Digital Image Processing

Image Enhancement

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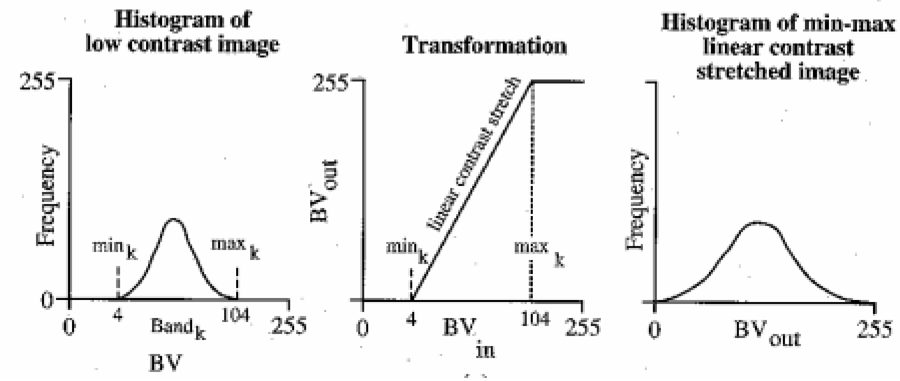
Satellite Image Enhancement

Enhancement algorithms are applied to remotely sensed data to **improve** the **appearance** of an **image** for **human visual analysis** or **occasionally** for **subsequent machine analysis**.

Remote sensing systems (**Sensors**) 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 **contrast** between the two types of material



CONTRAST ENHANCEMENT

- Contrast enhancement techniques expand the range of brightness values in an image
- The density values in a scene are literally pulled farther apart, that is, expanded over a greater range.
- The effect is to increase the visual contrast between two areas of different uniform densities.
- This enables the analyst to discriminate easily between areas initially having a small difference in density.

Contrast manipulation.

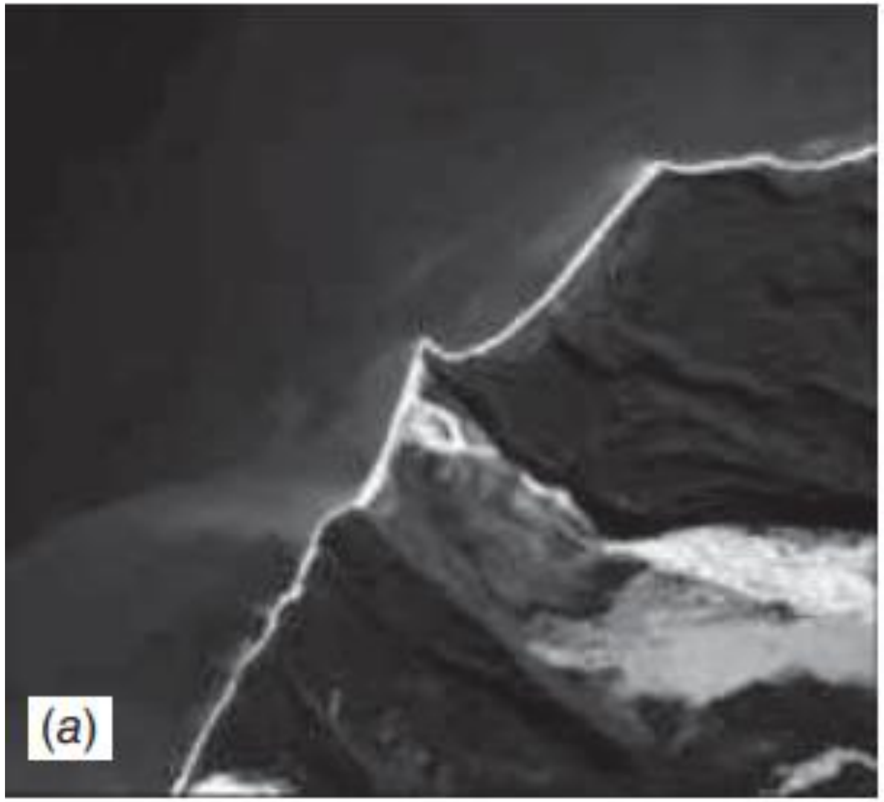
1.Gray-level thresholding, level slicing, and contrast stretching.

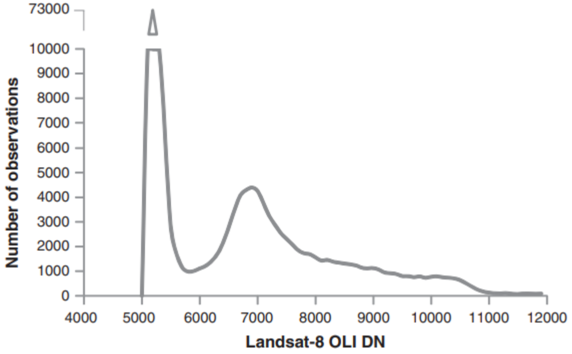
2. Spatial feature manipulation. Spatial filtering, edge enhancement, and Fourier analysis.

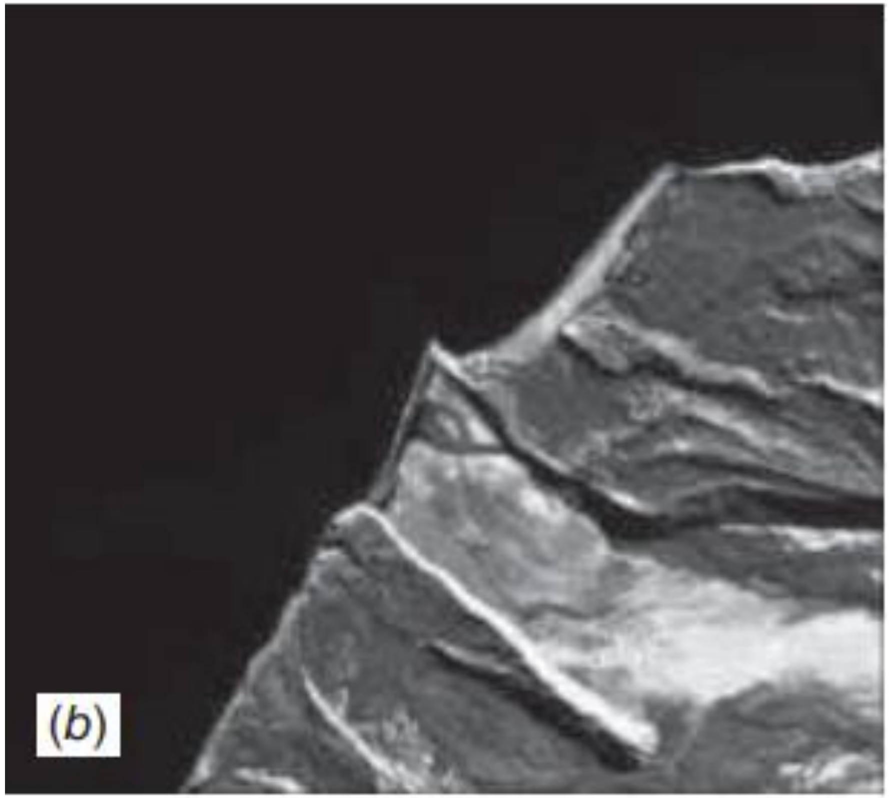
3. Multi-image manipulation. Multispectral band ratioing and differencing, vegetation and other indices, principal components, canonical components, vegetation components, intensity–hue–saturation (IHS) and other colour space transformations, and decorrelation stretching

Gray-level thresholding

Gray-level thresholding is used to segment an input image into two classes —one for those **pixels** having **values below** an analyst - defined gray level and one for those **above** this value. **Binary mask**

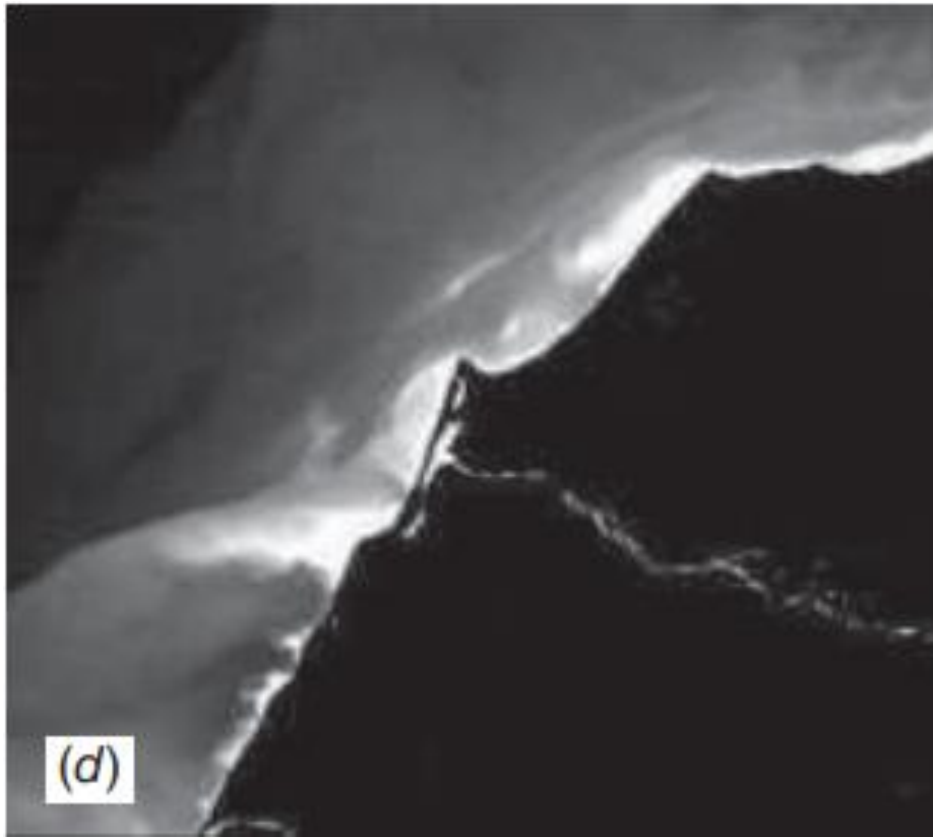


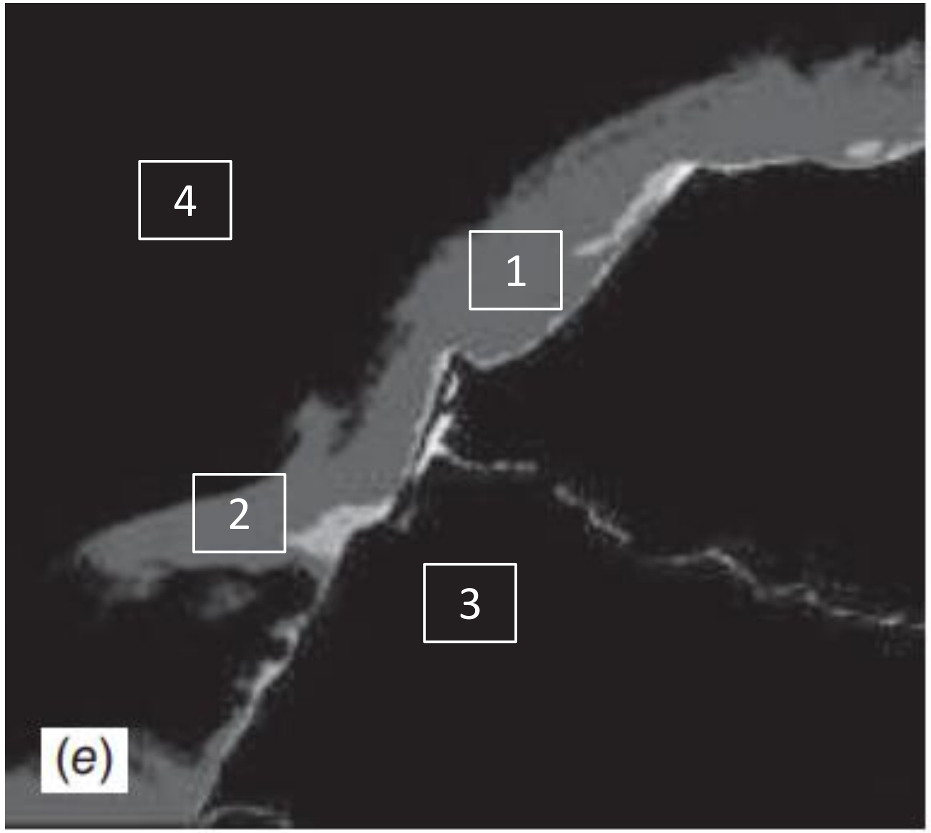




Level slicing

The enhancement technique whereby the DNs distributed along the x axis of an image histogram are **divided** into a **series** of **analyst-specified intervals** or slices. All of the DNs falling within a given interval in the input image are then displayed at a single DN in the output image





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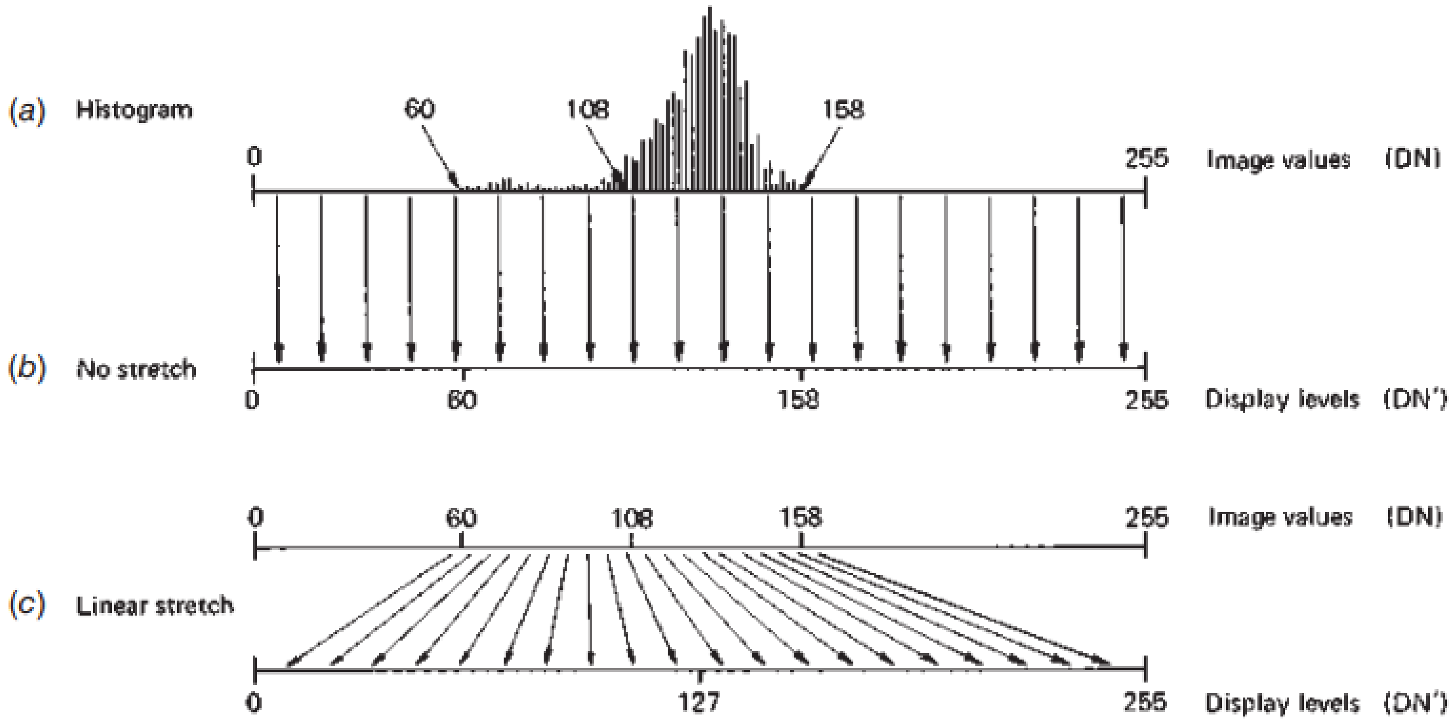
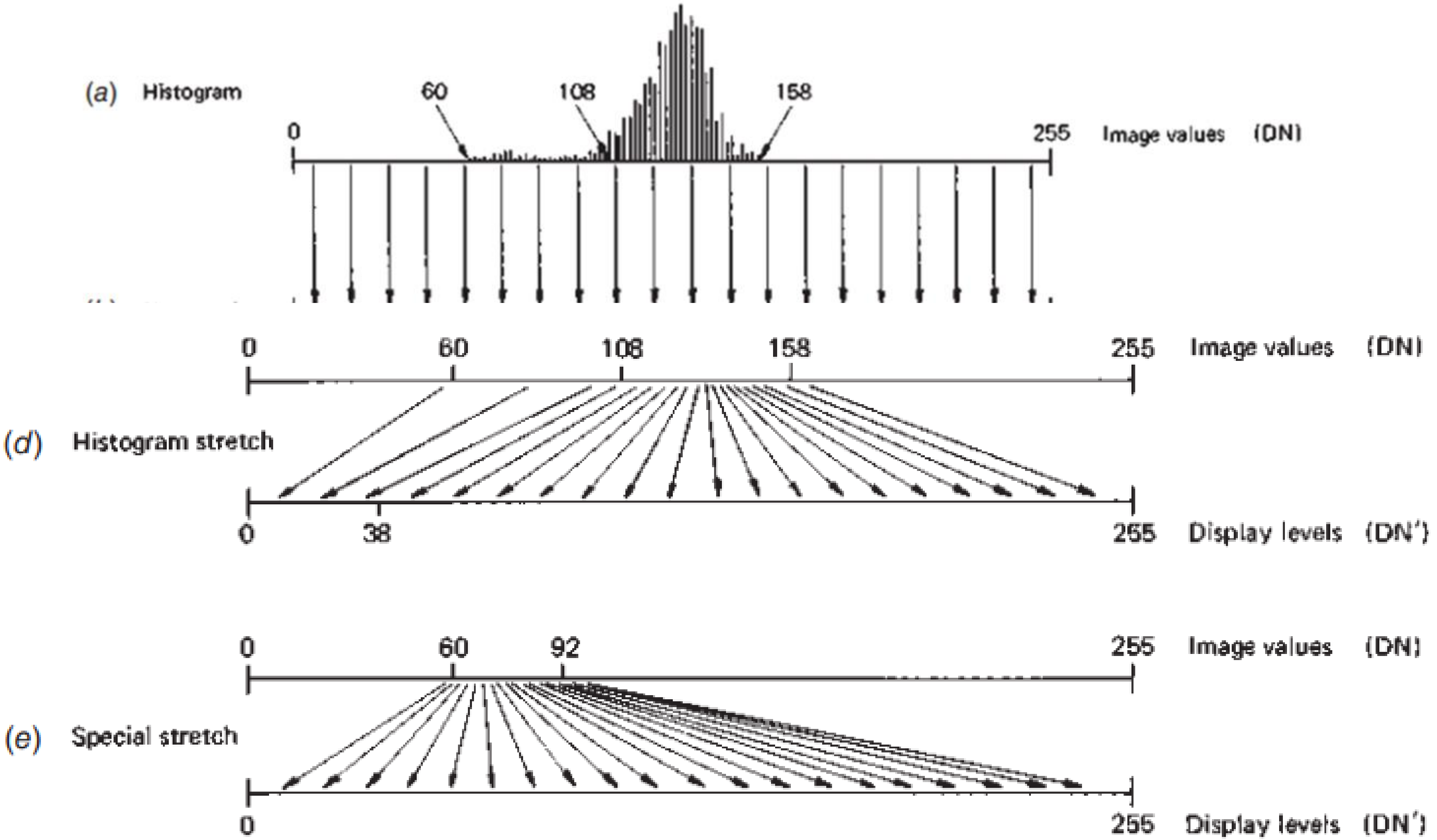



(a) Histogram
60
108
158
0
255
Image values (DN)
0
60
108
158
255
Image values (DN)
(d) Histogram stretch
0
38
255
Display levels (DN′)
0
60
92
255
Image values (DN)
(e) Special stretch
0
255
Display levels (DN′)

SPATIAL FEATURE MANIPULATION

Spatial frequency refers to the **roughness** of the tonal variations occurring in an image.

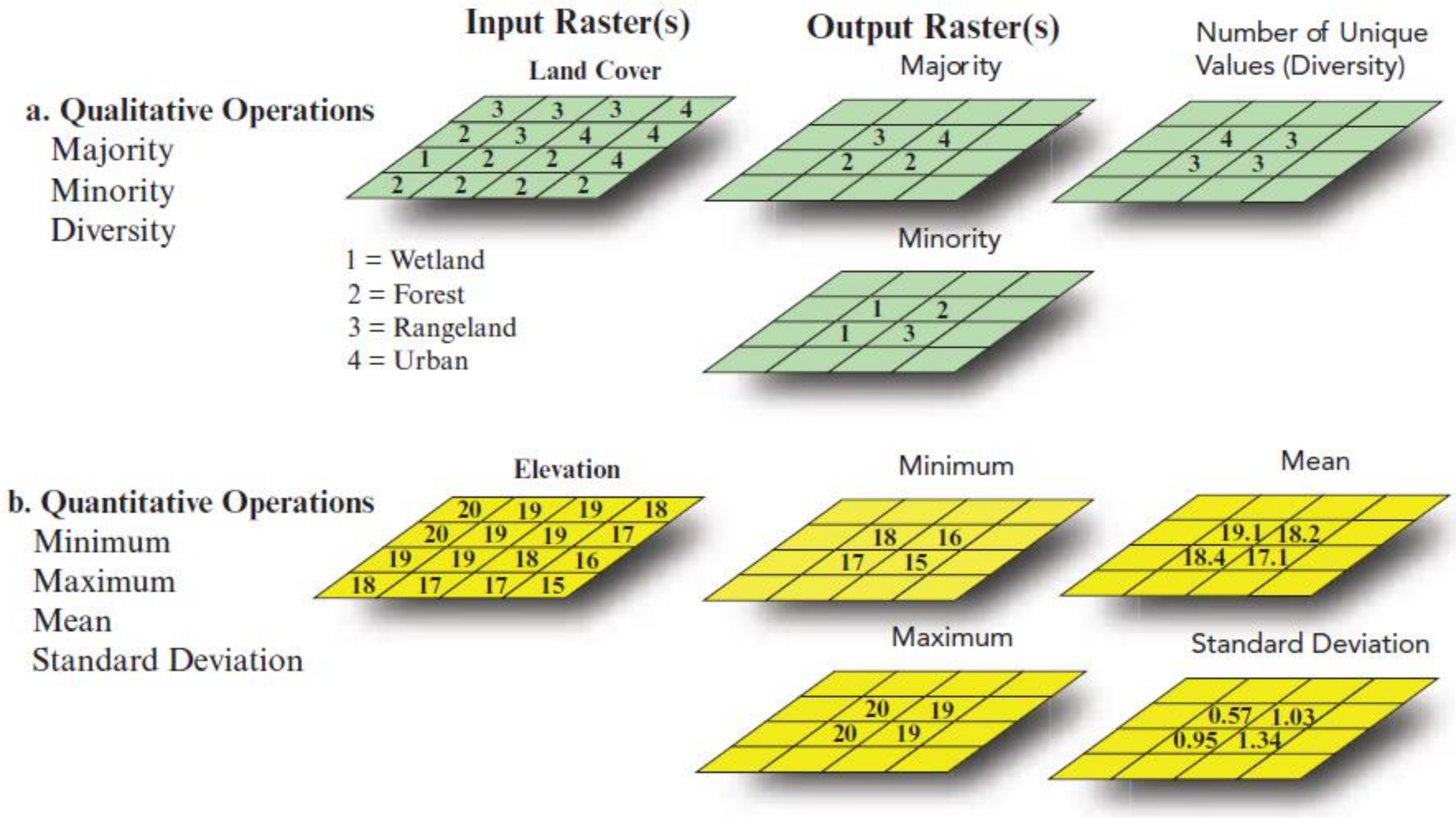
Image areas of high **spatial frequency** are tonally rough.
That is, the gray levels in these areas change abruptly over a relatively small number of pixels.

Smooth image areas are those of **low spatial frequency**, where gray levels vary only gradually over a relatively large number of pixels (e.g., large agricultural fields or water bodies).

Low-pass filters are designed to emphasize low frequency features (large-area changes in brightness) and deemphasize the high frequency components of an image (local detail).

High-pass filters do just the reverse. They emphasize the detailed **high frequency** components of an image and deemphasize the more general low frequency information

Neighborhood Operations Applied to A Single Raster Dataset Using A 3 × 3 Spatial Moving Window



spatial convolution filtering based primarily on the use of **convolution masks.** The **procedure** is relatively easy to understand and can be used to enhance **low- and high-frequency** detail, as well as edges in the imagery

Spatial Convolution Filtering

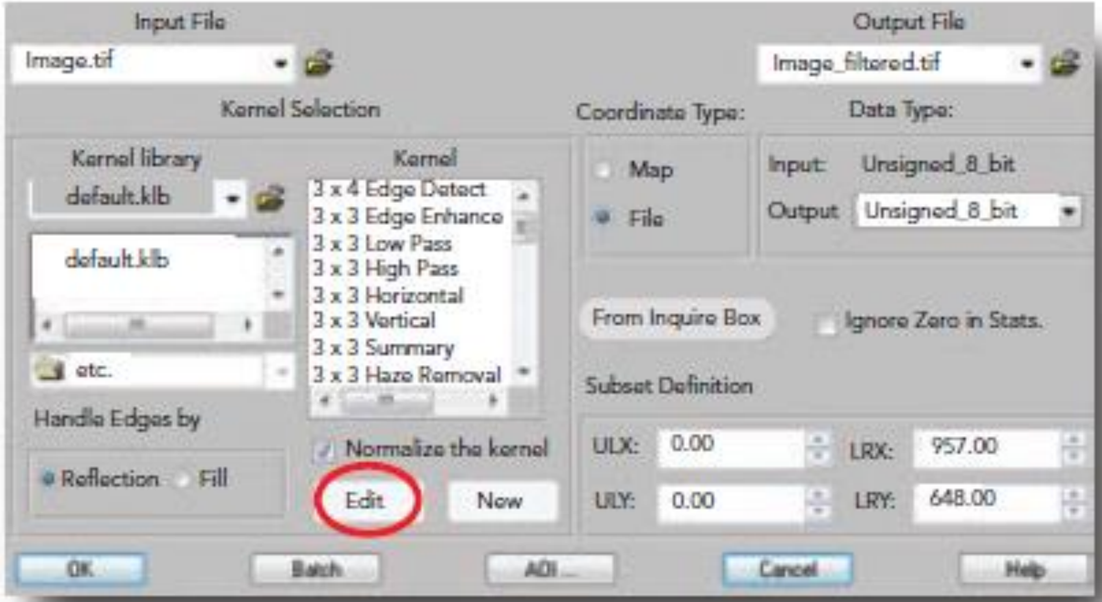
The process of evaluating the weighted neighboring pixel values is called ***two-dimensional con- volution filtering***

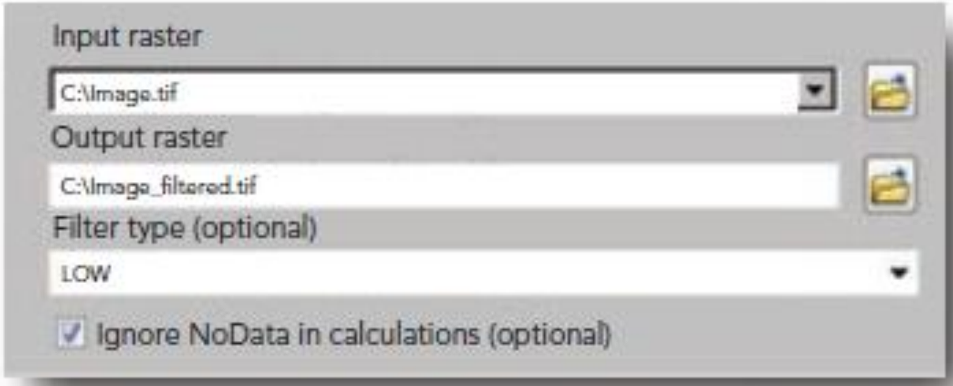
Low-frequency Filtering in the Spatial Domain Raster enhancements that block or minimize the high spatial frequency detail are called **low - frequency** or **low - pass** filters.

The size of the neighborhood **convolution mask or kernel** (***n***) is often **3 × 3, 5 × 5, 7 × 7, or 9 × 9.**

$$\text{Convolution mask template} = \begin{bmatrix} c_1 & c_2 & c_3 \\ c_4 & c_5 & c_6 \\ c_7 & c_8 & c_9 \end{bmatrix}$$

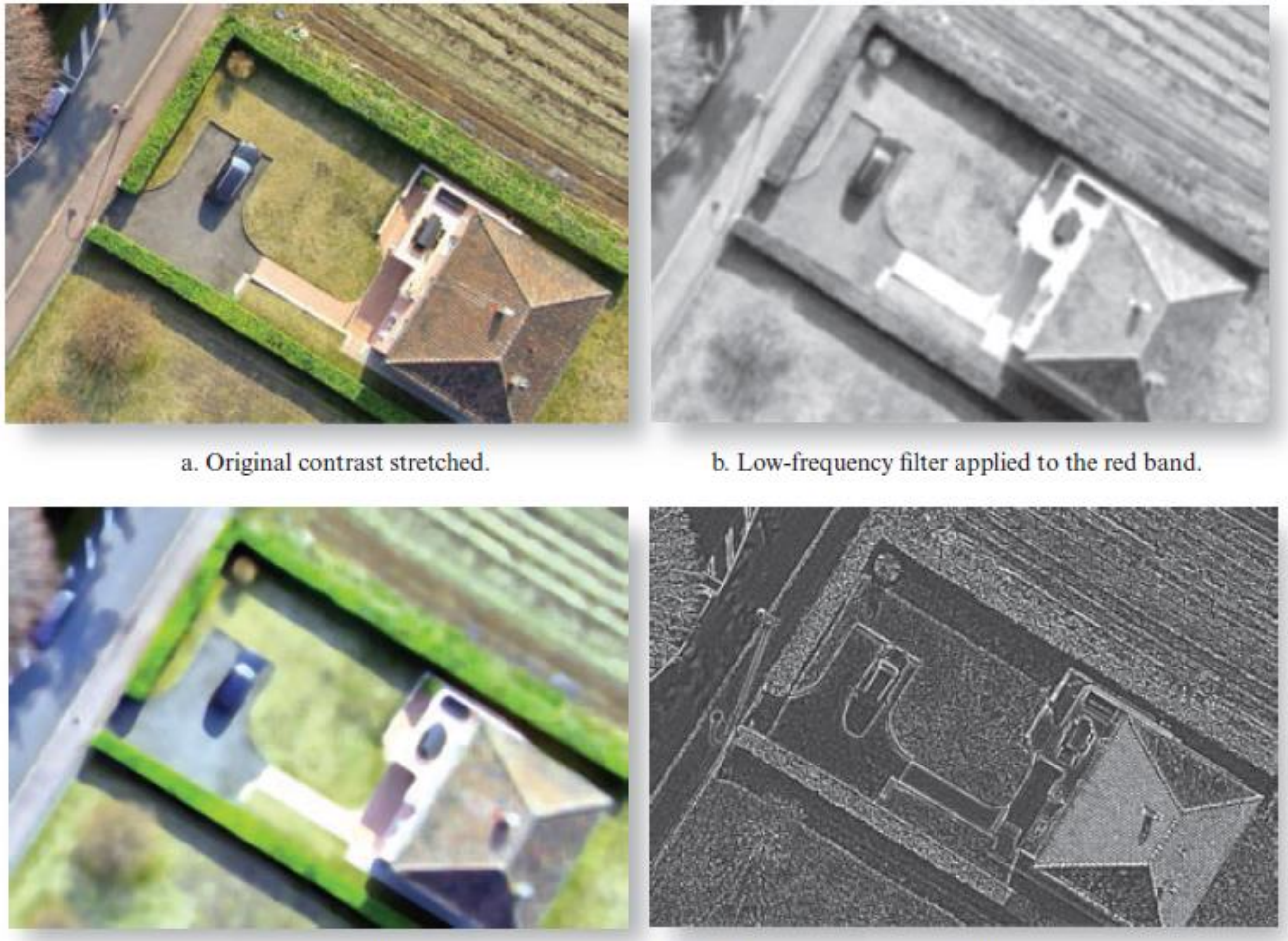
Spatial Convolution Filtering User Interfaces





High-frequency Filtering in the Spatial Domain High-pass filtering is applied to remotely-sensed data to **remove the slowly varying components** and enhance the **high-frequency local variations.**

Spatial Filtering of Raster Data



a. Original contrast stretched.

b. Low-frequency filter applied to the red band.

c. Median filter.

d. High-frequency sharp edge filter applied to the red band.

The high-frequency filtered image will have a relatively **narrow intensity histogram.**

Edge Enhancement in the Spatial Domain

1. A high frequency component image is produced containing the edge information. The kernel size used to produce this image is chosen based on the roughness of the image. Rough= images suggest small filter sizes (e.g., 3 X 3 pixels), whereas large sizes (e.g., 9 X 9 pixels) are used with smooth images.

2. All or a fraction of the gray level in each pixel of the original scene is added back to the high frequency component image.

3. The composite image is contrast stretched. This results in an image containing local contrast enhancement of high frequency features that also preserves the low frequency brightness information contained in the scene.

$$\text{Emboss East} = \begin{matrix} 0 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 0 \end{matrix}$$

$$\text{Emboss NW} = \begin{matrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{matrix}$$

$$\text{Laplacian 4} = \begin{matrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{matrix}$$

$$\text{Laplacian 5} = \begin{matrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{matrix}$$

$$\text{Laplacian 7} = \begin{matrix} 1 & 1 & 1 \\ 1 & -7 & 1 \\ 1 & 1 & 1 \end{matrix}$$

$$\text{Laplacian 8} = \begin{matrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{matrix}$$

Nonlinear Edge Enhancement

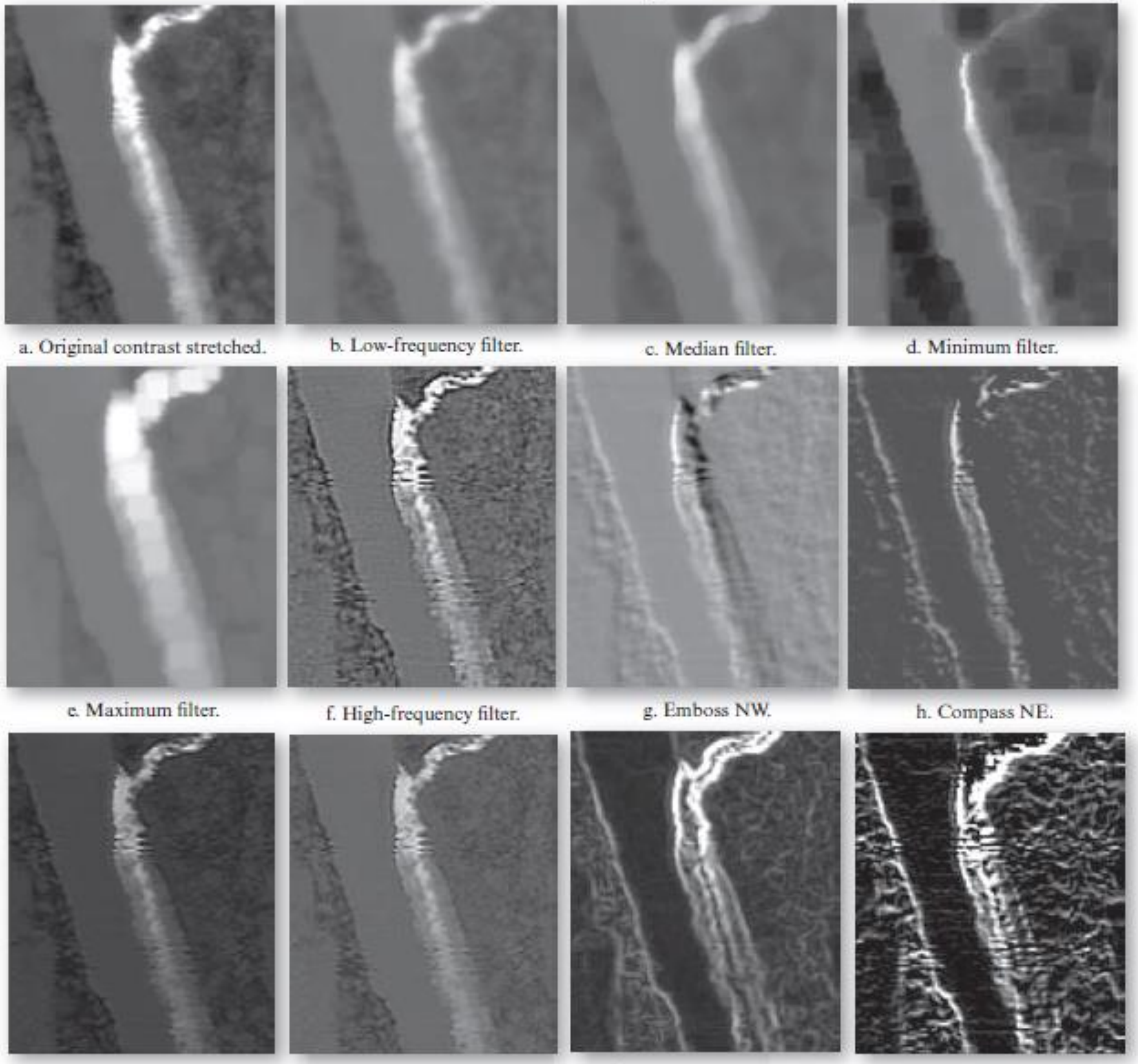
Nonlinear edge enhancements are performed using nonlinear combinations of pixels

Sobel edge detector

This procedure detects **horizontal, vertical, and diagonal edges**. The **Sobel** operator may also be computed by simultaneously applying the following 3 × 3 templates across the image

$$X = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix} \qquad Y = \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix}$$

Spatial Filtering



a. Original contrast stretched. b. Low-frequency filter. c. Median filter. d. Minimum filter.

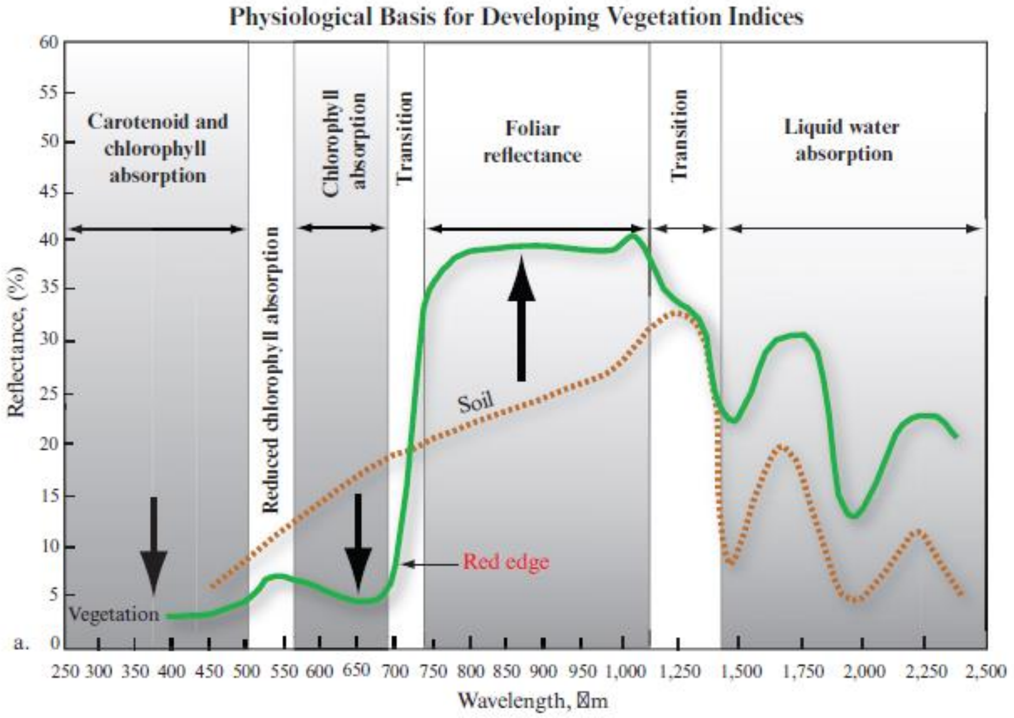
e. Maximum filter. f. High-frequency filter. g. Emboss NW. h. Compass NE.

i. Laplacian 4. j. Laplacian 5. k. Sobel edge enhancement. l. Roberts edge enhancement.

Spectral Ratioing

Since the 1960s, scientists have extracted and modeled various vegetation biophysical variables using remotely sensed data. Much of this effort has involved the use of **vegetation indices** Dimensionless, radiometric measures that indicate the relative abundance and activity of green vegetation, including leaf-area-index (LAI), percentage green cover, chlorophyll content, green biomass,

Ratio images are enhancements resulting from the division of DN values in one spectral band by the corresponding values in another band. A major advantage of ratio images is that they convey the **spectral or color characteristics of image**



Vegetation and soils indices

The **Modified Soil Adjusted Vegetation Index** (MSAVI2) method minimizes the effect of bare soil on the SAVI.

MSAVI2 = (1/2)*(2(NIR+1)-sqrt((2*NIR+1)2-8(NIR-Red)))

NIR = pixel values from the near-infrared band

Red = pixel values from the red band

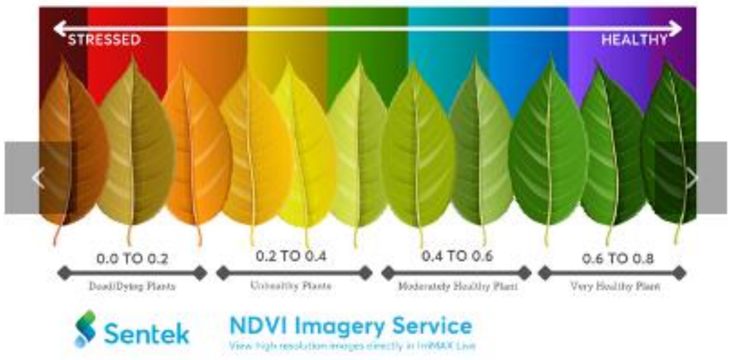
The Normalized Difference Vegetation Index (NDVI) method is a standardized index allowing you to generate an image displaying greenness (relative biomass). This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset—the chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the NIR band.

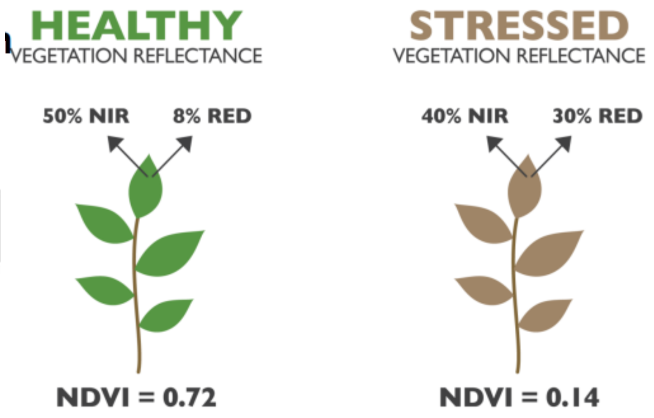
NDVI = ((NIR - Red)/(NIR + Red))

NIR = pixel values from the near-infrared band

Red = pixel values from the red band

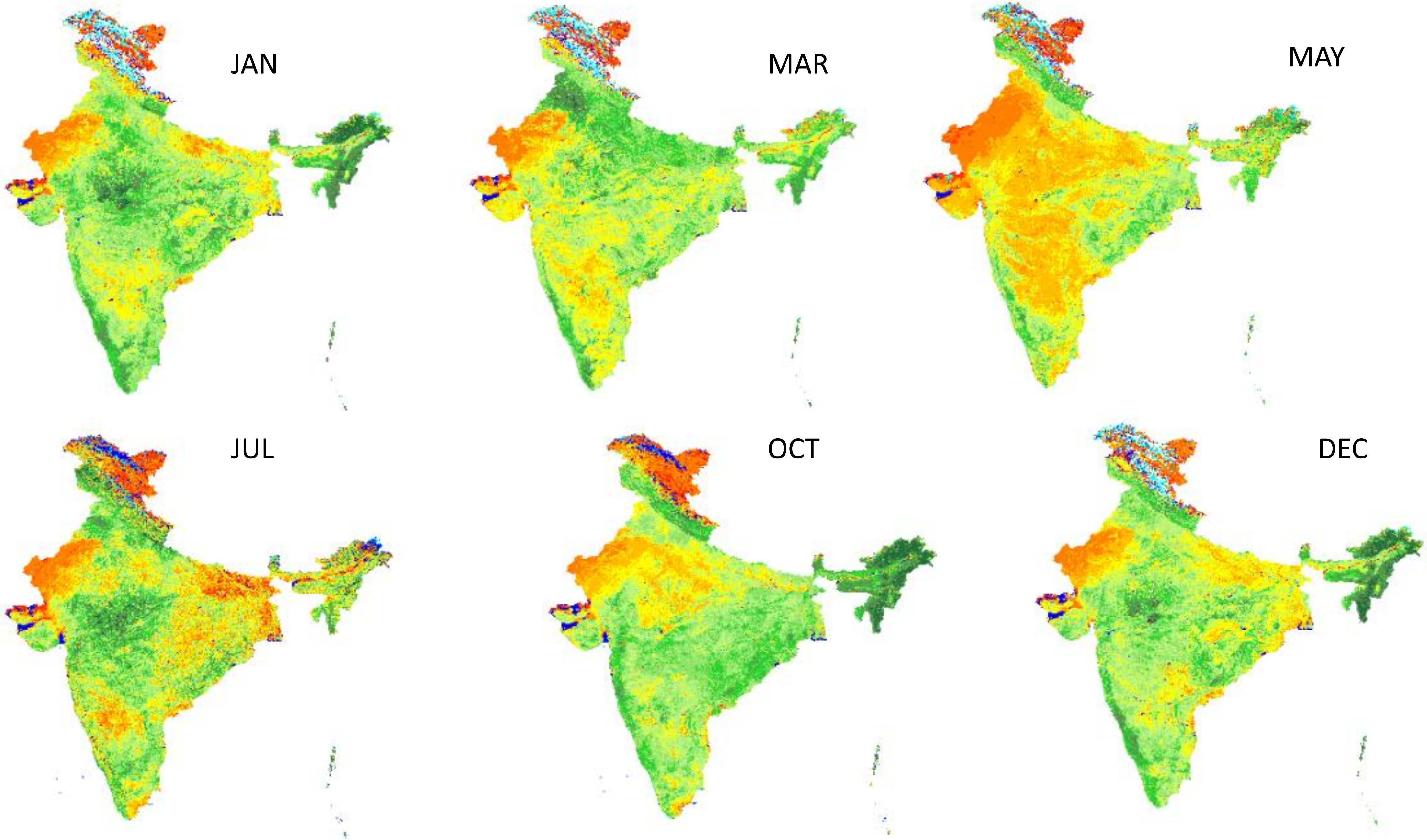
This index outputs values between -1.0 and 1.0





https://www.nv5geospatialsoftware.com/docs/AlphabeticalListSpectralIndices.html

https://www.indexdatabase.de/db/i.php


JAN
MAR
MAY
JUL
OCT
DEC

Water indices
NDSI

NDSI = (Green - SWIR) / (Green + SWIR)
Green = pixel values from the green band
SWIR = pixel values from the shortwave infrared band

The Modified Normalized Difference Water Index (MNDWI) uses green and SWIR bands for the enhancement of open water features. It also diminishes built-up area features that are often correlated with open water in other indices.
MNDWI = (Green - SWIR) / (Green + SWIR)
Green = pixel values from the green band
SWIR = pixel values from the short-wave infrared band

The Normalized Difference Moisture Index (NDMI) is sensitive to the moisture levels in vegetation. It is used to monitor droughts as well as monitor fuel levels in fire-prone areas. It uses NIR and SWIR bands to create a ratio designed to mitigate illumination and atmospheric effects.
NDMI = (NIR - SWIR1)/(NIR + SWIR1)
NIR = pixel values from the near infrared band
SWIR1 = pixel values from the short-wave infrared 1 band

Geology indices

Clay Minerals

The clay minerals ratio is a ratio of the SWIR1 and SWIR2 bands. This ratio leverages the fact that hydrous minerals such as the clays, alunite absorb radiation in the 2.0–2.3 micron portion of the spectrum. This index mitigates illumination changes due to terrain since it is a ratio.

Clay Minerals Ratio = SWIR1 / SWIR2

SWIR1 = pixel values from the short-wave infrared 1 band

SWIR2 = pixel values from the short-wave infrared 2 band

Ferrous Minerals

The ferrous minerals ratio highlights iron-bearing materials.

It uses ratio between the SWIR band and the NIR band.

Ferrous Minerals Ratio = SWIR / NIR

SWIR= pixel values from the short-wave infrared band

NIR = pixel values from the near infrared band

Landscape indices:

The Burn Area Index (BAI) uses the reflectance values in the red and NIR portion of the spectrum to identify the areas of the terrain affected by fire.

BAI = 1/((0.1 -RED)^2 + (0.06 - NIR)^2)

Red = pixel values from the red band

NIR = pixel values from the near infrared band

The Normalized Burn Ratio Index (NBRI) uses the NIR and SWIR bands to emphasize burned areas, while mitigating illumination and atmospheric effects. Your images should be corrected to reflectance values before using this index; see the Apparent Reflectance function for more details.

NBR = (NIR - SWIR) / (NIR+ SWIR)

NIR = pixel values from the near infrared band

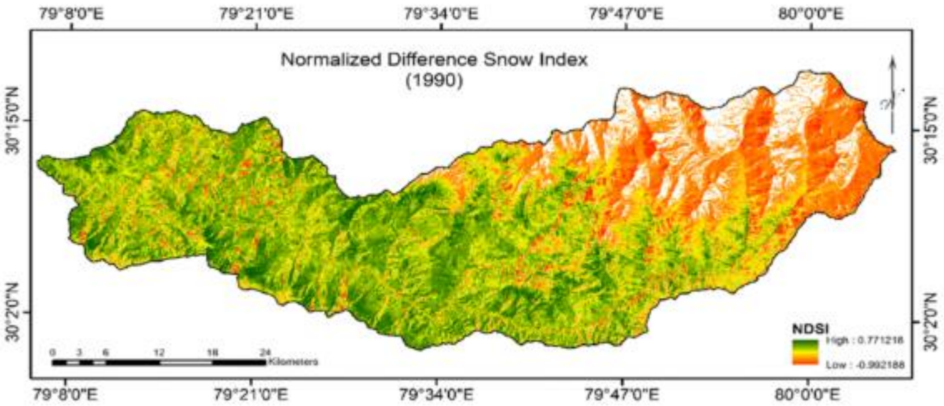
SWIR = pixel values from the short-wave infrared band

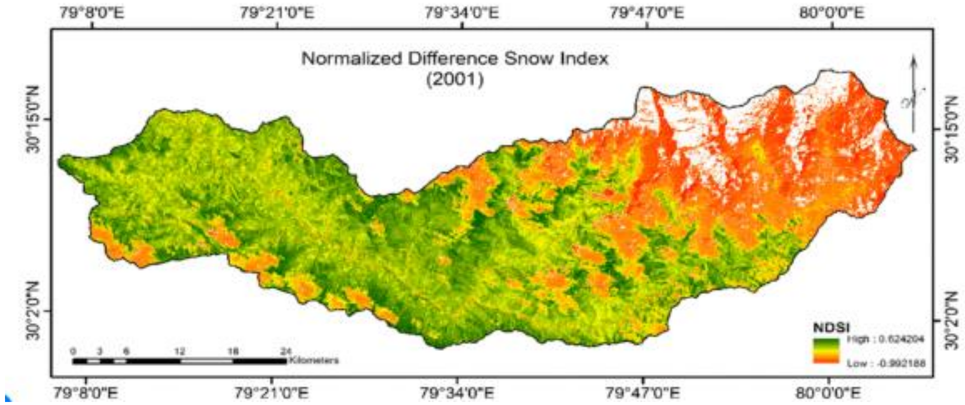
The Normalized Difference Built-up Index (NDBI) uses the NIR and SWIR bands to emphasize man-made built-up areas. It is ratio based to mitigate the effects of terrain illumination differences as well as atmospheric effects.

NDBI = (SWIR - NIR) / (SWIR + NIR)

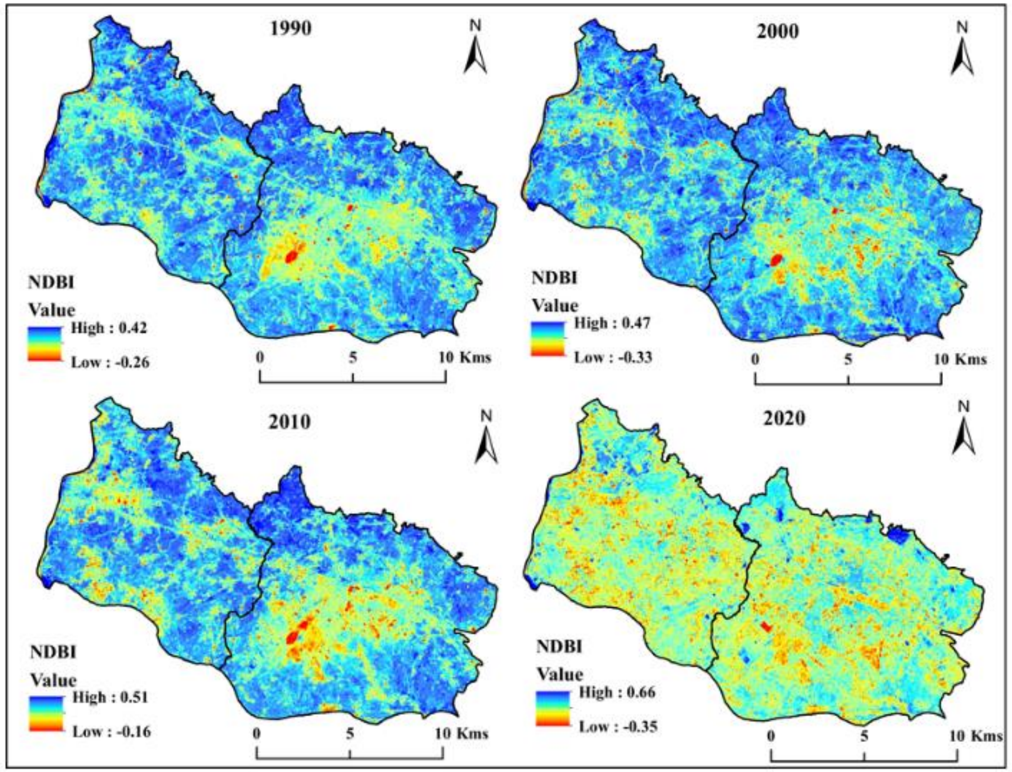
SWIR = pixel values from the short-wave infrared band

NIR = pixel values from the near infrared band





Thank You



Maps of the NDBI at different years (1990–2020)