Multi-polarized PALSAR and LandSat multi-modality data fusion for Crop Classification

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UNITED STATES DEPARTMENT OF AGRICULTURE

Outline

- Introduction
- Data
- Processing & Methods
- Classification Results and Discussion
- Conclusions

Introduction

- USDA NASS' Mission:
  - Provides timely, accurate and unbiased agricultural statistics
- NASS remote sensing based Crop Data Layer (CDL) program provides acreage estimation. Its classification accuracy relies on sufficient quality image data. But the reality is:
  - Limited images available because of limited budget, cloud cover, time constraint.
- Any type of image data available for improving crop identification should be studied
  - Leads this radar data application study.

Why Studying Radar Image

- Test site Central Valley, California has many varieties of crops.
- Radar's special characteristics may help to improve crop identification.
- Test images are available!

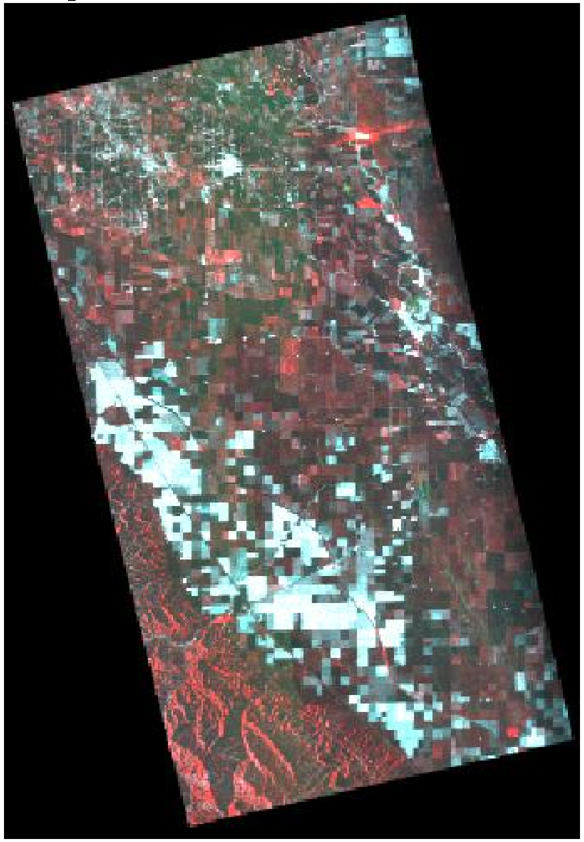
Objective of This Study

- Seeking answers to following questions:
  - Can fusion of Radar and LandSat data improve crop identification?
  - How big is the impact of the backscatter noise?
  - Can noise filtering help improving classification accuracy?
  - Can texture features help improving classification accuracy?
  - Can Radar images be helpful?

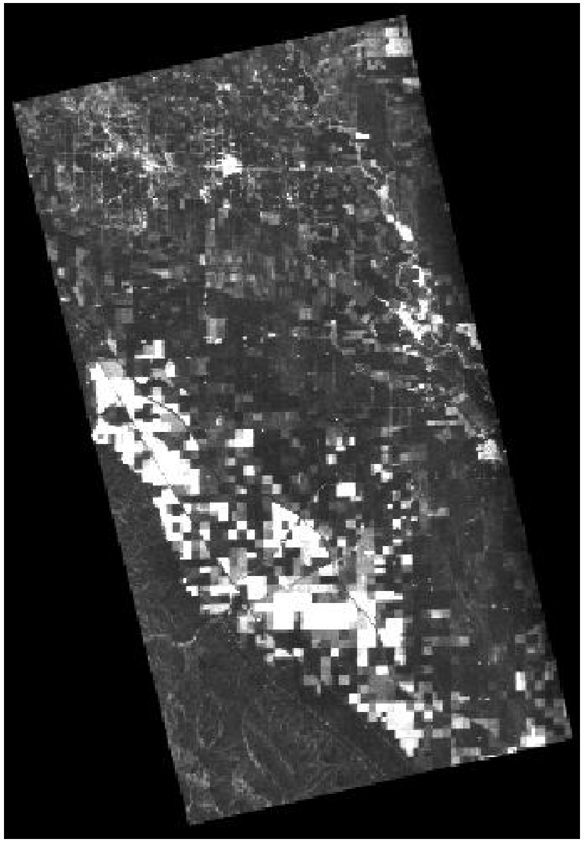
ALOS-PALSAR Radar Data

- L-band, polarimetric;
- Spatial resolution: 12.5m;
- Swath Width: 20-65km;
- Recorded on July 1, 2007
- Quad polarization: HH, HV, VH, VV

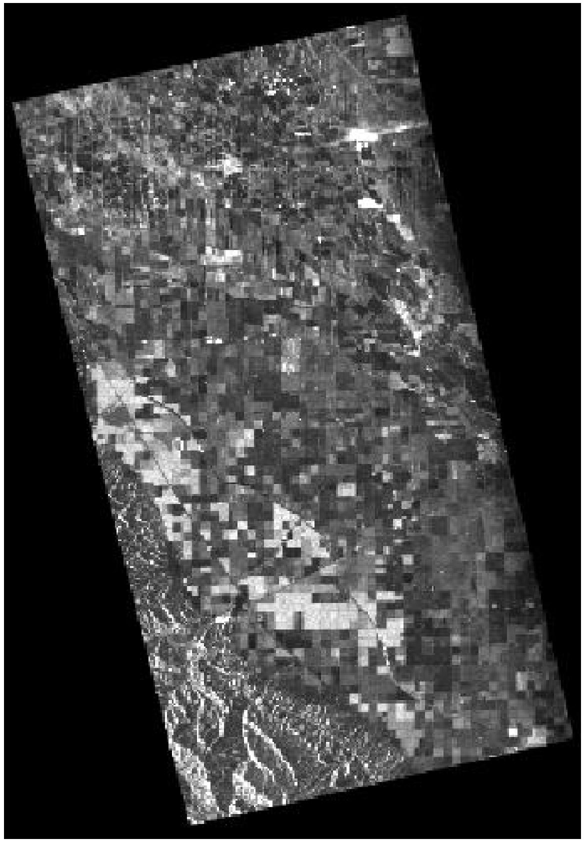
PALSAR Data – Central Valley, CA



Quad polarizations

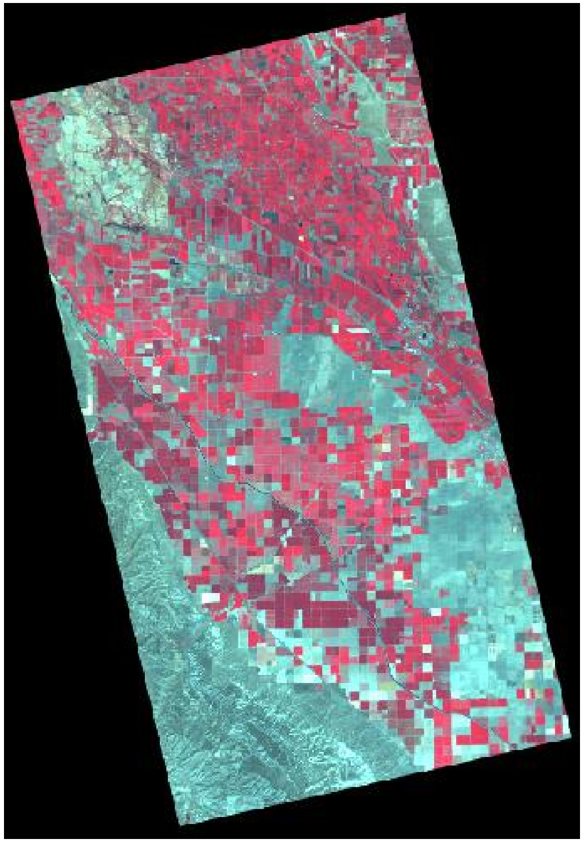


HH polarization



HV polarization

LandSat TM

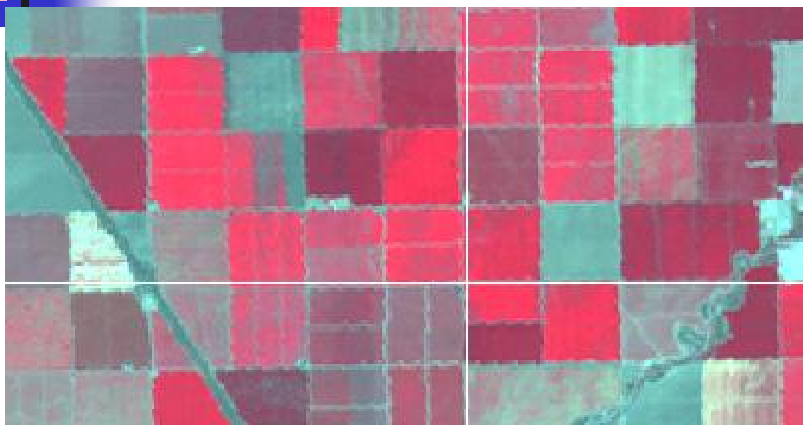


- Spatial resolution: 30m at nadir
- Quantization: 8 bits
- Spectral bands 7
  - Blue Band 1, 0.45-0.515
  - Green Band 2, 0.525-0.605 *μm*
  - Red Band 3, 0.63-0.69 *μm*
  - NIR Band 4, 0.75-0.90 *μm*
  - SWIR (Band 5, 1.55-175 *μm)*
  - Band 6, 10.4 -12.5 *μm*
  - Band 7, 2.09-2.35 *μm*
- Repeat period: 16days.
- Swath width: 185km
- Path 43 Row 34 and Path 43 and Row 35, July 30, 2007

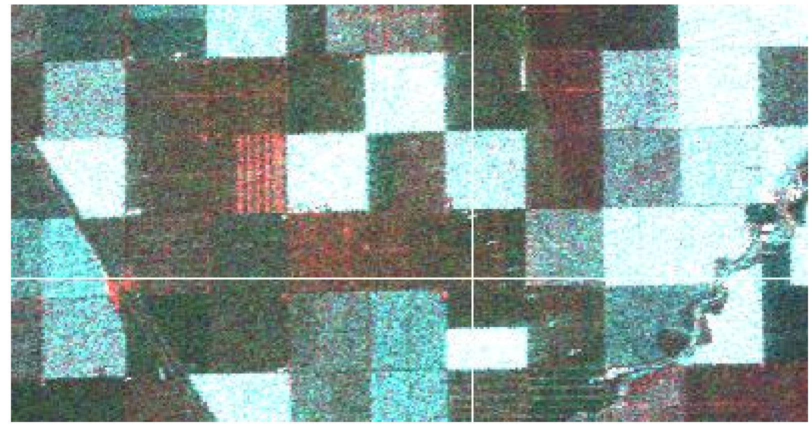
Data Processing

- LandSat mosaic (seamless and color balance)
- LandSat and PALSAR co-registration
- Radar noise filtering
- Image fusion
- Texture feature calculation
- Training & validation data preparation.

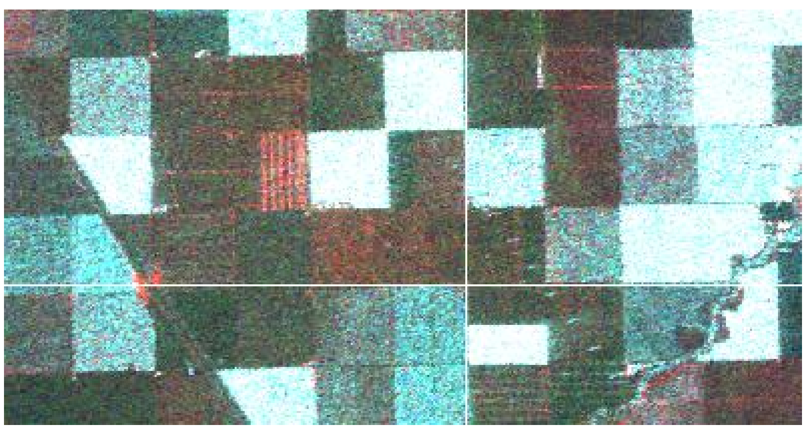
Image Registration



LandSat



Unregistered Quad pols



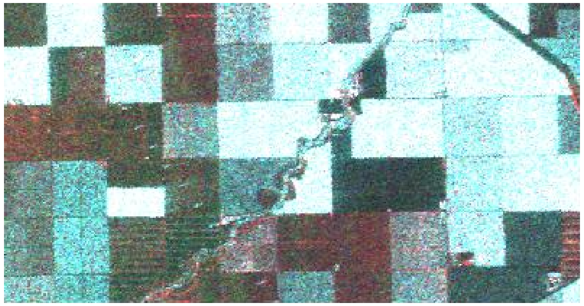
Registered Quad pols

- LandSat and Palsar Images were registered.

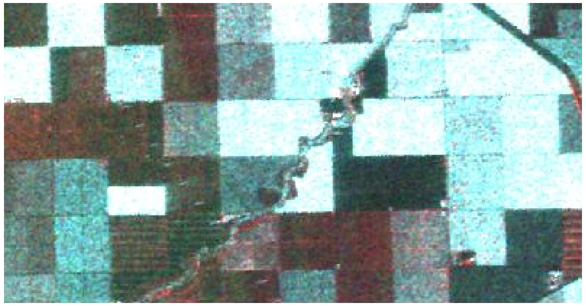
Noise Filtering

- A few filters tested
- Median filter
  - Selects the value in the middle of the range of values within the moving window.
- Lee-Sigma filter
  - Uses the average of all pixel values within the moving window that fall within the designated range of standard deviations.
- Gamma-MAP filter
  - Maximizes the a posteriori probability density function. This filter attempts to derive the original pixel value which must lie between the local average and the degraded pixel value.

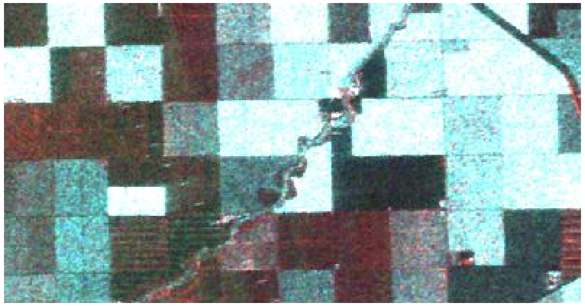
Filtered Images



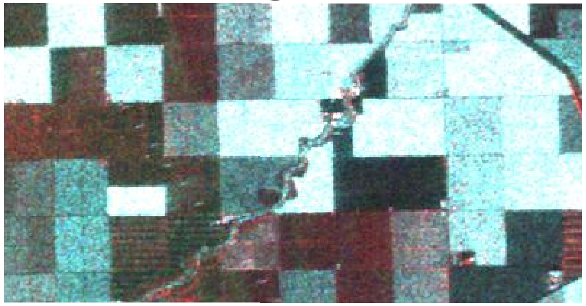
Quad polarization
(unfiltered)



Lee-Sigma 3x3



Median 3x3



Gamma-MAP 3x3

Median 5x5

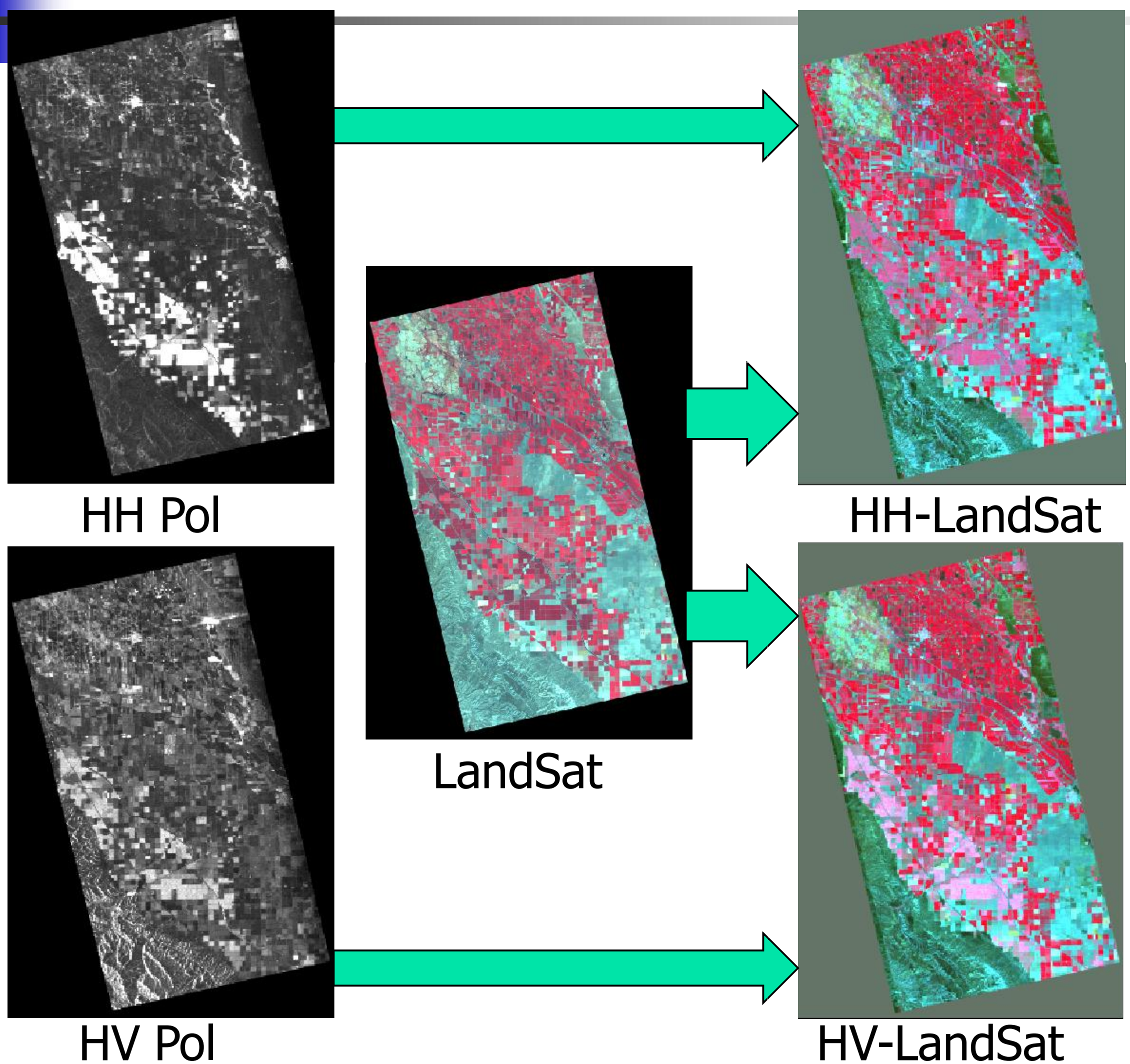
Image Fusion Methods

- 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.

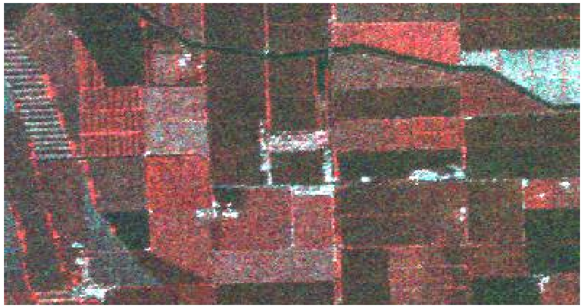
PALSAR-LandSat Fusion with PCA - Principal Component Analysis

- 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.
- Transformation settings:
  - Remap, Cubic convolution for resampling

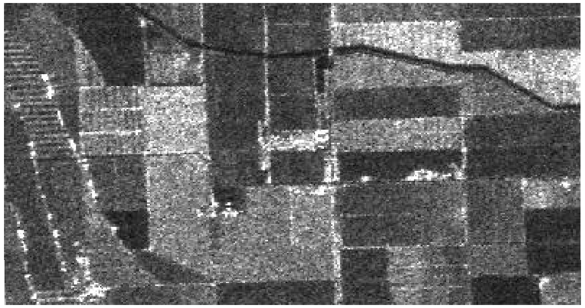
PALSAR-LandSat Fused Images



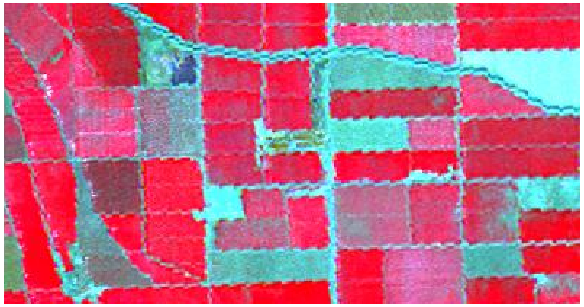
PALSAR-LandSat Fused Images - Zoom-in View



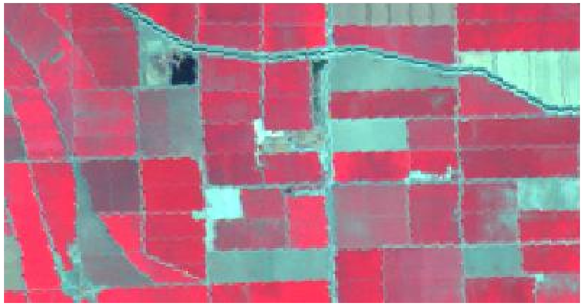
Quad polarization image



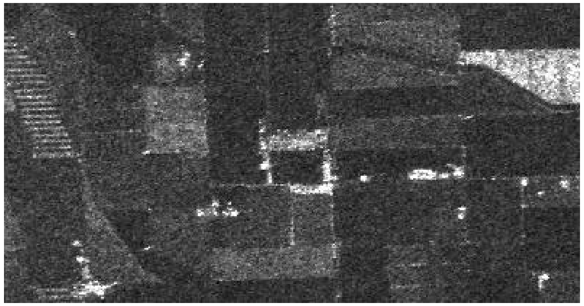
HH Pol



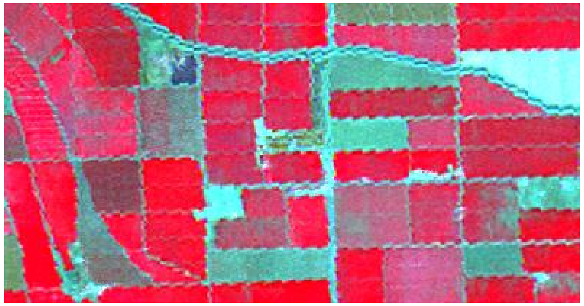
HH Pol-LandSat fusion



LandSat image



HV Pol



HV Pol-LandSat fusion

Texture Features

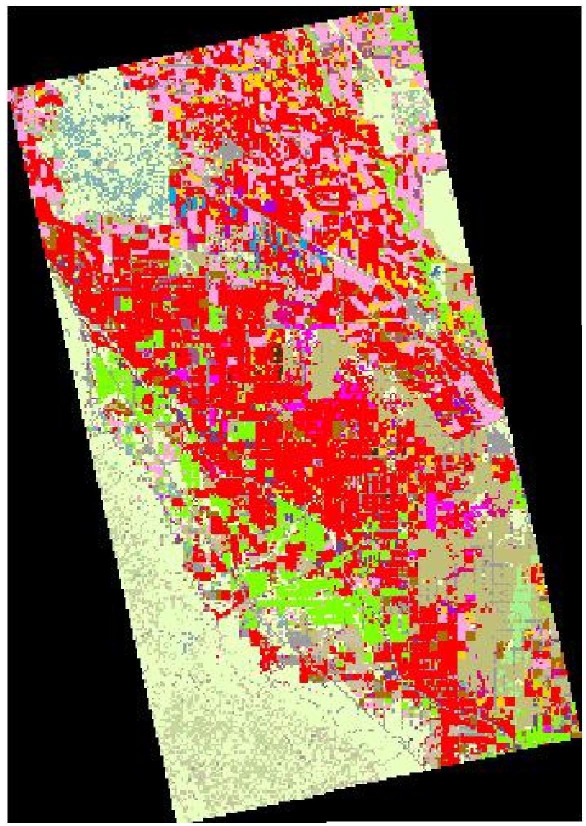
- There are many texture features. Two were tested here:
- Mean Euclidean distance with 7x7 window
- Variance with 7x7 window

Training & Validation Data

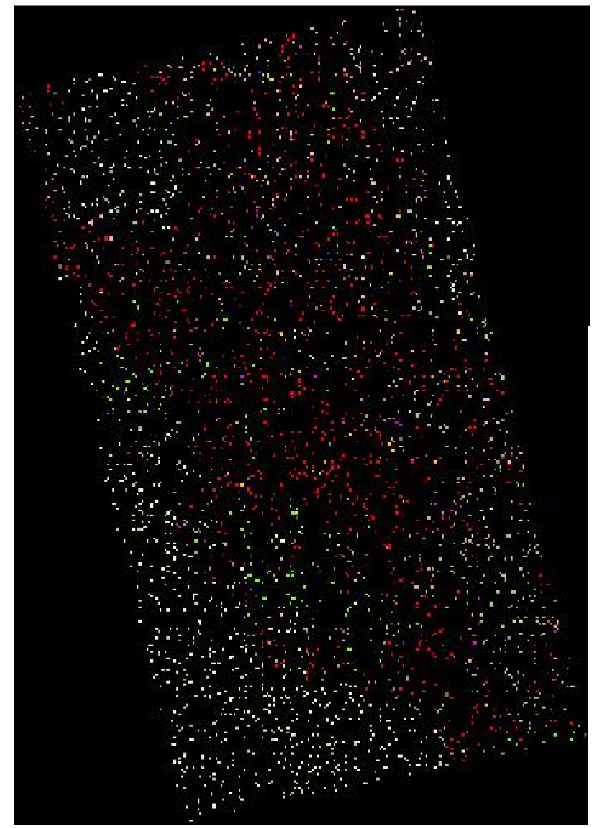
- The existing USDA ground truth data (CLU &Admin 578 data) do not cover all crop types since the scene covered area is too small.
- 2007 California Cropland Data Layer (CDL) used for both training and validation
- CDL - a crop land cover product annually generated by USAD/NASS. It's a raster data with crop identified.
- Both training and validation data are stratified in sampling.

Training & Validation Data

- Yellow (corn)
- Green(soybean)
- Red(Cotton)
- Blue(Rice)
- Purple(Grape)



2007 CDL



Validation Sample

Classification Method

- Classifier:
  - Supervised decision tree classifier
  - 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;
- Inputs:
  - Training data, various source radar/LandSat images

Classification with LandSat or PALSAR Pols

	Cotton			Rice			Alfalfa			Almonds			Overall
	Producer	User	Producer - Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	%
LandSat	72.35	57.64	0.6332	56.27	67.55	0.5615	64.76	60.61	0.6119	60.55	53.58	0.5760	61.78
hh	85.26	25.68	0.5752	0.00	0.00	N/A	0.00	0.00	0.0000	54.35	32.89	0.2850	34.86
hv	85.23	26.01	0.5845	0.00	0.00	N/A	38.11	16.76	0.2298	71.90	39.28	0.6835	41.69
vh	87.94	24.64	0.5954	0.00	0.00	0.0000	25.09	16.52	0.1378	72.18	38.21	0.6854	40.47
vv	81.20	25.51	0.4973	0.00	0.00	0.0000	0.00	0.00	0.0000	49.91	31.57	0.4453	33.20
Quad Pols	76.80	28.20	0.5003	0.05	0.92	0.0003	33.07	18.84	0.2111	62.64	45.35	0.5918	38.61

- LandSat performs better than Radar for all except for Almonds;
- Individual pols hh, hv, vh perform better than Quad pols for Cotton;
- Accuracies of Quad pol and individual pols are extremely low for Rice;
- For Almonds the producer accuracy of hv and vh are better than LandSat result;
- For cotton the producer accuracies of Quad pols and individual pols are significantly better than that of LandSat.

Filtered Data Classification Result

	Cotton			Rice			Alfalfa			Almonds			Overall
	Producer	User	Producer - Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	%
LandSat	72.35	57.64	0.6332	56.27	67.55	0.5615	64.76	60.61	0.6119	60.55	53.58	0.5760	61.78
hh	85.26	25.68	0.5752	0.00	0.00	N/A	0.00	0.00	0.0000	54.35	32.89	0.2850	34.86
hv	85.23	26.01	0.5845	0.00	0.00	N/A	38.11	16.76	0.2298	71.90	39.28	0.6835	41.69
vh	87.94	24.64	0.5954	0.00	0.00	0.0000	25.09	16.52	0.1378	72.18	38.21	0.6854	40.47
vv	81.20	25.51	0.4973	0.00	0.00	0.0000	0.00	0.00	0.0000	49.91	31.57	0.4453	33.20
qp_ gamma_map3	74.75	29.96	0.5043	0.19	6.56	0.0018	42.42	20.95	0.3022	64.67	45.95	0.6133	40.56
qp_ lee_sigma3	74.55	29.96	0.5015	0.00	0.00	0.0001	43.47	20.75	0.3098	64.08	46.89	0.6079	40.72
qp_median3	74.37	29.72	0.4953	0.05	1.49	0.0004	42.12	20.58	0.2969	63.91	46.94	0.6063	40.25
qp_median5	72.67	31.08	0.4940	0.38	14.29	0.0037	46.86	21.97	0.3486	64.94	48.29	0.6179	41.62
Quad Pols	76.80	28.20	0.5003	0.05	0.92	0.0003	33.07	18.84	0.2111	62.64	45.35	0.5918	38.61

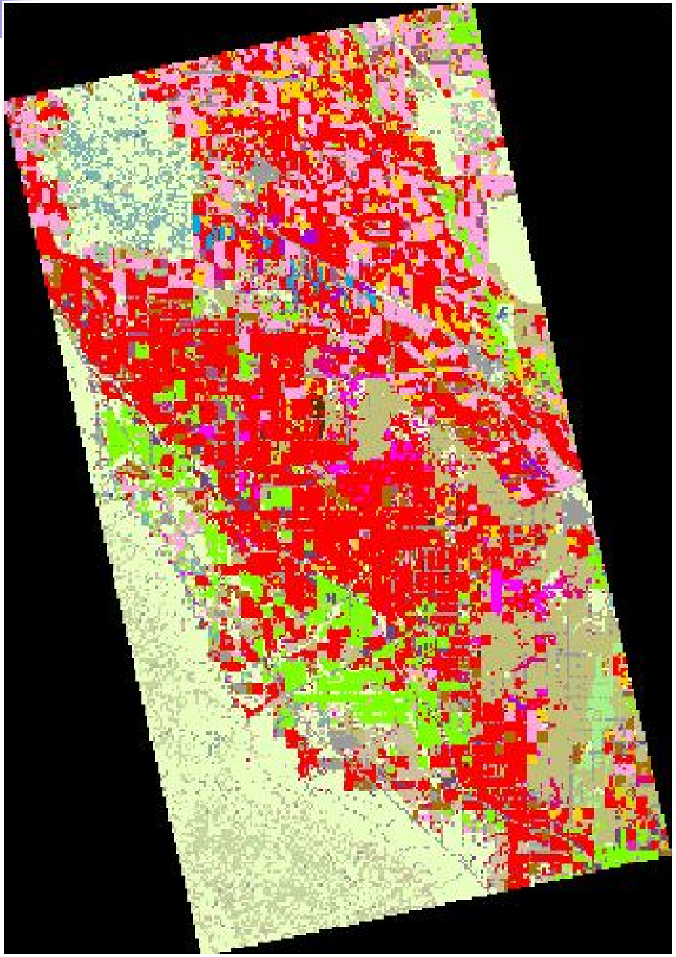
- For Cotton, filtered results are inferior to original polarization results
- For Rice, Alfalfa and Almonds, accuracies of filtered quad pols are better than unfiltered quad pols
- Among filtered data, different methods with smaller window 3x3 yield close results. The larger window 5x5 gives better result than 3x3 window for Median filter.

Classification Results using PALSAR-LandSat Fusion/Texture

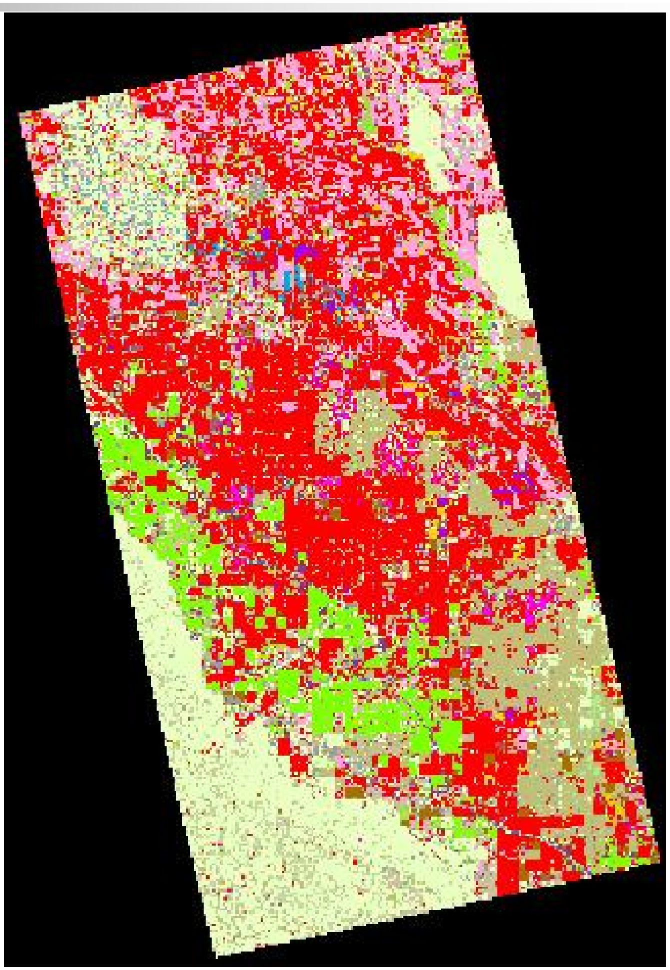
	Cotton			Rice			Alfalfa			Almonds			Overall
	Producer	User	Producer - Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	Producer	User	Producer Kappa	%
LandSat	72.35	57.64	0.6332	56.27	67.55	0.5615	64.76	60.61	0.6119	60.55	53.58	0.5760	61.78
hh_landsat	73.46	59.75	0.6500	48.92	56.43	0.4878	64.30	58.59	0.6057	65.47	55.33	0.6277	60.30
hv_landsat	74.70	60.52	0.6659	48.17	55.11	0.4803	64.73	58.72	0.6102	68.78	57.84	0.6633	60.90
vh _landsat	74.41	59.68	0.6609	49.44	55.64	0.4930	63.44	58.67	0.5967	68.19	57.47	0.6570	60.45
vv_ landsat	72.51	59.14	0.6377	48.21	55.44	0.6377	63.84	57.90	0.6004	64.39	54.79	0.6163	59.74
Quad Pols	76.80	28.20	0.5003	0.05	0.92	0.0003	33.07	18.84	0.2111	62.64	45.35	0.5918	38.61
qp_ med7 _var7	52.70	33.76	0.3021	1.69	7.64	0.0162	26.46	22.25	0.1762	62.38	48.56	0.5903	30.27

- Palsar-LandSat fusion performs better than both Quad pols and LandSat for Almonds and Cotton.
- Palsar-LandSat fusion results are worse than LandSat for Rice and similar to LandSat for Alfalfa;
- Overall, the fused results perform better than radar data alone
- Including texture features don't improve classification accuracy. They even deteriorate the results. This means that texture features computed with less than or equal to 7x7 window does not help classification accuracy improvement at all!

Classification Result - CDL



2007 CDL (LandSat)



VH_LandSat fusion result

Conclusions

- Texture features calculated with less than or equal to 7x7 windows don’t help classification accuracy improvement at all. They even reduced classification accuracy. However, it’s not clear that if using larger window size will be helpful or not.
- The backscatter noise significantly affects the classification accuracy this as evidenced by the facts that the filtered data with large window size performed better than the unfiltered Radar data.
- The fusion of Radar and LandSat data can improve crop identification as evidenced by the facts that the fused results performs better than radar data alone and Palsar-LandSat fusion performs better than both Quad pols and LandSat for Almonds and Cotton. However, it does not help for every crop type. In general, Radar images can be helpful if properly used.

THANK YOU

QUESTION?

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