MODIS and AWiFS Multi-sensor Imagery Data Fusion for Crop Classification Using Decision Tree Method

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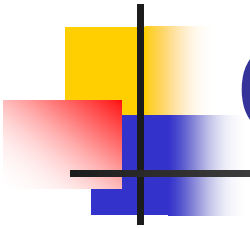


OUTLINE

- Introduction
- Image Data
- Image Fusion Methods
- Image Fusion Experiments
- Classification Experiments
- Conclusions

Introduction

- USDA NASS' Mission:
  - Provides timely, accurate and unbiased agricultural statistics
- NASS CDL program - remote sensing based acreage estimation relies on accurate classification of crop, which means:
  - Sufficient quality image data, proper resolutions
- But
  - Limited budget – limited image acquisition
  - Cloud cover, time constraint – limited images available
- What is solution?
  - This is what this investigation try to answer.

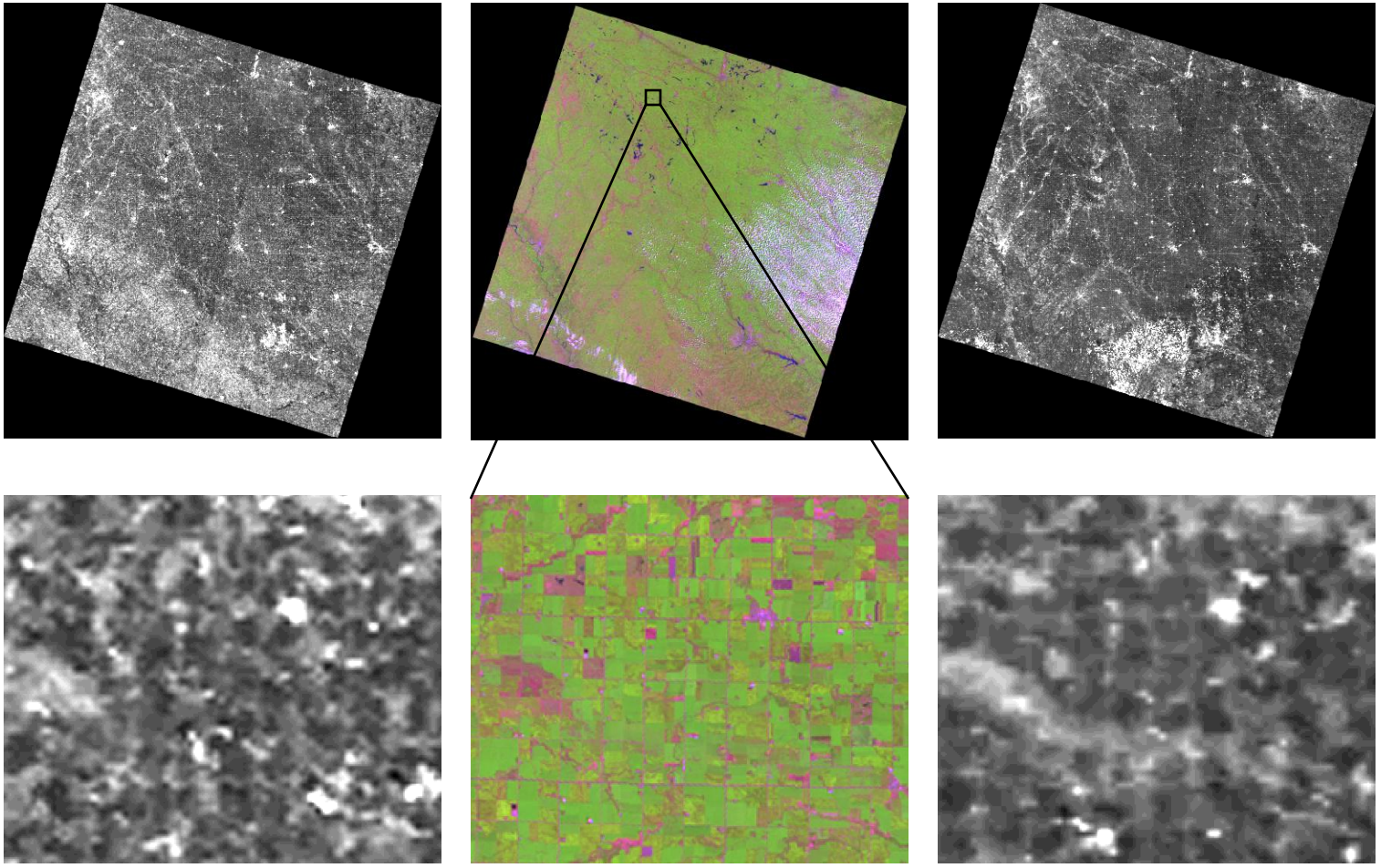
Why AWiFS & MODIS Fusion

- AWiFS images used at USDA NASS
  - 56m resolution, 5 day repeat, 4 bands;
- MODIS images
  - 250m resolution for R & NIR band, daily repeat;
- How to utilize information from both sensors? => image fusion!
- Benefits:
  - Higher spatial resolution of AWiFS, increased temporal resolution of MODIS.

Objective

- To determine if image fusion improves the accuracy of crop classification.

Image Data - AWiFS & MODIS 8-day composite



a) MODIS 2007-07-12 b) AWiFS 2007-07-20 c) MODIS 2007-07-28

Image Fusion Methods

- Many fusion methods: IHS, PCA, High pass filtering, Wavelet, Ehlers Fusion, Brovey, Difference& Ratio, Adding & Multiplication, etc.
- Image fusion can be performed at 3 fusion levels:
  - 1) Pixel; 2) Feature;3) Decision level;
- The most popular pixel level methods:
  - Intensity-Hue-Saturation;
  - Principal Component Analysis;
- For classification, image bands from different sensors acquired on different dates can be stacked for input.

IHS – Intensity-Hue-Saturation Transformation

a) IHS Transformation

$$\begin{pmatrix} I \\ v1 \\ v2 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & \frac{-2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$H = \tan^{-1}\left(\frac{v1}{v2}\right), \quad S = \sqrt{v_1^2 + v_2^2}$$

b) Reverse IHS Transformation

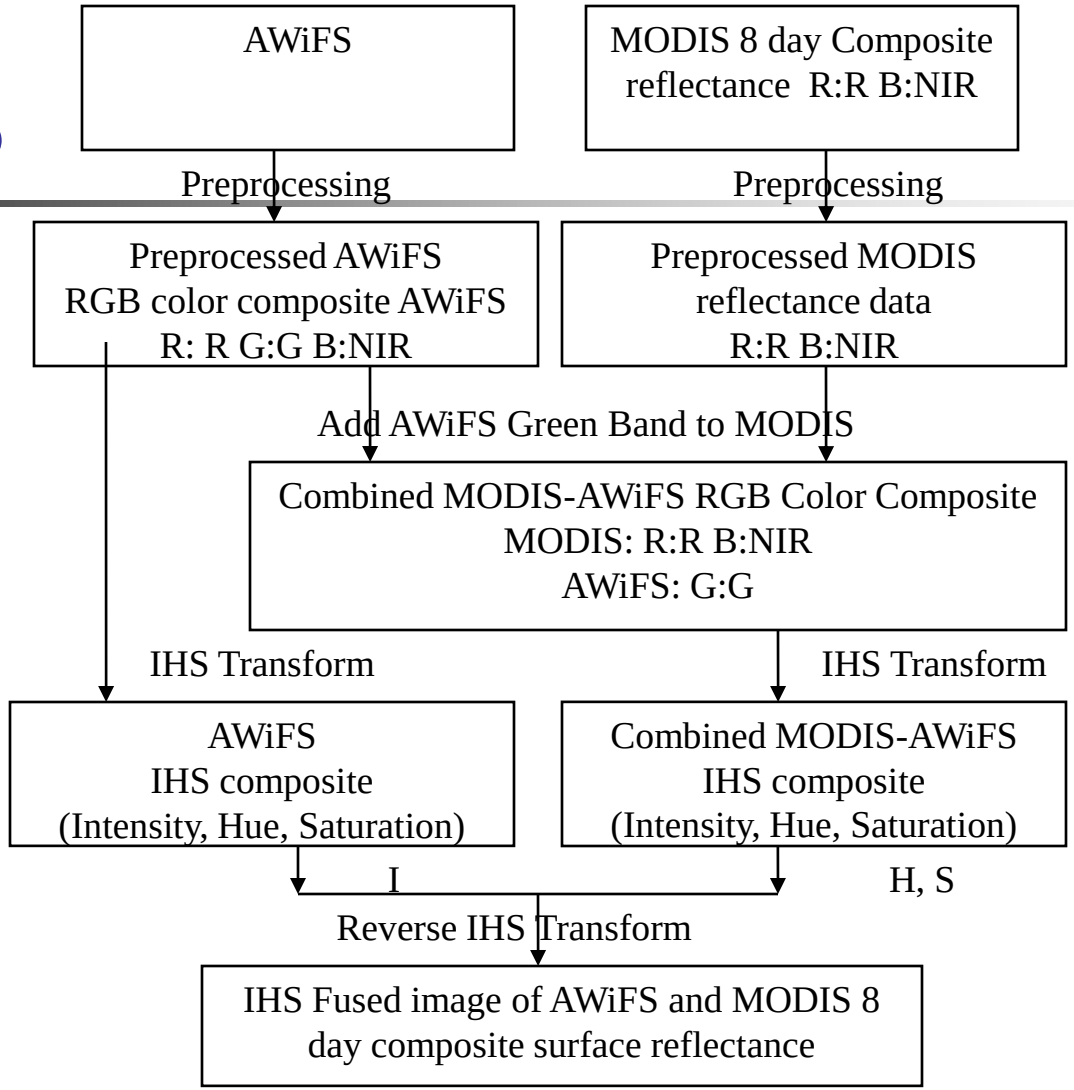
$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \end{pmatrix} \begin{pmatrix} I \\ v1 \\ v2 \end{pmatrix}$$

- Fusion with IHS – Replacing the intensity channel with a higher spatial resolution counterpart and reversing IHS.

PCA - Principal Component Analysis

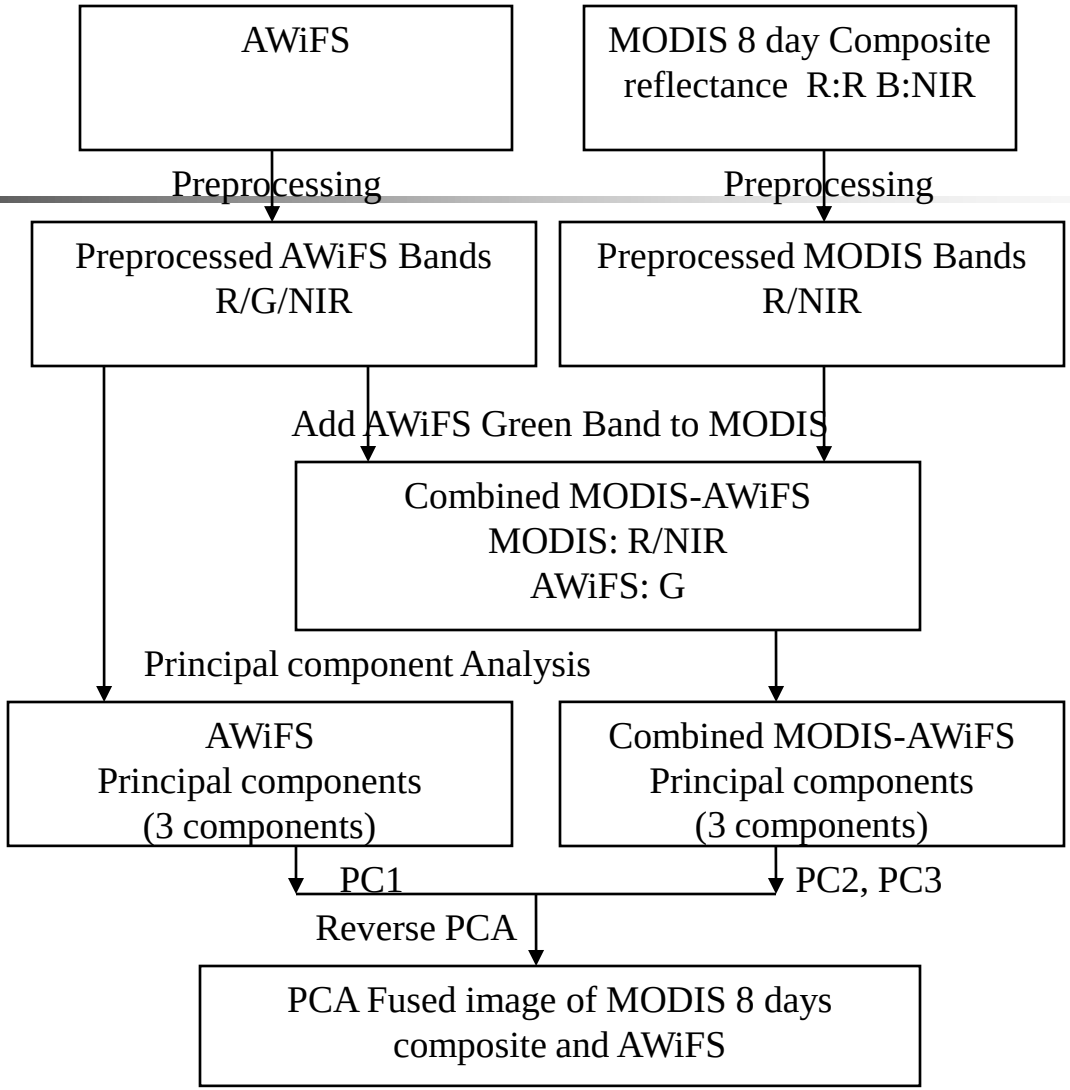
- The approach for the computation of the principal components (PCs) comprises the calculation of:
  - 1. Autocorrelation matrix;
  - 2. Eigen-values, Eigenvectors;
  - 3. Principal component;
- PCA Fusion:
  - 1. Replace the first principal component (Popular);
  - 2. PCA of all multi-image data channels;
  - 3. Reverse PCA.

IHS



AWiFS and MODIS Fusion with PCA

PCA



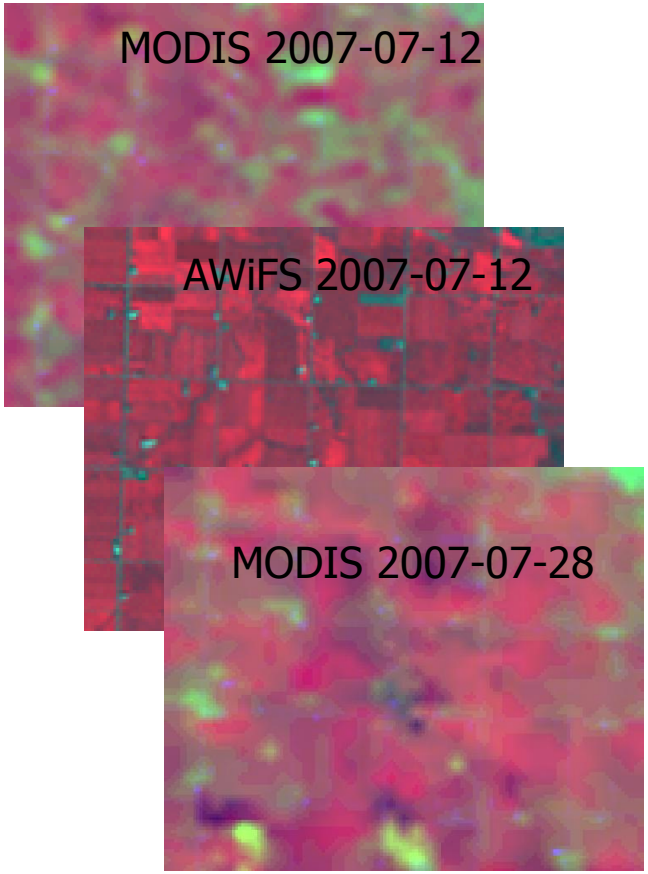
AWiFS and MODIS Fusion with IHS

Image Fusion Experiments

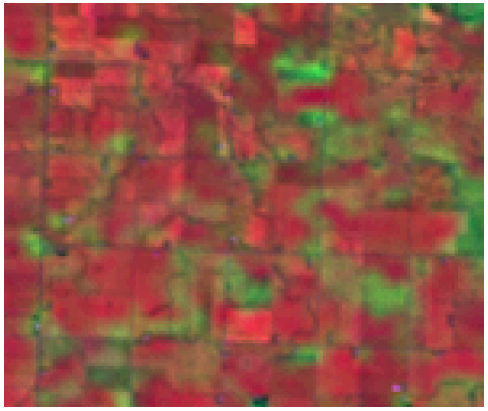
- One AWiFS scene;
- 2007/7/20 AWiFS

  =>2007/7/12, 2007/7/28 MODIS;
- Replacing MODIS green band with AWiFS green band;
- Pixel level fusion with IHS & PCA;
- Image stack.

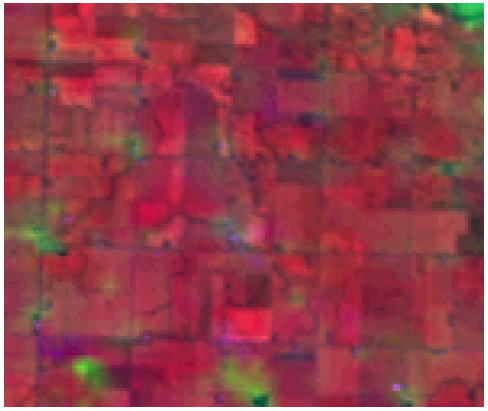
Fused Images



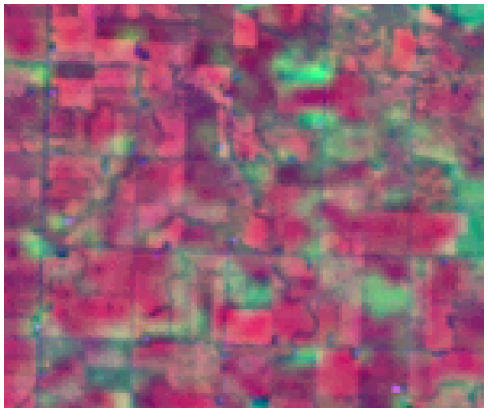
AWiFS-MODIS Band Combined



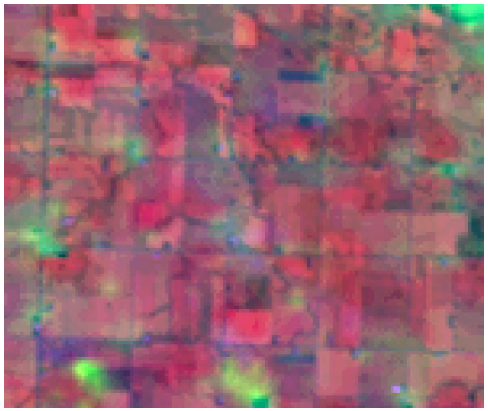
b) IHS 2007-07-12



c) IHS 2007-07-28



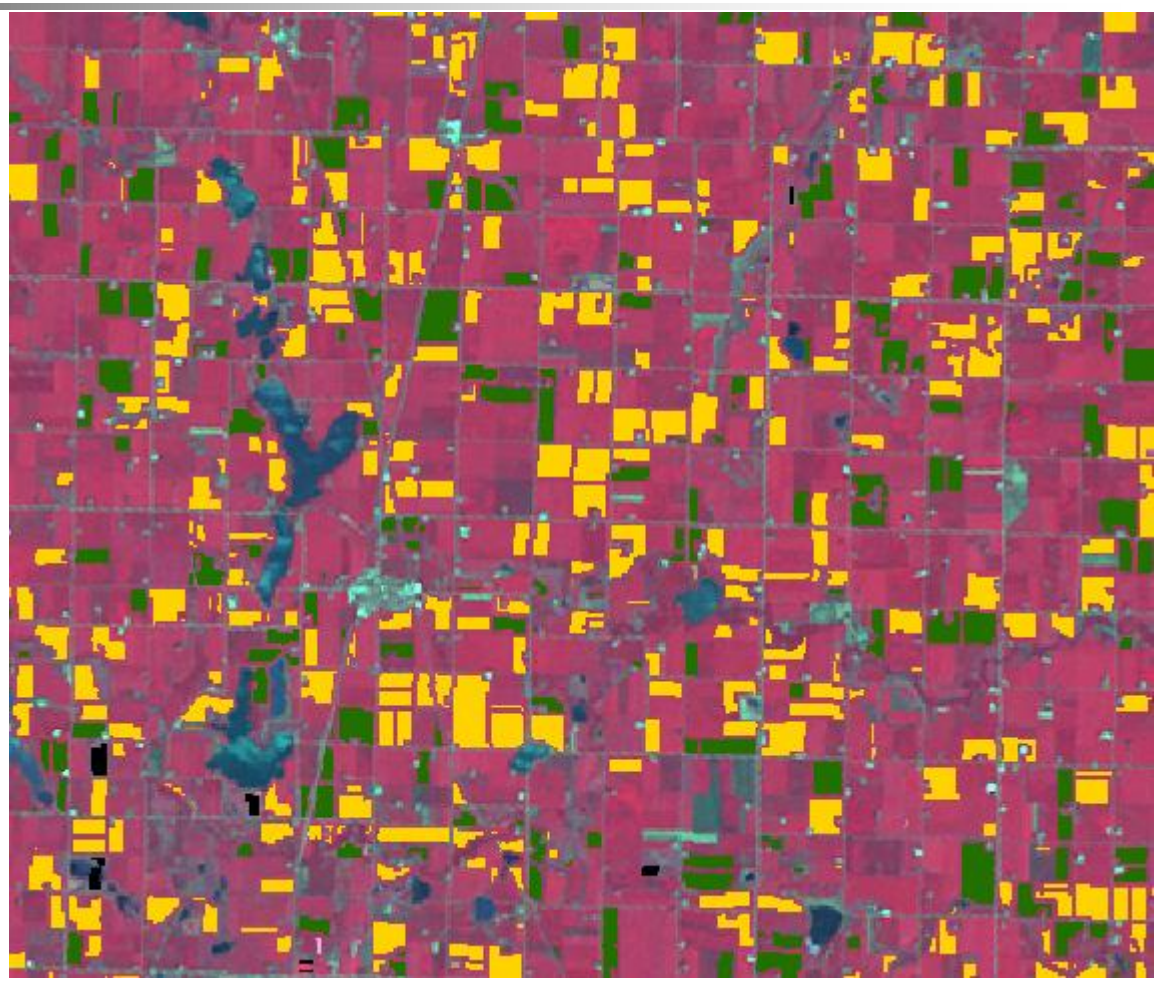
b) PCA 2007-07-20



c) PCA 2007-07-28

Training Data

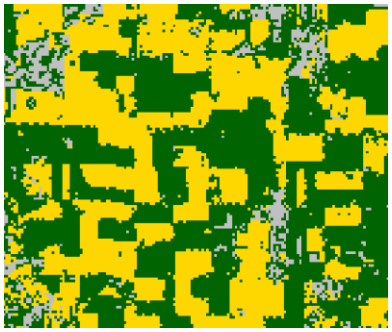
- FSA CLU
- FSA 578
- Yellow (corn)
- Green (soybean)



Decision Tree Classification

- Classifier:
  - Supervised decision tree classification method
- Why - advantages:
  - A white box model - easily explained by Boolean logic and easy to understand and interpret results;
  - Able to handle both numerical and categorical data;
  - Robust - tolerates training errors and cloud pixels;
  - Good computational performance.
  - No assumption of data distribution required;
  - Easy to validation;
  - Little data preparation needed;
  - Excellent scalability - no limit in number of data layers;

Classification Results

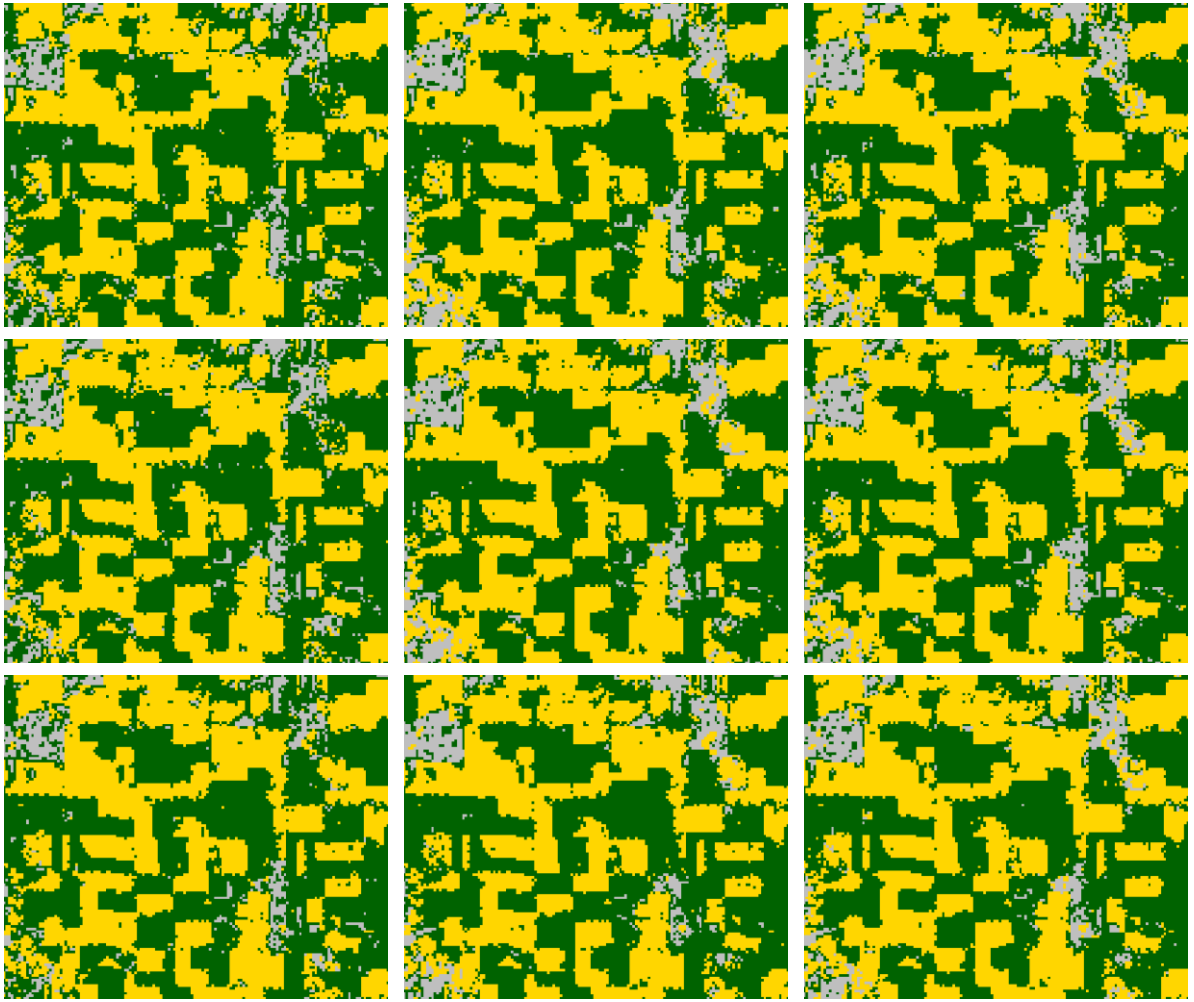


AWiFS Alone

IHS

PCA

STACK



Classification Accuracy

Fusion Method	Temporal	Class	Producer	Kappa	User	Kappa
AWiFS	720	corn	95.62%	0.8754	90.75%	0.7595
	720	soybean	83.49%	0.7551	85.53%	0.7829
IHS	193	corn	94.76%	0.8571	92.08%	0.7941
	193	soybean	86.02%	0.7878	84.16%	0.7623
IHS	209	corn	94.99%	0.8631	92.22%	0.7977
	209	soybean	87.78%	0.8021	87.14%	0.8069
IHS	193+209	corn	95.12%	0.869	93.33%	0.8267
	193+209	soybean	88.92%	0.8324	87.48%	0.812
PCA	193	corn	94.58%	0.8536	92.40%	0.8024
	193	soybean	86.15%	0.7899	84.37%	0.7654
PCA	209	corn	95.09%	0.8654	92.15%	0.7959
	209	soybean	87.05%	0.8054	86.79%	0.8017
PCA	193+209	corn	95.03%	0.8658	92.93%	0.8161
	193+209	soybean	88.34%	0.8237	87.28%	0.8091
STACK	193	corn	95.35%	0.8679	90.27%	0.7469
	193	soybean	83.08%	0.7489	85.03%	0.7754
STACK	209	corn	94.58%	0.8515	91.68%	0.7836
	209	soybean	86.26%	0.7933	85.78%	0.7866
STACK	193+209	corn	95.06%	0.8669	93.05%	0.8192
	193+209	soybean	88.64%	0.8282	87.36%	0.8102

Corn accuracy differences (Reference: AWiFS)

Fusion Method	Temporal	Producer	Kappa	User	Kappa
AWiFS	A720	95.62%	0.8754	90.75%	0.7595
IHS	M193	-0.86%	0.8571	1.33%	0.7941
IHS	209	-0.63%	0.8631	1.47%	0.7977
IHS	193+209	-0.50%	0.869	2.58%	0.8267
PCA	193	-1.04%	0.8536	1.65%	0.8024
PCA	209	-0.53%	0.8654	1.40%	0.7959
PCA	193+209	-0.59%	0.8658	2.18%	0.8161
STACK	193	-0.27%	0.8679	-0.48%	0.7469
STACK	209	-1.04%	0.8515	0.93%	0.7836
STACK	193+209	-0.56%	0.8669	2.30%	0.8192

Soybean accuracy differences (Reference: AWiFS)

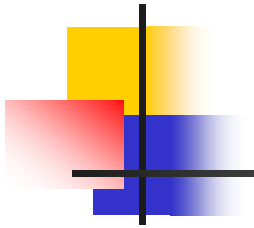
Fusion Method	Temporal	Producer	Kappa	User	Kappa
AWiFS	A720	83.49%	0.7551	85.53%	0.7829
IHS	M193	2.53%	0.7878	-1.37%	0.7623
IHS	209	4.29%	0.8021	1.61%	0.8069
IHS	193+209	5.43%	0.8324	1.95%	0.812
PCA	193	2.66%	0.7899	-1.16%	0.7654
PCA	209	3.56%	0.8054	1.26%	0.8017
PCA	193+209	4.85%	0.8237	1.75%	0.8091
STACK	193	-0.41%	0.7489	-0.50%	0.7754
STACK	209	2.77%	0.7933	0.25%	0.7866
STACK	193+209	5.15%	0.8282	1.83%	0.8102

Conclusions

- For Corn
  - The producer accuracy reduced -0.27% ~ -1.04% for all inputs;
  - The user accuracy is improved 1.3% ~2.58% for IHS and PCA; However, the earlier date user accuracy reduced by -0.48% for image stack. The later date stack accuracy improved slightly.
  - The multitemporal results showed 2.18% ~ 2.59% improvements in user accuracy with IHS giving the best result.
  - Overall, the user accuracy improvement is bigger than producer accuracy deterioration.

Conclusions - continued

- For Soybean
  - The later date MODIS fused with AWiFS improves accuracy up to 4.29% for producer accuracy and 1.61% for user accuracy; However, user accuracy reduced for earlier date fusion.
  - The overall multitemporal MODIS and AWiFS fused data analysis has accuracy improvement up to 5.43% for producer accuracy and 1.95% for user accuracy;
  - IHS performs best and PCA performs worst;
- Overall, additional temporal 250m MODIS images do improve classification accuracy;
- IHS fusion performed best;
- Fusion showed potential, but further investigation needed!



Questions & Comments?

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