CE671: Introduction to Remote Sensing
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Lab 4

Introduction

The focus is on understanding key concepts in remote sensing image processing. This lab emphasizes linear stretching, color composites, color representation, and Look-Up Tables (LUTs). The primary goal is to analyze how colors are represented in satellite images and to apply various image processing techniques to enhance and interpret these images effectively. The lab uses images from the LISS 3 sensor, which provides data across different spectral bands, including green, red, and near-infrared (NIR). By manipulating these images, we can explore different color combinations and apply linear stretching to improve image contrast.

Methodology

Image Loading and Preparation:

- Images from the L4_tiff folder are loaded into MATLAB. These images correspond to different spectral bands: Band 2 (Green), Band 3 (Red), and Band 4 (NIR). Each image is resized to ensure they have the same dimensions.

False Color Composite (FCC) Display:

- FCC images are created by assigning different bands to the RGB channels:
    - **FCC Image 1:** NIR (Band 4) is shown in red, Red (Band 3) in green, and Green (Band 2) in blue.
    - **FCC Image 2:** Green (Band 2) is shown in red, Red (Band 3) in green, and NIR (Band 4) in blue.
    - **FCC Image 3:** Red (Band 3) is shown in red, Green (Band 2) in green, and NIR (Band 4) in blue.
- The different FCC images are displayed side by side for comparison.

Pixel Value Analysis:

- Histograms for each band are generated to analyze the distribution of pixel values.
- Statistical measures (min, max, mean, standard deviation) are computed for each band to understand their value ranges and spread.

Linear Stretching:

- Linear stretching is applied to each band using the formula provided to enhance the contrast. The new pixel values are calculated and used to create a stretched FCC image.
- The stretched image is displayed to observe the effects of the linear stretching.

Pixel Value Extraction and LUT Creation:

- Specific pixels from the FCC image are selected, and their RGB values are recorded.
- The RGB values are compared with the stretched image values to create a Look-Up Table (LUT). The LUT helps in understanding how pixel values are transformed and aids in color mapping.

Results

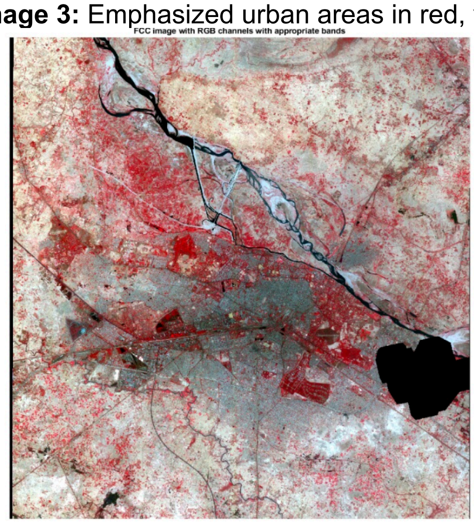
False Color Composite Images:

- Three FCC images were successfully generated, each showing different spectral band combinations:

    FCC Image 1: NIR band highlighted vegetation in red, with the red band highlighting urban areas in green.

    FCC Image 2: Revealed vegetation in green and built-up areas in blue, providing a different perspective.

    FCC Image 3: Emphasized urban areas in red, vegetation in green, and water bodies in blue.



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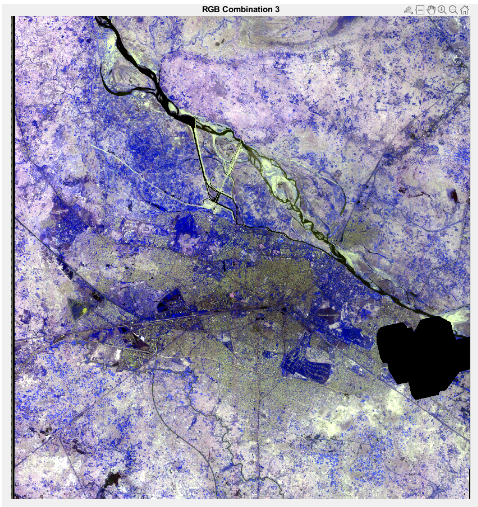

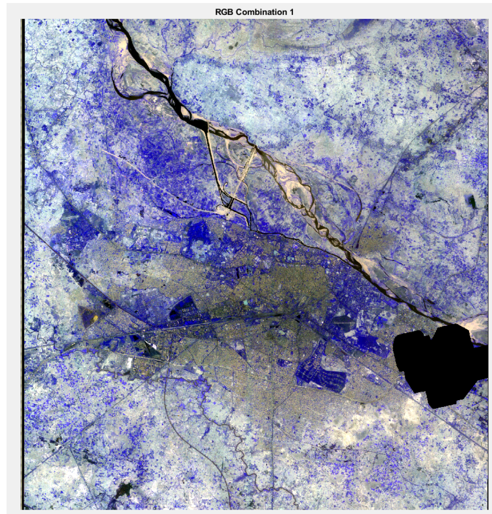

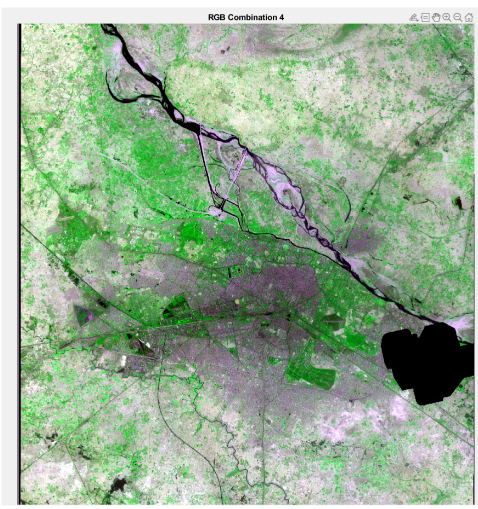

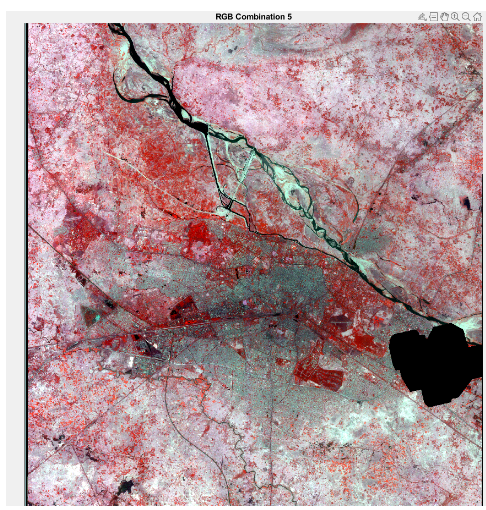

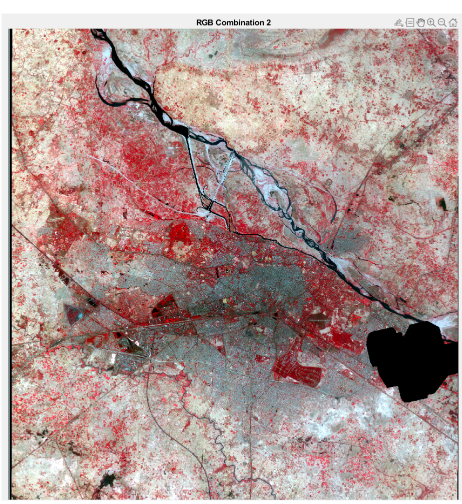

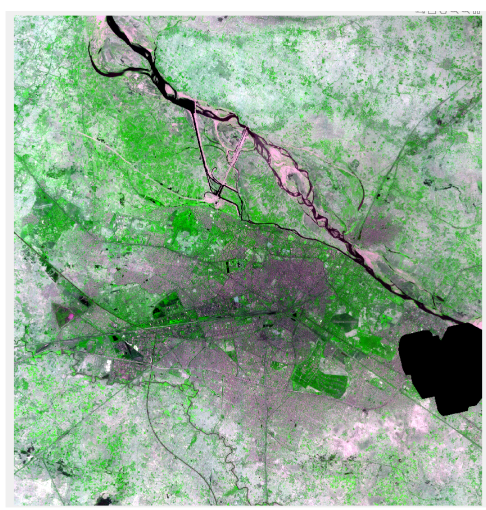

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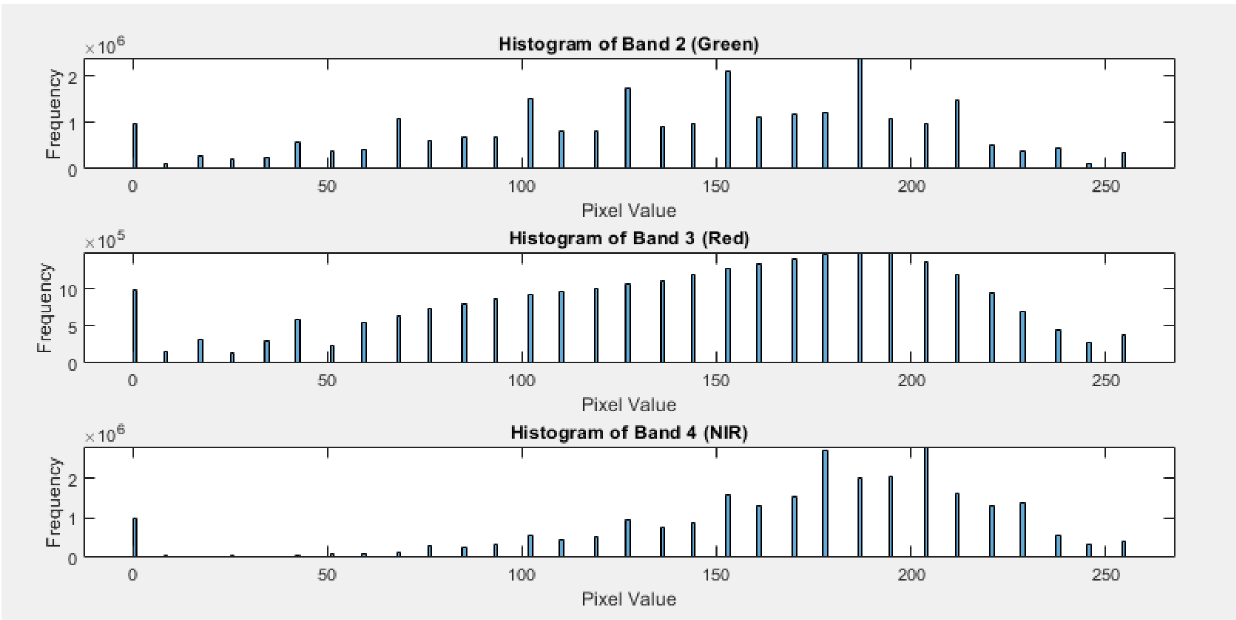
Histogram Analysis:

- Histograms showed varying ranges and distributions of pixel values across different bands. Band 4 (NIR) typically had higher values due to vegetation reflectance.
- The spread of values indicated varying contrast levels, with NIR often showing a wider range of pixel values compared to red and green bands.




```
Band 2 (Green) - Min: 0, Max: 255, Mean: 139.15, Std Dev: 60.94
Band 3 (Red) - Min: 0, Max: 255, Mean: 142.94, Std Dev: 63.00
Band 4 (NIR) - Min: 0, Max: 255, Mean: 169.41, Std Dev: 54.27
```

Combinations Calculation

For three bands, you can assign each band to one of the RGB channels (Red, Green, and Blue). The number of ways to assign these bands to the RGB channels is given by the number of permutations of the three bands.

The number of permutations of nnn items is given by n!n!n! (n factorial). For 3 bands, this is:

3!=6 3! = 6 3!=6

Listing the Combinations

Here are the 6 possible combinations:

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1. **Combination 1:**
    - **Red Channel:** Band 2
    - **Green Channel:** Band 3
    - **Blue Channel:** Band 4
2. **Combination 2:**
    - **Red Channel:** Band 2
    - **Green Channel:** Band 4
    - **Blue Channel:** Band 3
3. **Combination 3:**
    - **Red Channel:** Band 3
    - **Green Channel:** Band 2
    - **Blue Channel:** Band 4
4. **Combination 4:**
    - **Red Channel:** Band 3
    - **Green Channel:** Band 4
    - **Blue Channel:** Band 2
5. **Combination 5:**
    - **Red Channel:** Band 4
    - **Green Channel:** Band 2
    - **Blue Channel:** Band 3
6. **Combination 6:**
    - **Red Channel:** Band 4
    - **Green Channel:** Band 3
    - **Blue Channel:** Band 2

Linear Stretching Results:

- The linear stretching improved image contrast by expanding the pixel value range to cover the full 0-255 range. The stretched FCC image revealed enhanced details and features.

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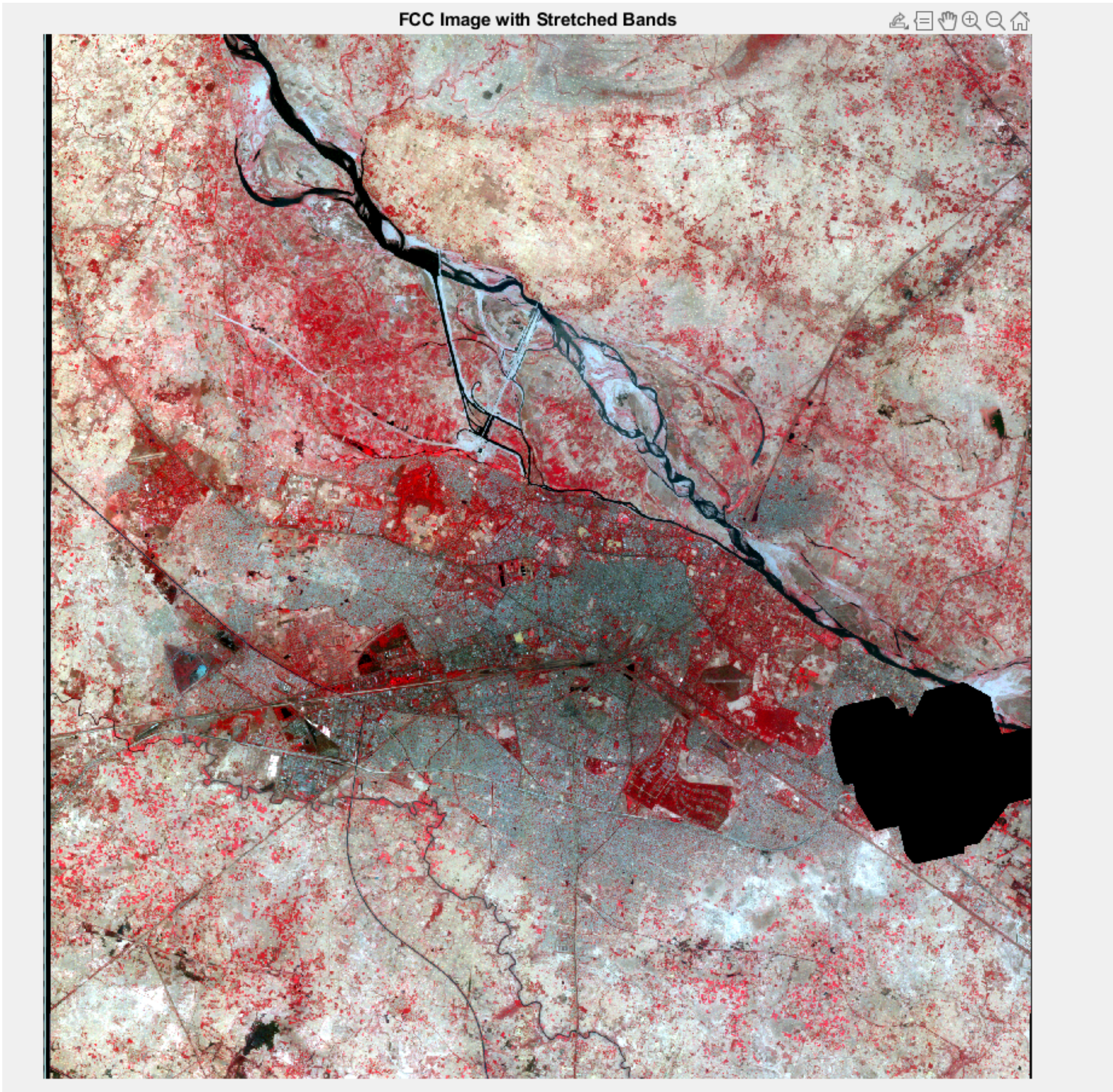
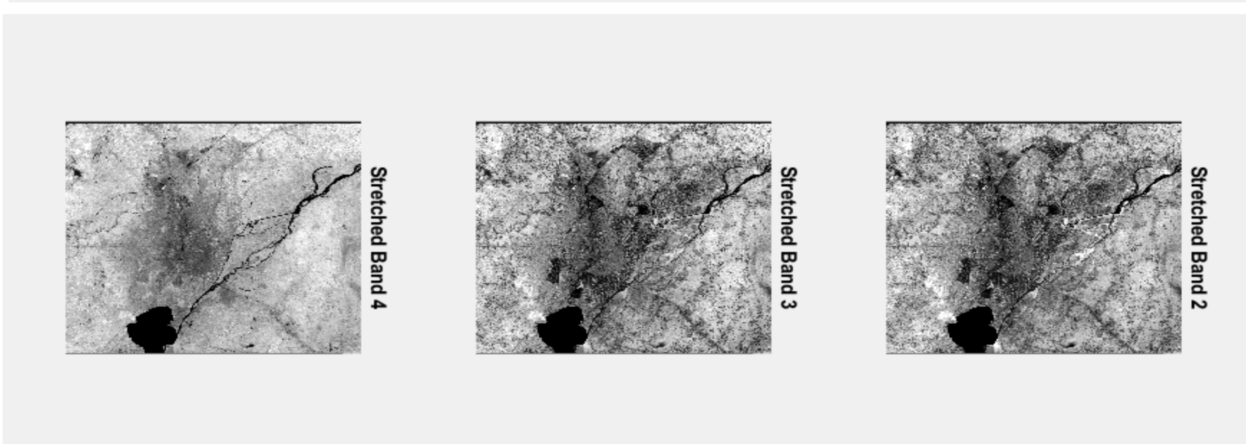
- 
FCC Image with Stretched Bands
- 
Stretched Band 4
Stretched Band 3
Stretched Band 2

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Pixel Value Analysis:

- Pixel values from selected areas (vegetation, water bodies, urban regions) were compared before and after stretching.
- The LUT was created to map the original and stretched pixel values, helping to visualize how stretching affects color representation.

pixel_indices	pixel_locations	Var3	original_rgb_values	original_hex_colors	stretched_rgb_values	stretched_hex_colors
1	{[1263 2293]}	{'Roof' }	{[178 144 110]}	{'#B2906E'}	{[178 144 110]}	{'#B2906E'}
2	{[1527 1495]}	{'Tree' }	{[178 85 102]}	{'#B25566'}	{[178 85 102]}	{'#B25566'}
3	{[1689 925]}	{'River'}	{[0 0 0]}	{'#000000'}	{[0 0 0]}	{'#000000'}
4	{[1318 1693]}	{'Road' }	{[195 93 102]}	{'#C35D66'}	{[195 93 102]}	{'#C35D66'}
5	{[915 4135]}	{'Farm' }	{[255 85 102]}	{'#FF5566'}	{[255 85 102]}	{'#FF5566'}

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Observations

Pixel Value Distribution:

- **Band 2 (Green):** The histogram revealed that Band 2 (Green) had a moderate range of pixel values with a central peak, indicating a generally uniform reflectance across most of the image area. The pixel values were not as widely distributed as in the other bands.
- **Band 3 (Red):** Band 3 (Red) showed a broader distribution of pixel values with a higher range compared to Band 2. This suggests that the red band captures more variation in the land cover, which is typical for identifying urban and built-up areas.
- **Band 4 (NIR):** Band 4 (NIR) had the widest range of pixel values, with a significant number of high values due to strong reflectance from vegetation. This is indicative of the NIR band's sensitivity to vegetation and its ability to distinguish between different types of land cover.

False Color Composite Images:

- **FCC Image 1:** NIR displayed in red, red band in green, and green band in blue provided a clear distinction between vegetation (highlighted in red) and other land cover types. Vegetation appeared prominently due to the high NIR reflectance.
- **FCC Image 2:** The combination with green in red, red in green, and NIR in blue provided a different perspective, where vegetation appeared in green. This helped in visualizing the distribution of vegetation in relation to other land cover types.
- **FCC Image 3:** Using red in red, green in green, and NIR in blue emphasized urban areas and water bodies effectively. Urban areas were highlighted in red, and water bodies were distinctly visible in blue.

Linear Stretching Effects:

- The application of linear stretching enhanced the contrast in each band, making features more discernible. The stretched FCC images exhibited improved visibility of various land cover types, particularly in areas with previously limited contrast.
- The pixel value ranges were adjusted to cover the full 0-255 range, which made the stretched images more suitable for analysis and interpretation.

Pixel Value Extraction and LUT Creation:

- Specific pixels from different land cover types (e.g., vegetation, water bodies, urban areas) were selected to analyze their RGB values. The LUT showed how pixel values changed after stretching, providing insights into the transformation process.

- The LUT allowed comparison between the original and stretched pixel values, demonstrating how stretching can alter color representation in the image.

Visual and Statistical Insights:

- The histograms and statistical measures provided a detailed view of how pixel values are distributed across different bands, influencing the appearance of features in the images.
- The spread of pixel values in each band varied significantly, with NIR showing the most extensive range due to its sensitivity to vegetation.

Discussion

- Color Representation:
  - Different FCC combinations highlight various features based on spectral reflectance. The choice of bands affects how land cover types are visualized, aiding in the interpretation of satellite images.
- Role of DNs:
  - Digital Numbers (DNs) in different bands influence color composites. The DNs directly impact the visual representation of features in the FCC images. Bands with higher reflectance, like NIR, can dominate certain colors (e.g., red in FCC Image 1).
- Linear Stretching:
  - Linear stretching effectively enhances image contrast by redistributing pixel values. This technique makes features more distinguishable, which is useful for analysis and interpretation.
- Look-Up Tables (LUTs):
  - LUTs are significant for mapping pixel values to colors, facilitating comparison between original and processed images. They help in understanding how image processing techniques transform pixel values.

1. Applications of Different FCC Combinations

Different False Color Combinations (FCCs) of satellite images can be used for various real-life applications. Here are three examples:

1. **Vegetation Analysis:**
   - **Application:** Differentiating between various types of vegetation and assessing their health.

- **FCC Combination:** Using Near-Infrared (NIR) in red, red in green, and green in blue (NIR -> R, Red -> G, Green -> B) highlights vegetation because healthy vegetation reflects strongly in the NIR band, making it appear bright red in this FCC. This combination helps in identifying vegetation types, stress levels, and biomass.

2. **Water Body and Urban Area Mapping:**
   - **Application:** Identifying water bodies and differentiating between urban and non-urban areas.
   - **FCC Combination:** Using green in red, red in green, and NIR in blue (Green -> R, Red -> G, NIR -> B) can enhance the visibility of water bodies, as water absorbs most of the NIR and appears dark in this combination. Urban areas often have different spectral characteristics that stand out in this FCC.
3. **Soil and Land Use Classification:**
   - **Application:** Classifying different soil types and land use categories.
   - **FCC Combination:** Using red in red, green in green, and NIR in blue (Red -> R, Green -> G, NIR -> B) can help in distinguishing between various soil types and land uses based on their spectral signatures. For instance, different soil types may have distinct colors and textures in this FCC, aiding in land management and agricultural planning.

2. Difference Between RGB and CMYK Models

RGB Model:

- **Color Mixing:** Additive mixing.
- **Description:** The RGB model uses red, green, and blue light to create colors. Adding these colors together in different intensities results in different colors. When combined at full intensity, they produce white light; when all are at zero intensity, the result is black.
- **Applications:** Used in digital screens (monitors, TVs) and cameras. It is based on light emission.

CMYK Model:

- **Color Mixing:** Subtractive mixing.
- **Description:** The CMYK model uses cyan, magenta, yellow, and black inks. Colors are created by subtracting varying amounts of light absorbed by these inks. When combined, they produce a range of colors and typically create black when all inks are mixed in equal amounts (though black ink is used separately to improve depth and detail).
- **Applications:** Used in color printing processes (e.g., newspapers, magazines) where colors are applied as ink on paper.

3. Significance of Look-Up Tables (LUTs)

Look-Up Tables (LUTs):

- **Definition:** A LUT is a mapping table used to transform input values into output values. It provides a way to apply a specific color or intensity adjustment to an image by referencing pre-defined values in the table.

Significance:

1. **Color Correction:** LUTs are essential for color correction in image processing. They allow for efficient adjustment of colors and intensities across an image, ensuring consistent color reproduction or enhancement.
2. **Image Enhancement:** LUTs help in enhancing the visual appearance of images by applying transformations like contrast stretching, gamma correction, or color balancing, thereby improving the interpretability of the image for various applications.
3. **Consistency in Output:** In processes where color accuracy is critical (e.g., graphic design, video editing), LUTs ensure that colors are reproduced consistently across different devices or media by standardizing color corrections.

Conclusion

The lab demonstrated fundamental image processing techniques in remote sensing, including the creation of False Color Composites (FCC), linear stretching, and the use of Look-Up Tables (LUTs). By analyzing different band combinations and applying contrast enhancement techniques, we gained insights into how satellite images can be interpreted more effectively. The histograms and statistical measures provided a detailed understanding of pixel value distributions, and the LUT created a practical tool for comparing original and processed images. Overall, these techniques are essential for enhancing and interpreting remote sensing data in various applications.

References

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2. **Jensen, J. R.** (2007). **Remote Sensing of the Environment: An Earth Resource Perspective** (2nd ed.). Pearson Education.
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6. **NASA Earth Observing System Data and Information System (EOSDIS)**. (2024). **MODIS Land Products**. Retrieved from https://modis.gsfc.nasa.gov/data/dataprod/