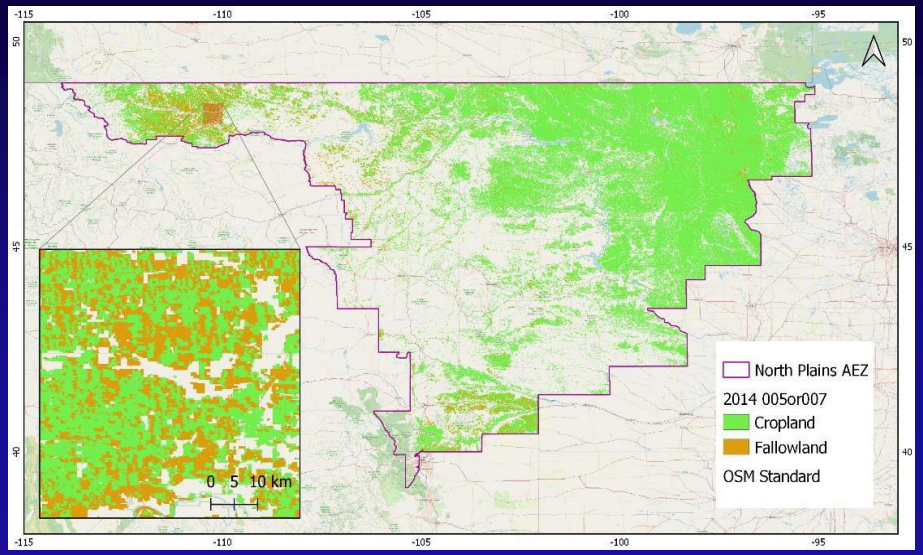
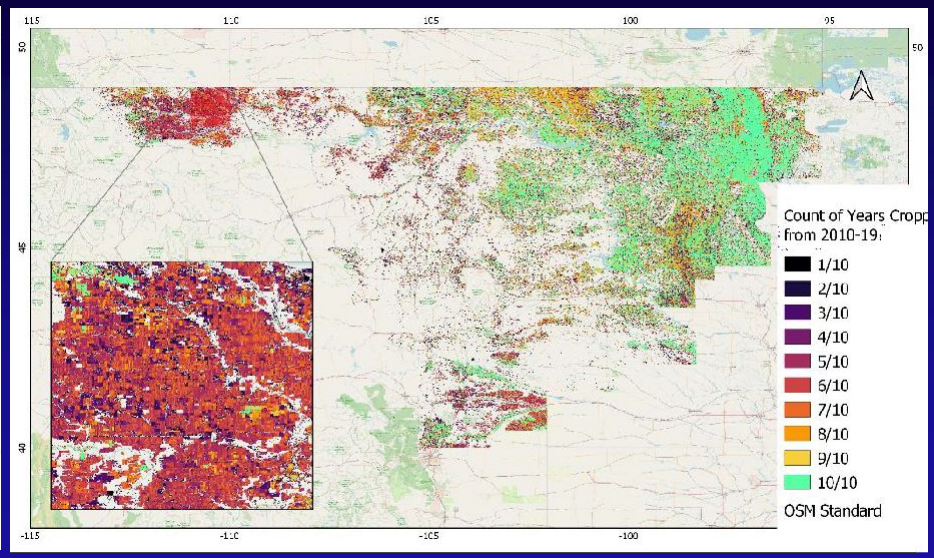
WaterSMART Project: Crop Water Productivity Studies of CONUS

Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA





2014	Cropland	Fallow	Row total	Commission error
Cropland	**5645**	96	5741	1.7%
Fallow	88	**396**	484	18.2%
Column total	5733	492	**6225**	
Omission error	1.5%	19.5%		
Producer accuracy	98.5%	80.5%		
User accuracy	98.3%	81.8%		
Overall accuracy				**97.0%**

Mr. Adam Oliphant*, Dr. Prasad Thenkabail*,

Dr. Pardha Teluguntla*, Dr. Itiya Aneece*, Mr. Daniel Foley*

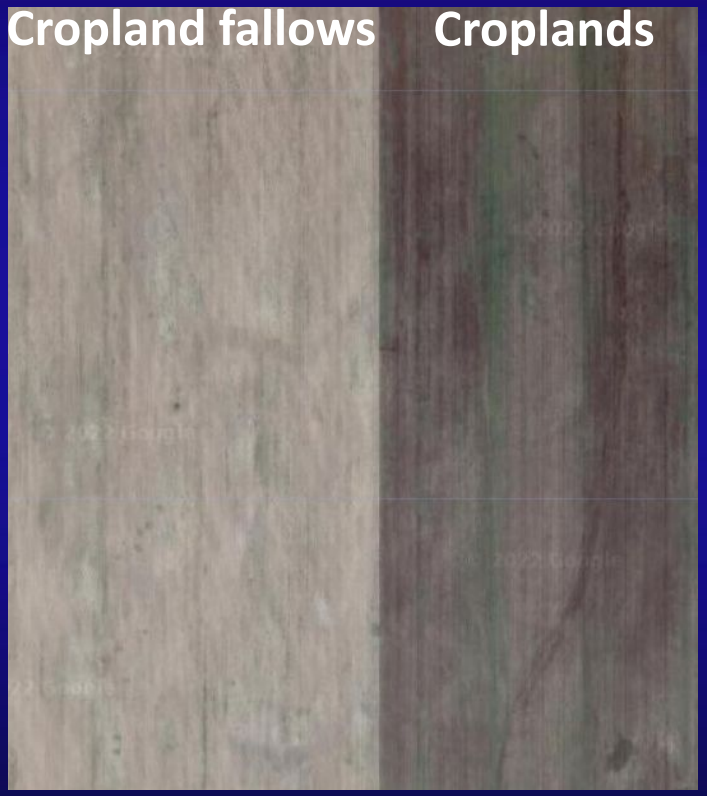
*** Western Geographic Science Center, US Geological Survey**

Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

What is a cropland fallow: Definition

Cropland fallows are farmlands that are NOT cultivated in a given season or or year or across seasons or across years. Hence, they are left fallow and referred to as cropland fallows.

Colorado



North Dakota

USGS

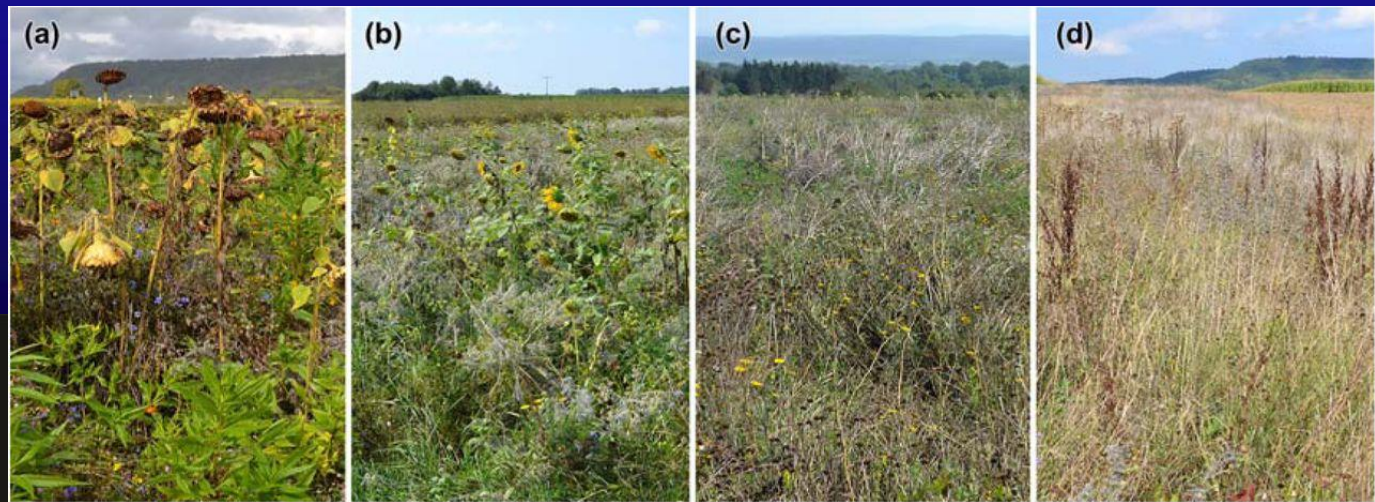
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

What is a cropland fallow: Definition

Cropland fallows are farmlands that are NOT cultivated in a given season or year or across seasons or across years. Hence, they are left fallow and referred to as cropland fallows.

How well we can map depends on how well we can capture through reference training, testing, and validation data cropland fallows

Examples of the four surveyed fallow field types: (a) 1yr-FAKT (25 Sep 2019), (b) 1yr-GM (27 Aug 2019), (c) 2yr-GM (30 Aug 2019), (d) 3+yr (11 Sep 2019). Photo © Sarah Mailänder.
Rieger et al., 2020; https://doi.org/10.1101/2020.10.07.329847



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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Benefits of Cropland Fallows

krishijagran.com/agripedia/fallow-ground-benefits-of-fallowing-soil/

Fallow Ground: Benefits of Fallowing Soil

Fallow ground is a ground that has been left unfarmed for a long period of time. It is basically a land which is left to repose and regenerate.

Ayushi Raina Updated 30 July, 2021 5:30 PM IST

bloomberg.com/news/articles/2022-03-23/eu-proposes-1-5-billion-euro-package-to-shore-u..

EU Proposes €1.5 Billion Package to Shore Up Food Security

- Funds to go to farmers most impacted by high energy costs
- EU also frees up 4 million hectares of land to grow crops

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Need for the Study: Water

Current Water Situation of the US Western States and Potential Remedial Measures

apnews.com/article/mexico-arizona-lakes-colorado-river-cc37e49759fabe8236a081286dfc61ee

Western states hit with more cuts to Colorado River water

By SAM METZ, SUMAN NAISHADHAM and KATHLEEN RONAYNE August 16, 2022

Touton has said a 15% to 30% reduction is necessary to ensure that water deliveries and hydroelectric power production are not disrupted. She was noncommittal on Tuesday about whether she planned to impose those cuts unilaterally if the states cannot reach agreement. After more than two decades of drought, Arizona, Nevada and Mexico were hit with mandatory cuts for the first time last year. Some of the region's farmers have been paid to leave their fields fallow. Residents of growing cities have been subjected to conservation measures such as limits on grass lawns.

Since, croplands use nearly 80-90% of all human water use globally……..

Cropland Fallows Help Save Water, Replenish Reservoirs, Help create water banks

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Need for the Study: Food

Current Food Situation of the US and Potential Remedial Measures

azcentral.com/story/opinion/op-ed/joannaallhands/2022/08/05/arizona-must-rethink-farming-

How many farms can Arizona and California lose before we feel it at the grocery store?

Opinion: Nearly two-thirds of our fruits and vegetables come from states where water is becoming increasingly scarce. How will that affect the nation's food supply?

Joanna Allhands
Arizona Republic

Published 7:00 a.m. MT Aug. 5, 2022 | **Updated 11:10 a.m. MT Aug. 8, 2022**

Nevertheless, loosing croplands means decreased food supply, increased food costs……so, how can we optimize cropland fallows to: A. save water, B. ensure sustained food and fodder supply

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Overarching Goal and Specific Objectives

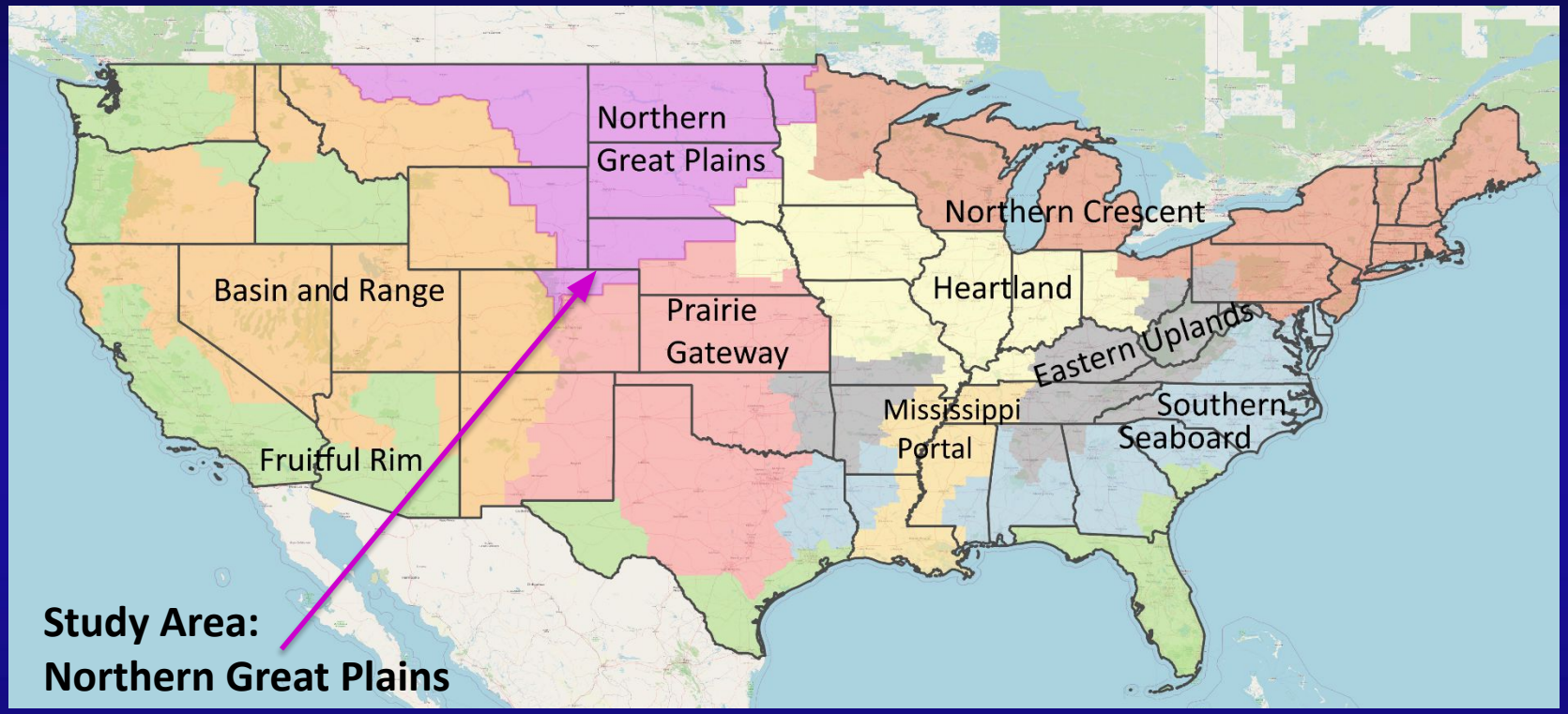
Thereby, our overarching goal is to model, map, and monitor cropland fallows over time and space across USA using Earth Observation (EO) data.

Specific Objectives of this project is to:

1. Develop cropland fallow mapping algorithm using MODIS 250m time series image composites, CART decision-tree machine learning algorithms, and GEE cloud computing for the 2010-2025 time period;
2. Produce cropland versus cropland fallow extent product for Northern Great Plains;
3. Establish accuracies, errors, and uncertainties of cropland fallow product; and
4. Compute areas for cropland fallow *versus* cropland, year after year, for every county in Northern Great Plains;

Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Study Areas

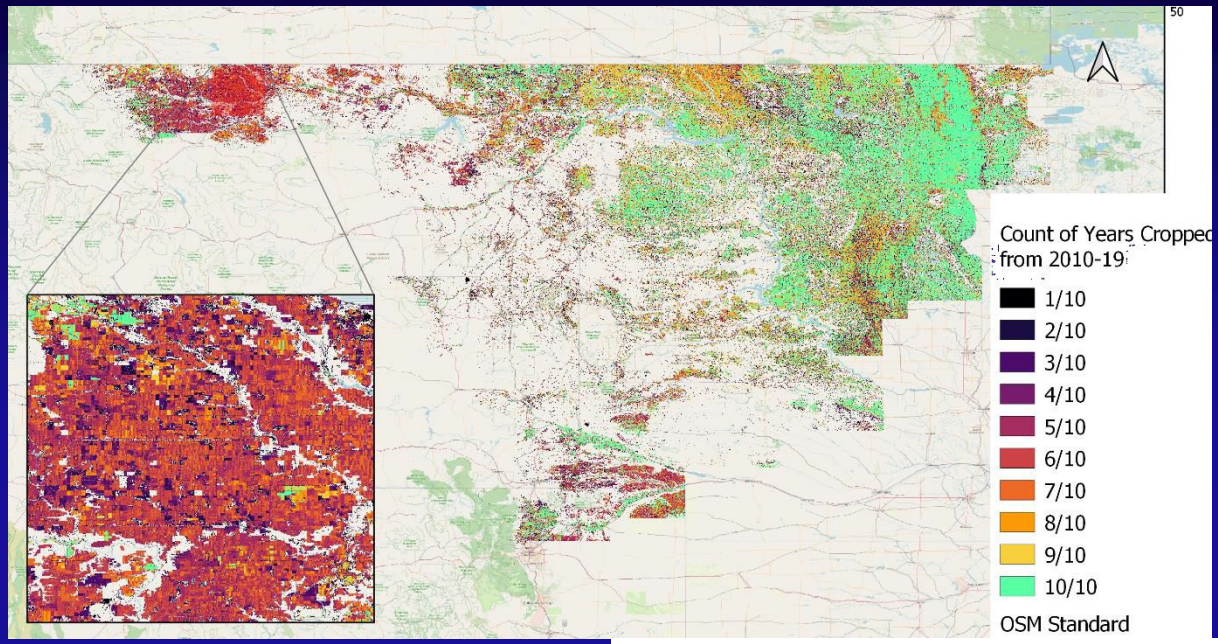


Cropland *versus* cropland fallow algorithm will be developed separately for each zone. In this presentation, I will focus on the US Northern Great Plains

USGS

Automated Croplands *versus* Fallow-land Algorithm (ACFA) for Great Plains

Study Area Characteristics



Of the 18.9 Mha of total cropland area in the Northern Plains:

1. Only 35% (6.5 Mha) was cropped in all 10 years (out of 10 yrs);
2. Only 50% (9.4 Mha) was cropped in 9 years out of 10 years;
3. 90% (17.07 Mha) was cropped at least once every 9 years out of 10 yrs.
4. 100% (18.9 Mha) was cropped at least once every 10 yrs.

Spatial distribution

Statistics

Actively Cropped Count in Years	Color	Cropland Area (ha)	Group Crop Area	Cumulative Crop Area	Cumulative Crop Area (ha)
10/10		6,528,000	35%	35%	6,528,000
9/10		2,900,000	15%	50%	9,428,000
8/10		1,669,000	9%	59%	11,097,000
7/10		1,265,000	7%	65%	12,362,000
6/10		1,178,000	6%	72%	13,540,000
5/10		1,103,000	6%	77%	14,643,000
4/10		675,000	4%	81%	15,318,000
3/10		735,000	4%	85%	16,053,000
2/10		1,021,000	5%	90%	17,074,000
1/10		1,824,000	10%	100%	18,898,000
All Fallow		15,000	0.08%	100%	18,913,000
Total Cropland Area		18,913,000	100%		
Geographic area of N Plains		75,512,446	25%		

Source of Data: USDA CDL

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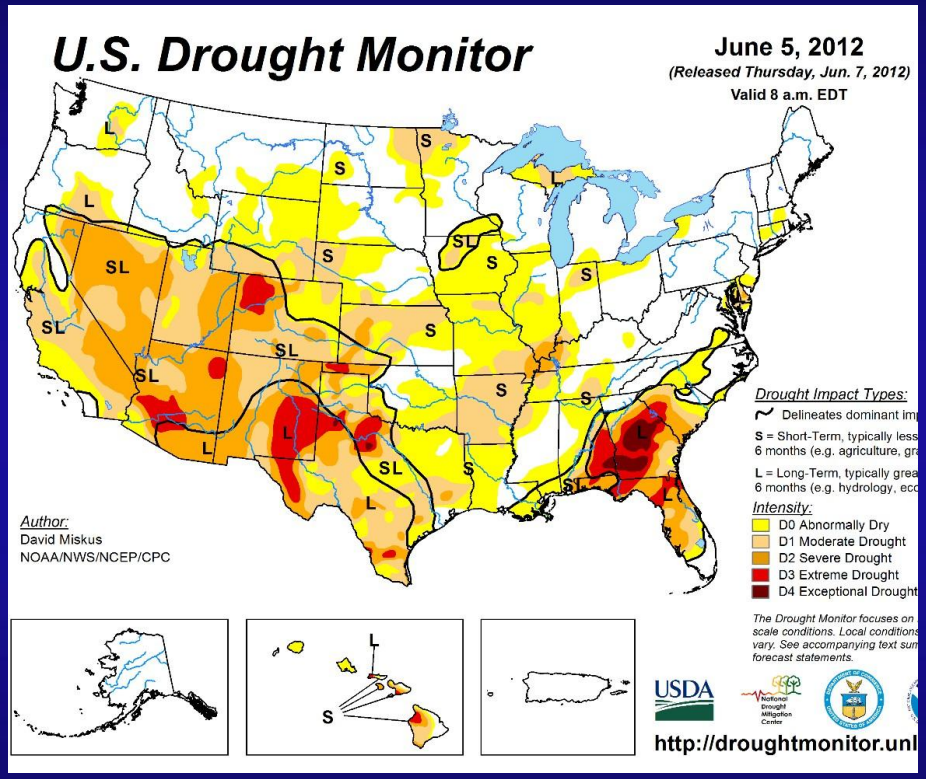
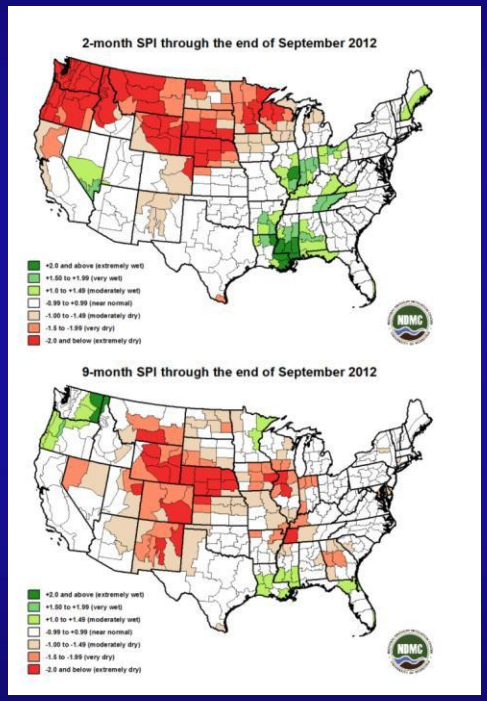
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Strategy for developing robust ACFA models by considering climate

Select Wet, Normal and Dry Years for model development





Years used in Model development:

2019 (wet),
2015 (normal),
2017 (dry)

Years used in Model validation:

2010, 2016 (wet),
2011, 2014, 2018 (normal),
2012, 2013 (dry)

National Drought Mitigation Center; USDA; NOAA. (2012). United States Drought Monitor: June 5, 2012. University of Nebraska-Lincoln. Accessed 2021-02-16. https://droughtmonitor.unl.edu/Maps/MapArchive.aspx

McKee, TB, Doesken, NJ and Kleist J. (1993) Standardized Precipitation Index (SPI). University of Nebraska-Lincoln. Accessed 2021-02-16 https://drought.unl.edu/droughtmonitoring/SPI/Maps.aspx

Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Methods: MODIS 250m time-series data cube

Total 18 layers of Data in the Analysis Ready Data (ARD) Cube (details on next slide)

- MODIS Terra 16-day EVI composites (MOD13Q1) were used to create the model;
- MOD13Q1 was chosen because it is a consistent and validated product which has robust cloud filtering and atmospheric correction;
- Because of large field sizes in Northern Plains of CONUS, the 250m pixel size is not a major hinderance;
- Ability to use ACFA algorithm consistently from 2001-2025.

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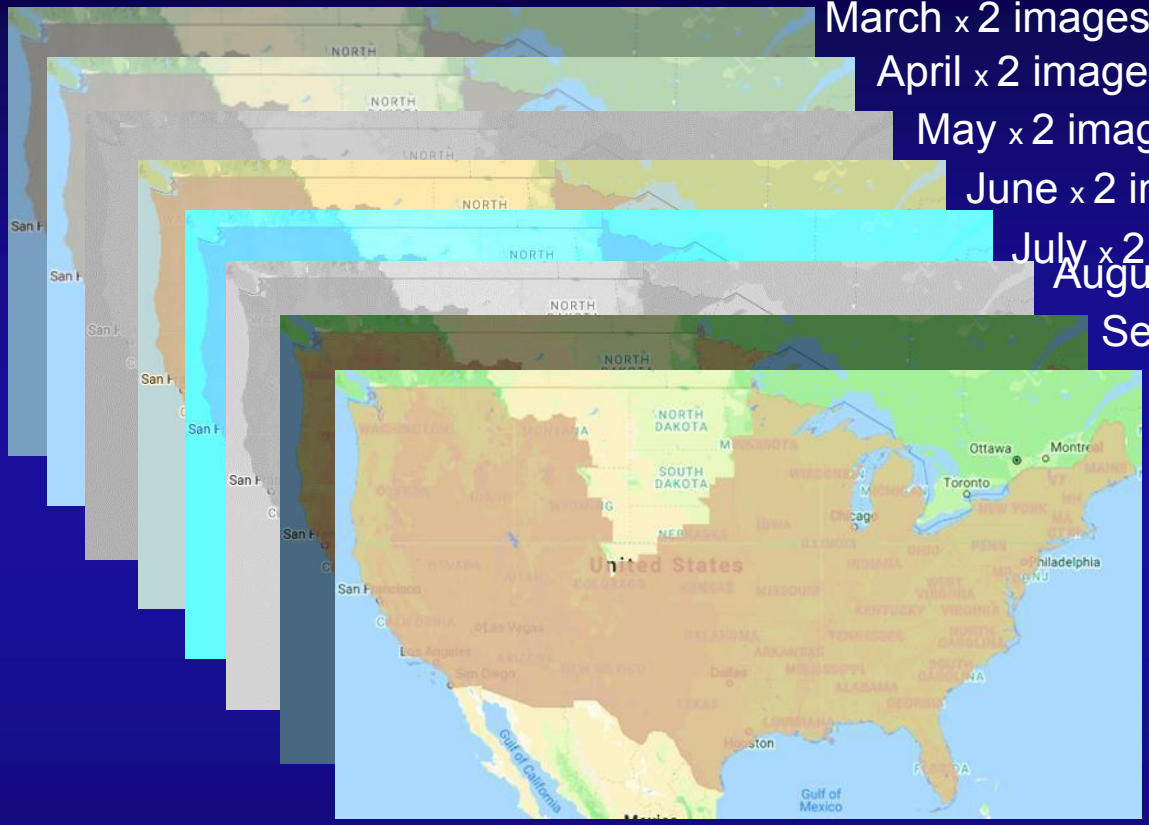
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Methods: MODIS 250m time-series data cube



1. 16 images from March to October; composited

PLUS

2 multi period composites

2. One image: Full Growing Season: Sum of Apr B, May A, May B, Jun A, Jun B, Jul A, Jul B, Aug A, Aug B, Sept A, Sept B

3. One image: Growing Season: Sum of May B, Jun A, Jun B, Jul A, Jul B

Total 18 layers of MODIS 250m data in the Analysis Ready Data (ARD) Cube

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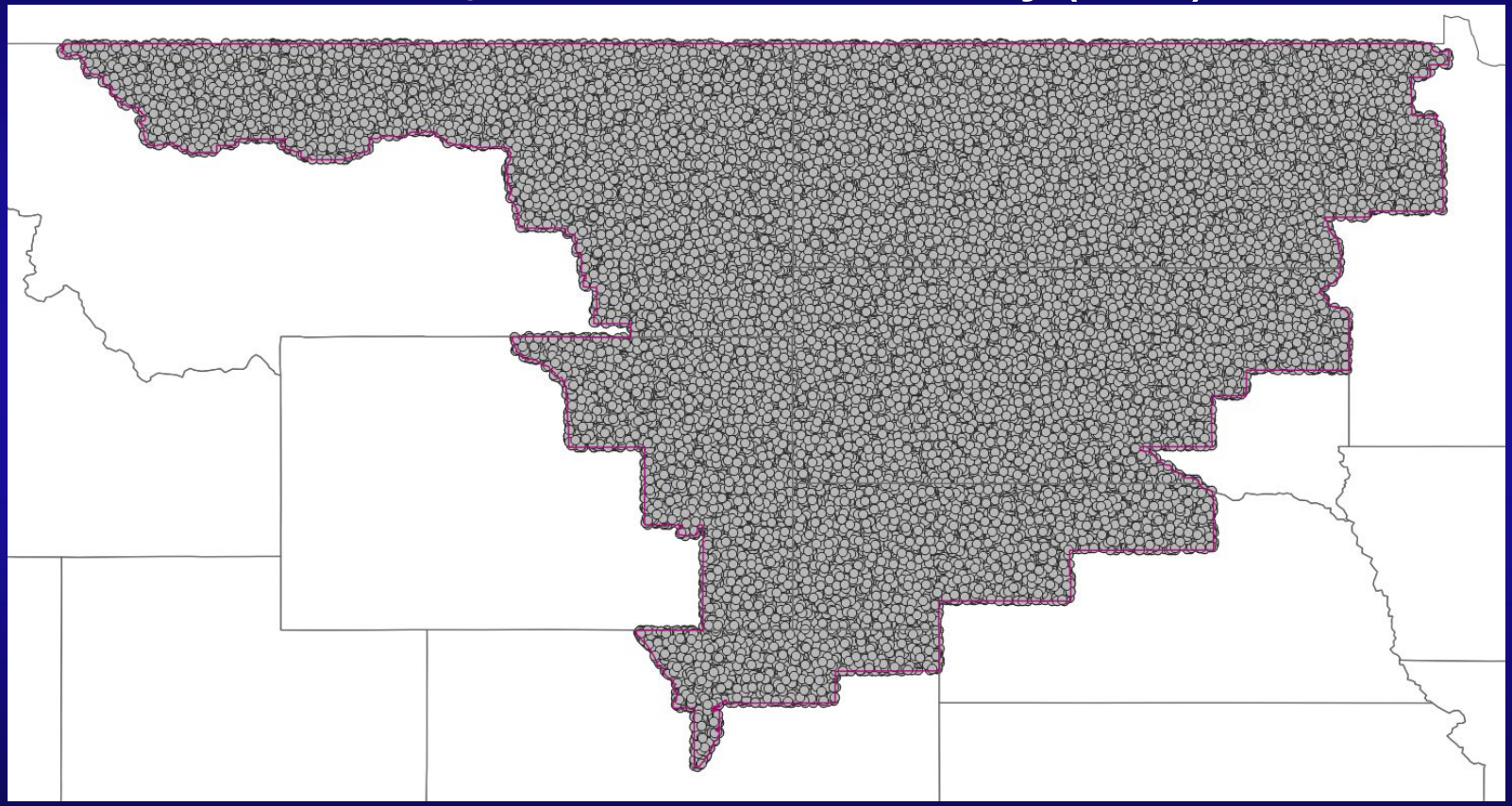
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Reference Training and Validation Data for ACFA Models

Training, Testing, and Validation Data Samples were gathered from three years: Wet (2019) years, Normal (2015), and Dry (2017)



Note: Source of training data is USDA CDL

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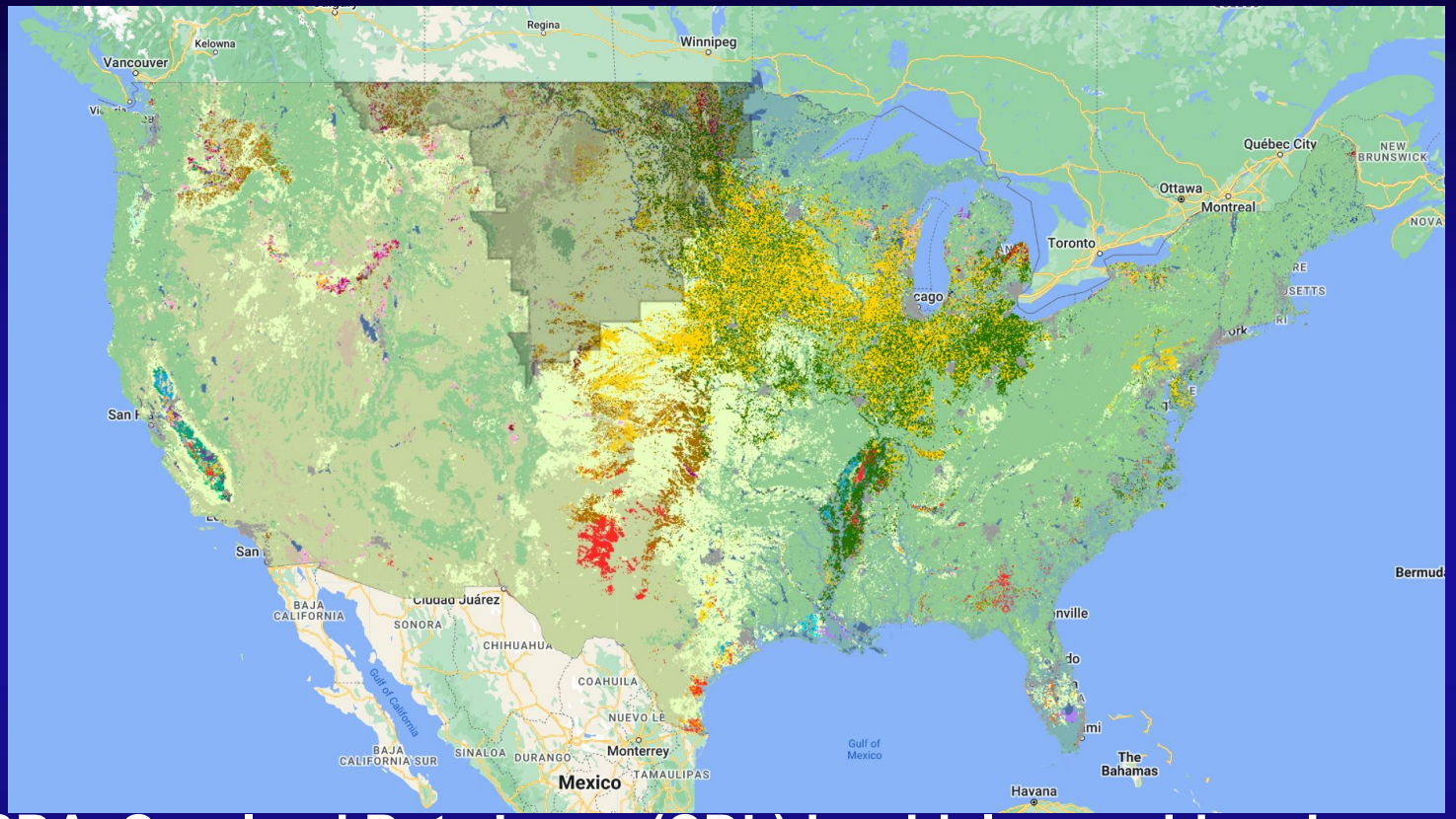
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Filtering Training and Validation Data for ACFA Models



The USDA Cropland Data Layer (CDL) is widely considered accurate product (gold standard) for croplands;

Known issues/errors in CDL fallowland classification

Note: Source of training data is USDA CDL

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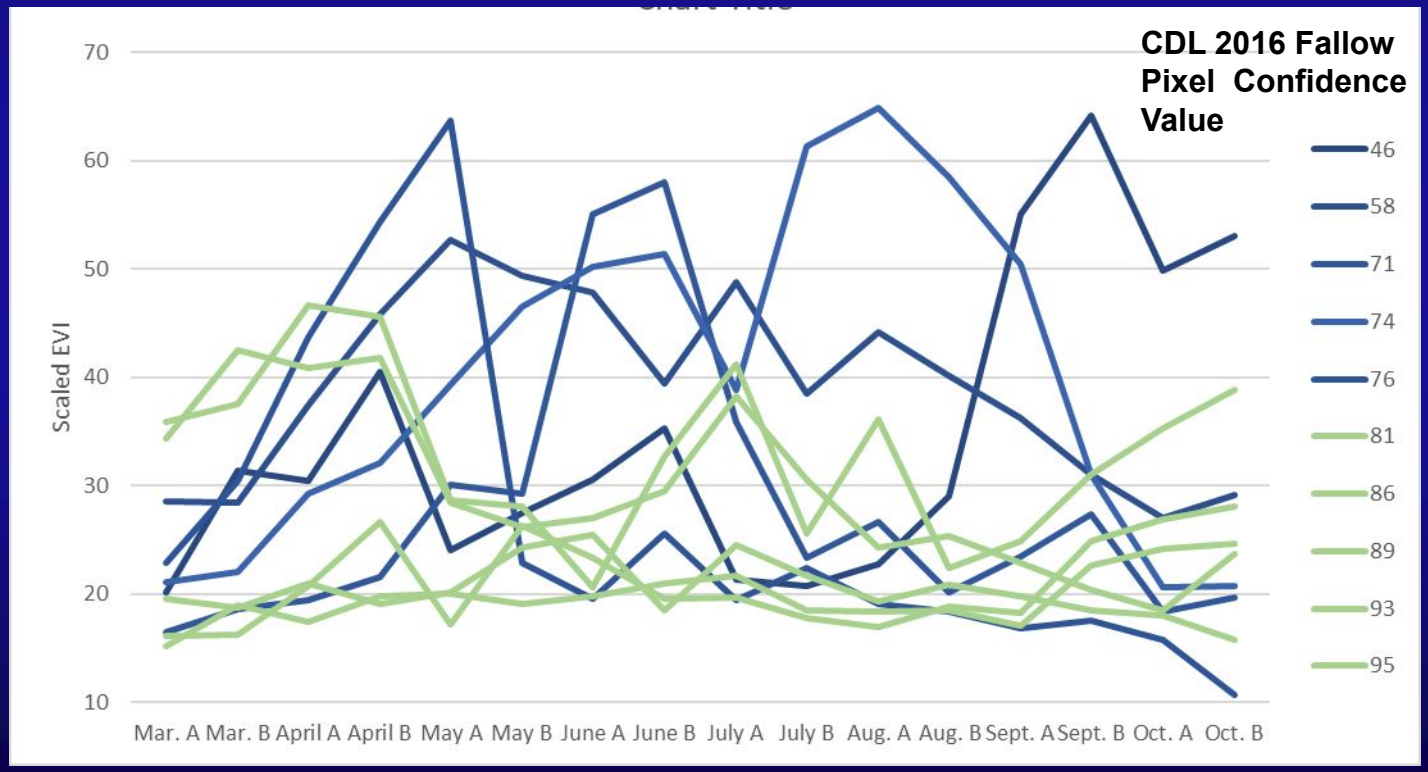
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Filtering Training and Validation Data for ACFA Models

CDLs have an internal confidence band which indicates level of confidence classifier has that the pixel was classified correctly. An examination of MODIS signatures indicates that a correlation exists between low confidence and low accuracy. We only used pixels with confidence greater or equal 80 for ACFA training and validation.



Pixels mapped with <80% confidence were NOT used

Only pixels mapped with >80% confidence were used

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Filtered Training and Validation Data for ACFA Models

To generate reference data, 70k random samples were generated for 2015, 2017, and 2019. Samples were filtered to remove samples closer than 1 km apart. Then samples falling outside North America GFSAD30 were removed along with samples with a CDL crop confidence rating of less

Finally, in order to remove samples which contained multiple landcover classes, a sieving filter was ran.

Class	Full Dataset	GFSAD	Confidence GTE 80	Used in Training	Used in Validation
Mixed Pixels	61,432	38,346	18,666		
Cropland	30,863	30,005	22,600	11,355	5,598
Fallow	1,647	1,624	1,194	618	305
Non-Cropland	114,548	3,672	2,376		
Total	208,490	73,647	44,836	11,973	5,903

2017, 2015, 2019 Pooled training data: Dry, Normal, and Wet years

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Additional Cropland Fallow Samples from Other Sources

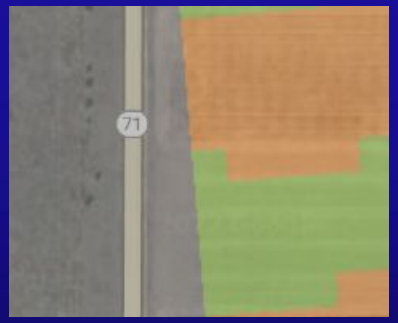
Croplands or Cropland Fallows from VHRI:

These are interpreted by zooming-into Very High Spatial-Resolution Imagery (VHRI) from Google Streetview and NAIP and observing for specific dates of a given year:

whether a crop exists or whether field is left fallow

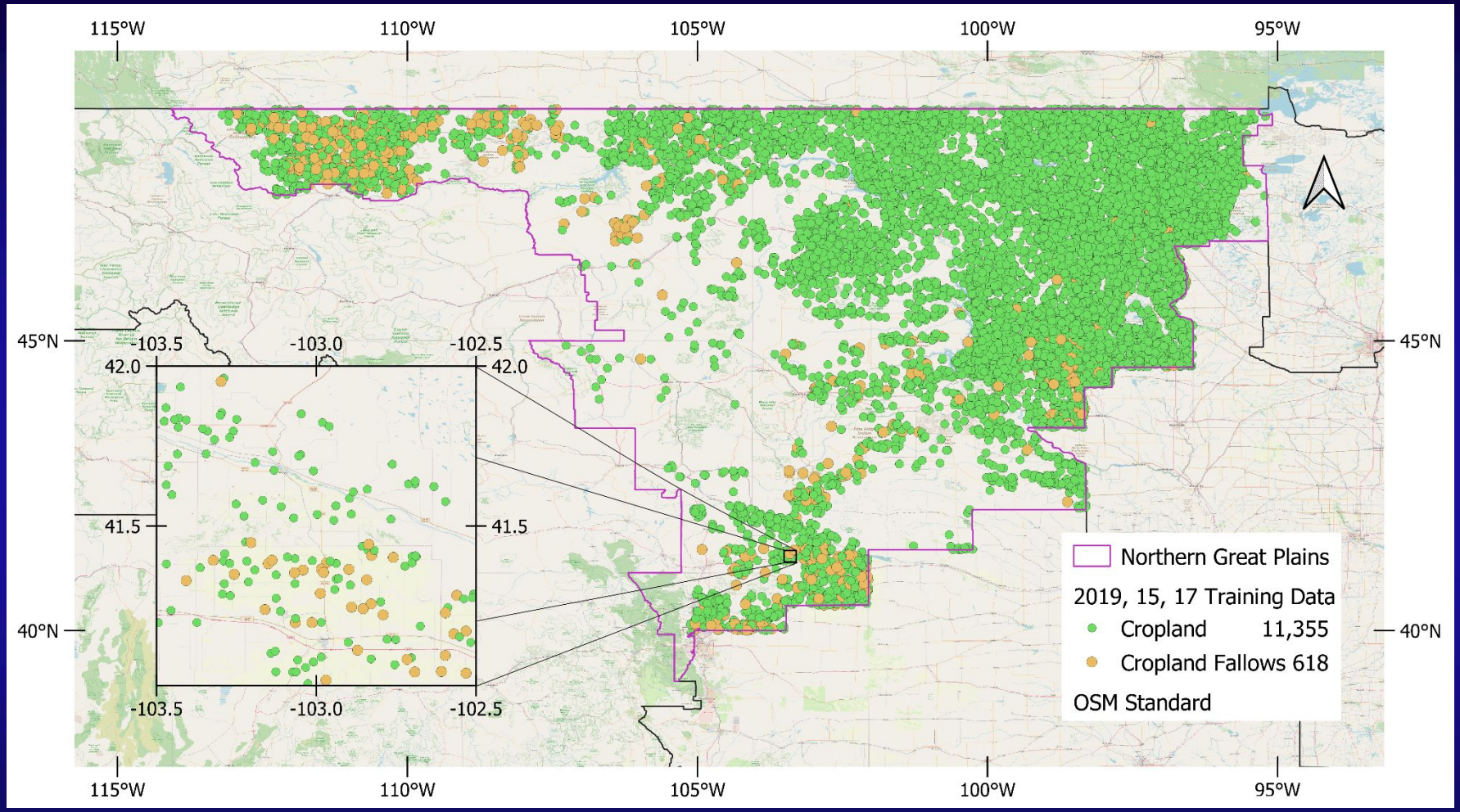
CDL data
Cropland
Cropland Fallows

Google Streetview



Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Final Distribution of Reference Training Samples



Pooled training data: Wet (2019) years, Normal (2015), and Dry (2017)

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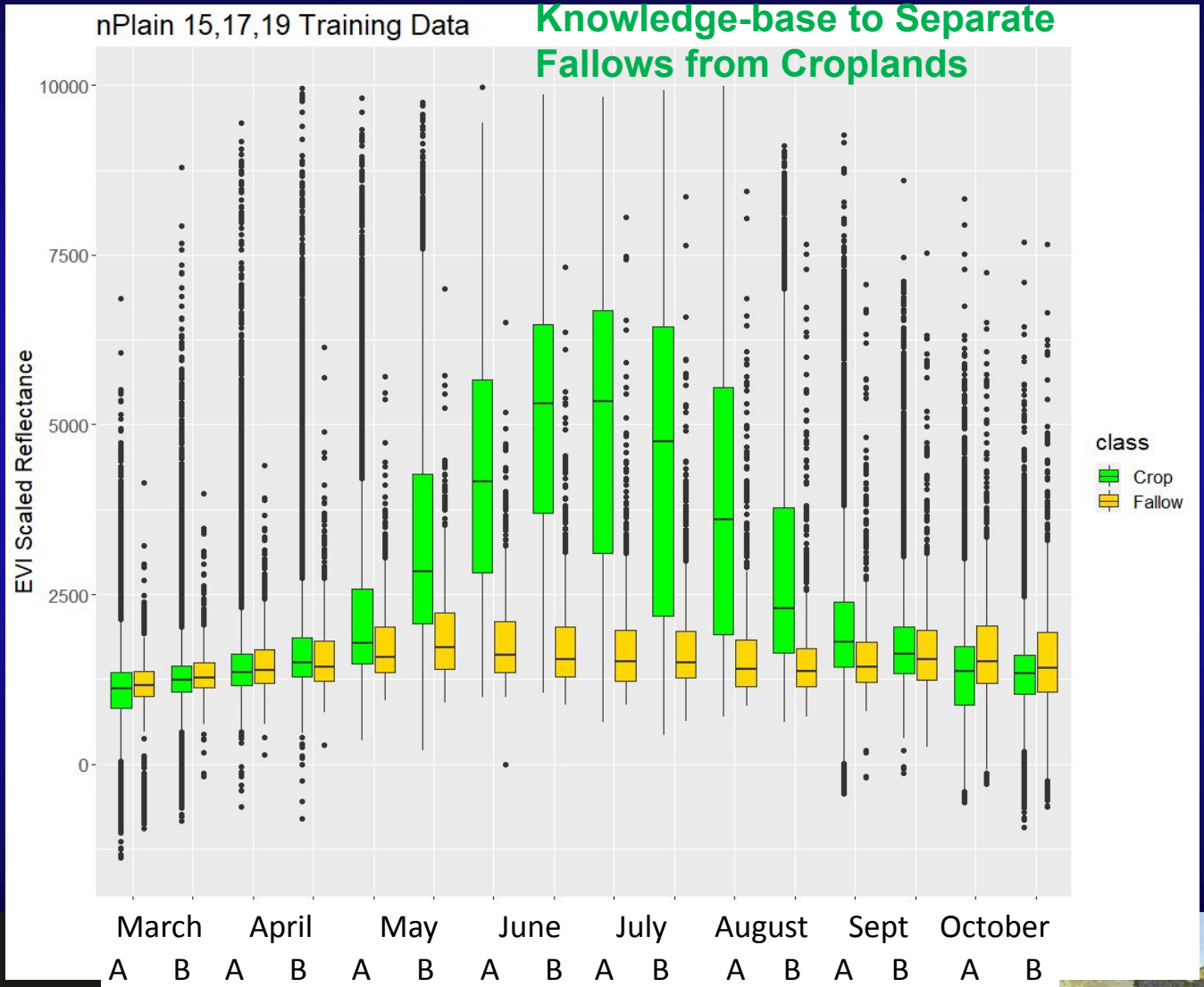
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Knowledge Base for the ACFA algorithm: EVI value illustration



Northern Great Plains 2019-2015-2017	
Cropland	11355
Fallow	618

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Methods: Classification and Decision Tree ACFA Model

1. **Decision trees** use machine learning to create a series of binary splits in data in order to categorize data based on a training datasets.

2. **Why decision trees:** Decision trees have advantages to Random Forest for research since the trees can be viewed and understood which makes analysis easier and more repeatable.

3. **Parameters:** rPart has a variety of optimization parameters which can be user selected to optimize the classification performance. The most important of which is loss matrix and CP which are defined on the following slides.

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Methods: Classification and Decision Tree ACFA Model

Cropland and Fallow samples randomly split 1/3 validation, 2/3 training.

- **Trained using data from 2019, 2015, 2017**
- **Many trees were tried by trial and error to obtain optimal solution**

- **Several parameters were optimized**
  1. **Loss Matrix: Since the goal of the work is to correctly classify cropland fallows, a rare class, fallowland classification was prioritized x2-times relative to croplands in classification to give more weightage to cropland fallow classes.**
  2. **Complexity parameter (CP): CP optimizes tree size by limiting size of final nodes. Too many nodes creates mathematical artifact that doesn't add to accuracies but creates an artificial artifact.**

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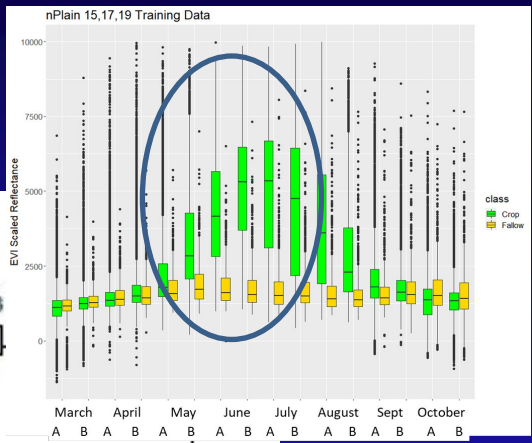
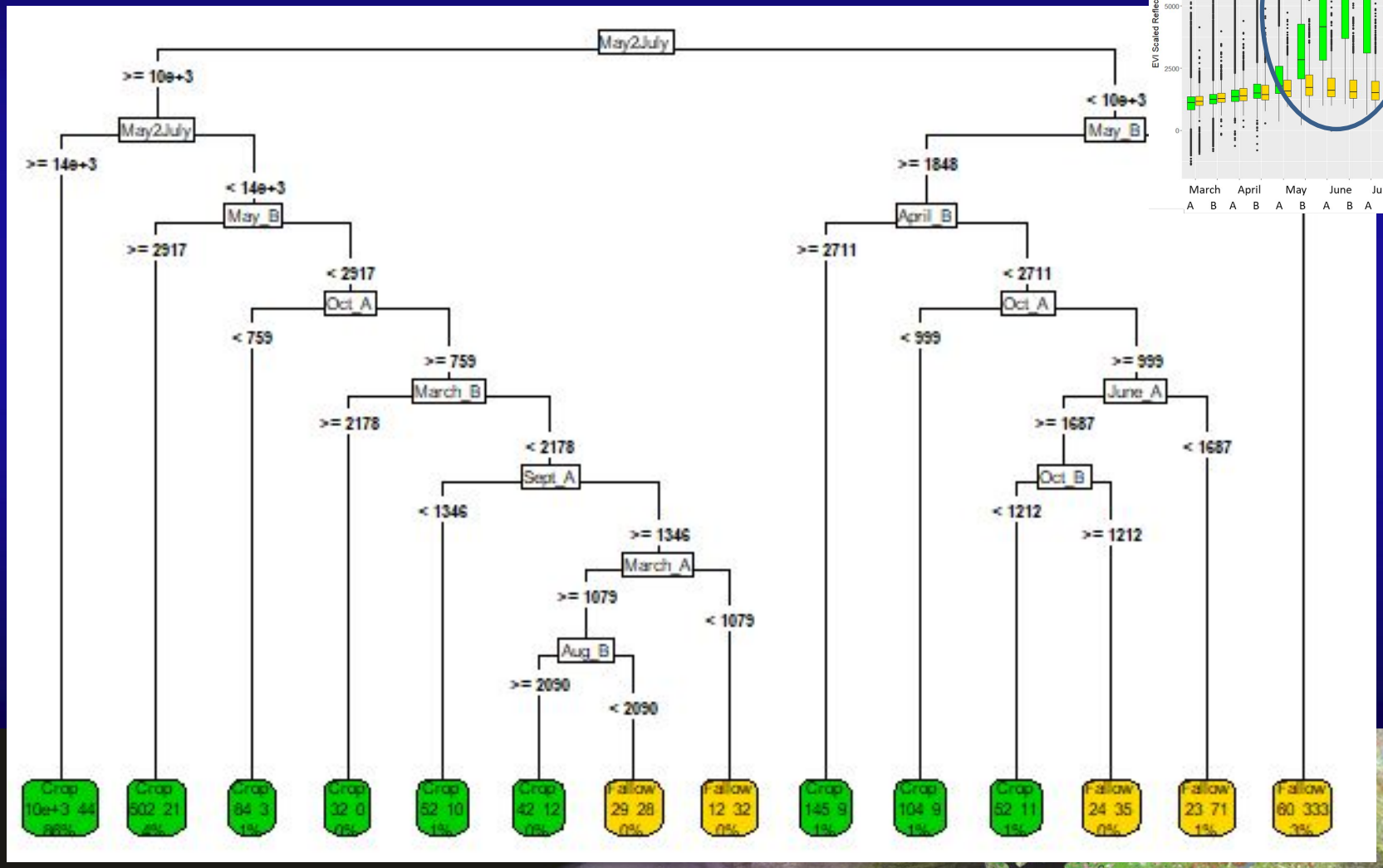
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Methods: Decision Tree ACFA Model, the Best one

Cropland *versus* cropland fallows are best separated during second half of May through second half of July. So, that becomes primary node.





Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Results: Accuracy Error Matrices from Multi-year ACFA Model

Cropland and Fallow samples from 2015, 2017, 2019
randomly split 1/3 validation, 2/3 training
Penalty Matrix priorities Fallow accuracy x2 more than Cropland accuracy

Error Matrix for Training Data

Training	Cropland	Fallow	Row total	Commission error
Cropland	**11207**	119	11326	1.1%
Fallow	148	**499**	647	22.9%
Column total	11355	618	**11973**	
Omission error	1.3%	19.3%		
Producer accuracy	98.7%	80.7%		
User accuracy	98.9%	77.1%		
Overall accuracy				**97.8%**

Final decision tree model results for training and validation data for the years 2017 (dry), 2015 (normal), and 2019 (wet).

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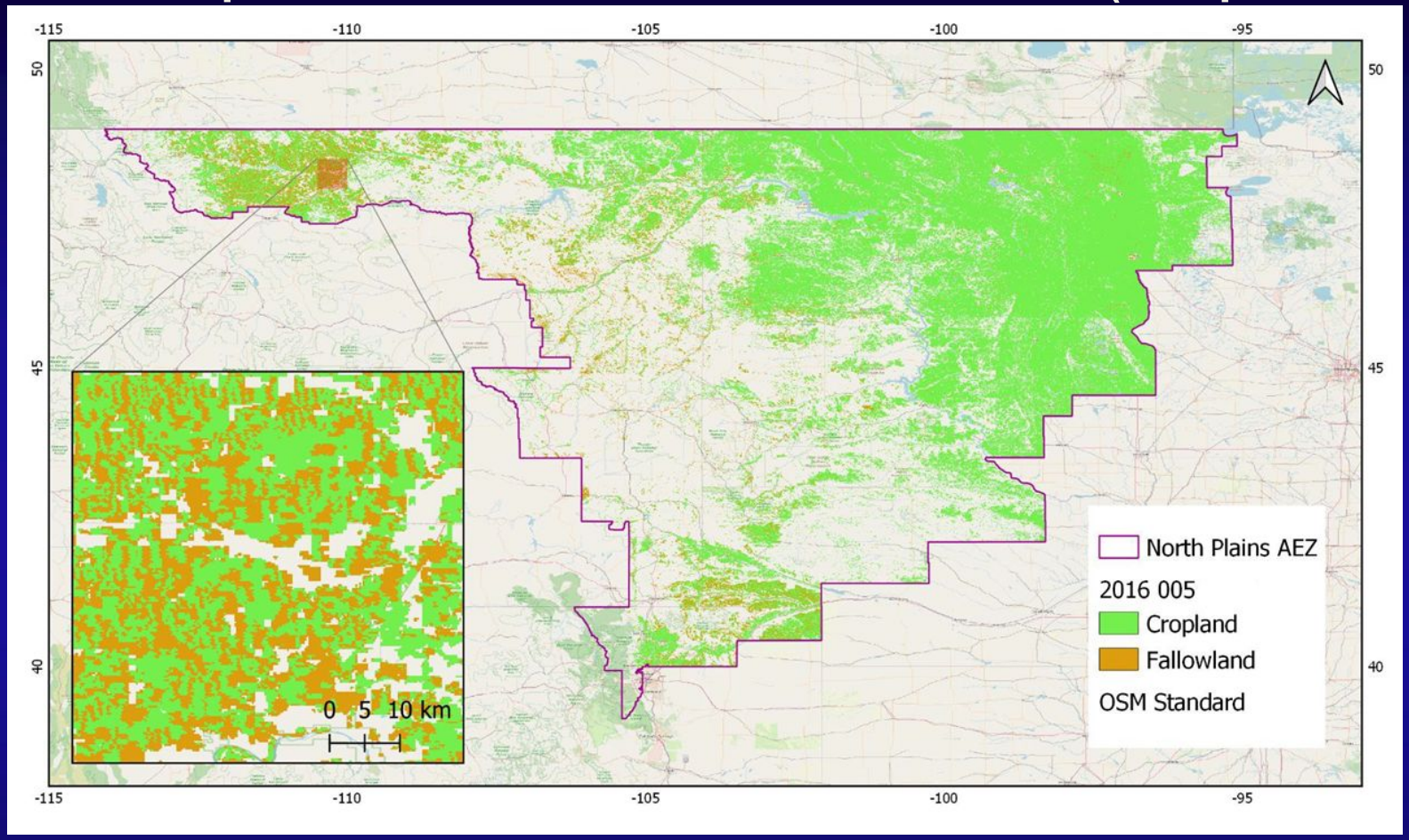
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Results: Cropland Fallow Product for the Year 2016 (independent year)



This is automatically generated cropland fallow and cropland product by ACFA for a independent year 2016 (a wet year)

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Accuracies: Cropland Fallow Product of Year 2016 (independent year)

Error Matrix/ comparison matrix for AFCA map
2016 Validation data Normal Year

2016	Cropland	Fallow	Row total	Commission error
Cropland	**6270**	75	6345	1.2%
Fallow	80	**330**	410	19.5%
Column total	6350	405	**6755**	
Omission error	1.3%	18.5%		
Producer accuracy	98.7%	81.5%		
User accuracy	98.8%	80.5%		
Overall accuracy				**97.7%**

Overall accuracies 97.7%

Cropland fallows had 81.5% producer's accuracies (18.5% errors of omissions) and 80.5% user's accuracies (19.5% errors of commissions)

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Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

Accuracies: Cropland Fallow Product for Independent Years

Year	Fallowland Accuracy		Overall
	Producer's	Users %	Accuracy %
2020	78.3	79.6	94.2
2018	69.3	72.5	98.9
2016	79.4	82.9	97.8
2014	78.0	84.1	97.0
2013	81.1	79.3	96.3
2012	72.2	80.4	96.6
2011	76.3	79.7	96.0
2010	73.0	88.1	96.3

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Conclusions

1. A robust automated cropland fallowland algorithm (ACFA) was successfully developed for the US Northern Great Plains based on MODIS remote sensing data;

2. Ability to compute cropland fallows accurately, repeatedly year after year for the past, present, and future years is a great strength of ACFA;

3. The model can be substantially improved if the cropland fallow reference training and validation data have perfect reliability and accuracy. This we are further working on based on using Planetscope 3-4 meter data as reference.

Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

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Wallace, C.S.A., Thenkabail, P.S., Rodriguez, J.R., and Brown, M.K. 2017. Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA) to Map Croplands versus Cropland Fallows using MODIS Data to Assist in Drought Studies Leading to Water and Food Security Assessments. Special Issue on Advances in Remote Sensing and GIS-based Drought Monitoring. GIScience and Remote Sensing. 54(2): 258-282. http://dx.doi.org/10.1080/15481603.2017.1290913.

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Thenkabail P.S., Wu Z. An Automated Cropland Classification Algorithm (ACCA) for Tajikistan by Combining Landsat, MODIS, and Secondary Data. Remote Sensing. 2012; 4(10):2890-2918. (65%). Download the paper @ this link: http://www.mdpi.com/2072-4292/4/10/2890. ACCA algorithm at this link:http://www.sciencebase.gov/catalog/folder/4f79f1b7e4b0009bd827f548.

Wu, Z., Thenkabail, P.S., Zakzeski, A., Mueller, R., Melton, F., Rosevelt, C., Dwyer, J., Johnson, J., Verdin, J. P., 2014. Seasonal cultivated and fallow cropland mapping using modis-based automated cropland classification algorithm. J. Appl. Remote Sens. 0001;8(1):083685. doi: 10.1117/1.JRS.8.083685. IP-044862.

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USGS

Thank you

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Dr. Pardha Teluguntla*, Dr. Itiya Aneece*, Mr. Daniel Foley*
*** Western Geographic Science Center, US Geological Survey**

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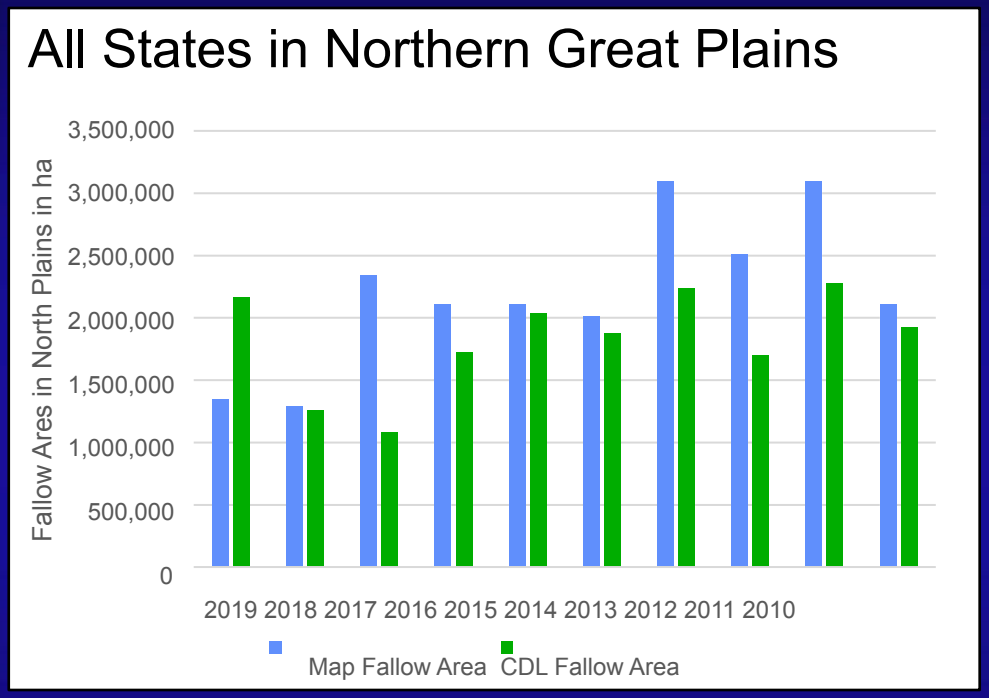
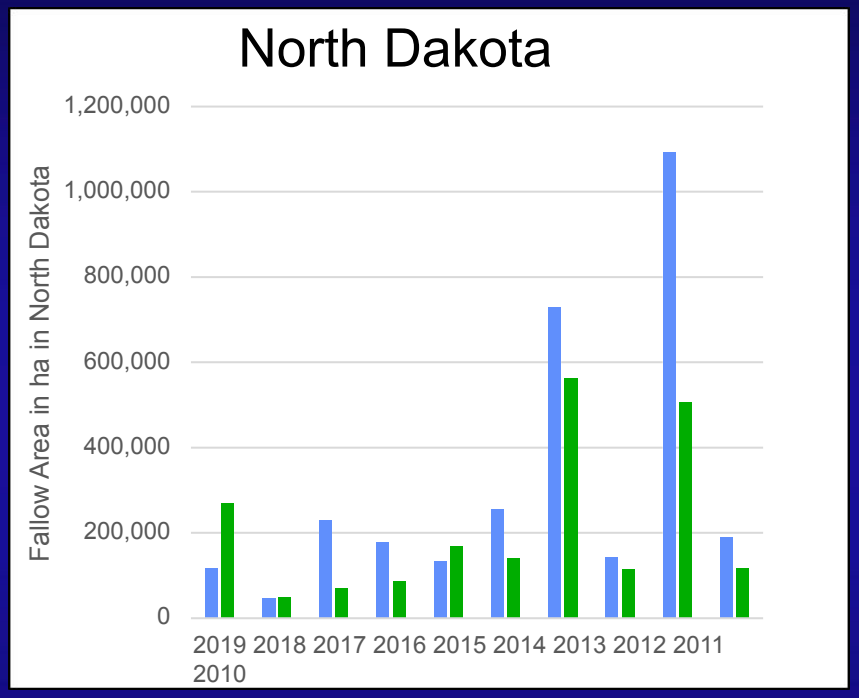
Automated Cropland Fallow Algorithm (ACFA) for the Great Plains of USA

CDL Area Comparisons





1. **The ACFA algorithm overall estimated higher cropland fallows area than CDL**

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