Assessment of Landsat 7 ETM+ SLC-off Data for an Agricultural Crop Type Mapping Application

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Approach

Landsat SLC-off data were tested using an object-based/rule-based image classification system that is currently being implemented to produce South Dakota crop maps. In object-based systems, the image is first segmented into homogeneous land units based on three parameters (scale, color/shape, and smoothness/compactness). For our purposes, this segmentation essentially creates agricultural field boundaries. These image objects (agricultural fields) are then classified, as opposed to individual pixels as in traditional image classification systems.

Rules for classifying the image objects into crop types were derived from thresholds based on interpretation of bivariate feature space images (figure 1) of Landsat Band 4 (near infrared) and Band 5 (middle infrared). The same segmentation parameters and rule set were applied to both the original Landsat image and the gap-filled SLC-off image produced using localized histogram matching of a second date.

Five classes were identified: water, corn, soybeans, grassland, and other crops (PG4_crops). Non-agricultural cover types (e.g., urban, riparian, forest) were eliminated by applying a mask using the USGS 1992 National Land Cover Dataset prior to segmentation and classification.

The original image was Landsat Path 29 Row 30 for September 8, 2002 and the image used to fill the SLC-off gaps was October 10, 2002. Minnehaha County (211,000 hectares) and Hanson County (112,000 hectares) in South Dakota were selected for this analysis. Minnehaha County is located in the north central portion of the image where the scan line gaps are relatively small. Hanson County is in the northwestern portion of the image where the scan line gaps are the widest.

Results

Minnehaha County (located in the north central area of Landsat image where scan line gaps are the smallest)

Figure 2 shows a close-up of the original Landsat image, object boundaries and results of the classification for Minnehaha County compared to the SLC-off gap-filled image with its resulting classification. Artifacts from the filled scan line are apparent due to change in vegetation condition from the original image (September 8, 2002) to the image selected to fill the gaps (October 10, 2002).

Summary of comparison of the classified map based on the original Landsat image to the classified map based on the SLC-off gap-filled image:

- 8.2% of the pixels in the SLC-off gap-filled map were misclassified when compared to the original map; the errors increase from left to right (figure 3a); note that larger scan line gaps occur as off-nadir position increases
- differences between the total area for most of the cover types were small (figure 4a); < 1.0% for water and corn, 2.3% for soybeans, 4.0% for grassland; 'other crops' (PG4_crops) were 17.7% different, however this is a minor class in this county.

Hanson County, South Dakota (located at the northwestern edge of the Landsat scene where scan line gaps are the largest)

Summary of comparison of the classified map based on the original Landsat image to the classified map based on the SLC-off gap-filled image:

- 15.2% of the pixels in the SLC-off gap-filled map were misclassified when compared to the original map (figure 3b); the errors appear to follow the pattern of the scan line error.
- differences between the total area for most of the cover types were higher for Hanson County as compared to Minnehaha County – although still relatively small (figure 4b); differences ranged from 2.1% for soybeans and grassland to 9.8% for 'other crops'.

Discussion

The date of the image selected to fill the gaps (October 10, 2002) was not optimum for separating corn from soybeans as vegetation begins senescing after mid-September. An August image would have been preferred, however this appeared to have only a small impact on the results of the total acreage classified for each cover type within the county.

Normally, crop classifications are based on multiple dates. This may have a greater negative impact on the results that were not found through this single-date analysis.

Filling the gaps with spectral information from the same date would be optimum for crop type mapping and monitoring applications. One option may be to use object boundaries created from a previous Landsat image (e.g., anniversary image, Landsat 5 image) and overlay the boundaries over the Landsat 7 SLC-off image. The gaps would be filled using pixels that fall within the object boundary (e.g., mean of all pixels within boundary). This option was tested on the Hanson County data set. Figures 5 and 6 compare the original image, SLC-off gap-filled image using the histogram matched method, and SLC-off gap-filled image using the object-based method.

Summary of comparison of the classified map based on the original Landsat image to the classified map based on the SLC-off gap-filled image using the object-based method:

- 8.0% of the pixels in the SLC-off objected based map were misclassified when compared to the original map (figure 7); in contrast, 15.2% were misclassified using the histogram match method
- average differences between the total area for all cover types were less than 2.3% compared to 2.1-9.8% using the histogram matched method.

The object-based gap-fill method resulted in approximately half as many misclassifications as the histogram matched gap-fill method. Difference in the total percentage for each cover type were not significantly different however varying only by a few percent for major cover types.

Imagery corrected using the object-based method may be more useful than the localized histogram matching method for applications that require the SLC-off gap to be filled with 'same day' spectral information (e.g., crop monitoring/classification, fire mapping). Preliminary tests of the object-based approach appear promising and warrant further evaluation.

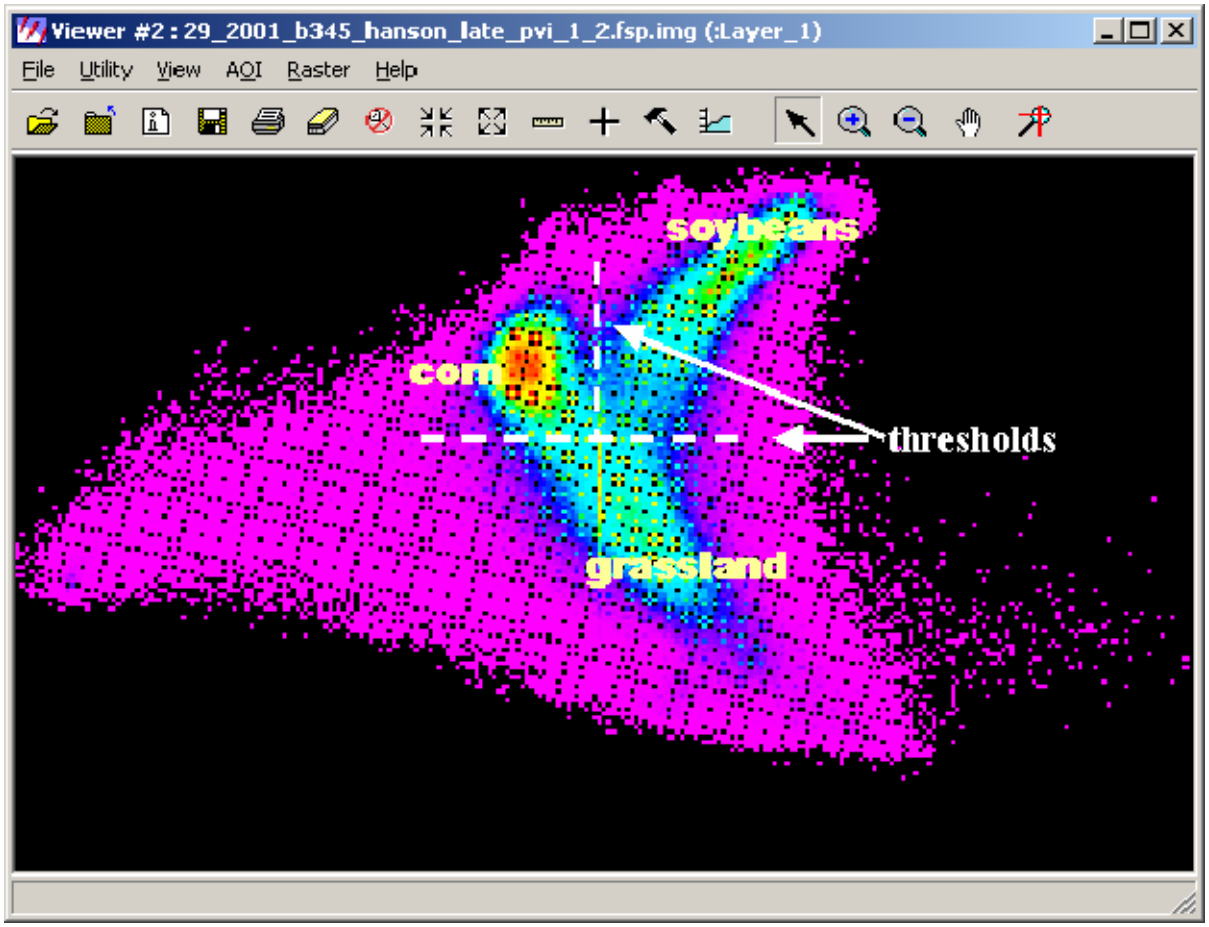


Figure 1. Example of a bivariate density-sliced histogram plot of Landsat Band 5_{index} (x-axis) and Band 4_{index} (y-axis) with thresholds for separating corn, soybeans, and grassland noted by dashed lines.

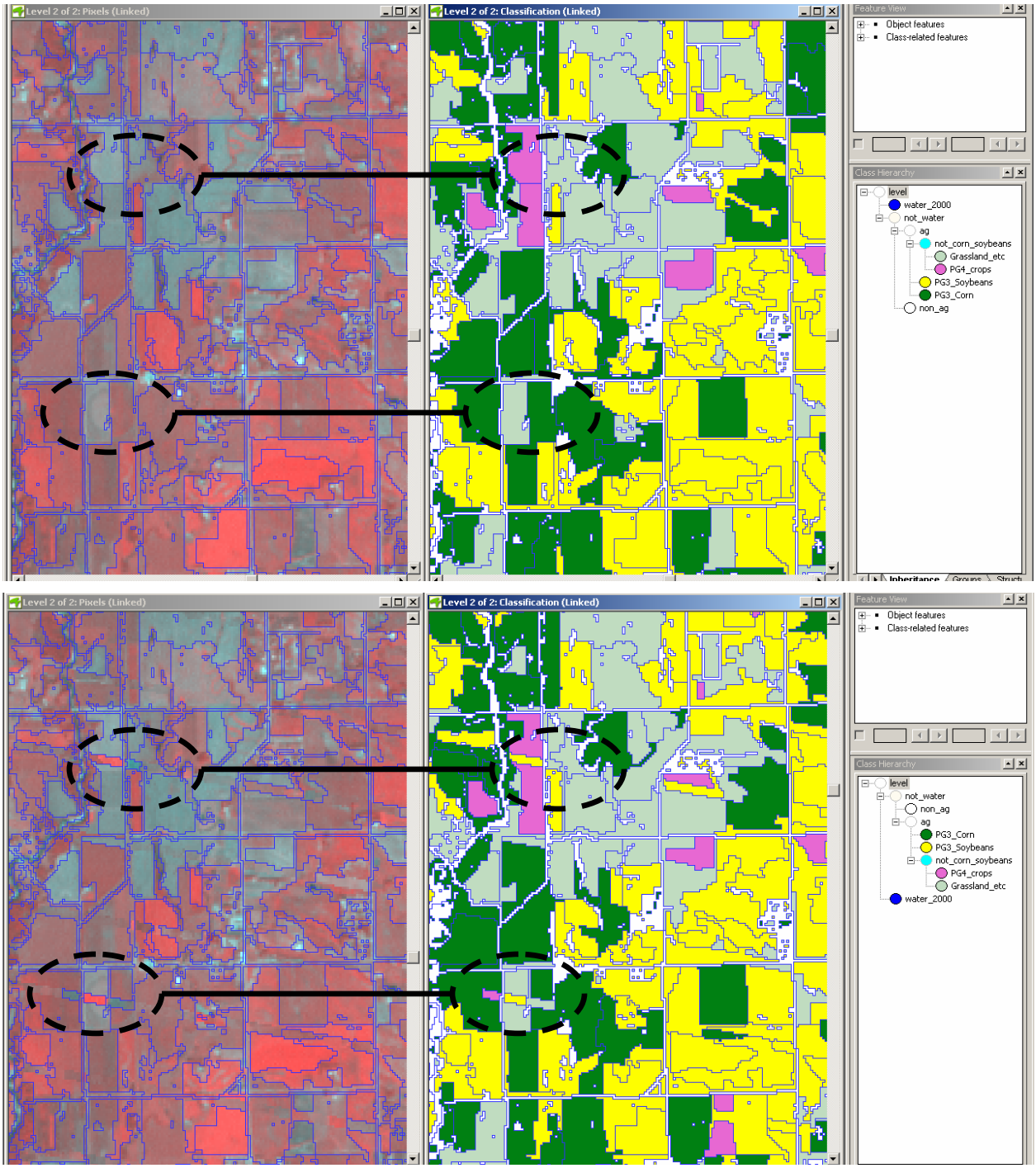
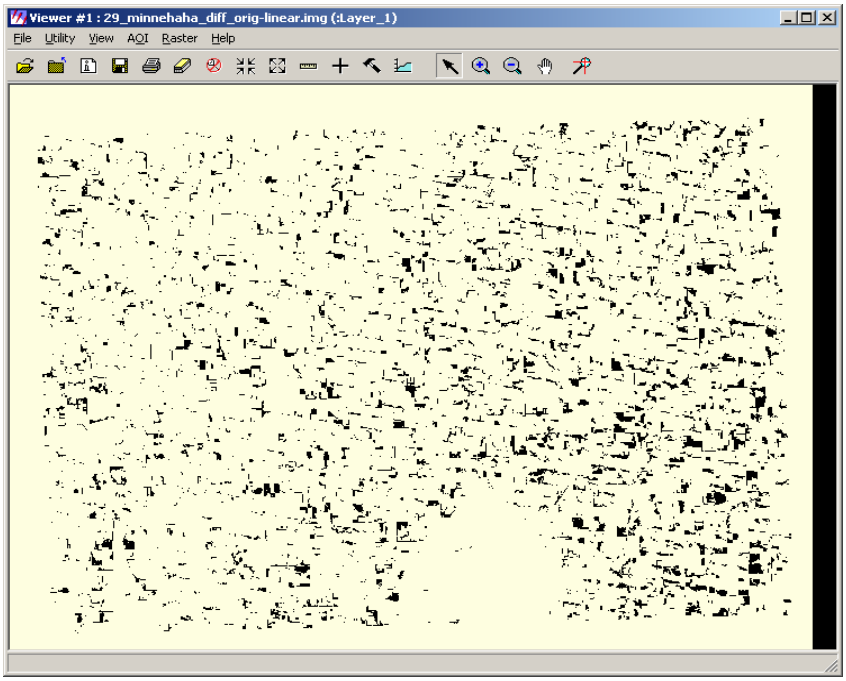


Figure 2. Original Landsat image (Path 29 Row 30, September 8, 2002) and crop map (upper) compared to Landsat SLC-off gap-filled image (localized histogram matching method using October 10, 2002) and crop map (lower).

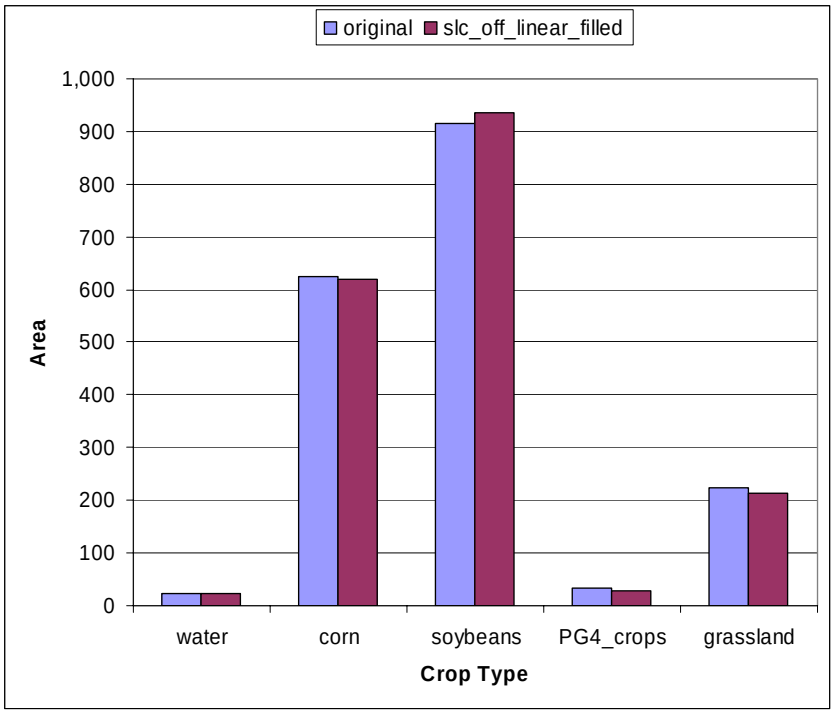
A)



B)

Figure 3. Difference map for Minnehaha County (A) and Hanson County (B). Black areas denote pixels where the classification map produced using the original image was different than the classification map produced using the localized histogram matched gap-filled image.

A)



B)

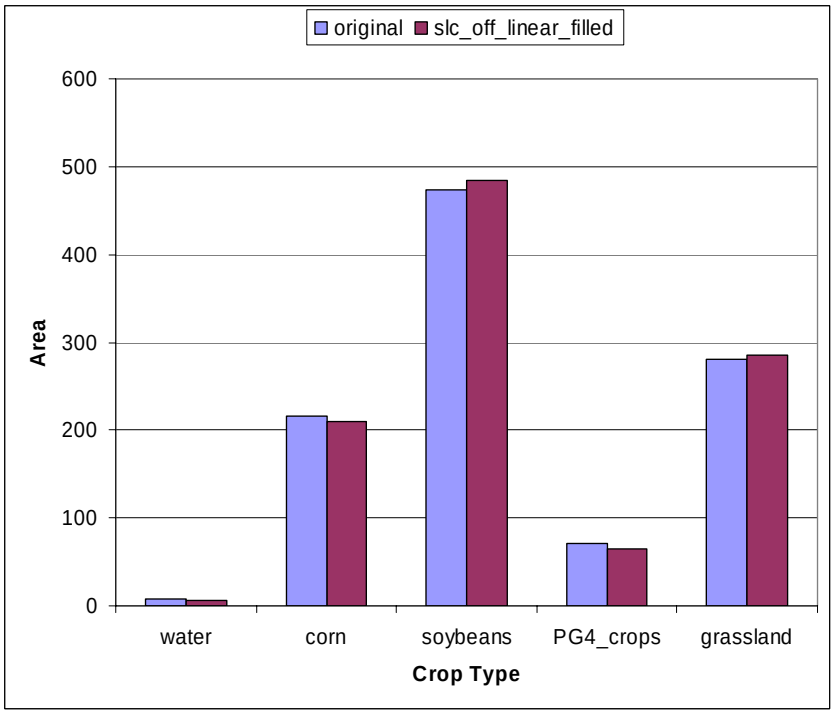
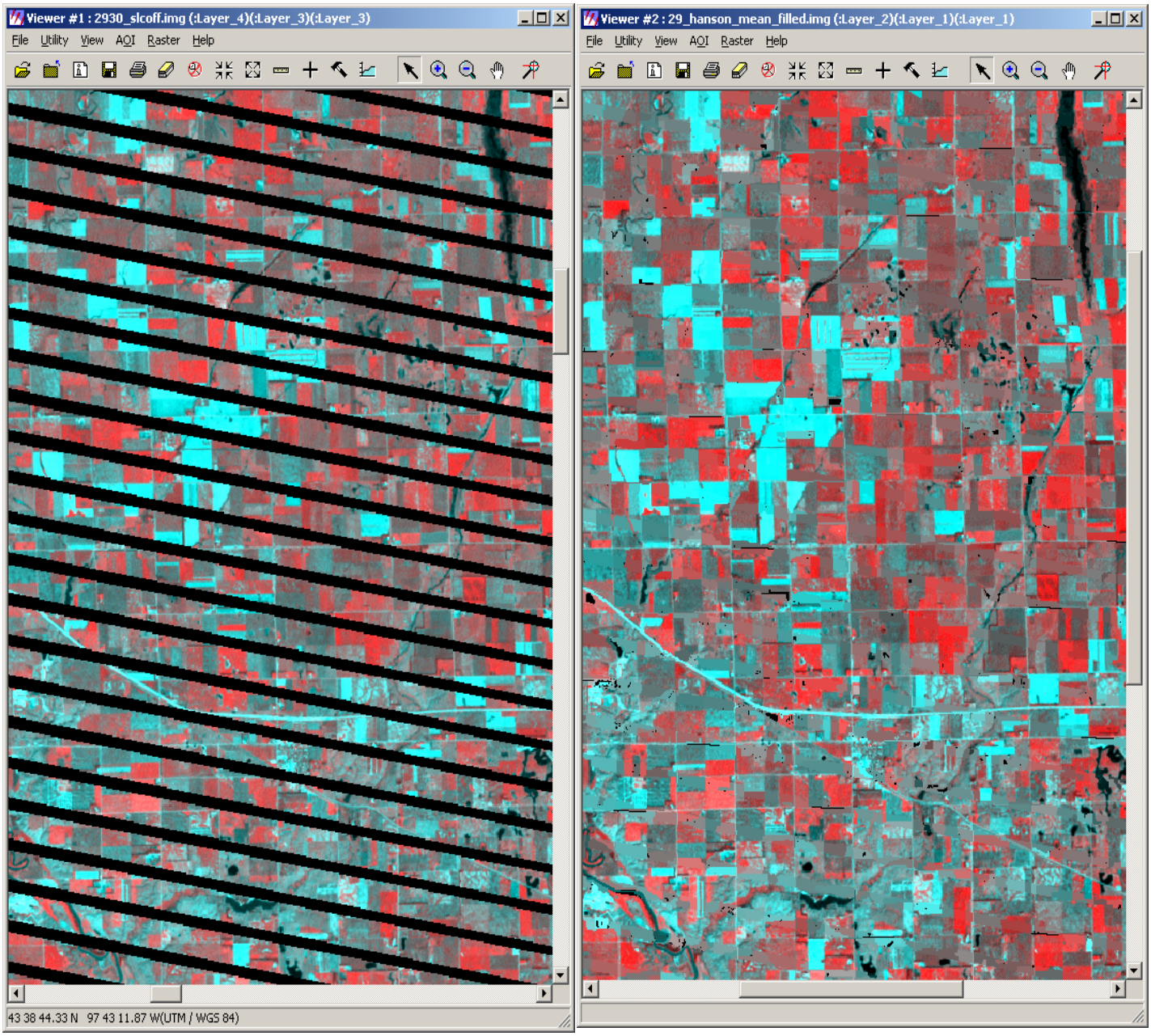
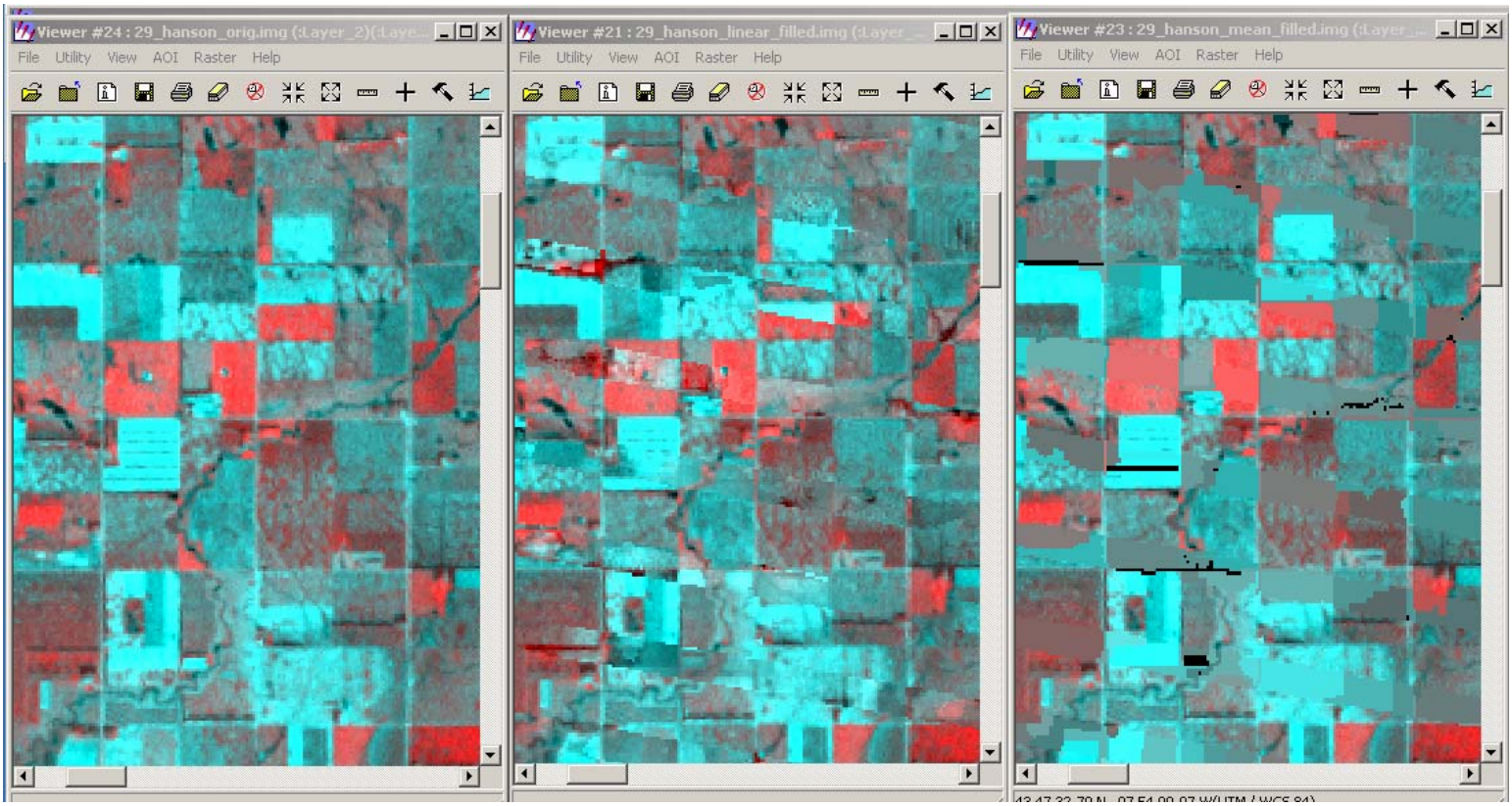


Figure 4. Comparison of total area for all cover types classified for Minnehaha County (A) and Hanson County (B).



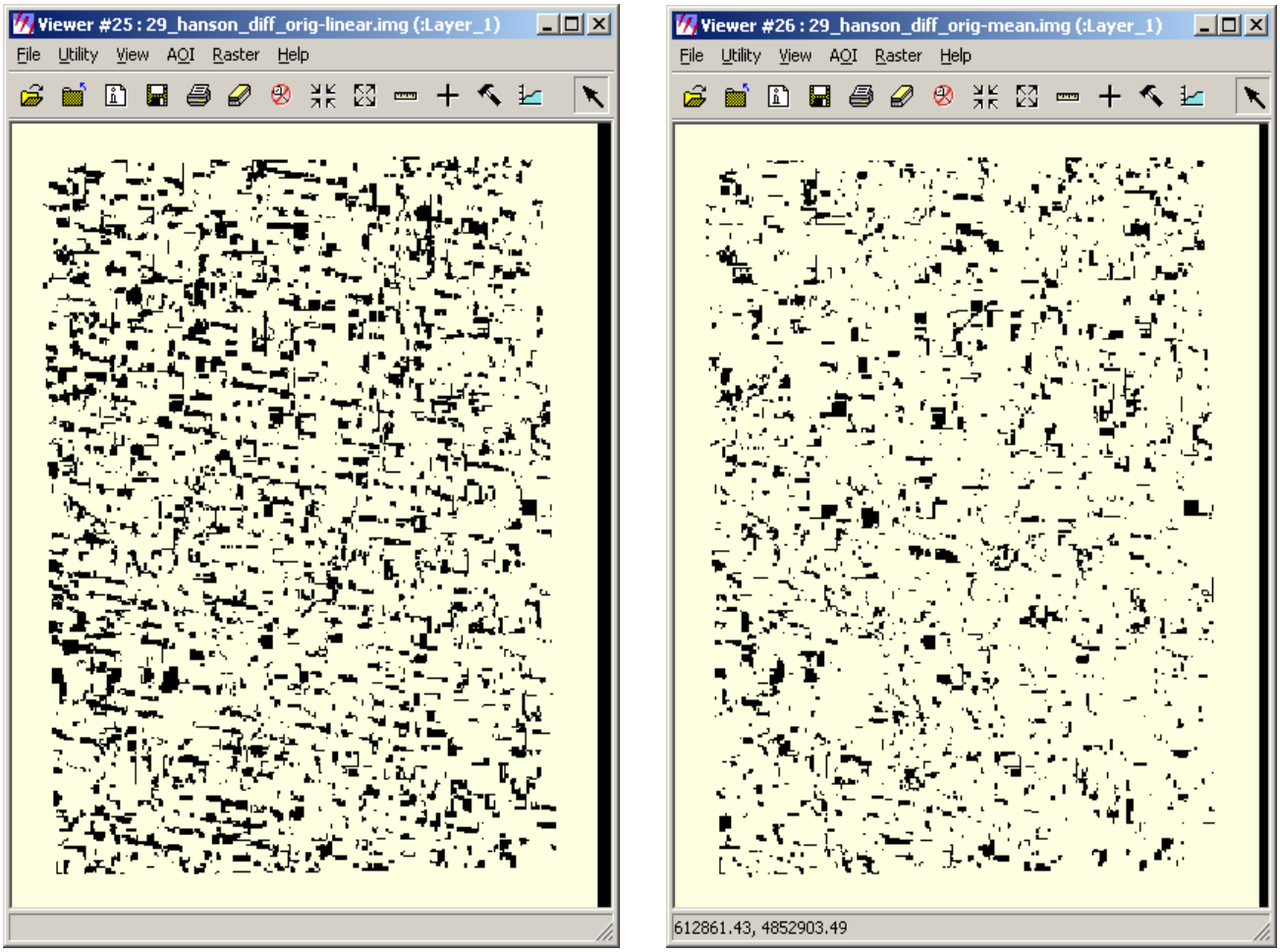
A B

Figure 5. Original Landsat image (A) compared to SLC-off using object-based correction method (B). Note: some 'black' areas occur on the object-based image because none of the pixels within those objects overlapped on the SLC-off image.



A B C

Figure 6. Original Landsat image (A) compared to SLC-off gap-filled image using localized histogram matching method (B) and SLC-off gap-filled image using object-based method (C). Note: Some 'black' areas occur on the object-based image because none of the pixels within those objects overlapped on the SLC-off image.



A B

Figure 7. Comparison of difference maps for the original map minus the map created using the localized histogram match image (A) and the original map minus the map created using the object-based image (B). 15.4% of pixels were misclassified in A, 8.0% of pixels were misclassified in B.