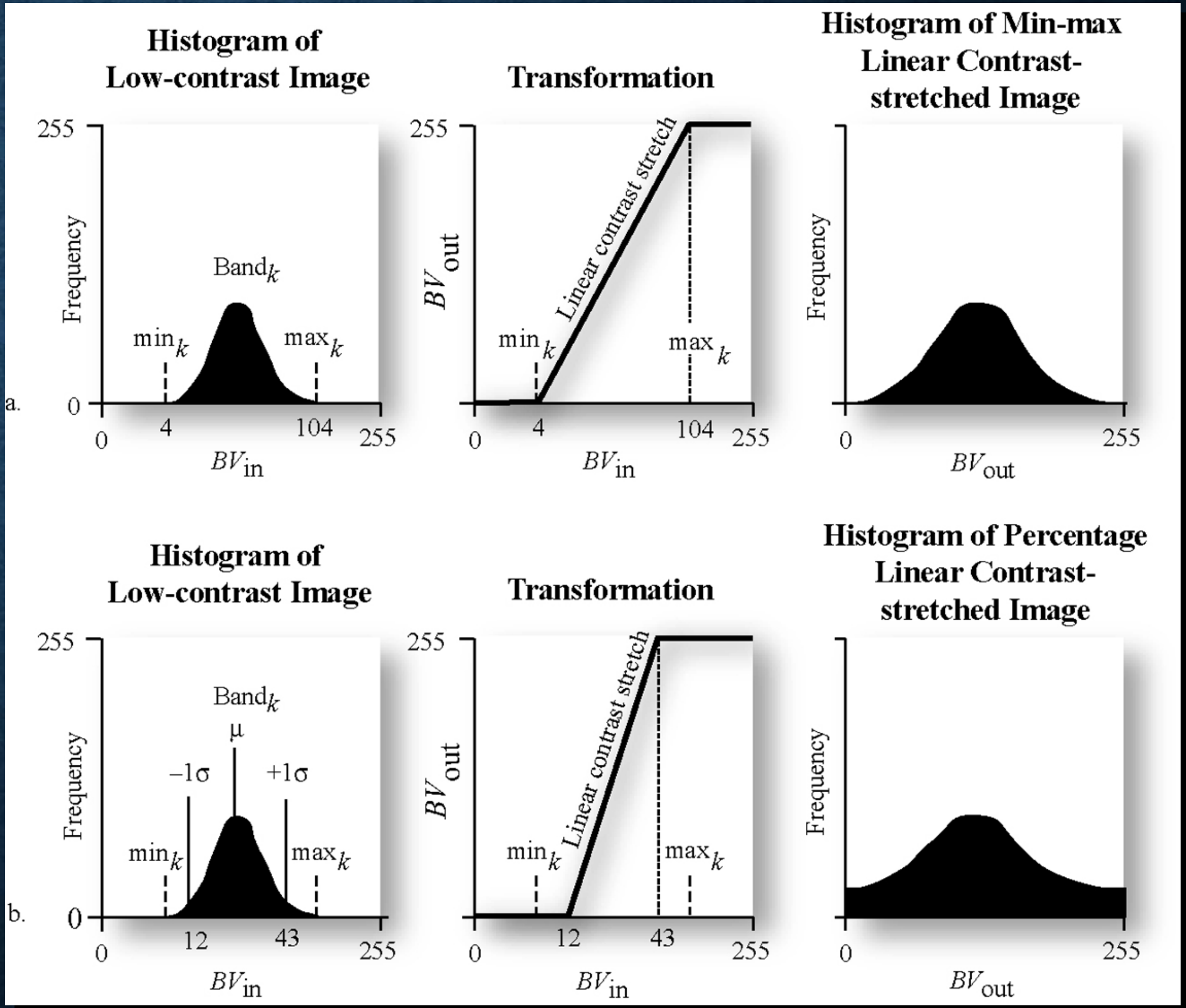
Source: John R. Jesen, 2015, 4th Ed; original imagery courtesy of NASA.

Linear Contrast Enhancement- Min-Max contrast enhancement

a) The result of applying a min-max um contrast stretch to normally distributed remotely sensed data.

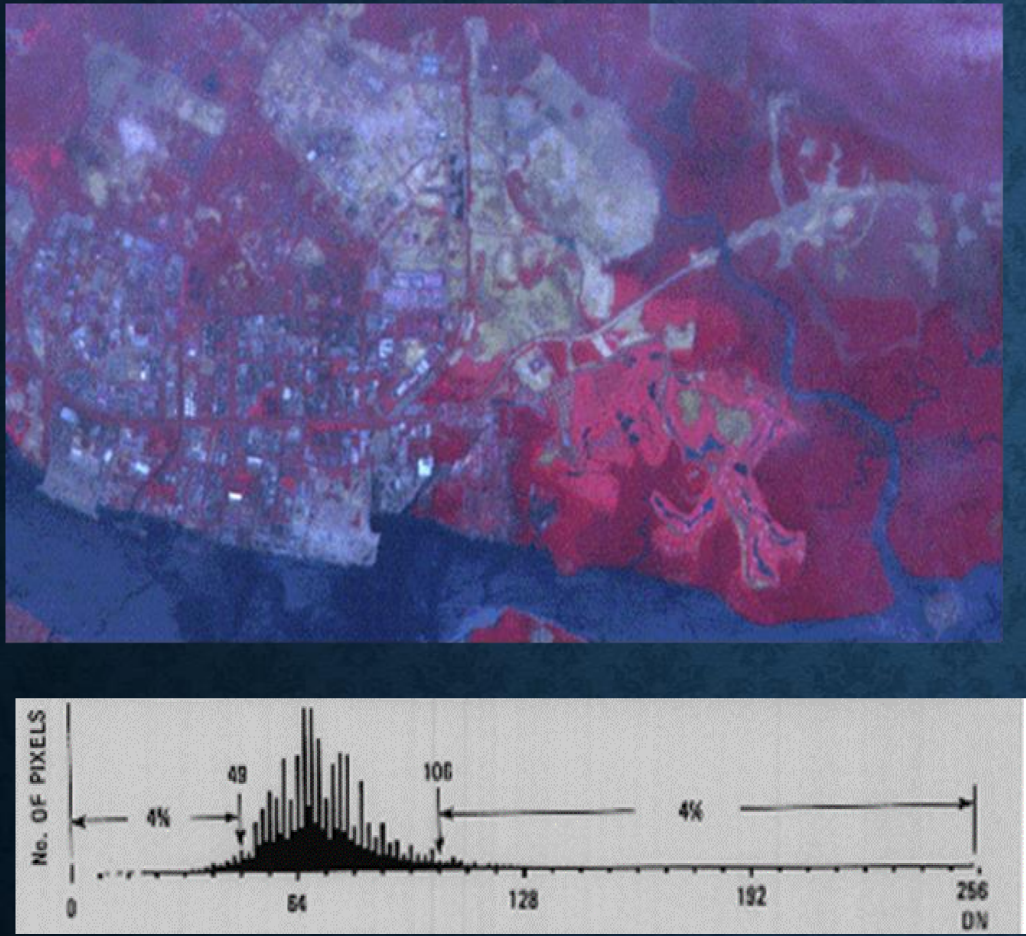
b) Theoretical result of applying a ± 1 standard deviation percentage linear contrast stretch.

This moves the min_k and max_k values ± 34% from the mean into the tails of the distribution.

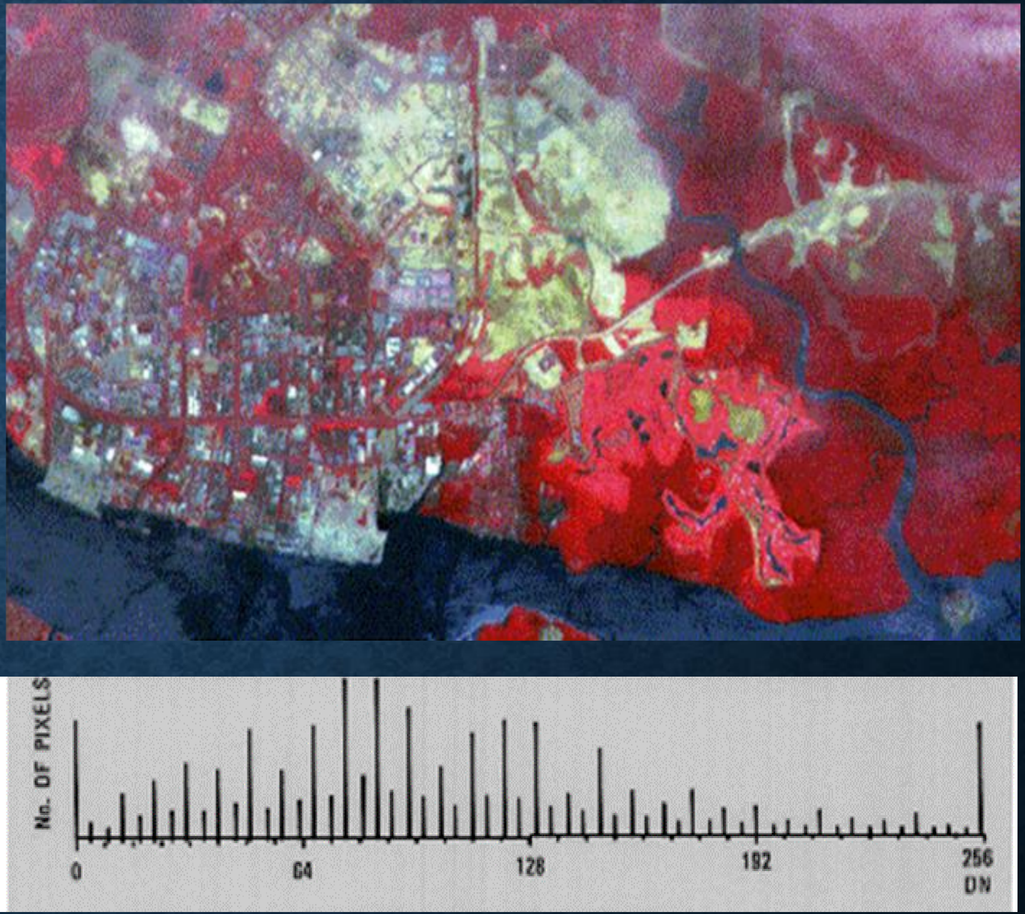


Source: John R. Jesen, 2015, 4th Ed;

Linear Contrast Enhancement- Min-Max contrast enhancement



SPOT Image with out Enhancement

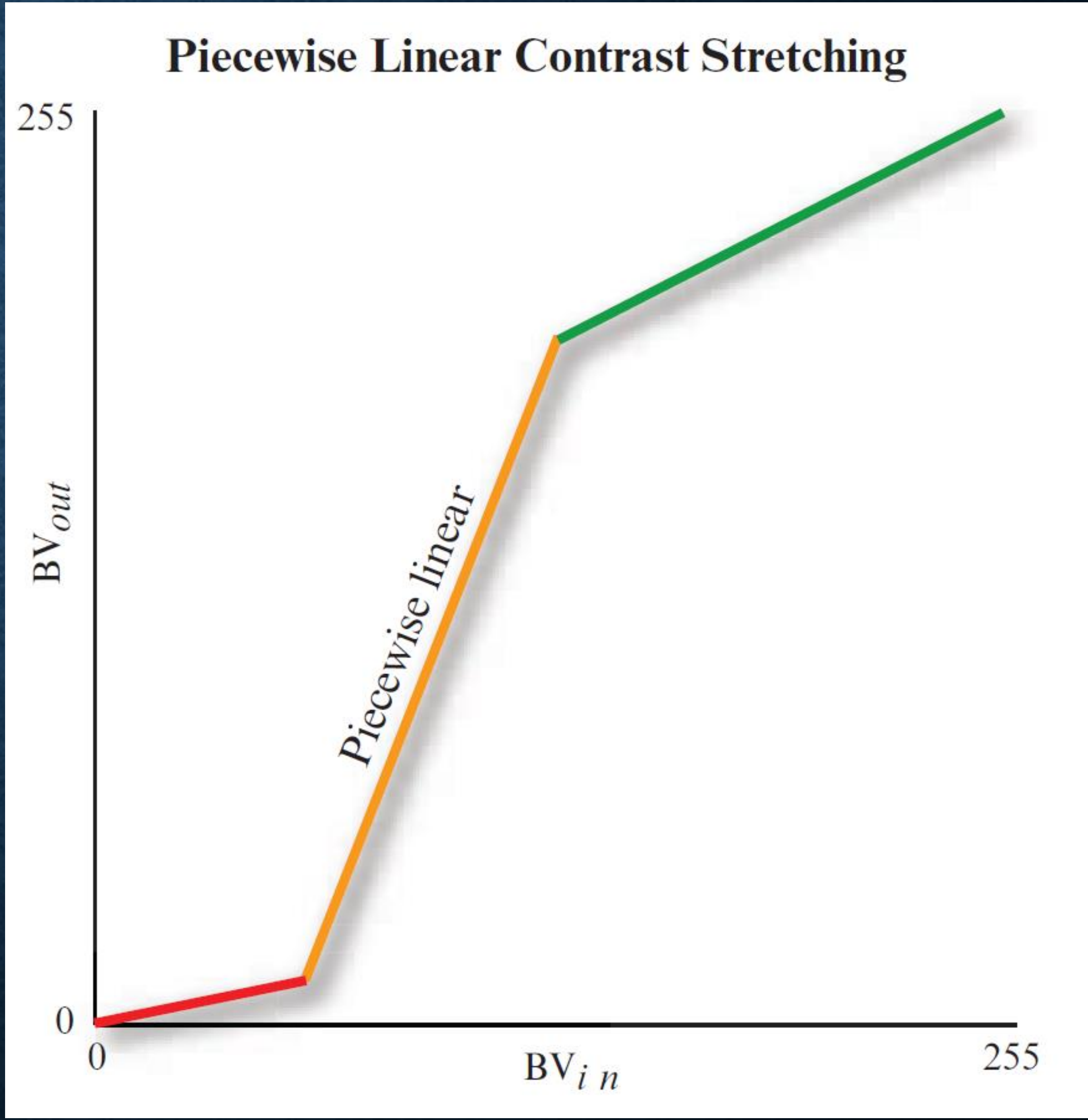


SPOT Image after linear Enhancement

Source: CRISP, 2021; retrieved: https://crisp.nus.edu.sg/~research/tutorial/process.htm

Piecewise Linear Contrast Enhancement

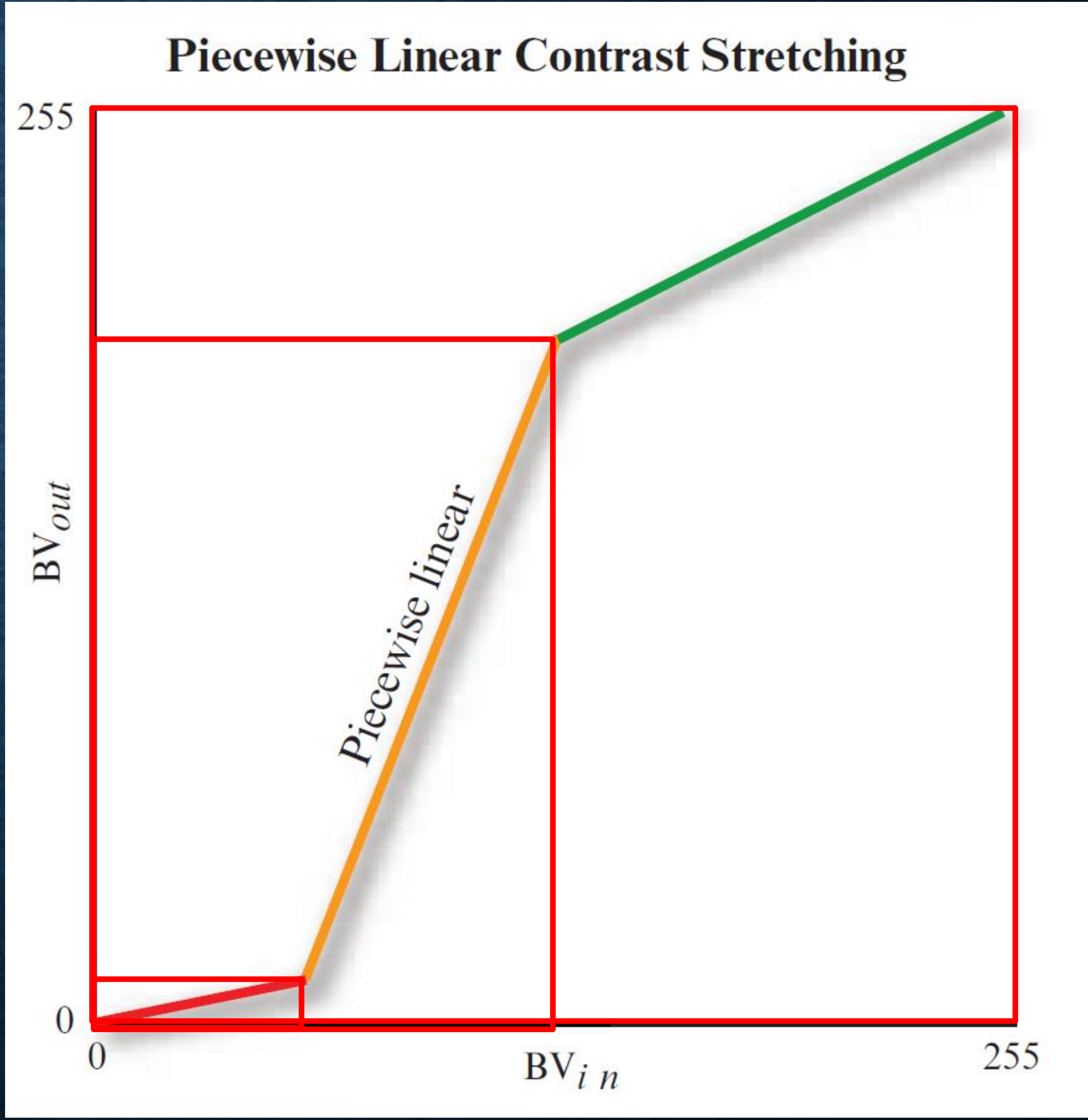
- When the histogram of an image is not Gaussian (i.e., it is bimodal, trimodal, etc.),- exhibit multiple peaks or modes, it is possible to apply a piecewise linear contrast stretch to the imagery



Source: John R. Jesen, 2015, 4th Ed;

Piecewise Linear Contrast Enhancement

- Here the analyst identifies a number of linear enhancement steps that expand the brightness ranges in the modes of the histogram.
- In effect, this corresponds to setting up a series of min_k and Max_k and using above Equation within user-selected regions of the histogram
- Analyst must intimately familiar with the various modes of the histogram and what they represent in the real world/image



Source: John R. Jesen, 2015, 4th Ed;

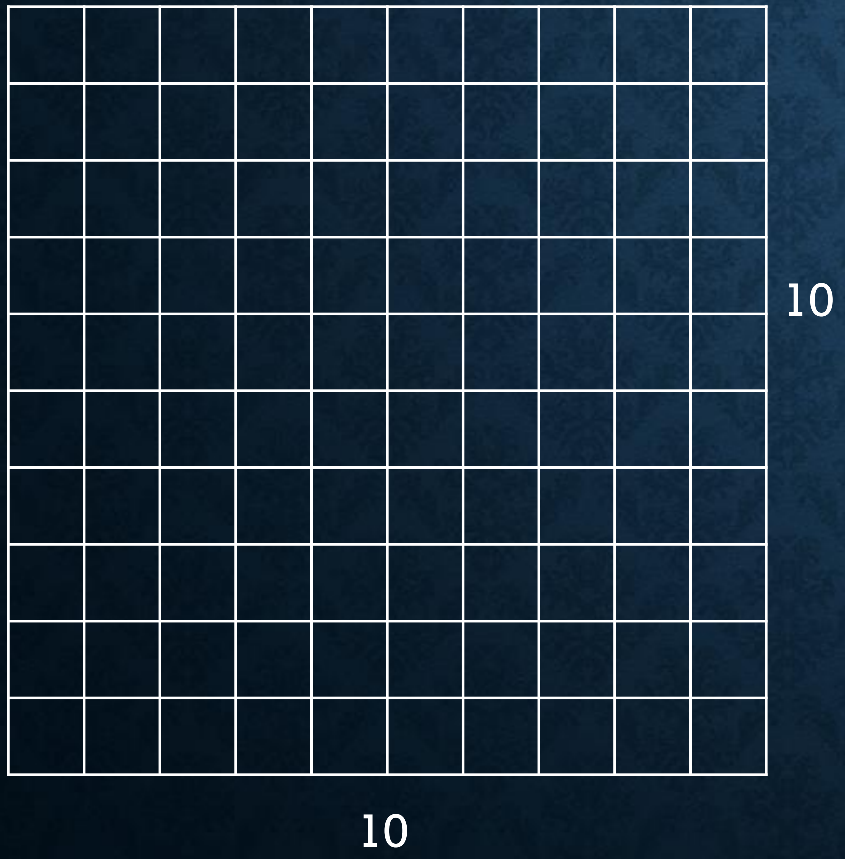
Non-linear contrast enhancement – Histogram equalization

- Nonlinear contrast enhancements may also be applied.
- One of the most useful enhancements is histogram equalization.
- The algorithm passes through the individual bands of the dataset and assigns approximately an equal number of pixels to each of the user-specified output grayscale classes (e.g., 32, 64, 256).
- Histogram equalization applies the greatest contrast enhancement to the most populated range of brightness values in the image.
- It automatically reduces the contrast in the very light or dark parts of the image associated with the tails of a normally distributed histogram.

Source: John R. Jesen, 2015, 4th Ed;

Non-linear contrast enhancement – Histogram equalization

Statistics for a 64 × 64 hypothetical image with Brightness Values from 0 to 7 (n = 4,096 pixels).



Brightness Value, BV_i	L_i	Frequency $f(BV_i)$	Probability $p_i = f(BV_i)/n$
BV_0	0/7 = 0.00	790	0.19
BV_1	1/7 = 0.14	1023	0.25
BV_2	2/7 = 0.28	850	0.21
BV_3	3/7 = 0.42	656	0.16
BV_4	4/7 = 0.57	329	0.08
BV_5	5/7 = 0.71	245	0.06
BV_6	6/7 = 0.85	122	0.03
BV_7	7/7 = 1.00	81	0.02

Source: John R. Jesen, 2015, 4th Ed; modified from Gonzalez and Wintz, 1977

Non-linear contrast enhancement – Histogram equalization

For each brightness value level *BVi* in the quant_k range of 0 to 7 of the original histogram, a new cumulative frequency value *ki* is calculated:

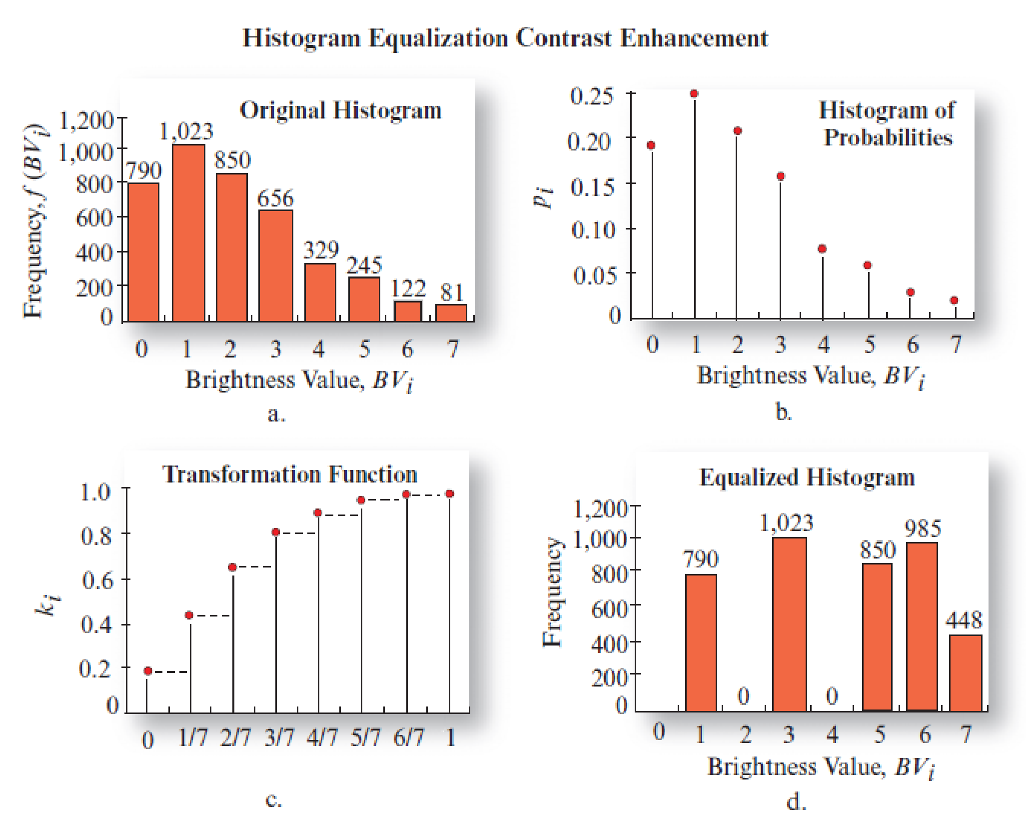
$$k_i = \sum_{i=0}^{\text{quant}_k} \frac{f(BV_i)}{n}$$

Source: John R. Jesen, 2015, 4th Ed; modified from Gonzalez and Wintz, 1977

Non-linear contrast enhancement – Histogram equalization

Example of how a hypothetical 64 × 64 image with brightness values from 0 to 7 is histogram equalized.

Frequency, $f(BV_i)$	790	1023	850	656	329	245	122	81
Original brightness value, BV_i	0	1	2	3	4	5	6	7
$L_i = \frac{\text{brightness value}}{n}$	0	0.14	0.28	0.42	0.57	0.71	0.85	1.0
Cumulative frequency transformation: $k_i = \sum_{i=0}^{\text{quant}_k} \frac{f(BV_i)}{n}$	$\frac{790}{4{,}096}$ =0.19	$\frac{1{,}813}{4{,}096}$ = 0.44	$\frac{2{,}663}{4{,}096}$ = 0.65	$\frac{3{,}319}{4{,}096}$ = 0.81	$\frac{3{,}648}{4{,}096}$ = 0.89	$\frac{3{,}893}{4{,}096}$ = 0.95	$\frac{4{,}015}{4{,}096}$ = 0.98	$\frac{4{,}096}{4{,}096}$ = 1.0
Assign original BV_i class to the new class it is closest to in value.	1	3	5	6	6	7	7	7



Source: John R. Jesen, 2015, 4th Ed; modified from Gonzalez and Wintz, 1977

References:

R.Richter and D.Schlapfer, (2012), Atmospheric/Topographic Correction for Satellite Imagery (ATCOR-2/3UserGuide,Version8.2BETA. Retrieve: https://www.dlr.de/eoc/en/Portaldata/60/Resources/dokumente/5_tech_mod/atcor3_manual_2012.pdf

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina. pages cm. -- (Pearson series in geographic information science) 4th ed.

Tammy E. Parece John A. McGee III (2023). Remote Sensing with ArcGIS® Pro 2nd Edition; retrieve: https://pressbooks.lib.vt.edu/remotesensing/front-matter/cover-page/