02_Segmentation

March 12, 2025

[11]:

```
import sys
import os

# Append the project root to sys.path (one level up from notebooks)
project_root = os.path.abspath(os.path.join(os.getcwd(), ".."))
if project_root not in sys.path:
    sys.path.insert(0, project_root)

print("Project root added to sys.path:", project_root)
```

```
Project root added to sys.path:
c:\Users\rober\Desktop\516FP\EuroSat_Segmentation_Project
```

[12]:

```
import numpy as np
import matplotlib.pyplot as plt
import cv2
import os

# Import your segmentation functions from the src package
from src.segmentation.kmeans import kmeans_segmentation
from src.segmentation.fuzzy_cmeans import fuzzy_cmeans_segmentation

# Verify that the imports work by printing a success message
print("Segmentation modules imported successfully.")
```

```
Segmentation modules imported successfully.
```

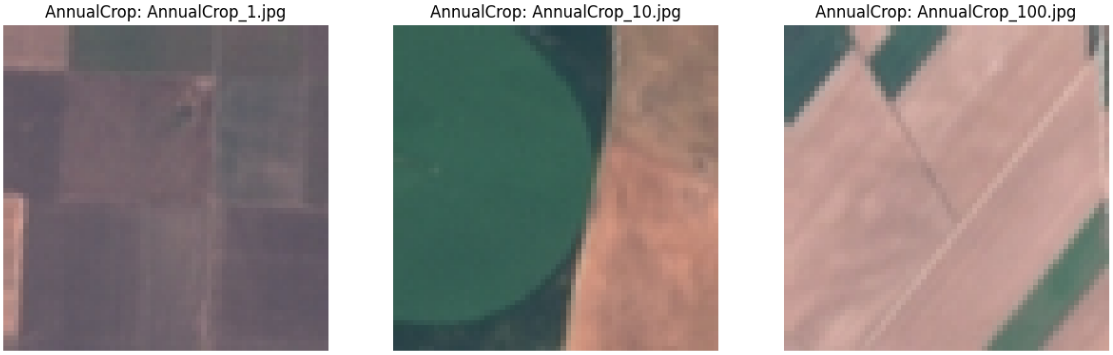
[13]:

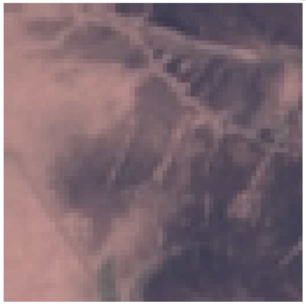
```
# Define path to the EuroSAT (RGB) dataset folder
data_dir = "../data/raw/EuroSAT"

# List the available classes (folder names)
classes = [d for d in os.listdir(data_dir) if os.path.isdir(os.path.
  ↪join(data_dir, d))]
print("Available Classes in EuroSAT:", classes)
```

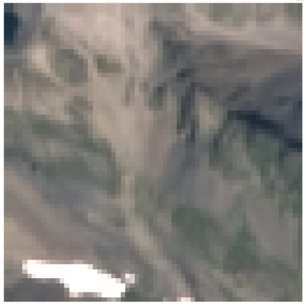
```
Available Classes in EuroSAT: ['AnnualCrop', 'Forest', 'HerbaceousVegetation',
'Highway', 'Industrial', 'Pasture', 'PermanentCrop', 'Residential', 'River',
'SeaLake']
```

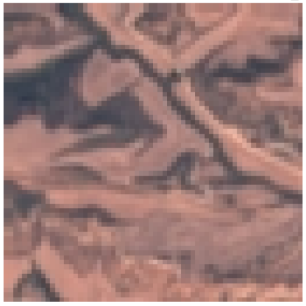
[14]:

```
def show_sample_images(class_name, num_images=3):
    class_path = os.path.join(data_dir, class_name)
    image_files = os.listdir(class_path)[:num_images]
    plt.figure(figsize=(15, 5))
    for i, img_file in enumerate(image_files):
        img_path = os.path.join(class_path, img_file)
        img = cv2.imread(img_path)
        if img is not None:
            img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
            plt.subplot(1, num_images, i+1)
            plt.imshow(img)
            plt.title(f"{class_name}: {img_file}")
            plt.axis("off")
        else:
            print(f"Failed to load {img_path}")
    plt.show()

# Display sample images for the first two classes
for cls in classes[:10]:
    show_sample_images(cls)
```


AnnualCrop: AnnualCrop_1.jpg
AnnualCrop: AnnualCrop_10.jpg
AnnualCrop: AnnualCrop_100.jpg

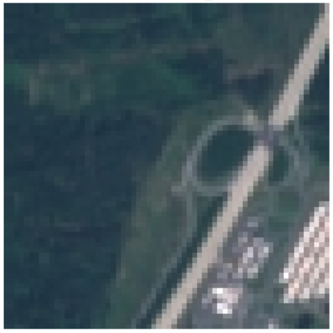

HerbaceousVegetation: HerbaceousVegetation_1.jpg


HerbaceousVegetation: HerbaceousVegetation_10.jpg

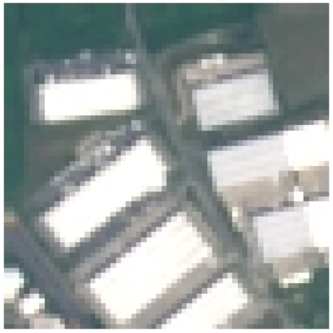

HerbaceousVegetation: HerbaceousVegetation_100.jpg

Highway: Highway_1.jpg

Highway: Highway_10.jpg


Highway: Highway_100.jpg

Industrial: Industrial_1.jpg


Industrial: Industrial_10.jpg

Industrial: Industrial_100.jpg

Pasture: Pasture_1.jpg
Pasture: Pasture_10.jpg
Pasture: Pasture_100.jpg
PermanentCrop: PermanentCrop_1.jpg
PermanentCrop: PermanentCrop_10.jpg
PermanentCrop: PermanentCrop_100.jpg
Residential: Residential_1.jpg
Residential: Residential_10.jpg
Residential: Residential_100.jpg

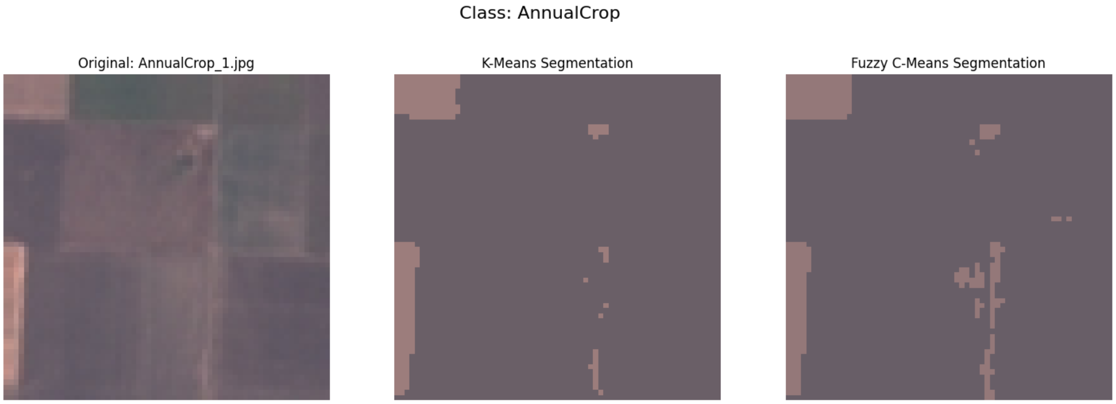
River: River_1.jpg River: River_10.jpg River: River_100.jpg

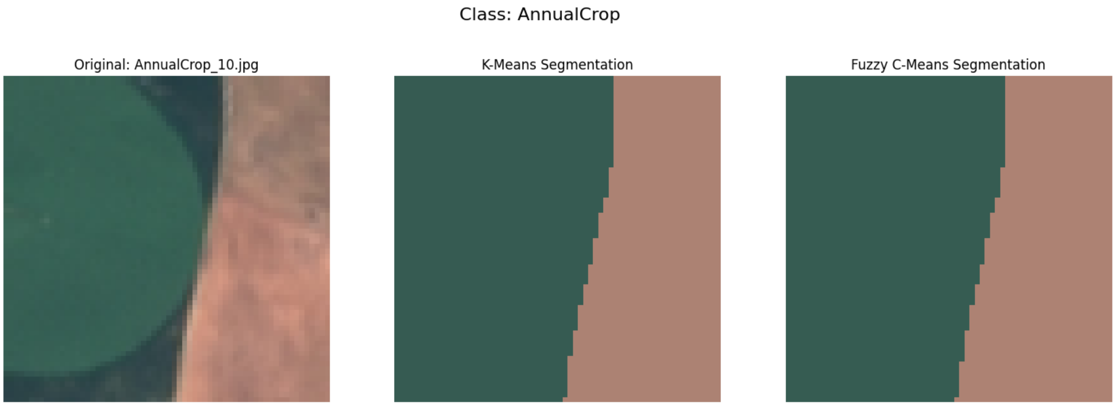
SeaLake: SeaLake_1.jpg SeaLake: SeaLake_10.jpg SeaLake: SeaLake_100.jpg

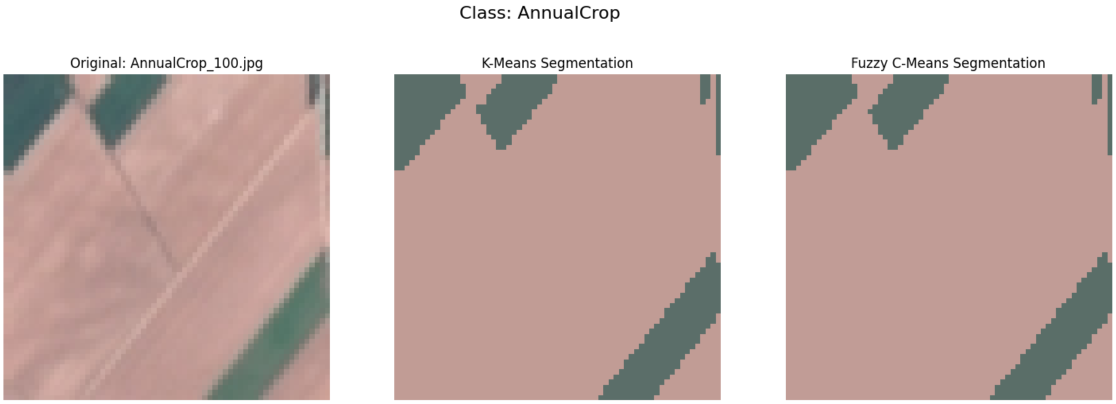
[15]:

```
# Choose a subset of classes for testing (you can modify this list as needed)
test_classes = classes[:10]  # For example, use the first 3 classes
num_images_per_class = 3     # Number of sample images to process per class

# Set segmentation parameters.
k = 2      # Number of clusters for both methods
m = 2      # Fuzziness parameter for Fuzzy C-Means

for class_name in test_classes:
    class_path = os.path.join(data_dir, class_name)
    image_files = os.listdir(class_path)[:num_images_per_class]
    print(f"Processing class '{class_name}' with {len(image_files)} images...")

    for img_file in image_files:
        img_path = os.path.join(class_path, img_file)
        image = cv2.imread(img_path)
        if image is None:
            print(f"Failed to load {img_path}")
            continue
        # Convert the image from BGR to RGB.
        image_rgb = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

        # Apply K-Means segmentation.
        labels_km, centroids_km, segmented_image_km =␣
↪kmeans_segmentation(image_rgb, k)
        segmented_image_km = centroids_km[labels_km]

        # Apply Fuzzy C-Means segmentation.
        labels_fcm, centroids_fcm, _ = fuzzy_cmeans_segmentation(image_rgb, k,␣
↪m)
        segmented_image_fcm = centroids_fcm[labels_fcm]

        # Display original and segmented images side by side.
        plt.figure(figsize=(18, 6))

        plt.subplot(1, 3, 1)
        plt.imshow(image_rgb)
        plt.title(f"Original: {img_file}")
        plt.axis("off")

        plt.subplot(1, 3, 2)
        plt.imshow(segmented_image_km.astype(np.uint8))
        plt.title("K-Means Segmentation")
        plt.axis("off")

        plt.subplot(1, 3, 3)
        plt.imshow(segmented_image_fcm.astype(np.uint8))
        plt.title("Fuzzy C-Means Segmentation")
        plt.axis("off")

        plt.suptitle(f"Class: {class_name}", fontsize=16)
        plt.show()
```

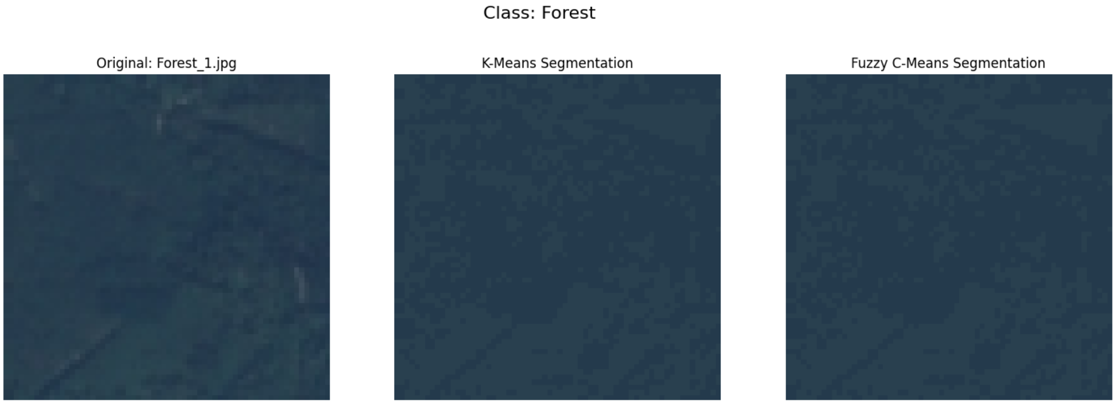
```
Processing class 'AnnualCrop' with 3 images…
```



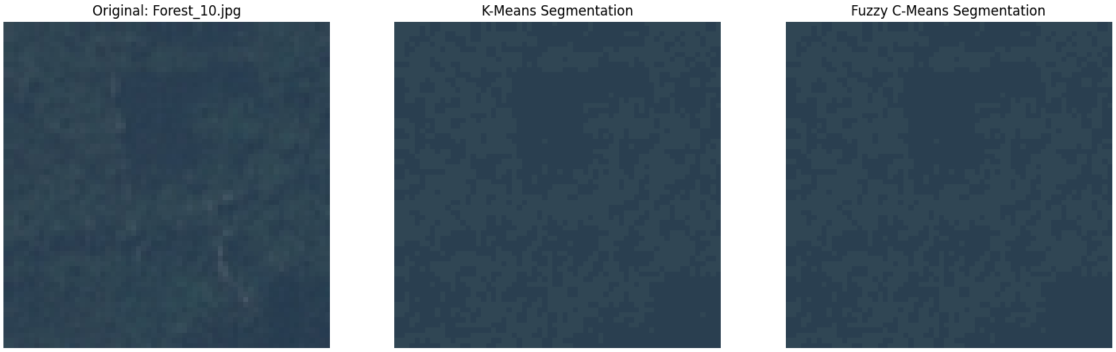




```
Processing class 'Forest' with 3 images…
```



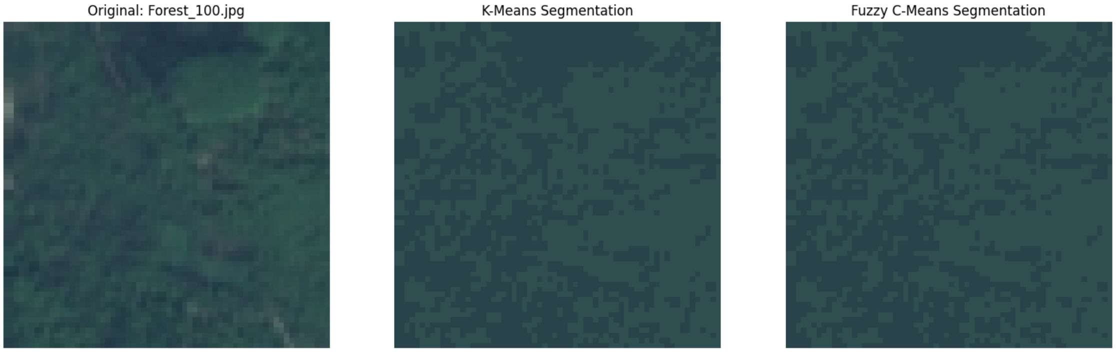
Class: Forest


Original: Forest_10.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

Class: Forest

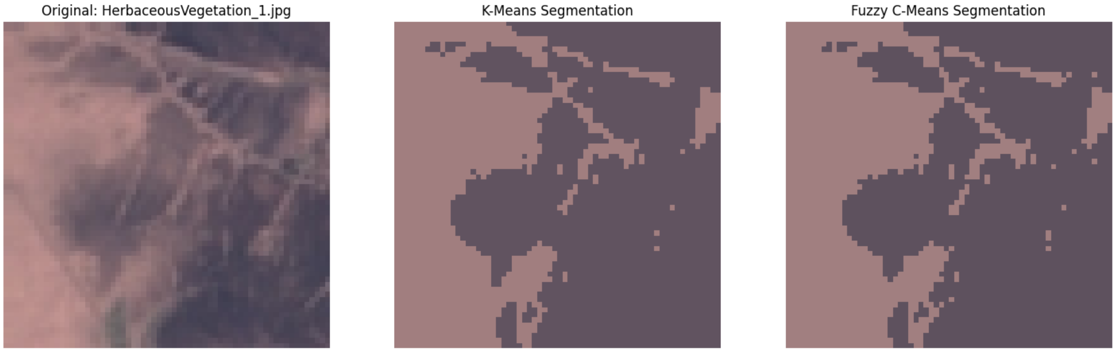

Original: Forest_100.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

```
Processing class 'HerbaceousVegetation' with 3 images…
```

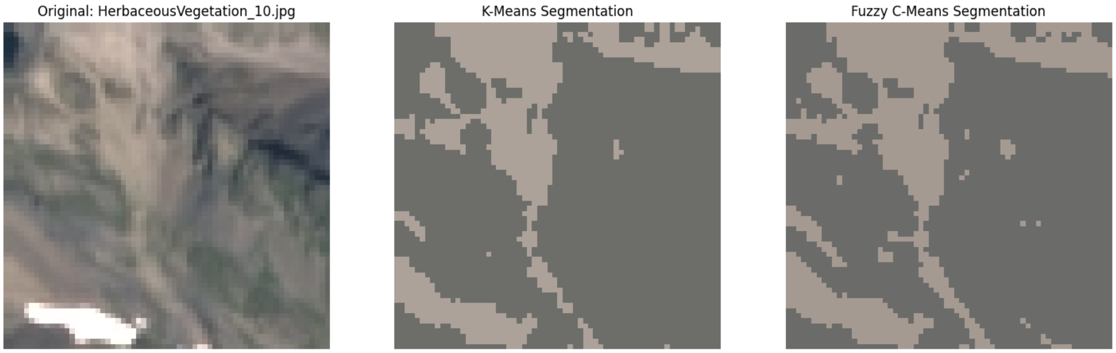
Class: HerbaceousVegetation


Original: HerbaceousVegetation_1.jpg

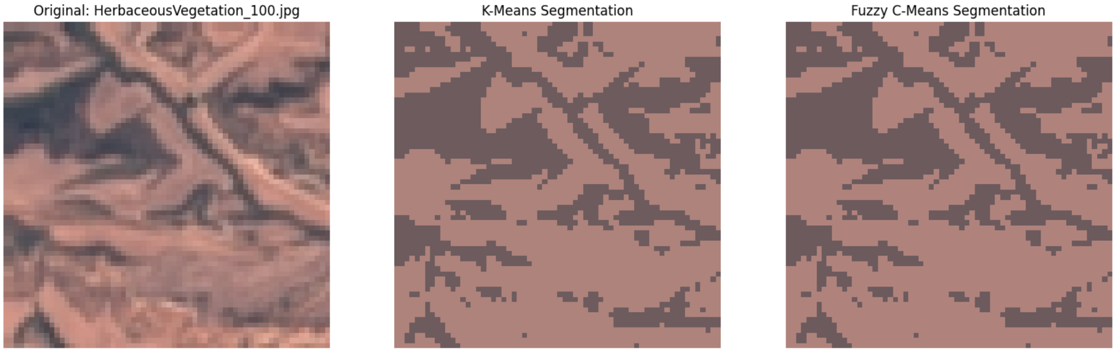
K-Means Segmentation

Fuzzy C-Means Segmentation

Class: HerbaceousVegetation

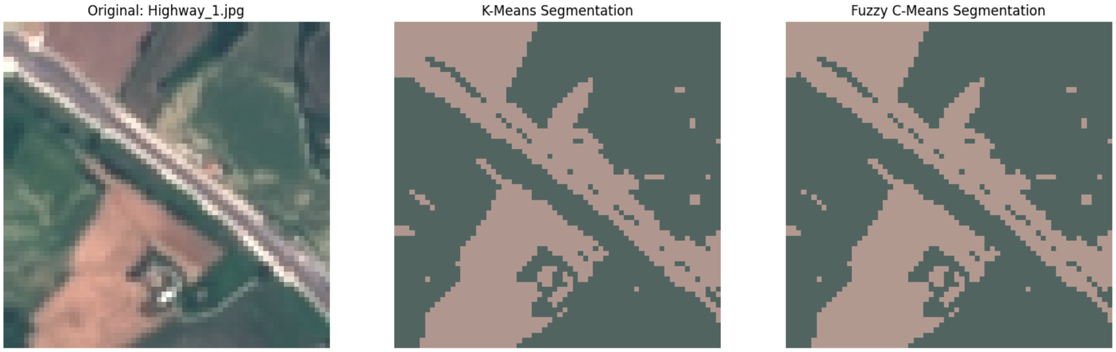

Original: HerbaceousVegetation_10.jpg
K-Means Segmentation
Fuzzy C-Means Segmentation

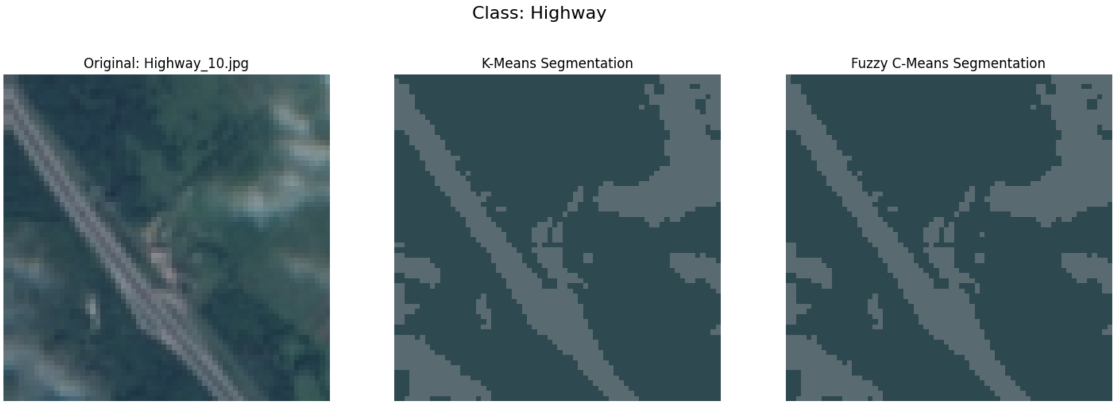
Class: HerbaceousVegetation

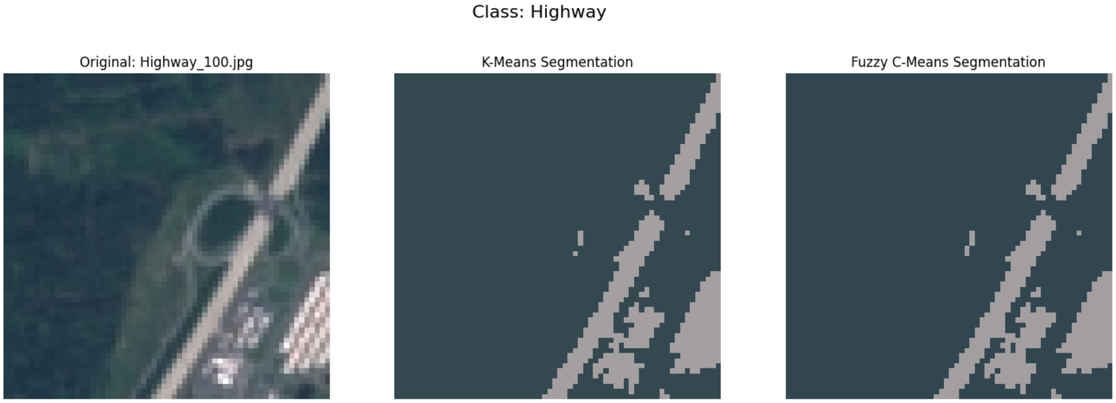

Original: HerbaceousVegetation_100.jpg
K-Means Segmentation
Fuzzy C-Means Segmentation

```
Processing class 'Highway' with 3 images…
```

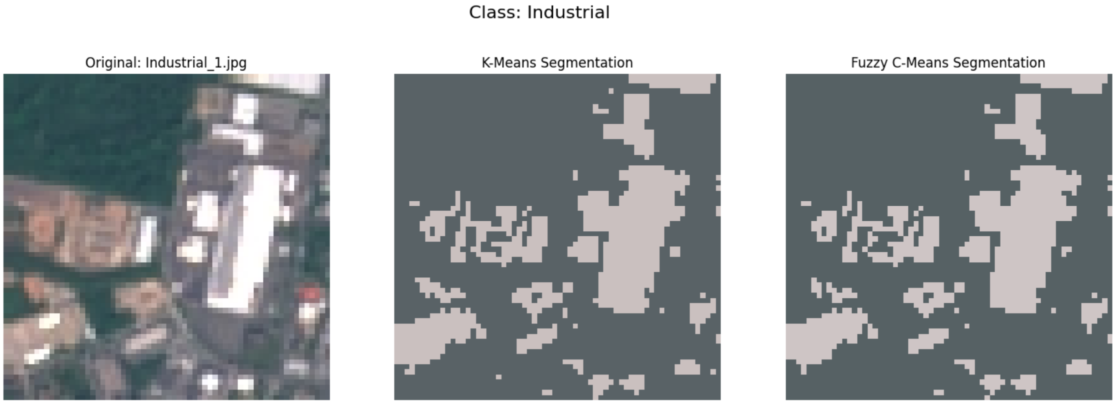
Class: Highway

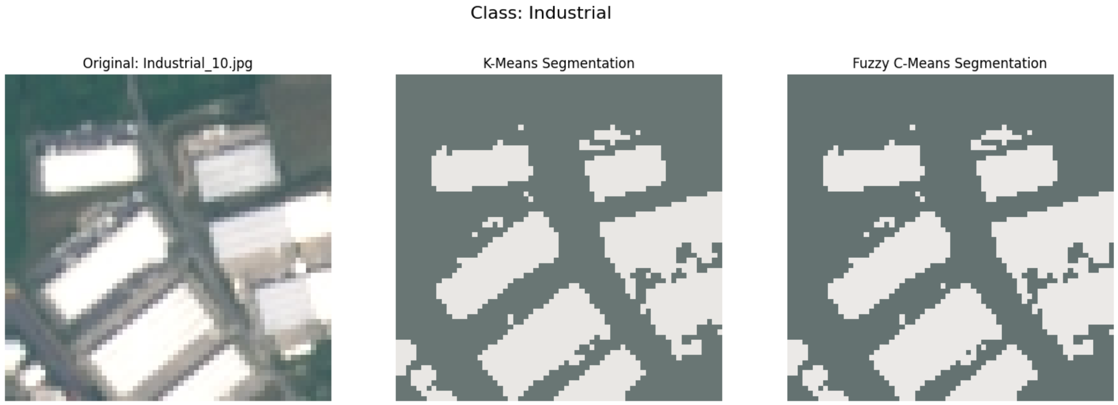


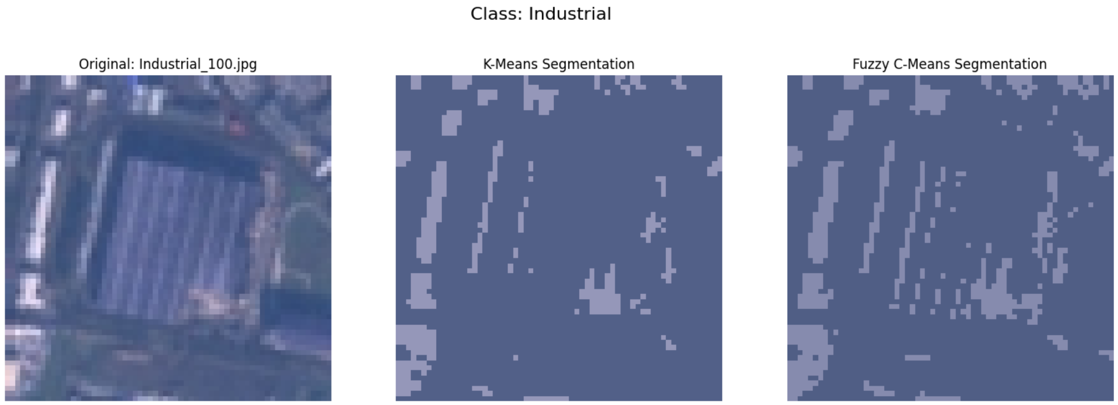




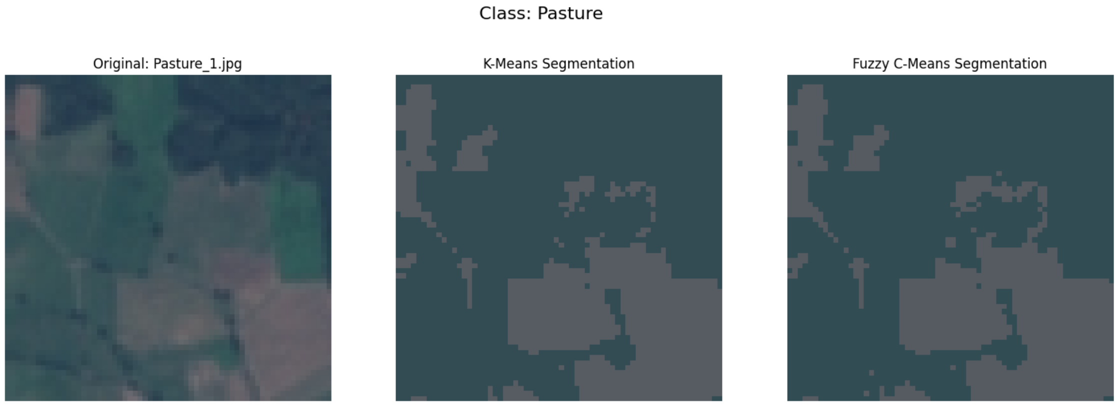
```
Processing class 'Industrial' with 3 images…
```



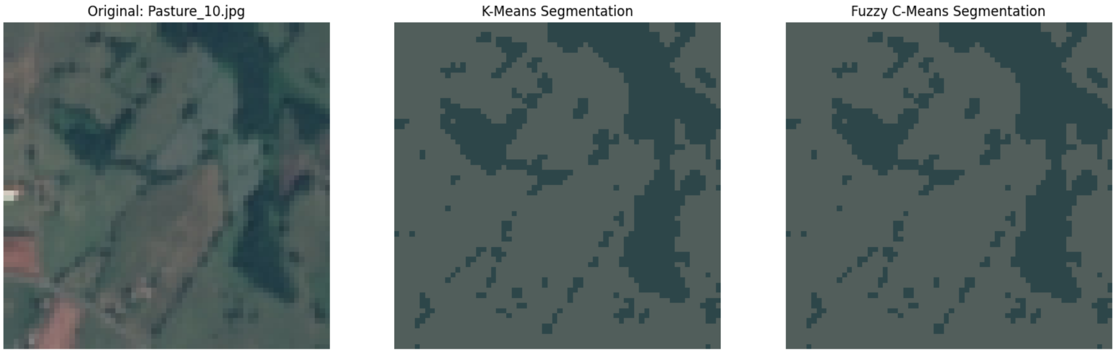




```
Processing class 'Pasture' with 3 images…
```



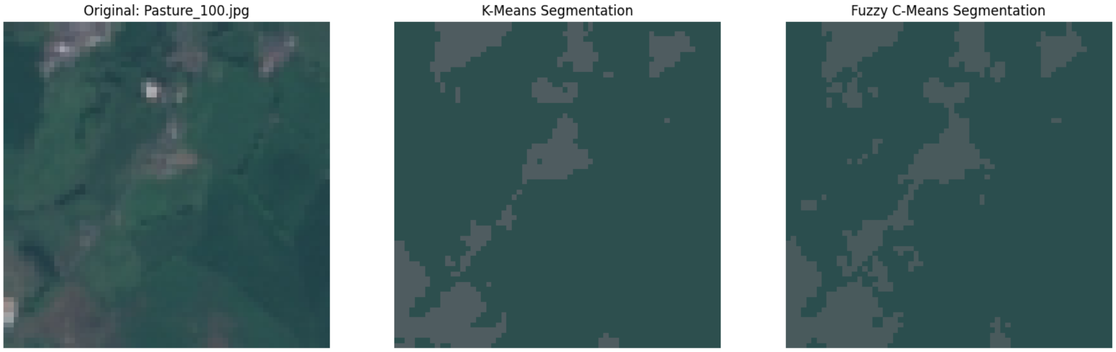
Class: Pasture


Original: Pasture_10.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

Class: Pasture

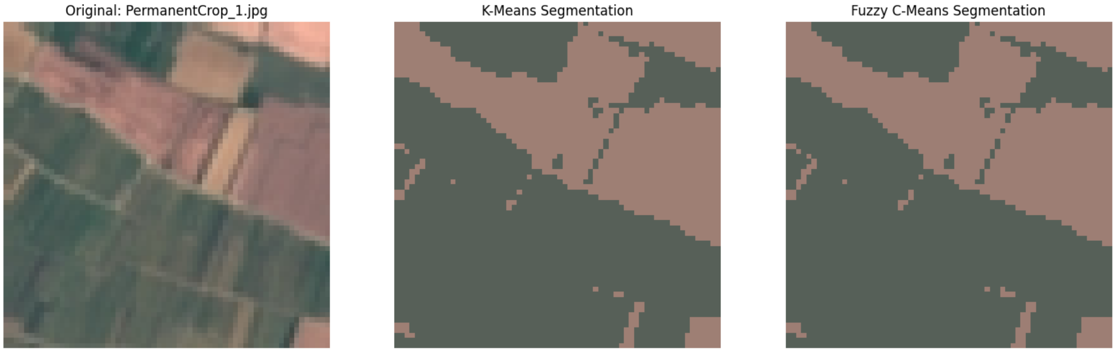

Original: Pasture_100.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

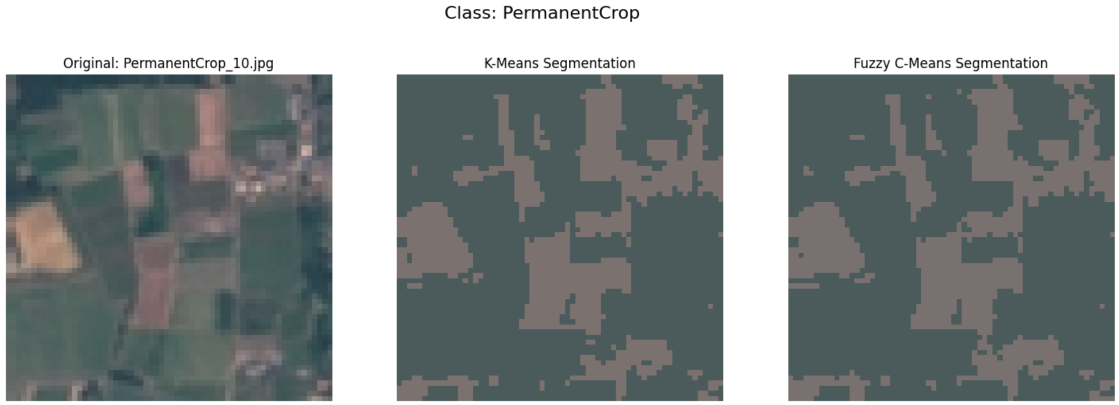
```
Processing class 'PermanentCrop' with 3 images…
```

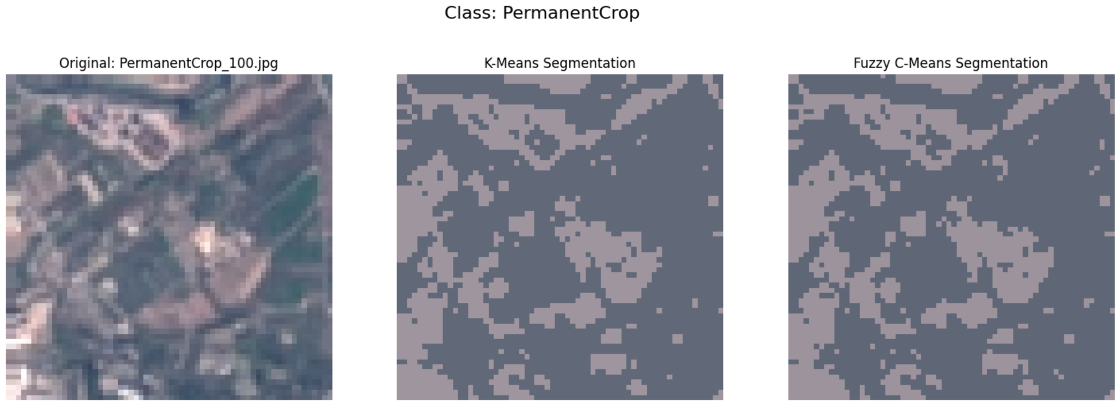
Class: PermanentCrop


Original: PermanentCrop_1.jpg

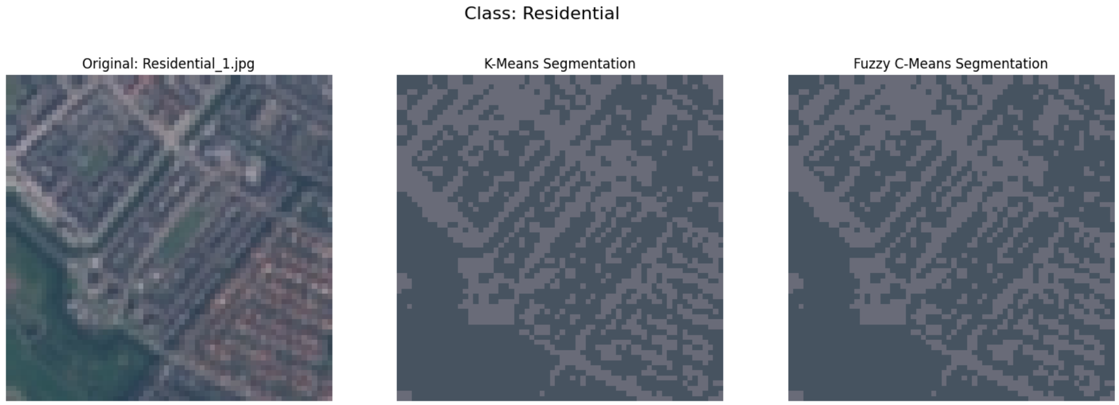
K-Means Segmentation

Fuzzy C-Means Segmentation

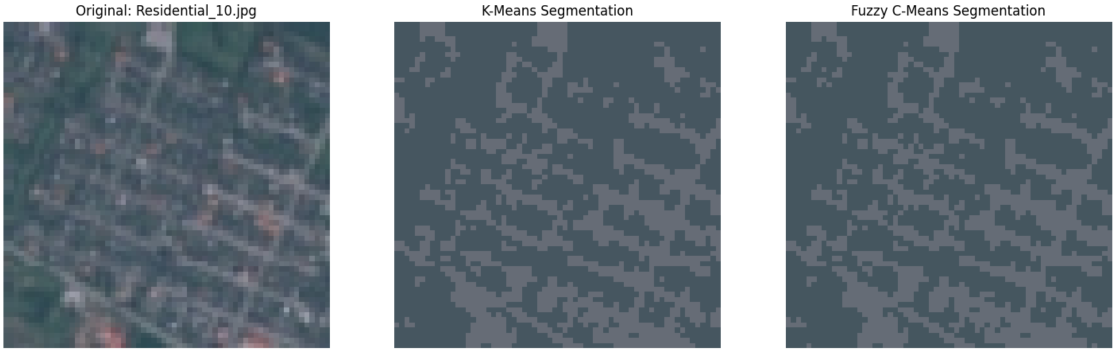




```
Processing class 'Residential' with 3 images…
```



Class: Residential

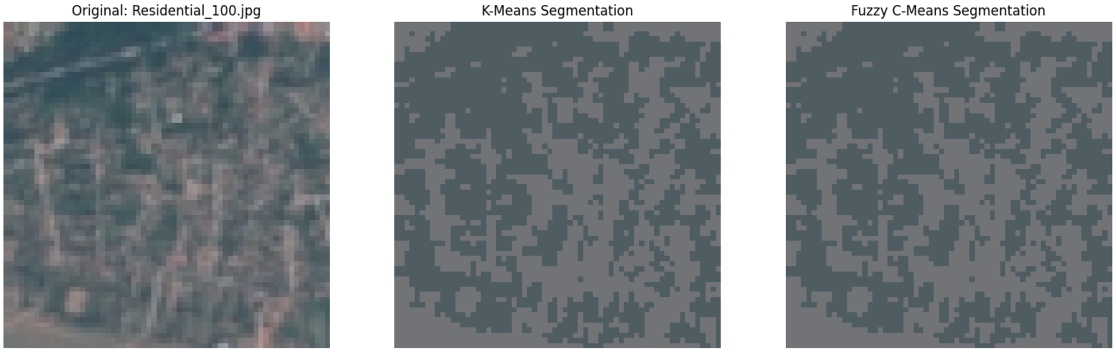


Original: Residential_10.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

Class: Residential



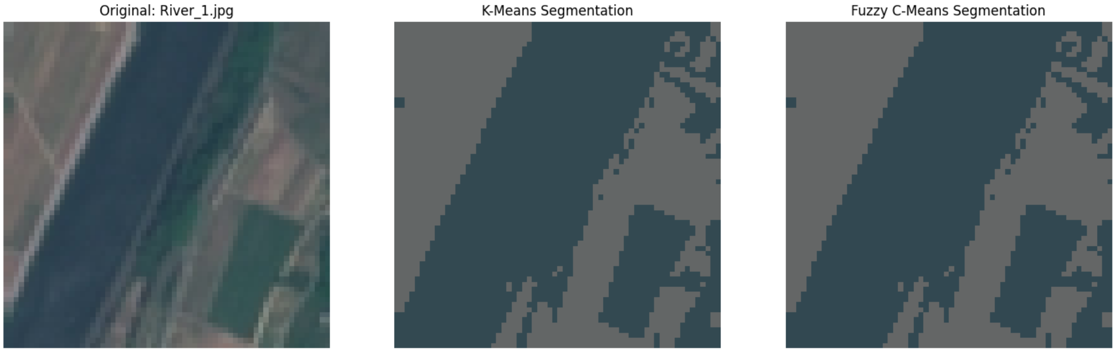
Original: Residential_100.jpg

K-Means Segmentation

Fuzzy C-Means Segmentation

```
Processing class 'River' with 3 images…
```

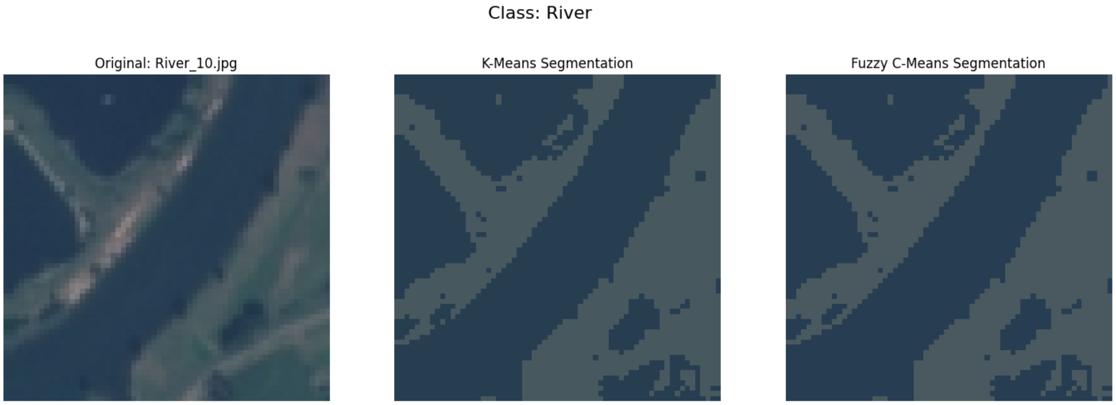
Class: River

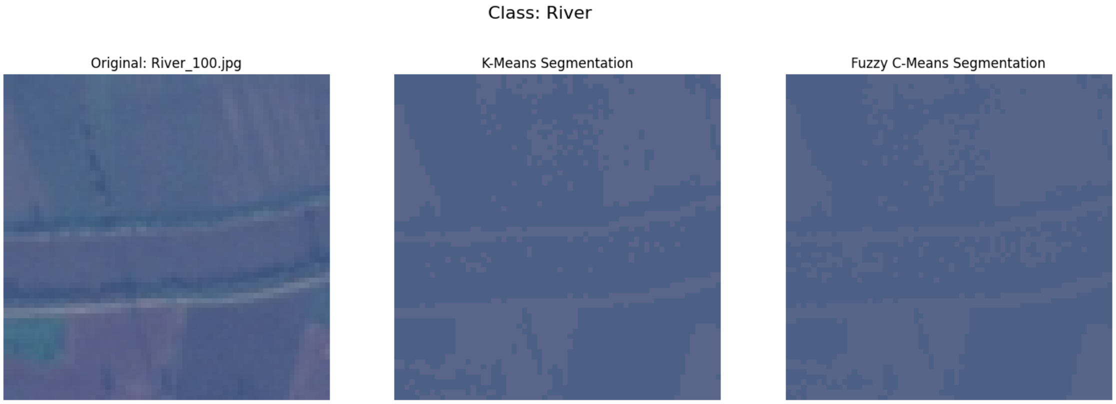


Original: River_1.jpg

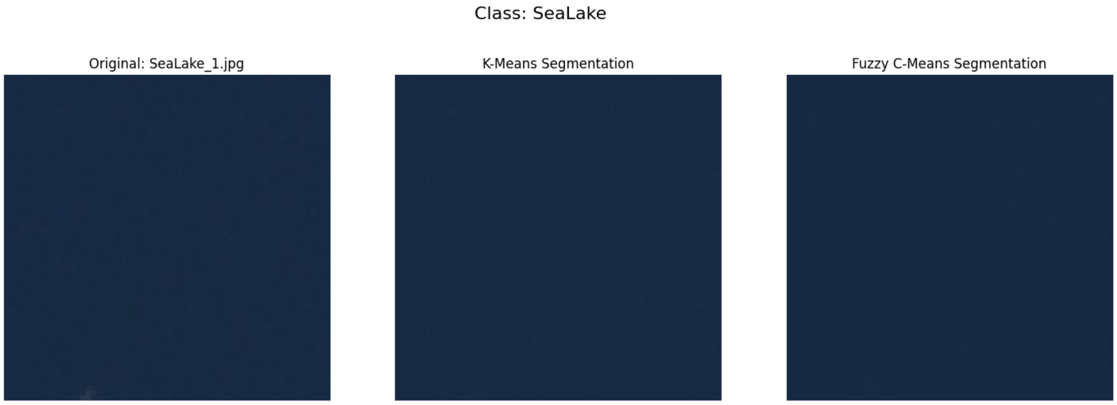
K-Means Segmentation

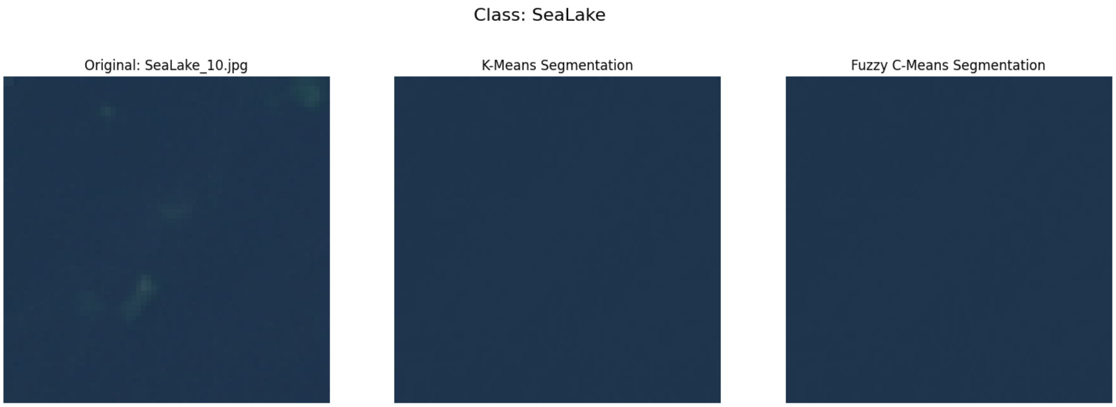
Fuzzy C-Means Segmentation

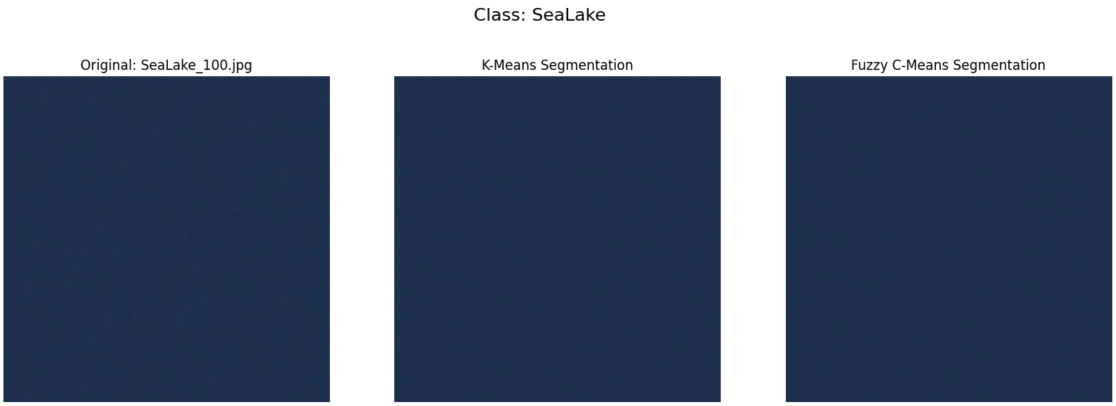




```
Processing class 'SeaLake' with 3 images…
```



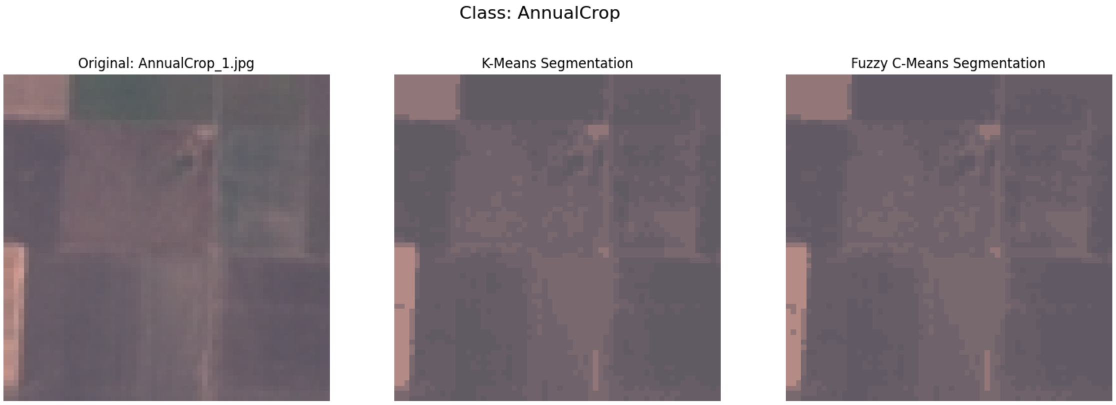


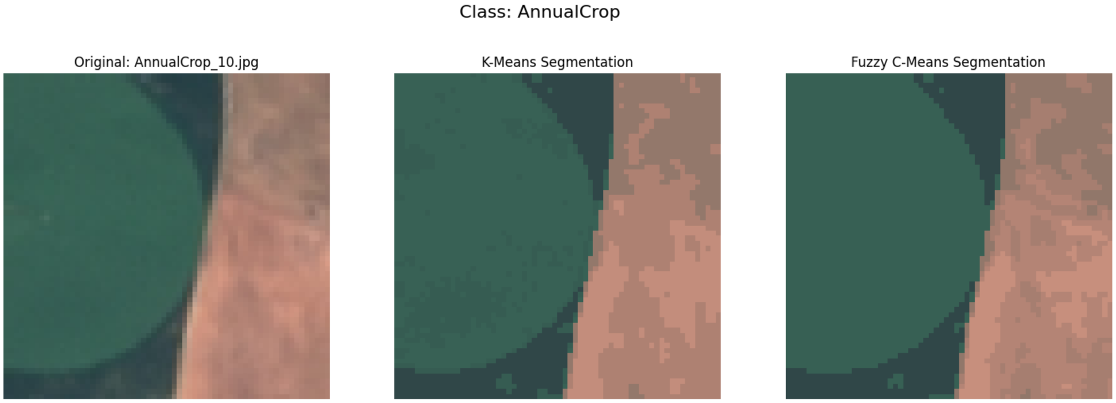


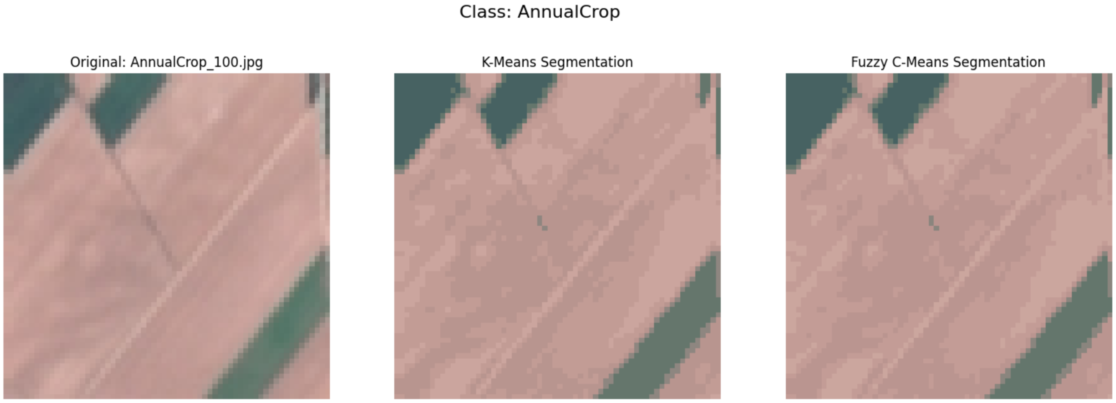
[ ]:

```python
# Choose a subset of classes for testing (you can modify this list as needed)
test_classes = classes[:10]  # For example, use the first 3 classes
num_images_per_class = 3     # Number of sample images to process per class

# Set segmentation parameters.
k = 4      # Number of clusters for both methods
m = 2      # Fuzziness parameter for Fuzzy C-Means

for class_name in test_classes:
    class_path = os.path.join(data_dir, class_name)
    image_files = os.listdir(class_path)[:num_images_per_class]
    print(f"Processing class '{class_name}' with {len(image_files)} images...")

    for img_file in image_files:
        img_path = os.path.join(class_path, img_file)
        image = cv2.imread(img_path)
        if image is None:
            print(f"Failed to load {img_path}")
            continue

        # Convert the image from BGR to RGB.
        image_rgb = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

        # Apply K-Means segmentation.
        labels_km, centroids_km, segmented_image_km =␣
↪kmeans_segmentation(image_rgb, k)
        segmented_image_km = centroids_km[labels_km]

        # Apply Fuzzy C-Means segmentation.
        labels_fcm, centroids_fcm, _ = fuzzy_cmeans_segmentation(image_rgb, k,␣
↪m)
        segmented_image_fcm = centroids_fcm[labels_fcm]

        # Display original and segmented images side by side.
        plt.figure(figsize=(18, 6))

        plt.subplot(1, 3, 1)
        plt.imshow(image_rgb)
        plt.title(f"Original: {img_file}")
        plt.axis("off")

        plt.subplot(1, 3, 2)
        plt.imshow(segmented_image_km.astype(np.uint8))
        plt.title("K-Means Segmentation")
        plt.axis("off")

        plt.subplot(1, 3, 3)
        plt.imshow(segmented_image_fcm.astype(np.uint8))
        plt.title("Fuzzy C-Means Segmentation")
        plt.axis("off")

        plt.suptitle(f"Class: {class_name}", fontsize=16)
        plt.show()
```

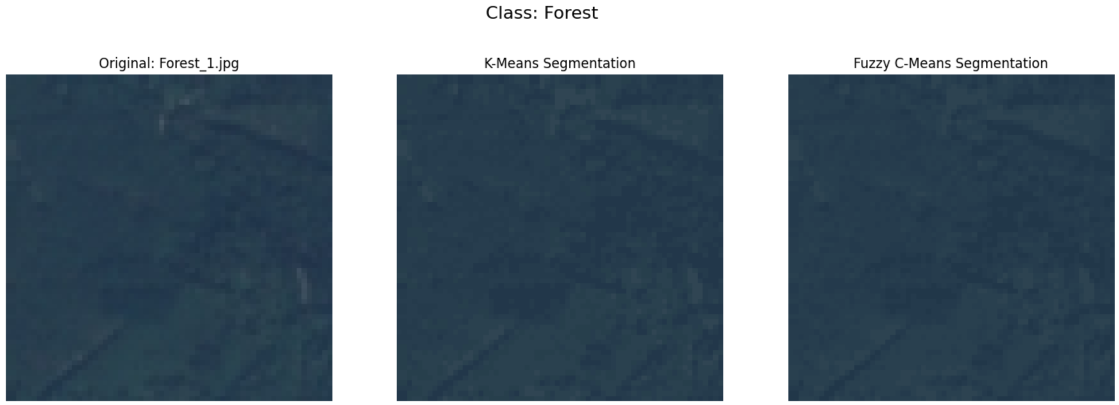
```
Processing class 'AnnualCrop' with 3 images…
```

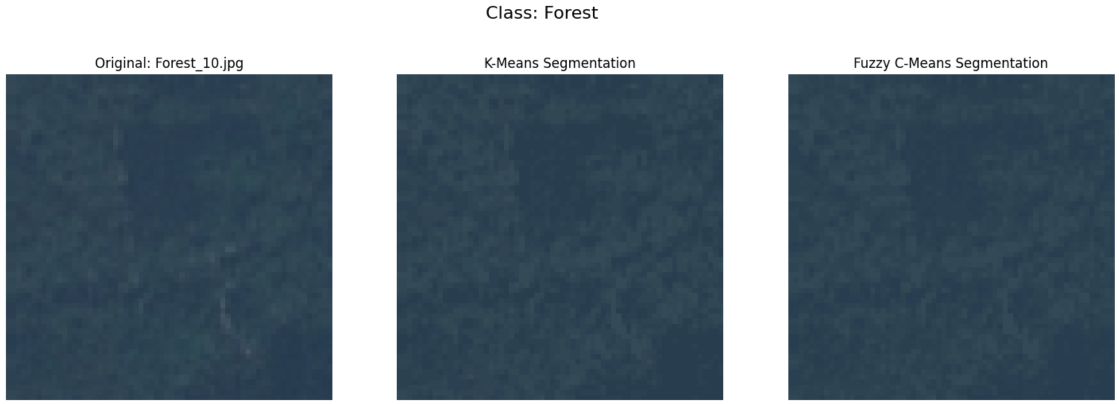


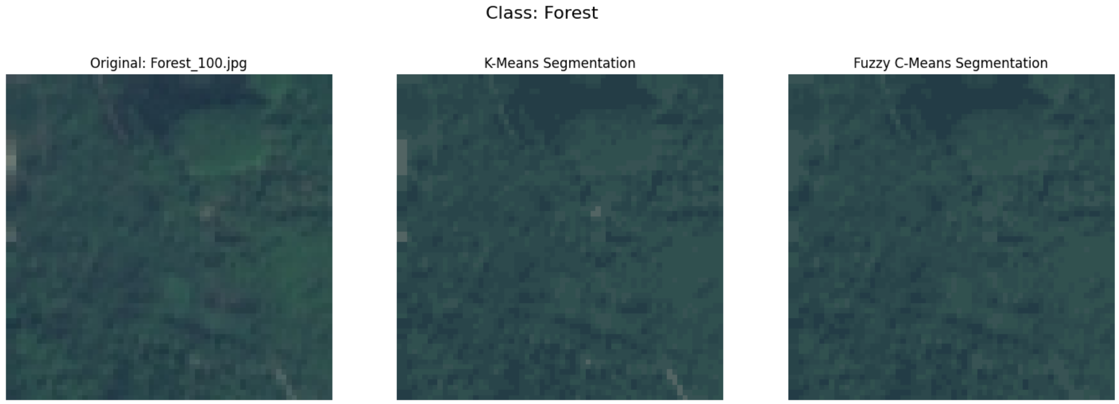




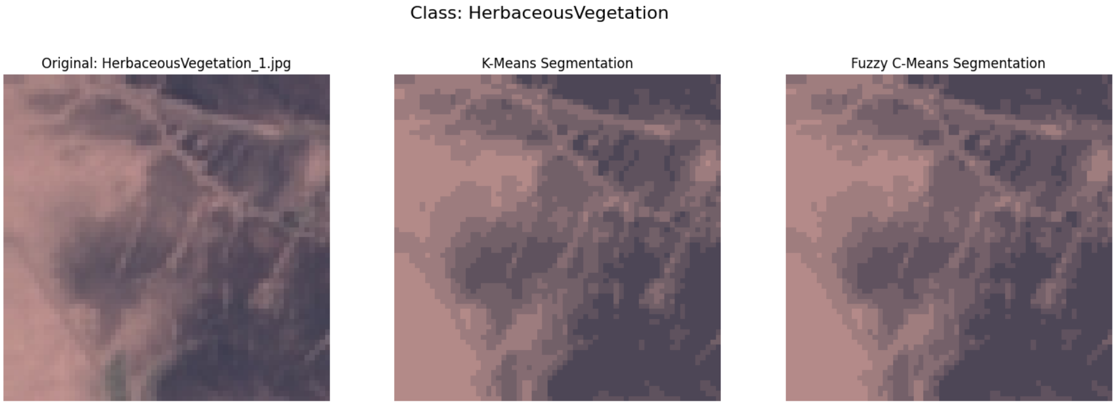
```
Processing class 'Forest' with 3 images…
```

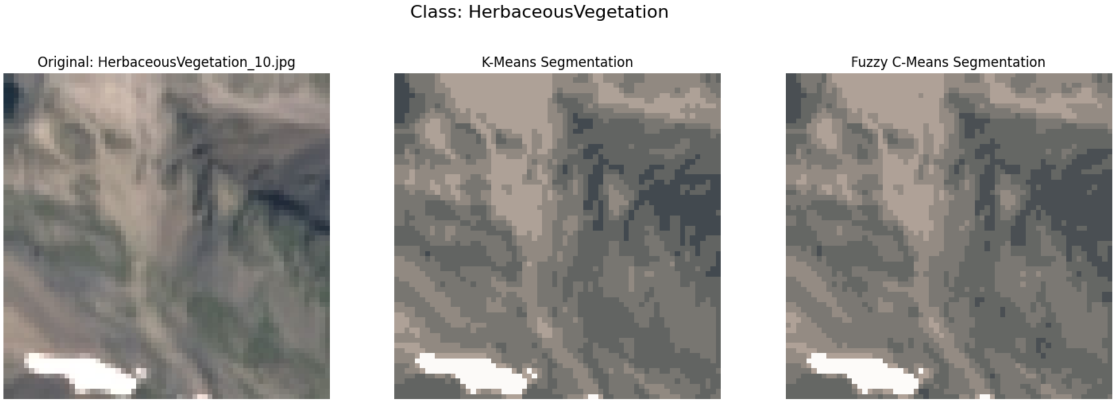


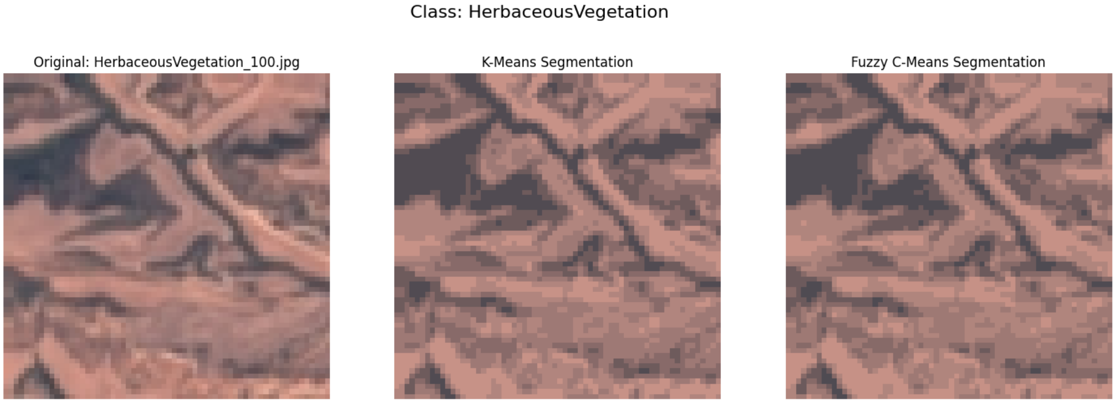




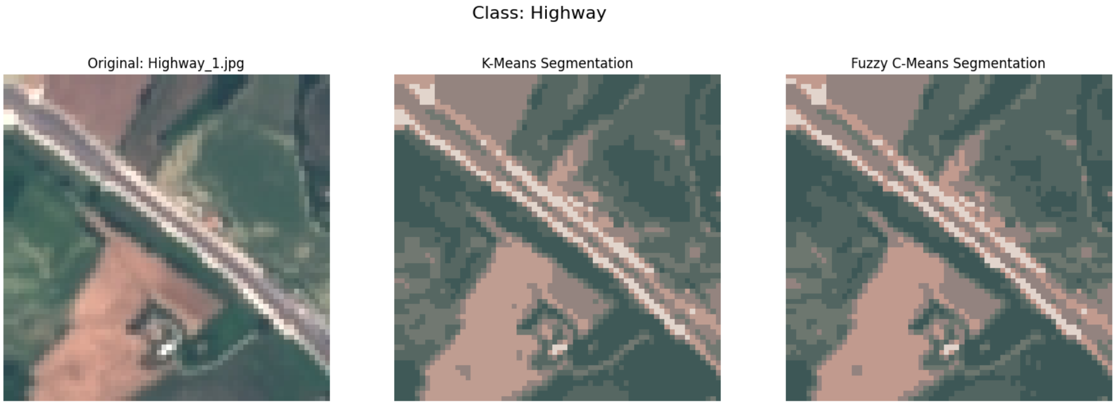
```
Processing class 'HerbaceousVegetation' with 3 images…
```

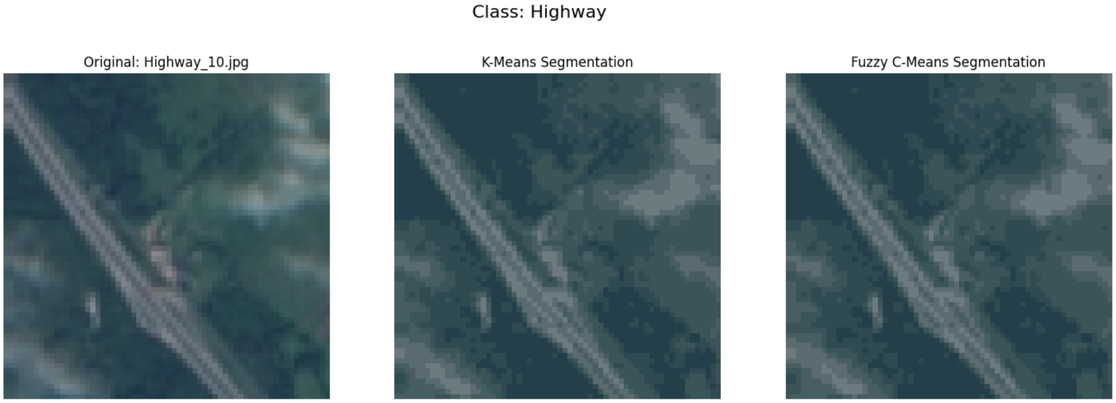

Class: HerbaceousVegetation
Original: HerbaceousVegetation_1.jpg
K-Means Segmentation
Fuzzy C-Means Segmentation

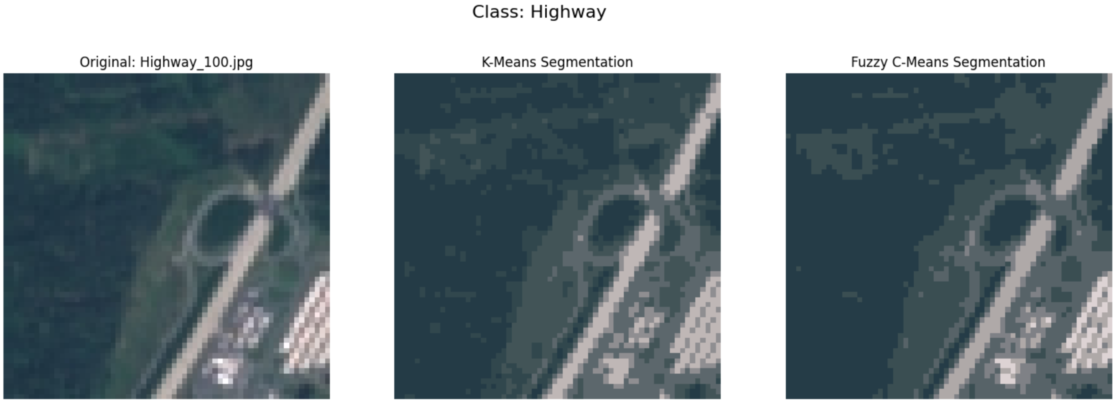

Class: HerbaceousVegetation
Original: HerbaceousVegetation_10.jpg
K-Means Segmentation
Fuzzy C-Means Segmentation


Class: HerbaceousVegetation
Original: HerbaceousVegetation_100.jpg
K-Means Segmentation
Fuzzy C-Means Segmentation

```
Processing class 'Highway' with 3 images…
```







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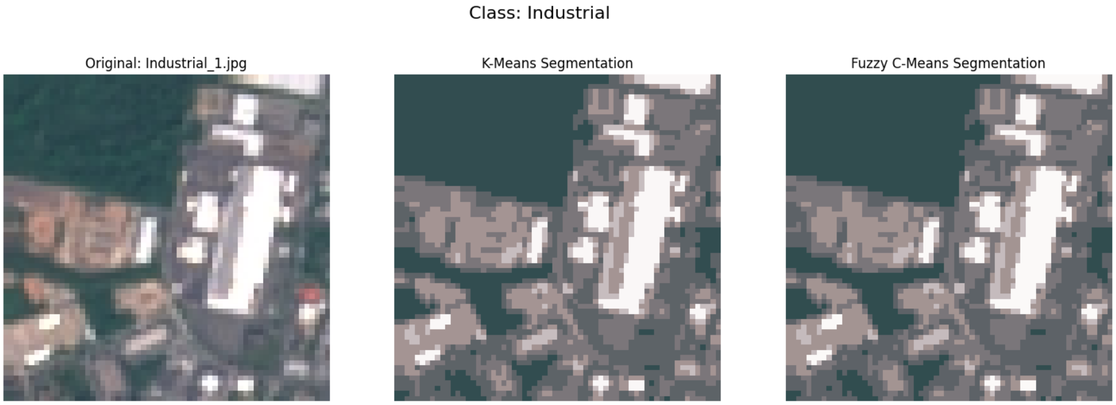

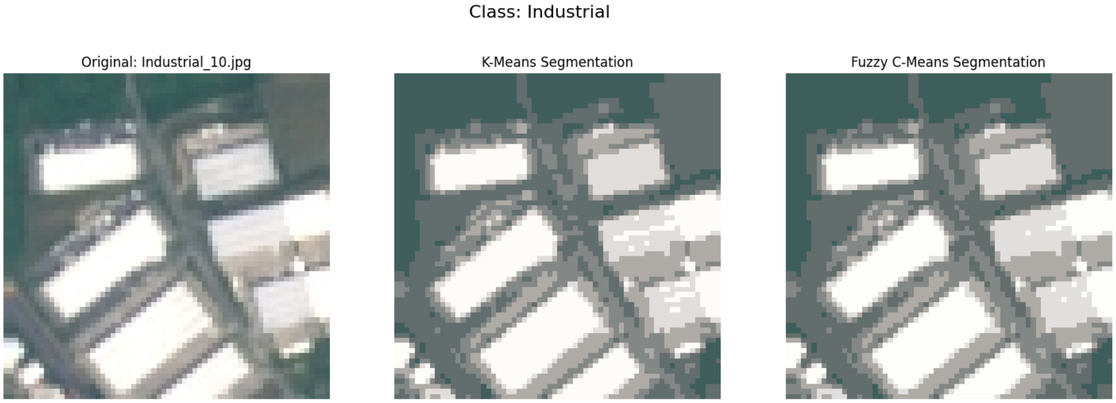

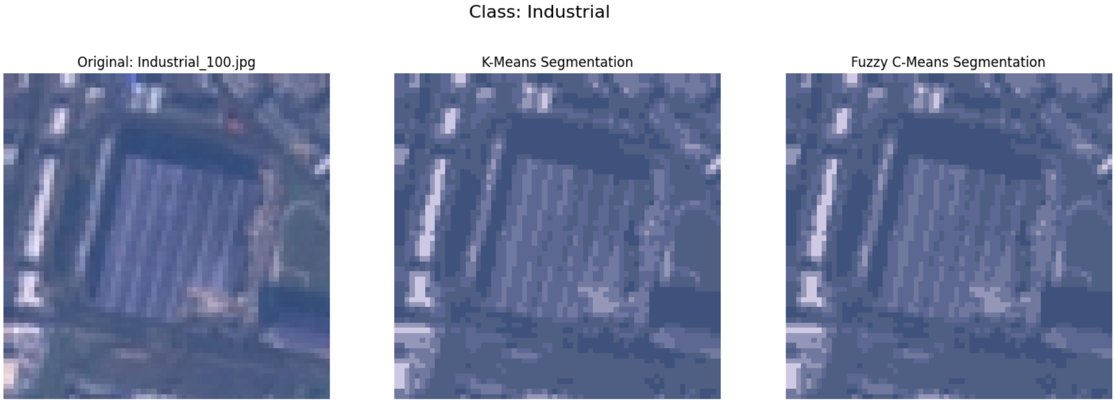

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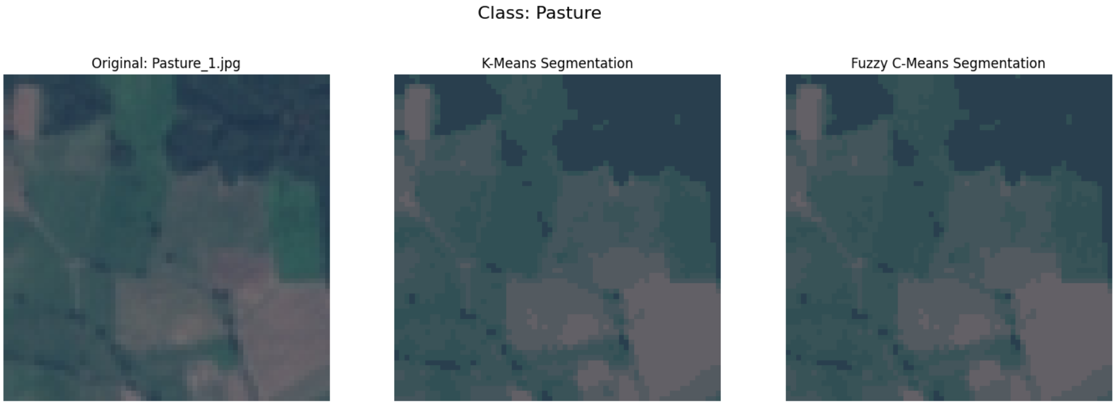

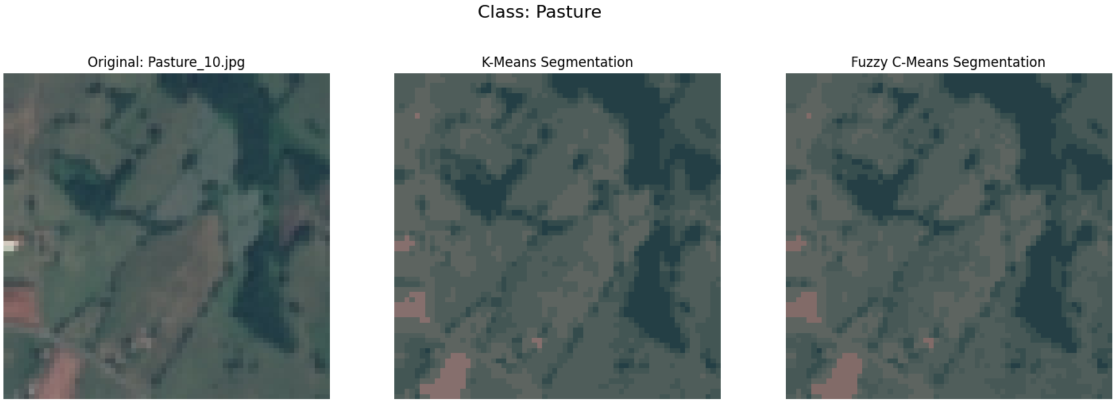

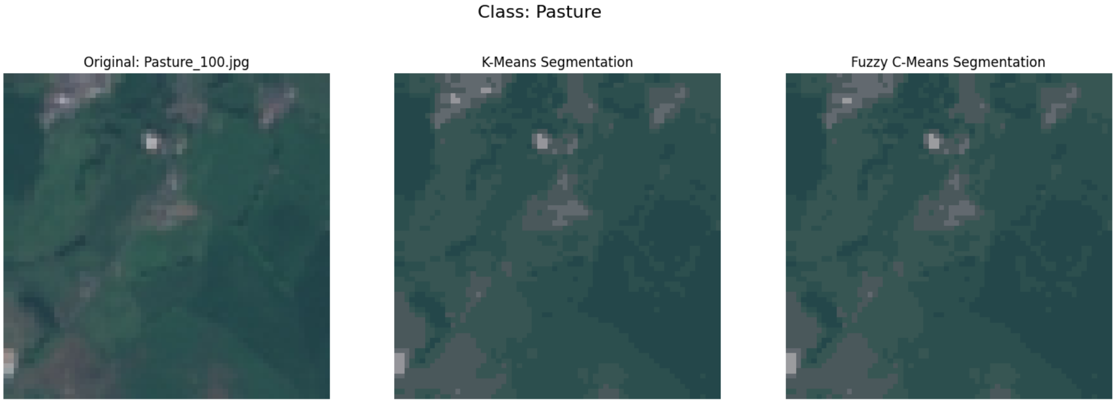

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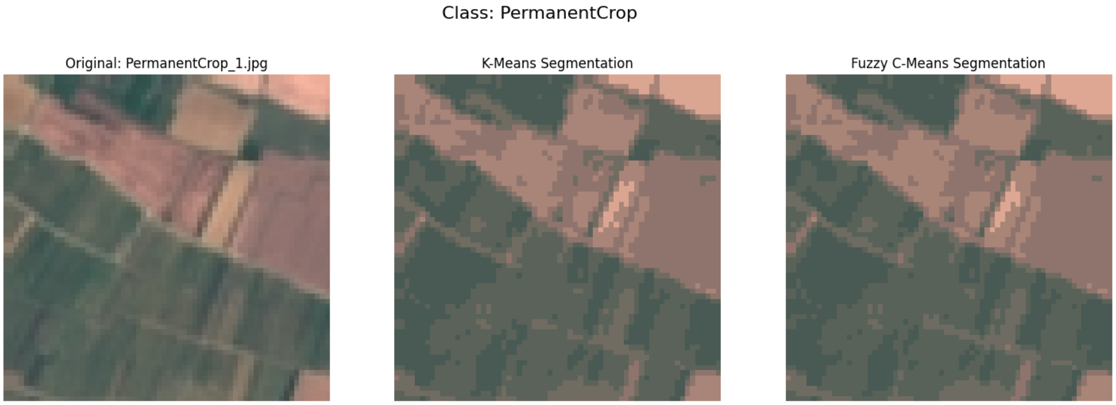

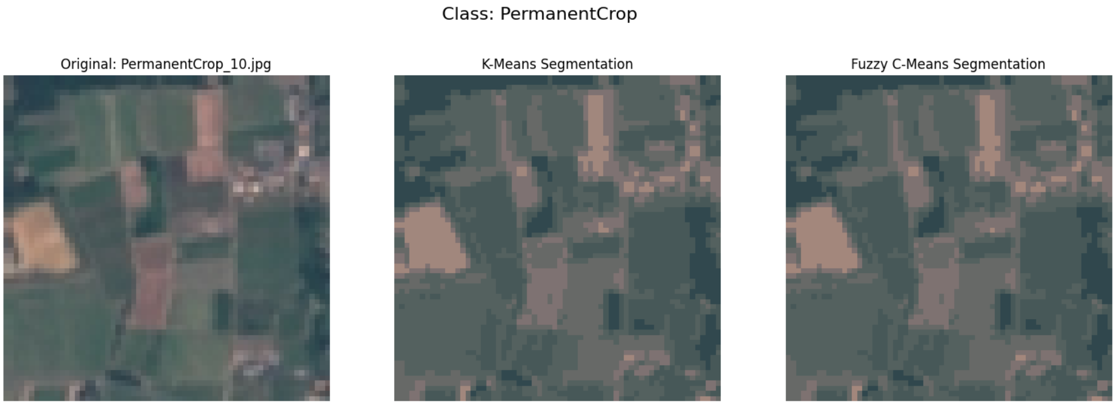

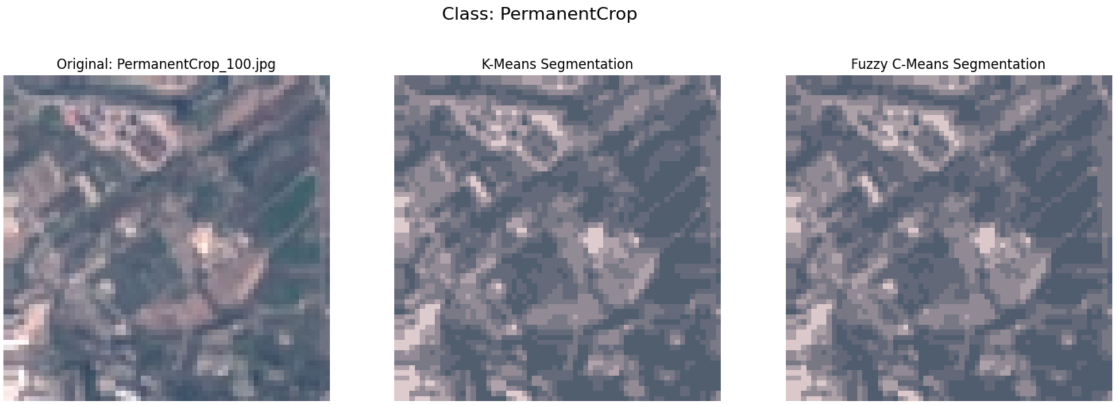

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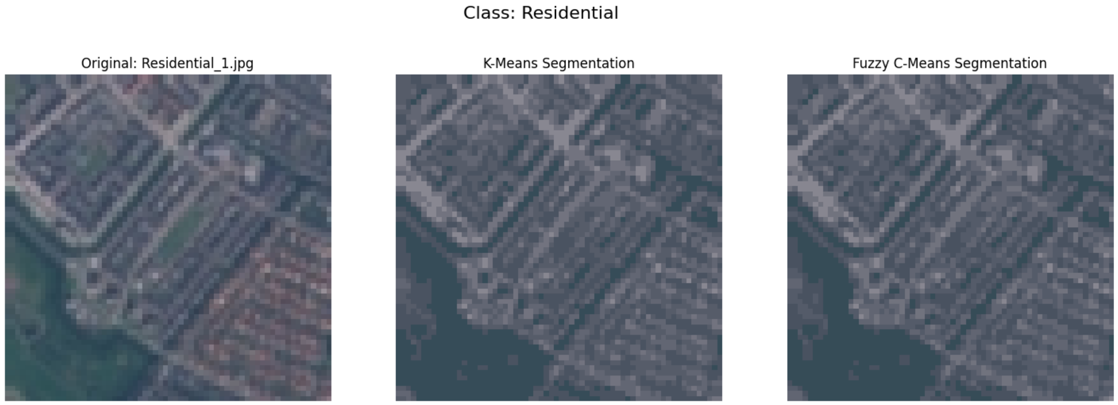

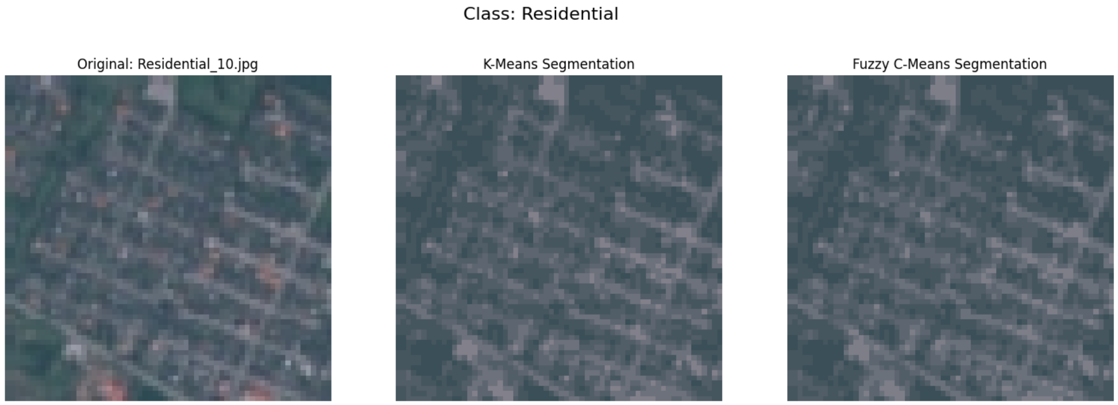

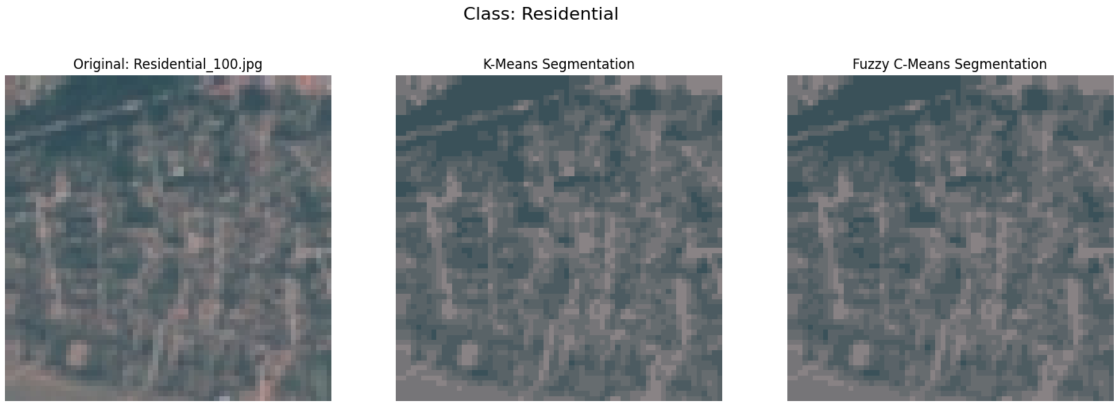

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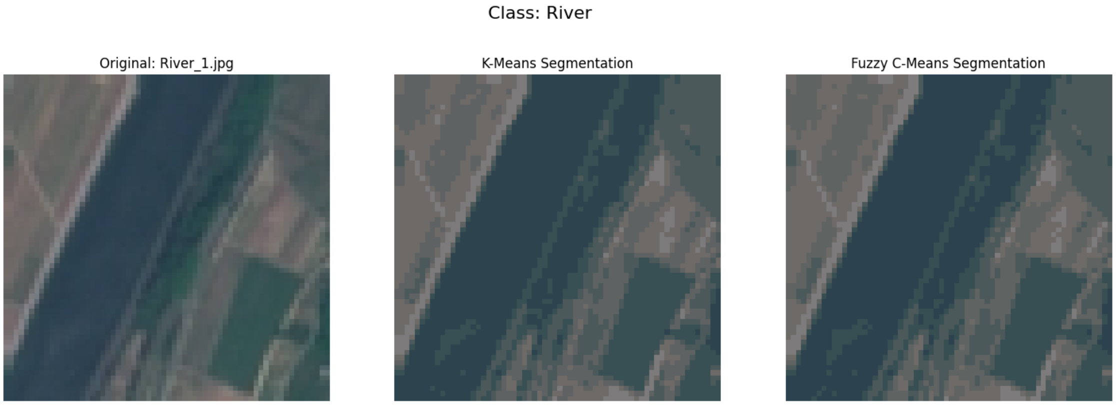

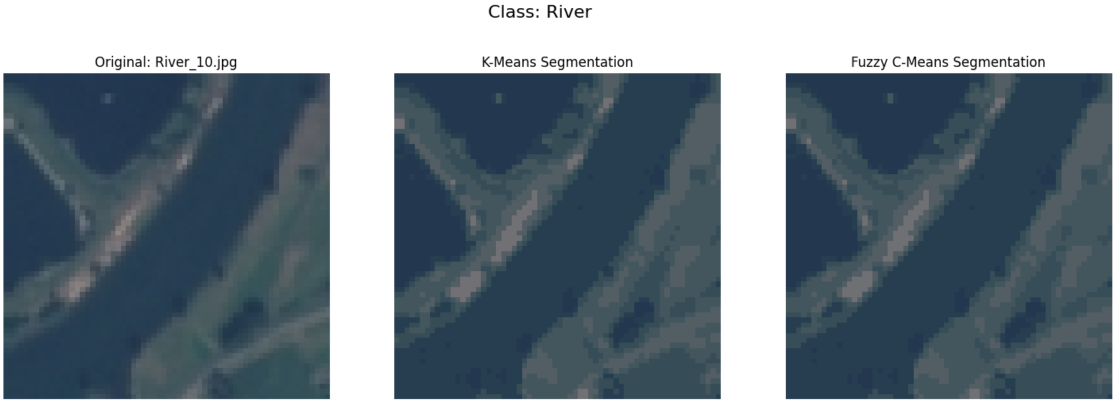

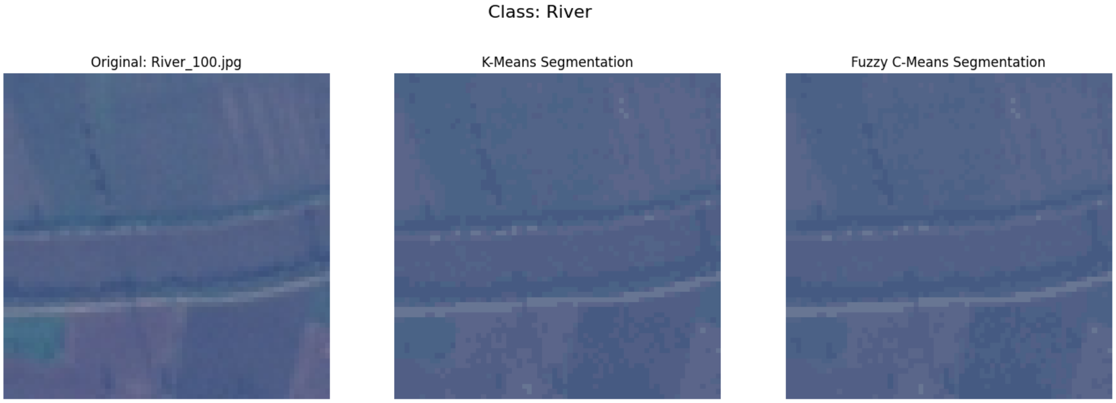

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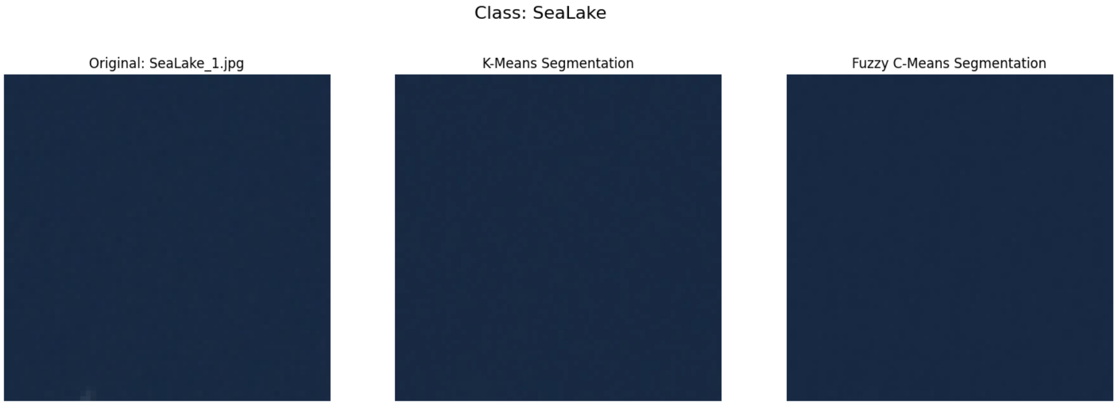

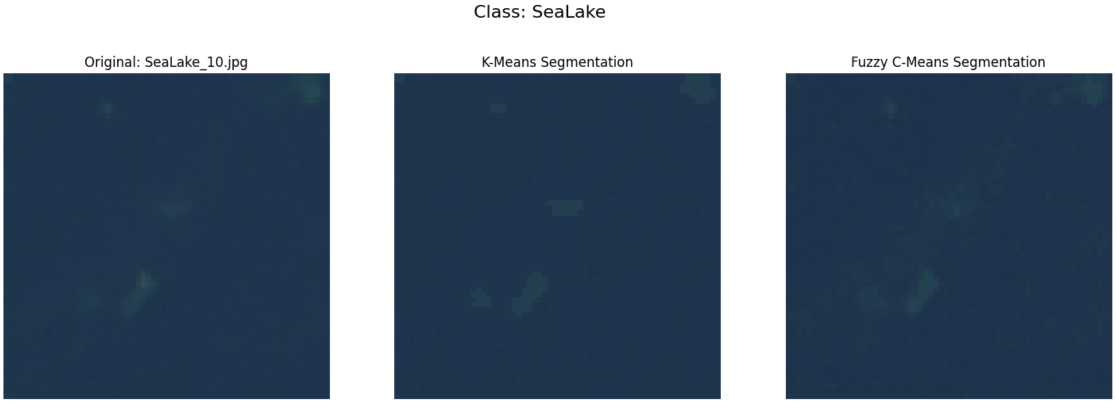

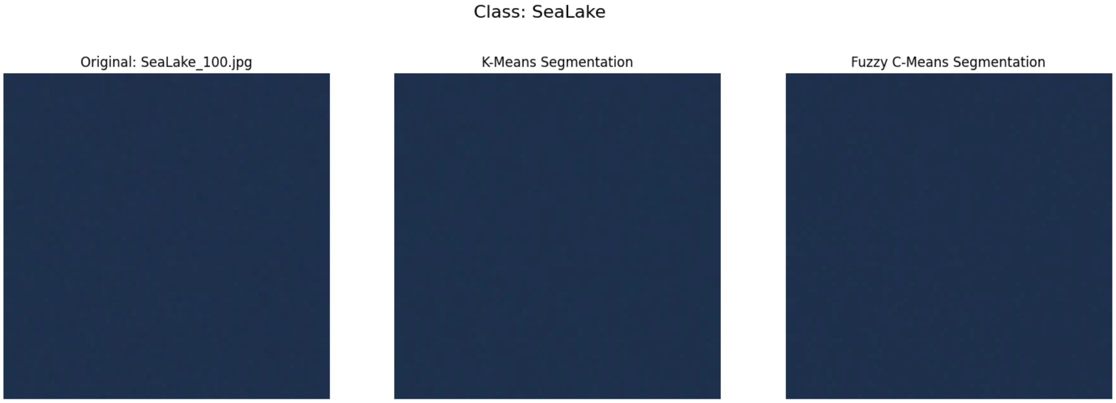

0.1 Observations

- **K-Means Segmentation:**
  The segmented image shows distinct regions with uniform colors corresponding to the k

centroids. The boundaries are relatively crisp.

- **Fuzzy C-Means Segmentation:**
  The segmented image appears similar in the final output since we are taking the maximum membership to assign each pixel a label. However, the underlying membership matrix indicates soft clustering where pixels may have partial membership across clusters.

- **Comparison:**
  The two methods have slightly different results, but one does not appear to have a distinct advantage over the other. They both performed similarly in terms of segmentation quality, with only minor differences observed in the output.

- **Performance:**
  One major difference is the computation time. The Fuzzy C-Means method took significantly longer (34.4 seconds) than K-Means (which took 0.0 seconds over 21 iterations), highlighting a clear trade-off between the methods in terms of efficiency.