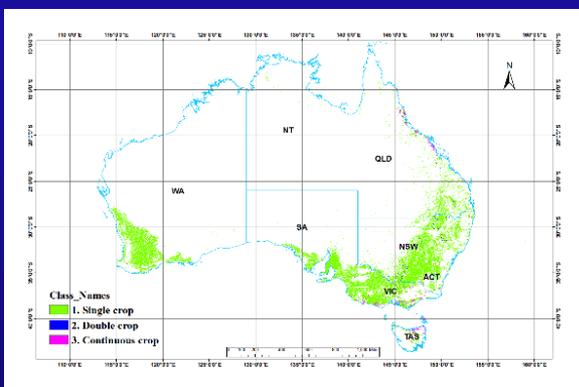
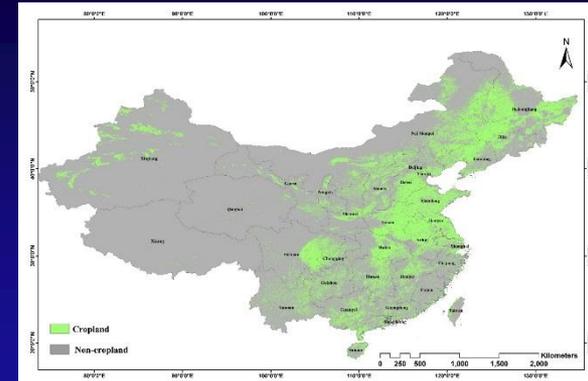
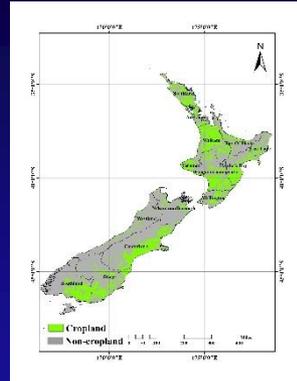
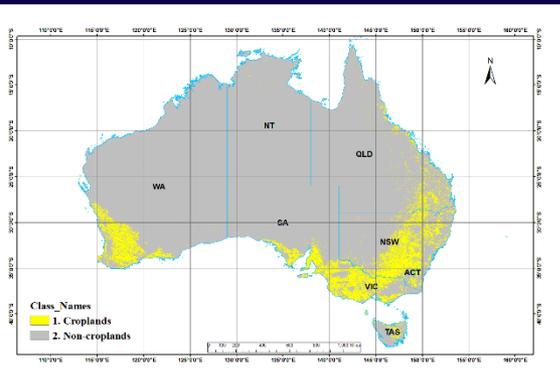
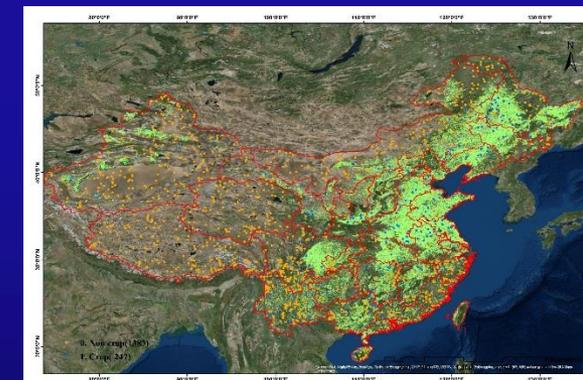


Cropland Mapping of Australia, New Zealand and China @ Landsat 30-m using Random Forest Algorithm and Google Earth Engine (GEE) Cloud Computing



Pardhasaradhi Teluguntla¹
Prasad S. Thenkabail
1= Research Scientist
Bay Area Environmental Research Institute (BAERI) and U. S. Geological Survey



February 7-9, 2017

GFSAD30 Workshop, NASA Ames Research Center, CA, USA



U.S. Geological Survey
U.S. Department of Interior



Cropland Products Overview

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



U.S. Geological Survey
U.S. Department of Interior



Overview: Mapping @ 3 Resolutions

Recall our Goal:

“The Ultimate Goal of the GFSAD30 project is to produce accurate global cropland products @ nominal 30 m resolution”

What we have done and what we will do:

However, we are doing this at three levels to better understand, model, and map croplands of the world. The 3 resolutions are:

- 1 km for nominal year 2010 (Teluguntla et al., 2015),
- 250m for 2000-2015 for Australia (Teluguntla et al., 2017), and
- 30m nominal Year 2014 (Focus of this presentation)

GFSAD30 cropland products:

1. cropland extent\areas,
2. cropland watering method (irrigated or rainfed),
3. cropping intensities (single, double, triple, or continuous cropping),
4. crop type and\or dominance; and
5. croplands versus cropland fallows.



Croplands of Australia, New Zealand and China

Background

- Australia is a major agriculture Producer and exporter
- Cereals, Oil seeds and grain legumes are produced on a large scale in Australia for human **consumption** and **livestock feed**
- Each Australian farmer produces enough food to feed 600 people; 150 at home and 450 overseas.
- Contribute \$ 48 billion to the Australian Economy (3% of GDP) and its closely related sectors contribute another \$120 Billion (9% of GDP)
- Pastoral farming for sheep and dairy is also major land/use in Australia



Croplands of Australia, New Zealand and China

Background

- Agriculture in New Zealand is the largest sector of the tradable economy.
- Value of exports \$16 billion per annum
- Approximately which is 2/3rd of total production
- Pastoral farming is the major land use but there are increases in land area devoted to horticulture.



Croplands of Australia, New Zealand and China

Background

- Agriculture is a vital industry in China, employing over 300 million farmers.
- China ranks first in worldwide farm output
- Primarily producing rice, wheat, potatoes, sorghum, peanuts, tea, millet, barley, cotton, oilseed and soybeans.
- China produces food for 20 percent of the world's population. Although accounting for only 10 percent of arable land worldwide.



Cropland Products

~1-km for nominal 2010

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



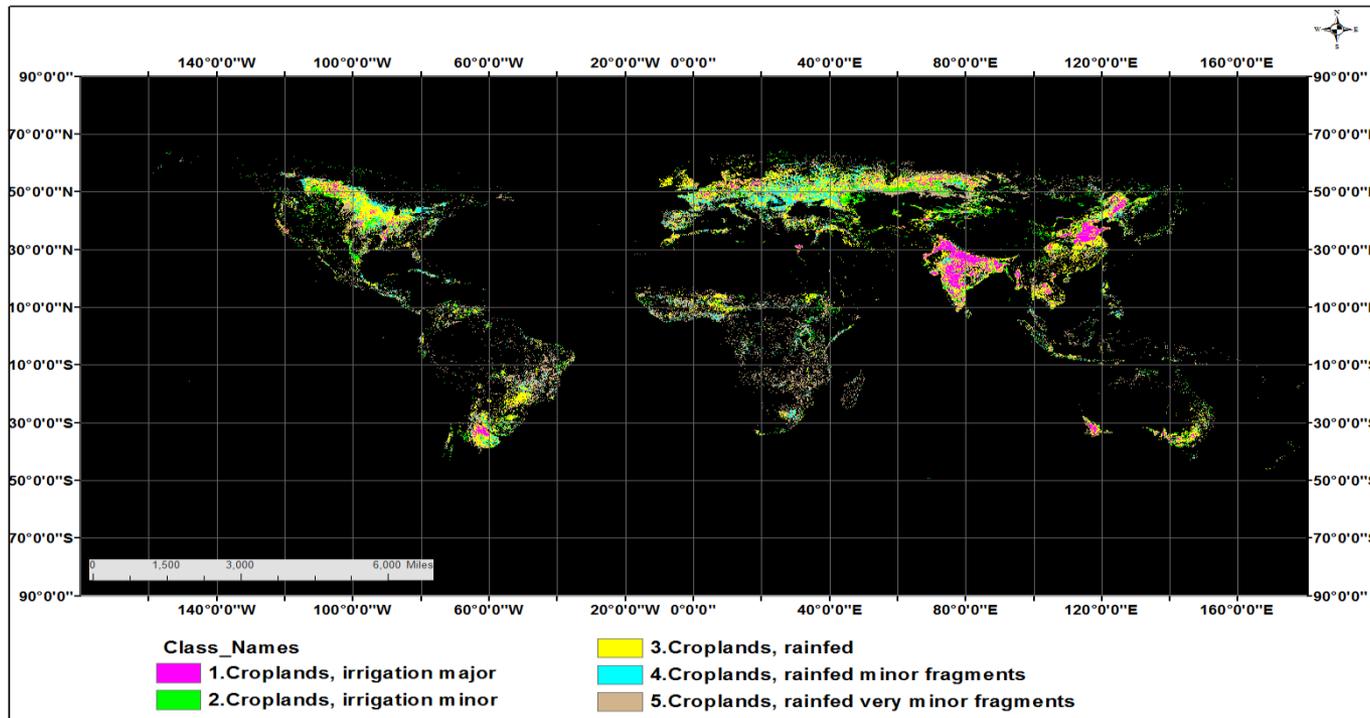
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Global Cropland Extent Version 1.0 (GCE V1.0)

based on Thenkabail et al. 2009, Pittman et al. 2010, Yu et al., 2013 and Fried et al.2010

5 Classes



~2.3 billion hectares full pixel area (FPAs) with 34% irrigated and 66% rainfed.

This product is available @:

<http://geography.wr.usgs.gov/science/croplands/products.html>



U.S. Geological Survey
U.S. Department of Interior

Teluguntla, P., Thenkabail, P.S., Xiong, J., Gumma, M.K., Giri, C., Milesi, C., Ozdogan, M., Congalton, R., Tilton, J., Sankey, T.R., Massey, R., Phalke, A., and Yadav, K. 2015. Global Food Security Support Analysis Data at Nominal 1 km (GFSAD1km) Derived from Remote Sensing in Support of Food Security in the Twenty-First Century: Current Achievements and Future Possibilities, Chapter 6. In Thenkabail, P.S., (Editor-in-Chief), 2015. "Remote Sensing Handbook" (Volume II): Land Resources Monitoring, Modeling, and Mapping with Remote Sensing, Taylor and Francis Inc./CRC Press, Boca Raton, London, New York. ISBN 9781482217957 - CAT# K22130. Pp. 131-160.

Australia
Cropland Products
~250-m for 2000-2015+

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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Cropland Mapping @ 250-m Resolution

MODIS 16-day time-series data and automated cropland classification algorithm (ACCA)

A. Products

Products:

1. Croplands vs. non-croplands;
2. Irrigated vs. rainfed;
3. Cropping intensity;
4. Croplands versus cropland falls

C. Manuscripts/Publications

<http://www.tandfonline.com/doi/pdf/10.1080/17538947.2016.1267269?needAccess=true>

B. Algorithms

http://geography.wr.usgs.gov/science/croplands/algorithms/australia_250m.html

Automated Cropland Classification Algorithm (ACCA) for Australia using MODIS 250-m Time-series

Pardhasaradhi Teluguntla 1,2 (pteluguntla@usgs.gov) and Prasad S. Thenkabail 1 (pthenkabail@usgs.gov)

1 - U.S. Geological Survey, 2 - Bay Area Environmental Research Institute

We have provided here automated cropland classification algorithm (ACCA) model (Figure 1) for Australia along with sample: (A) MODIS 250-m time-series data used to produce (B) cropland masks, and (C) output cropland product (Figure 2), and a readme file. User's can download the ACCA algorithm (Figure 1, in .gmd format downloadable (see below) that is in ERDAS Imagine modeler compatible format (.Lands file) and run using the MODIS 250-m time-series data and re-produce the output (Figure 2).

Details of the process is provided in the readme file. So, please download the readme file first and then follow the detailed procedure.

ACCA algorithm of Australia can be used to re-produce the cropland products of Australia year after year using MODIS 250-m time-series data for the corresponding year. Thereby, ACCA algorithm has the ability to reproduce cropland products of the past years (hind-cast), present year (now-cast), and future years (future-cast) as we report in the paper.

The automated cropland classification algorithm (ACCA) is written in ERDAS Modeler, and hence the algorithm file is available in .gmd format.

- Algorithm
 - Models (GMD Format)
- Output
 - Outputs
- Readme
 - Automated cropland classification algorithm (ACCA) Readme for the .gmd ACCA algorithm
- Dataset
 - Modis
 - Mask

1. MODIS 250m, every 16-day NDVI time series data for year 2014

2. Unique and distinct knowledge of Croplands established

International Journal of Digital Earth

ISSN: 1753-8947 (Print) 1753-8955 (Online) Journal homepage: <http://www.tandfonline.com/loi/ijde20>

Spectral matching techniques (SMTs) and automated cropland classification algorithms (ACCAs) for mapping croplands of Australia using MODIS 250-m time-series (2000–2015) data

Pardhasaradhi Teluguntla, Prasad S. Thenkabail, Jun Xiong, Murali Krishna Gumma, Russell G. Congalton, Adam Oliphant, Justin Poehnel, Kamini Yadav, Mahesh Rao & Richard Massey

To cite this article: Pardhasaradhi Teluguntla, Prasad S. Thenkabail, Jun Xiong, Murali Krishna Gumma, Russell G. Congalton, Adam Oliphant, Justin Poehnel, Kamini Yadav, Mahesh Rao & Richard Massey (2017): Spectral matching techniques (SMTs) and automated cropland classification algorithms (ACCAs) for mapping croplands of Australia using MODIS 250-m time-series (2000–2015) data, International Journal of Digital Earth, DOI: [10.1080/17538947.2016.1267269](https://doi.org/10.1080/17538947.2016.1267269)

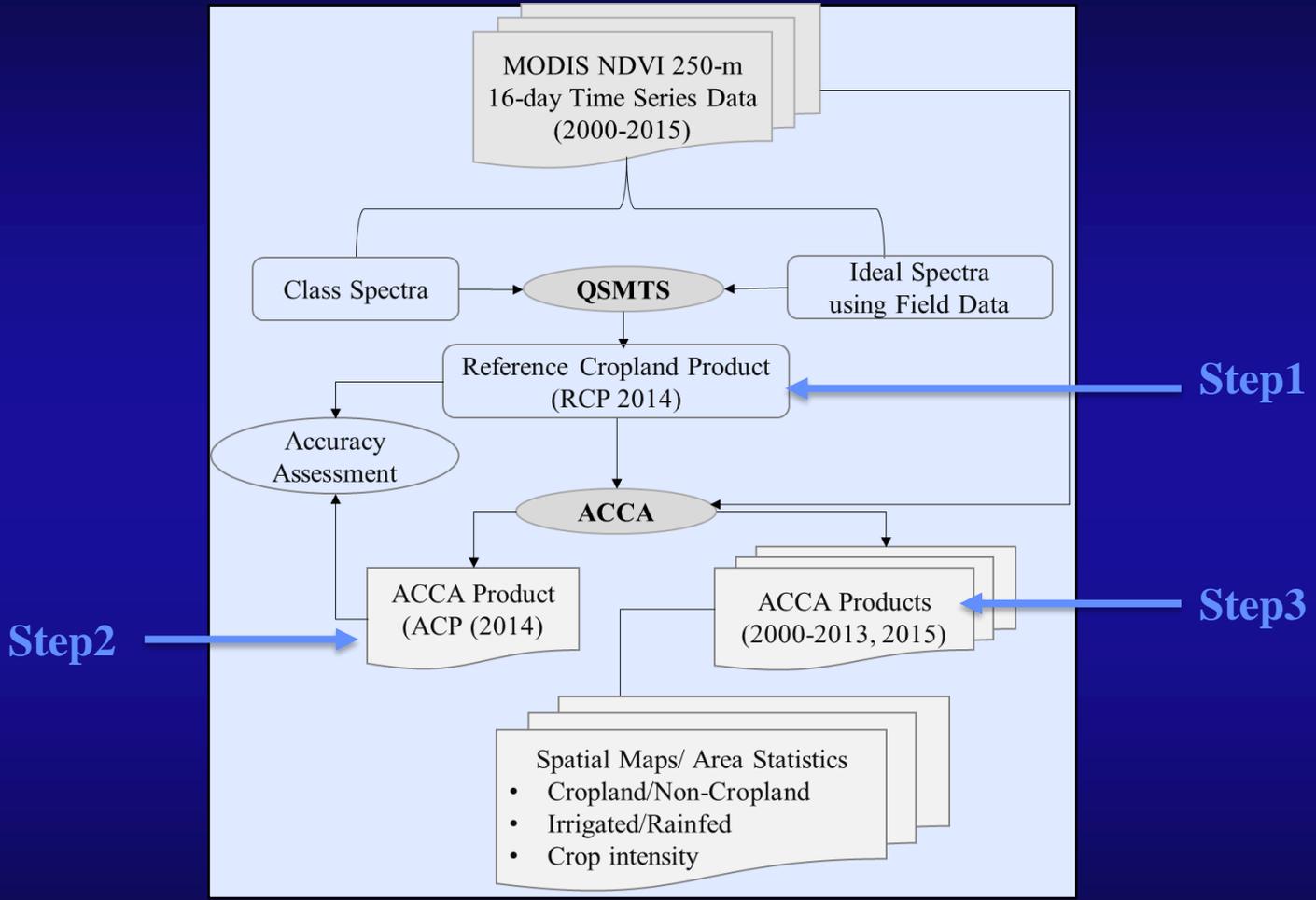
To link to this article: <http://dx.doi.org/10.1080/17538947.2016.1267269>

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Published online: 06 Jan 2017.

Cropland Products of Australia @ Nominal 250 m

Approach for Producing Cropland Products from Years 2000 through 2015



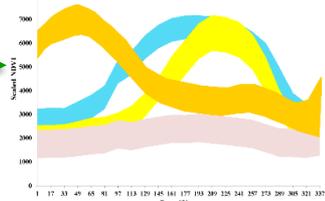
Automated Cropland Classification Algorithm (ACCA) for Australia

Knowledge Capture and Coding for Each Mask Separately

Knowledge Capture

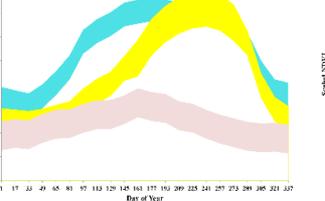
2. Unique Knowledge of Croplands established

Class spectra (unique) Knowledge for Rainfed Mask Area



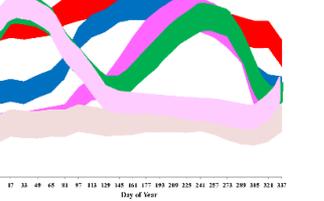
- 1c. Croplands, rainfed, SC (season1), all crops (3classes)...1a
- 2c. Croplands, rainfed, SC, pastures (16classes).....2
- 3c. Croplands, rainfed, SC (season2), all crops (1class).....1b
- 11c. Croplands, fallows (80) (2classes).....6

Class spectra (unique) Knowledge for Pasture Mask Area



- 4c. Croplands, rainfed, SC (season1), all crops (5classes)...1
- 5c. Croplands, rainfed, SC, pastures (14 classes).....2
- 11c. Croplands, fallows (1class).....6

Class spectra (unique) Knowledge for Irrigated Mask Area



- 6c. Croplands, irrigated, SC (season1), all crops (3classes)...3a
- 7c. Croplands, irrigated, SC, pastures(6classes).....4
- 8c. Croplands, irrigated, continuous crop, Orchards (7classes)...5
- 9c. Croplands, irrigated, SC (season2), all crops (1class)...3b
- 10c. Croplands, irrigated, DC, all crops (1class).....3c
- 11c. Croplands, fallows (1class).....6

3. ACCA coding based on above unique and distinct knowledge of croplands

ACCA for Rainfed Mask Area

Class 1a (Rainfed, single crop, season 2)

If $\Sigma NDVI \geq 22400$ in time period 2 to 5 then Croplands, rainfed, Season2 crops

Class 6 (Rainfed, fallows)

If $\Sigma NDVI \leq 19600$ in time period 11 to 17 then Croplands, rainfed, fallows

Class 1b (Rainfed, single crop, season 1)

If $\Sigma NDVI \leq 10200$ in time period 6 to 8 then Croplands, rainfed, Season1 all crops

Class 2 (Rainfed, pasture)

If $\Sigma NDVI > 10200$ in time period 6 to 8 then Croplands, rainfed, pastures

Note: When coding this order must be noted to achieve best results:

1. First, class 1a is coded and the class 1a area is removed from further analysis;
2. Second, class 6 is coded and the class 6 area is removed from further analysis;
3. Third, class 1b is coded and the class 1b area is removed from further analysis;
4. Fourth, rest of the area is class 2;
5. Finally, we merge class 1a and 1b into a single class 1. Even though they are significantly different in signature, class 1a is a very small area compared to class 1b. Both are rainfed single crop classes.

ACCA for Pasture Mask Area

Class 6 (Rainfed, fallows)

If $\Sigma NDVI \leq 14600$ in time period 11 to 14 then Croplands, rainfed, fallows

Class 2 (Rainfed, pasture)

If $NDVI(1) > 3800$ or if $\Sigma NDVI > 9000$ in time period 5 to 7 or if $NDVI(5) > 6000$ or $NDVI(6) > 6000$ or $NDVI(7) > 6000$ or $NDVI(8) > 6000$ or $NDVI(9) > 6000$ or $NDVI(10) > 6000$ or $\Sigma NDVI > 9000$ and $\Sigma NDVI < 12000$ in time period 15 to 17 then Croplands, rainfed, pastures

Class 1 (Rainfed, single crop, season 1)

else Croplands, rainfed, Season1 all crops

Note: When coding this order must be noted to achieve best results:

1. First, class 6 is coded and the class 6 area is removed from further analysis;
2. Second, class 2 is coded and the class 2 area is removed from further analysis;
3. Third, rest of the area is class 1

ACCA for Irrigated Mask Area

Class 6 (Irrigated, fallows)

If $\Sigma NDVI \leq 10400$ in time period 8 to 11 then Croplands, irrigated, fallows

Class 5 (Irrigated, continuous)

If $\Sigma NDVI \geq 28000$ in time period 19 to 22 then Croplands, irrigated, continuous orchards or If $\Sigma NDVI \geq 18000$ in time period 2 to 4 or $(\Sigma NDVI \leq 32400$ and $\Sigma NDVI \geq 21600)$ in time period 13 to 18 then Croplands, irrigated, continuous, orchards

Class 3a (Irrigated, double crop)

If $\Sigma NDVI \geq 16800$ in time period 2 to 4 and $\Sigma NDVI \leq 13800$ in time period 8 to 10 and $\Sigma NDVI > 22400$ in time period 15 to 18 then Croplands, irrigated, double crop

Class 3b (Irrigated, single crop, season2)

If $\Sigma NDVI \geq 16800$ in time period 2 to 4 and $\Sigma NDVI \leq 8000$ in time period 12 to 13 then Croplands, irrigated, season#2

Class 4 (Irrigated, pastures)

If $\Sigma NDVI \geq 16200$ in time period 8 to 10 then Croplands, irrigated, pastures

Class 3c (Irrigated, single crop, season1)

else Croplands, irrigated, all crops

Note: When coding this order must be noted to achieve best results:

1. First, class 6 is coded and the class 6 area is removed from further analysis
2. Second, class 5 is coded and the class 5 area is removed from further Third, class 3a is coded and the class 3a area is removed from further analysis; then class 3b coded and the class 3b area is removed from further analysis;
3. Fourth, class 4 is coded and the class 4 area is removed from further analysis;
4. rest of the area is class 3c; Finally, we merge class 3a, 3b and 3c into a single class 3. Even though they are significantly different in signature, the areas are very smaller.

Note: This is coded in ERDAS Imagine Modeler, but can be coded anywhere (e.g., Google Earth Engine for Cloud Computing)

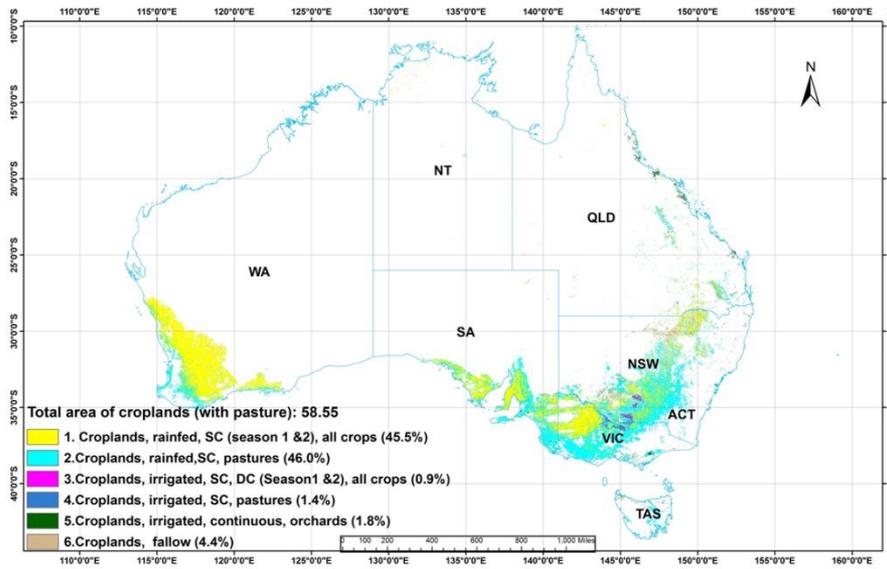


Cropland Products of Australia for the Year 2014

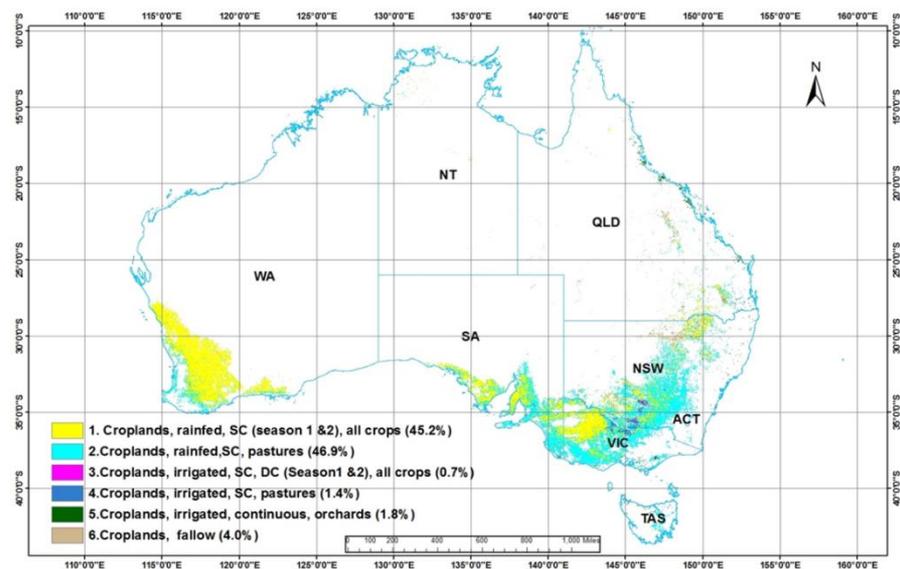
Reference Cropland Product *versus* ACCA derived Cropland Product

6 Classes: 1 rainfed sc, 1 rainfed pasture, 1 irrigated sc, 1 irrigated dc, 1 irrigated continuous, 1 cropland fallows

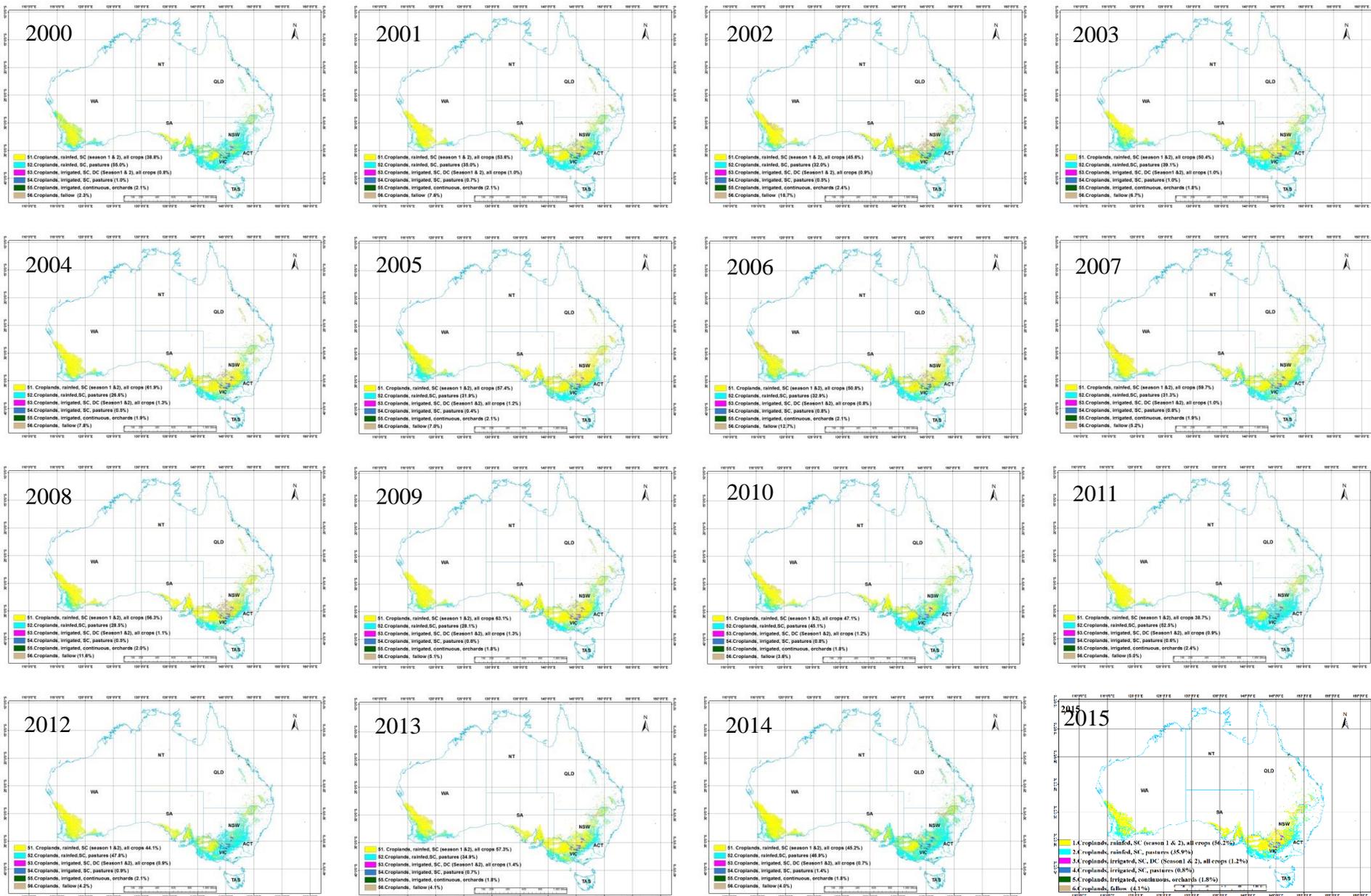
Reference Cropland Product: SMT approach



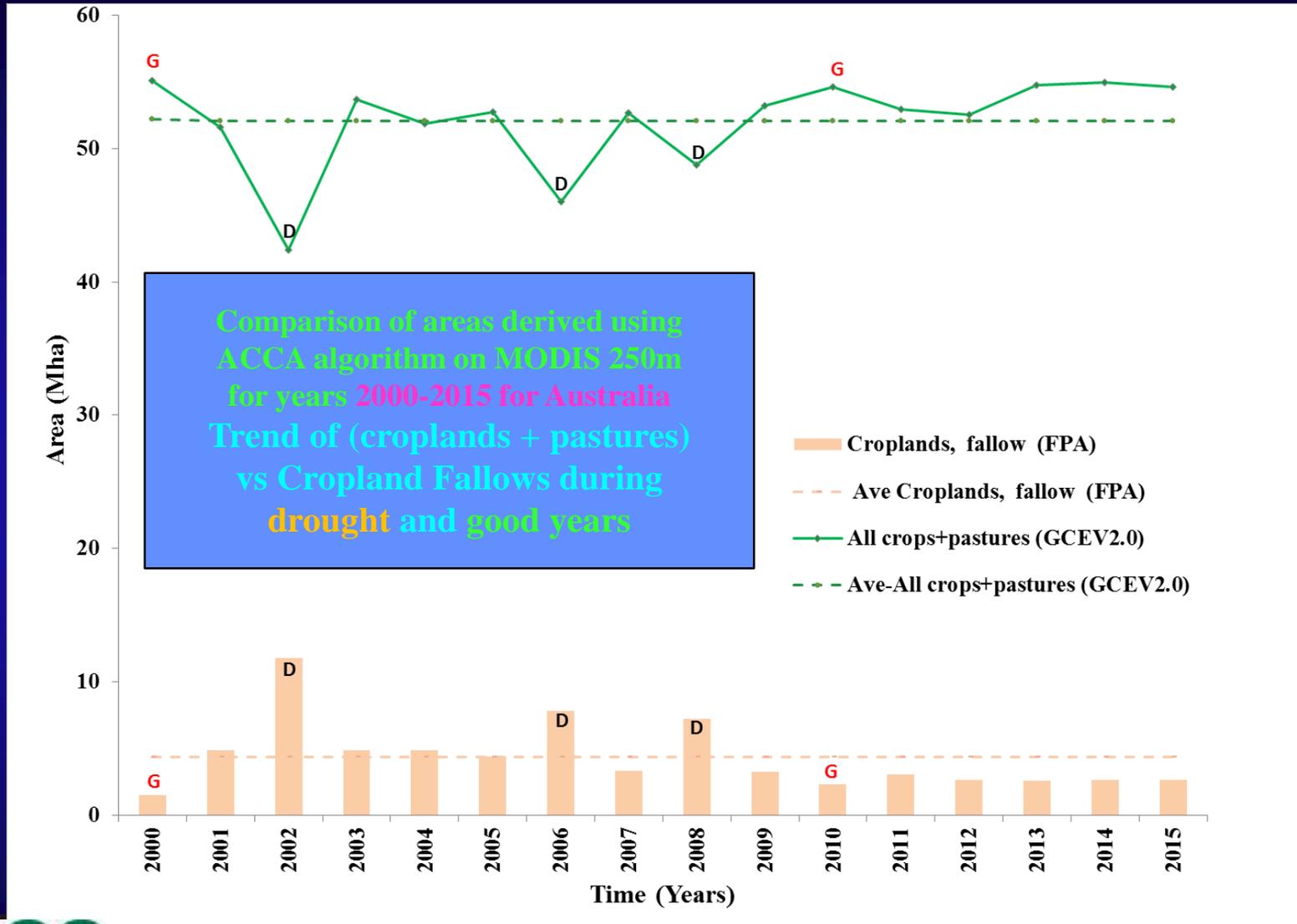
ACCA derived cropland product



ACCA Algorithm Derived Cropland Product (6 class map) of Australia @ MODIS 250 m: 2000 through 2015



ACCA Algorithm Derived Cropland Product (crops vs fallows) of Australia @ MODIS 250 m: 2000 through 2015

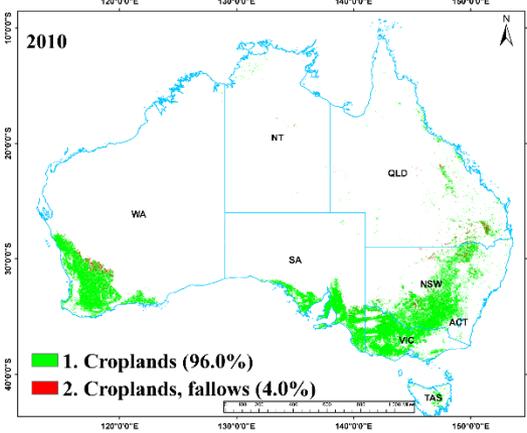
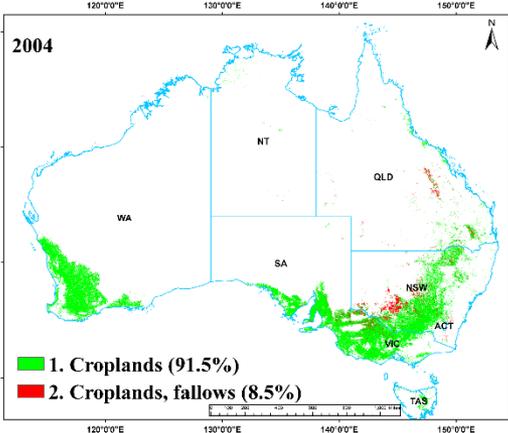
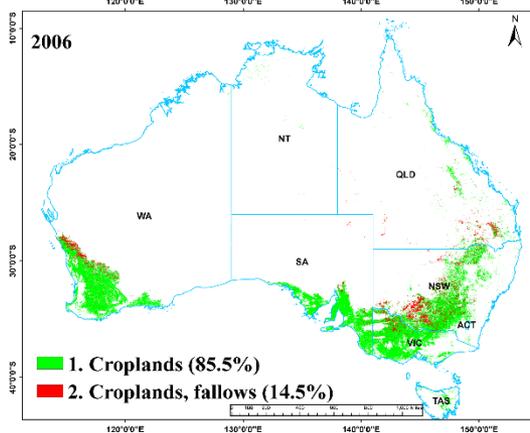
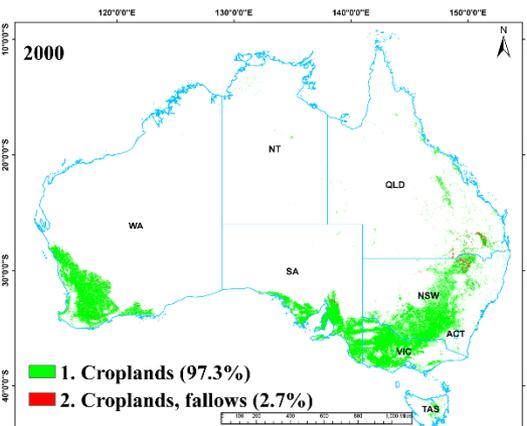
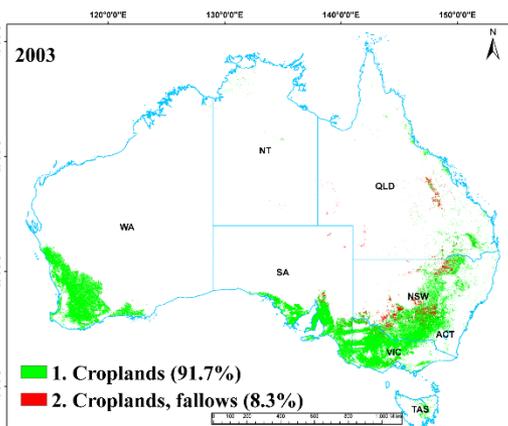
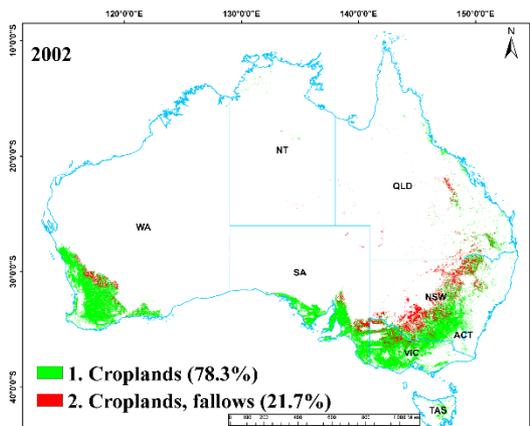


ACCA Algorithm Derived Cropland *versus* fallows(2 class map) of Australia @ MODIS 250 m: Drought *versus* Normal *versus* Good Years

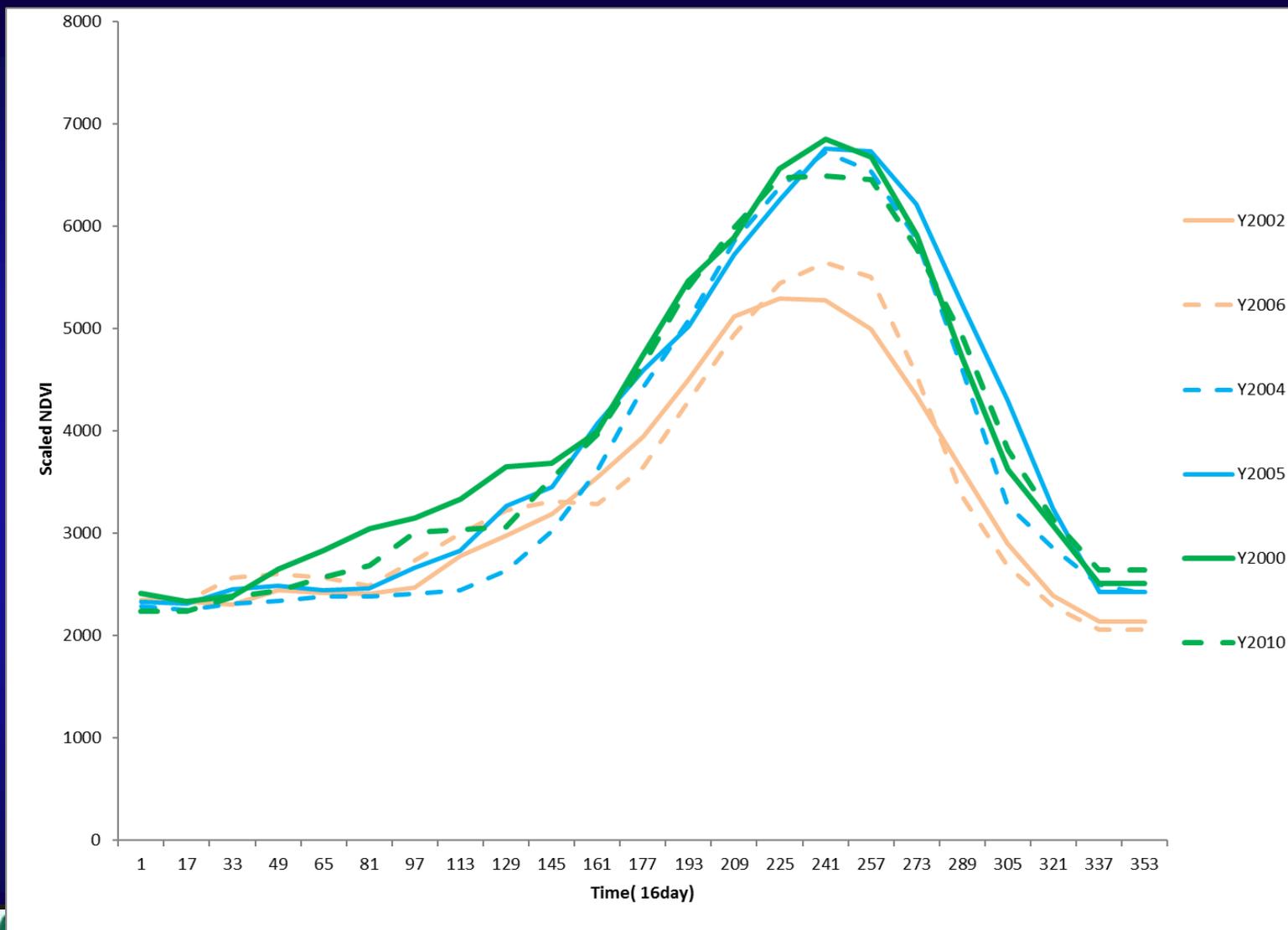
Drought Years

Normal Years

Good Years



ACCA Algorithm Derived Cropland *versus* non-Cropland Product (6 class map) of Australia @ MODIS 250 m: Drought *versus* Normal *versus* Good Years



Cropland Products Nominal 30-m for 2014

Australia, New Zealand and China

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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Cropland Products for Australia, New Zealand and China

@ 30-m based on Landsat data

Outline

- **Goal/Objective of this study**
- **Study area/ Regions**
- **Data**
 - Satellite Data (Landsat)/ Ground Reference Data
- **Mapping Algorithms (Approach)**
- **Knowledge for Mapping Algorithm (Compositing data)**
- **GEE Cloud Computing**
- **Results**
- **Accurcy assement**
- **Compasion of other products**
 - Spatial comparsion / Area comparision
- **Discussions**



Cropland Products for Australia, New Zealand and China @ 30-m Resolution based on Landsat Data Using Google Earth Engine (GEE) Cloud Computing using Random Forest Algorithm

Goal:

“The Ultimate Goal of the GFSAD30 project is to produce accurate global cropland products @ nominal 30 m resolution”

- Develop and apply appropriate cropland algorithms to produce cropland extent of Australia, New Zealand & China using Landsat 30m data



Cropland Products Nominal 30-m for 2014

Study Area:

Australia, New Zealand and China

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

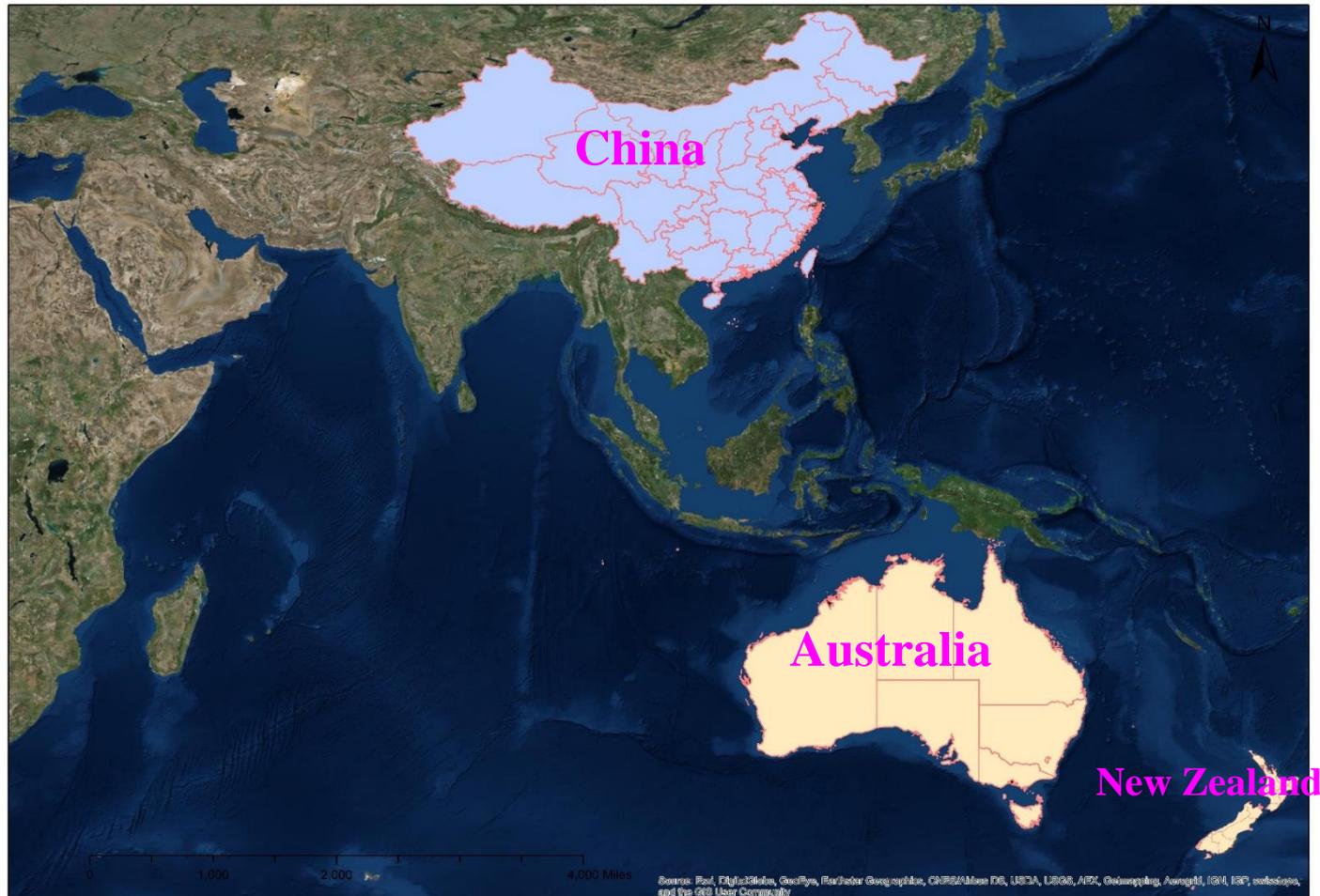
<https://www.croplands.org/>



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Cropland Products for Australia, New Zealand and China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat Data Study Area



Cropland Products Nominal 30-m for 2014

Data: Satellite Data

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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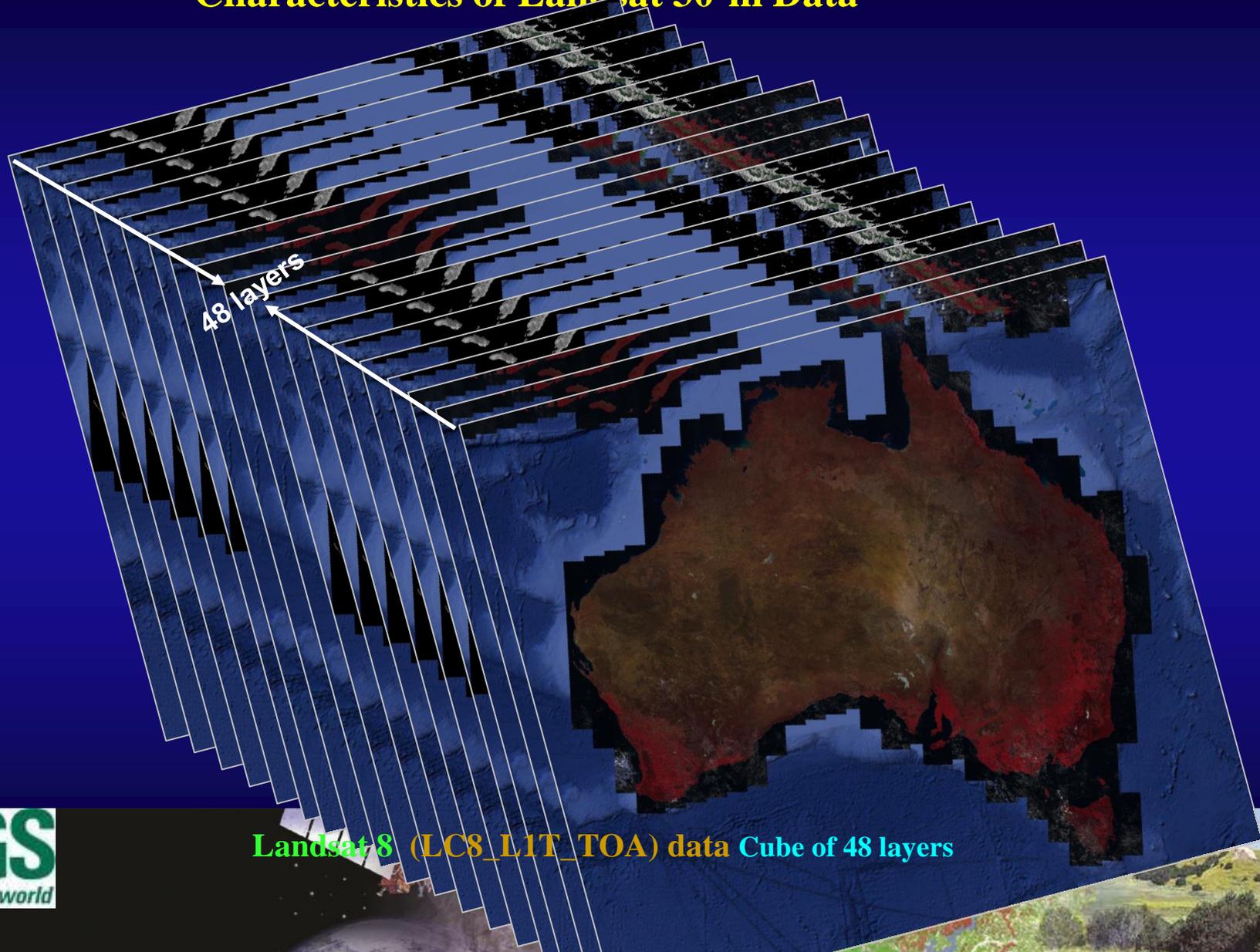


**Cropland Products for Australia, New Zealand and China using
Google Earth Engine (GEE) Cloud Computing
@ 30-m Resolution based on Landsat Data
Characteristics of Satellite data used for Different Regions**

Region/ Country	Landsat image Series	Years of Data	# Composites	Bands per composite	Total # bands used
Australia & New Zealand	LS8	2014 & 2015	1-60 61-120 121- 180 181-240 241-300 301-365 (N= 6)	blue, green, red, NIR, SWIR1, temp, SWIR2 and NDVI (n= 8)	48
China	LS7 & LS8	2013, 2014& 2015	1-90 91- 180 181-270 271-365 (N= 4)	blue, green, red, NIR, SWIR1, temp, SWIR2 and NDVI (n= 8)	32



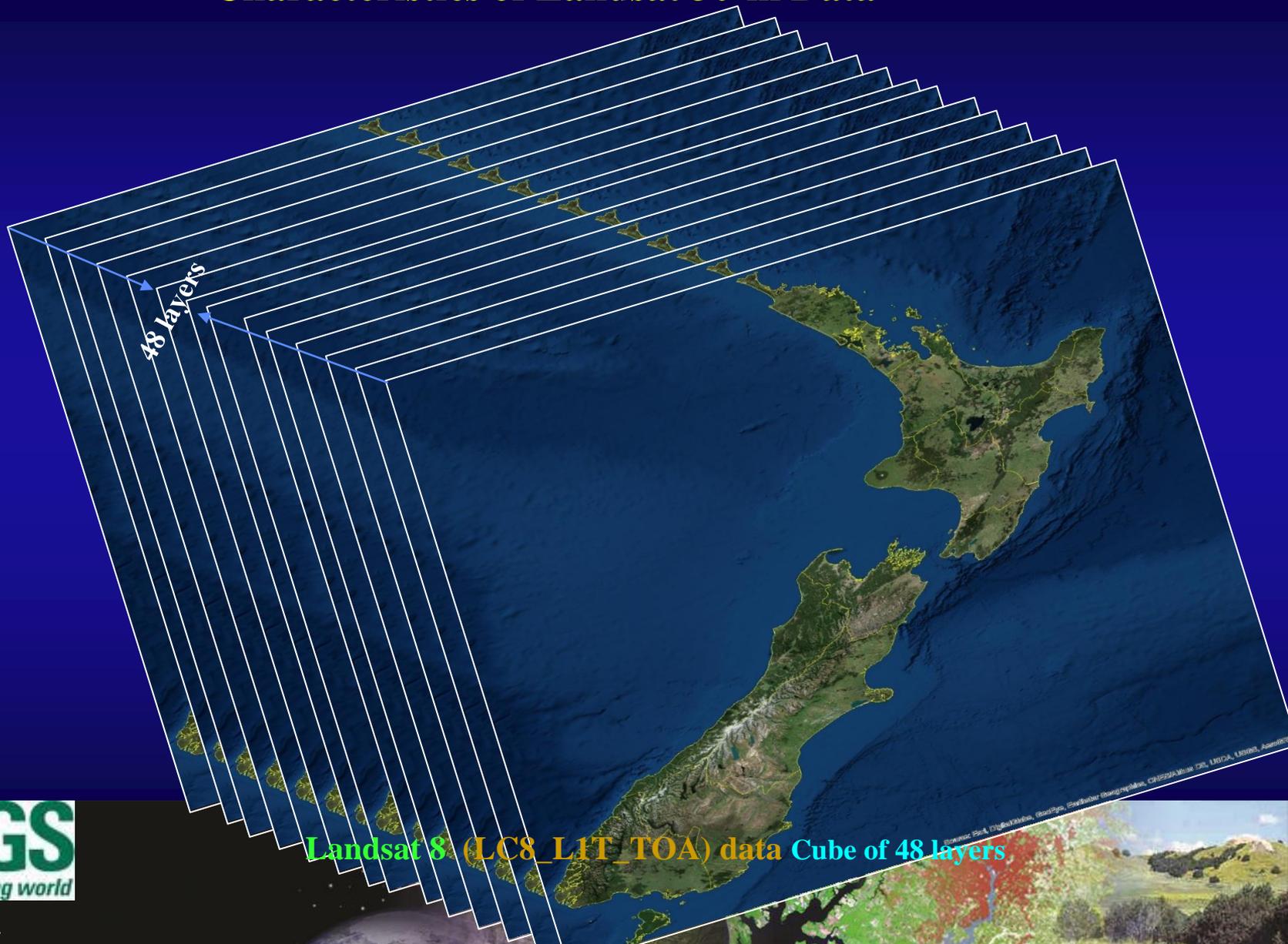
Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Landsat 30-m Data



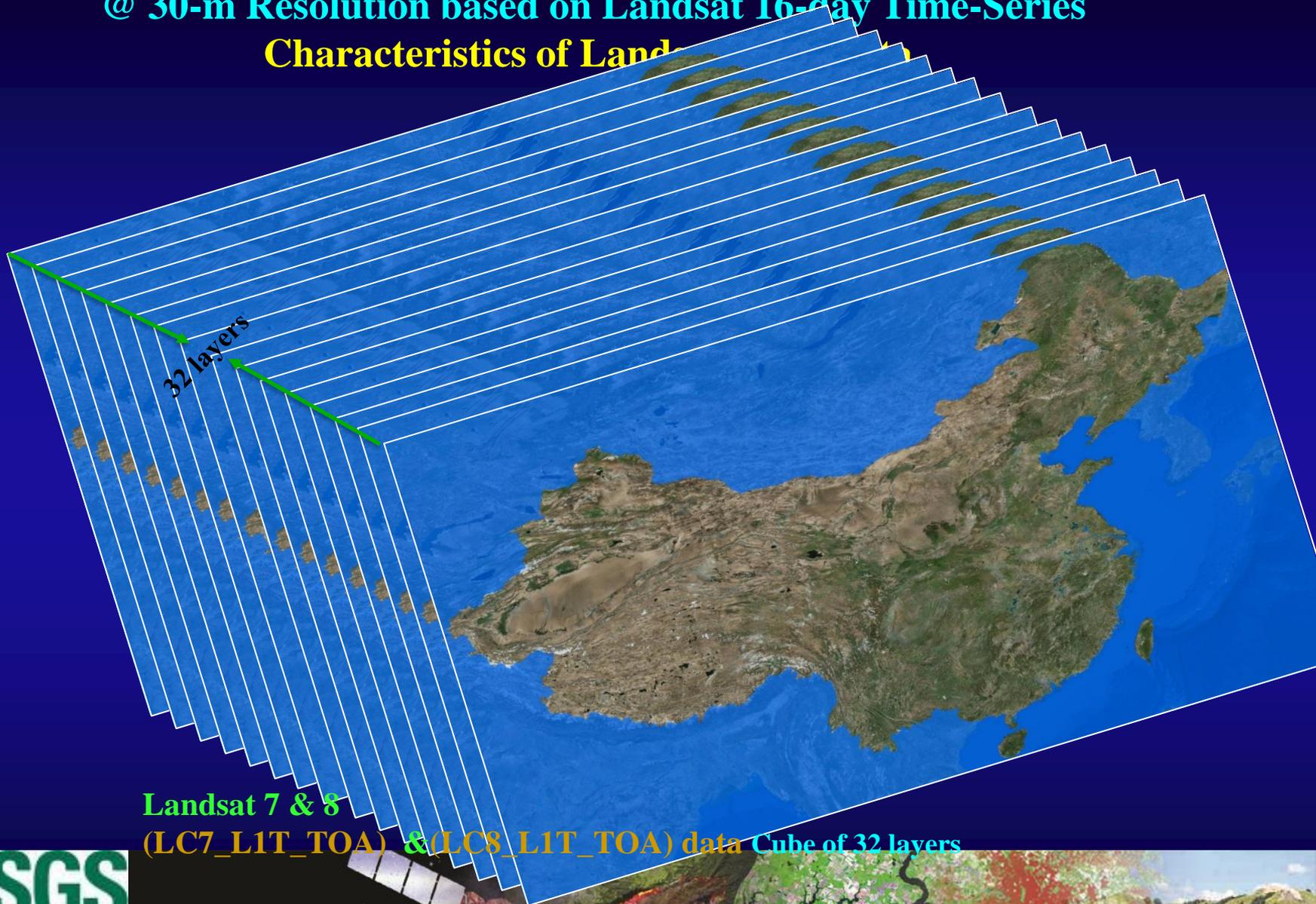
U.S. Geological Survey
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Landsat 8 (LC8_L1T_TOA) data Cube of 48 layers

Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Landsat 30-m Data



Cropland Products for China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Land



Landsat 7 & 8
(LC7_L1T_TOA) & (LC8_L1T_TOA) data Cube of 32 layers



Cropland Products Nominal 30-m for 2014

Methodology: Random Forest and GEE

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

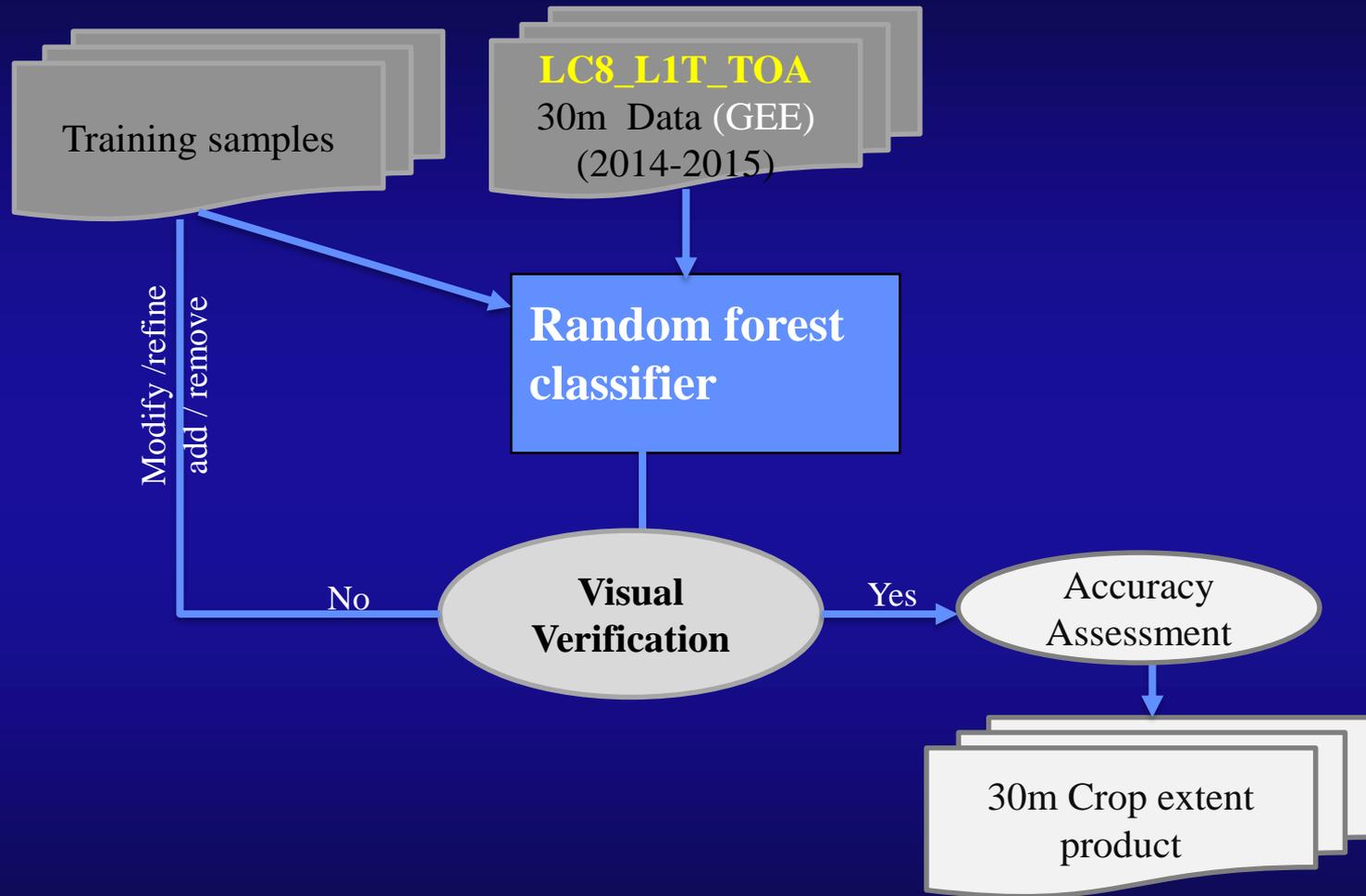
<https://www.croplands.org/>



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Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Random Forest Classification Methodology Flow-chart



Cropland Products for Australia

@ 30-m based on Landsat data

Using Random Forest Algorithm

Random Forest (RF) Classifier: Characteristics

A random forest classifier is an ensemble classifier that produces multiple decision trees, using a randomly selected subset of training samples and variables.

- **Generally superior/reliable/accurate classification results compared to decision trees;**
- **Can successfully handle high data dimensionality and multicollinearity;**
- **More resilient to highly correlated data than SVM;**
- **Leave-one-out sample training makes Random forest resistant to model overfitting;**
- **Internal accuracy assessment and variable importance assessment;**
- **Potentially faster than SVM;**
- **Supported by Google Earth Engine cloud computing**



Cropland Products for Australia

**@ 30-m Resolution based on Landsat data Using
Google Earth Engine Cloud Computing**

Google Earth Engine (GEE) Cloud Computing: Characteristics

- **Bring model to data, traditionally the reverse occurred**
- **Eliminated tedious input imagery downloading and preprocessing**
- **Eliminates need for expensive software and powerful workstations**
- **Used by researchers across the world at no charge and unlimited access**



Cropland Products Nominal 30-m for 2014

Data: Reference Data for Training and Validation

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

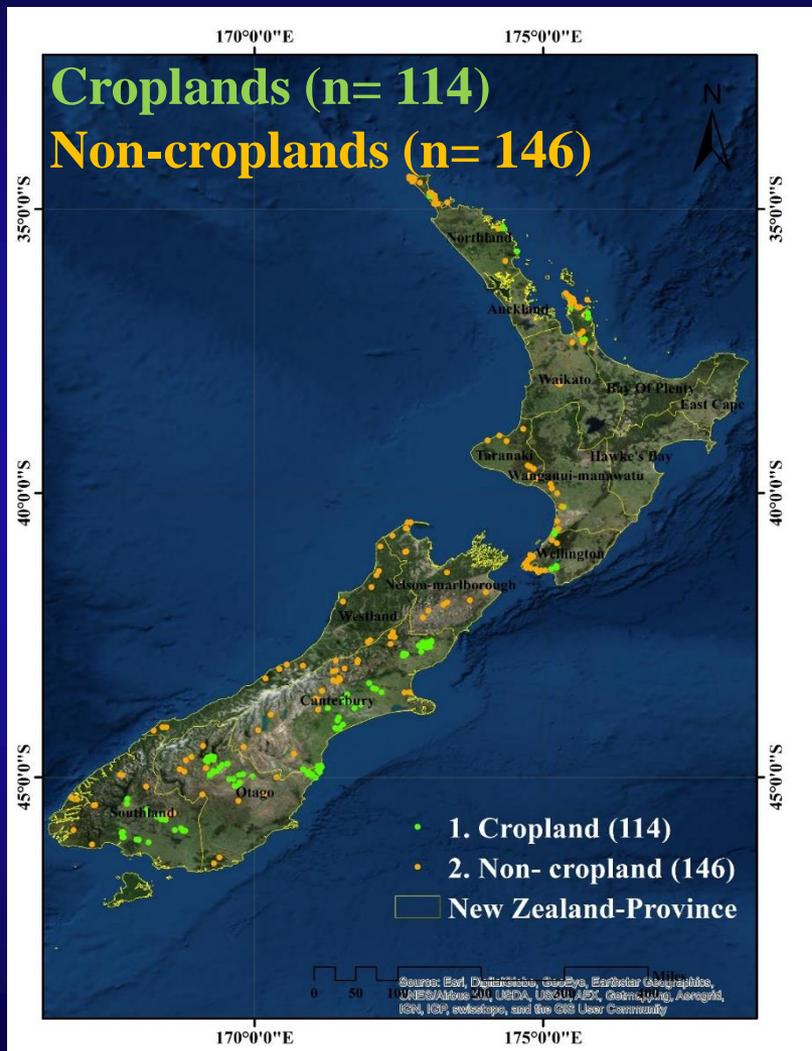
<https://www.croplands.org/>



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Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Distribution of Training Samples for Random Forest Algorithm



Cropland Products Nominal 30-m for 2014

Methodology: Knowledge generation for
training algorithms

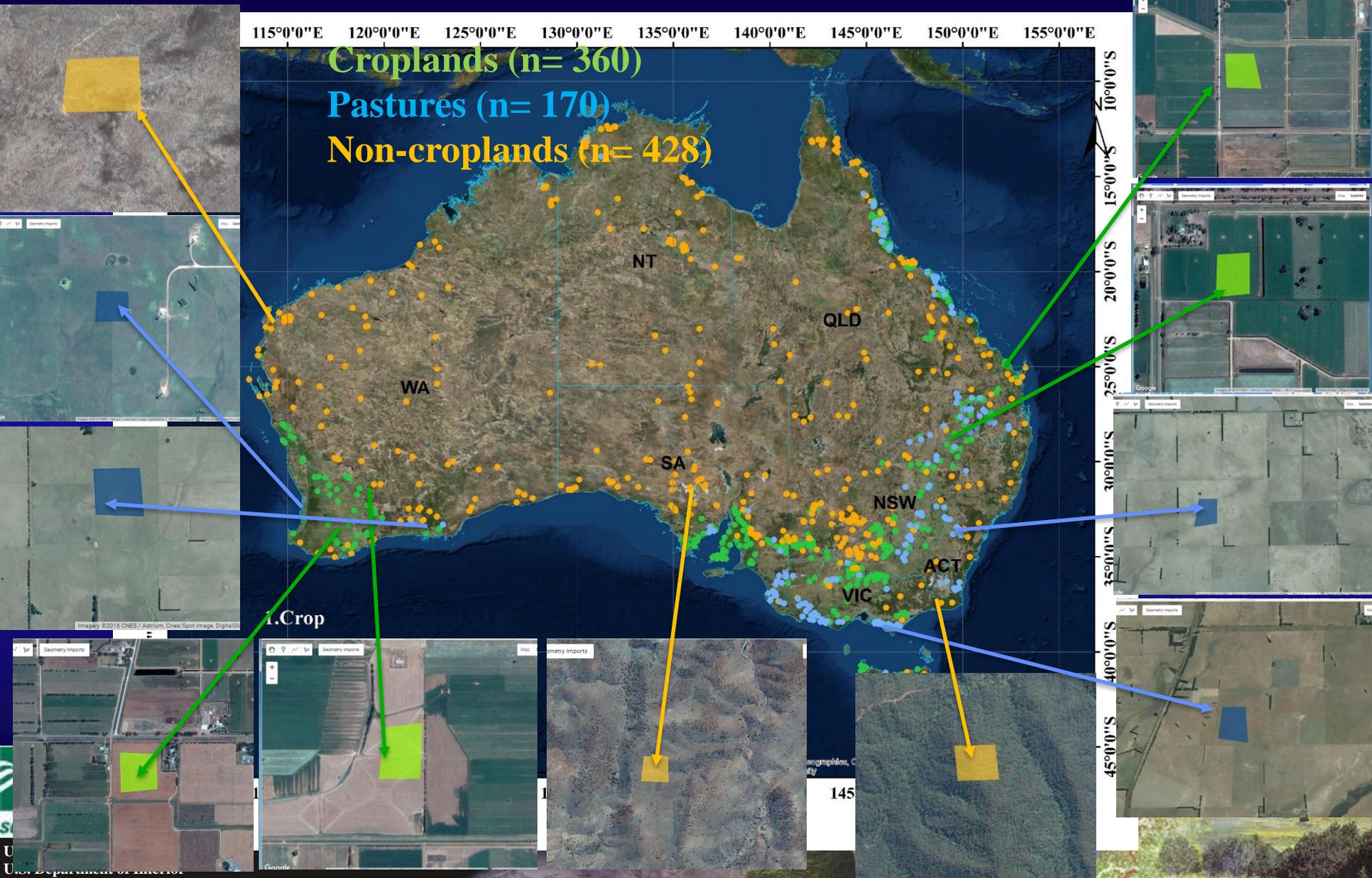
<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

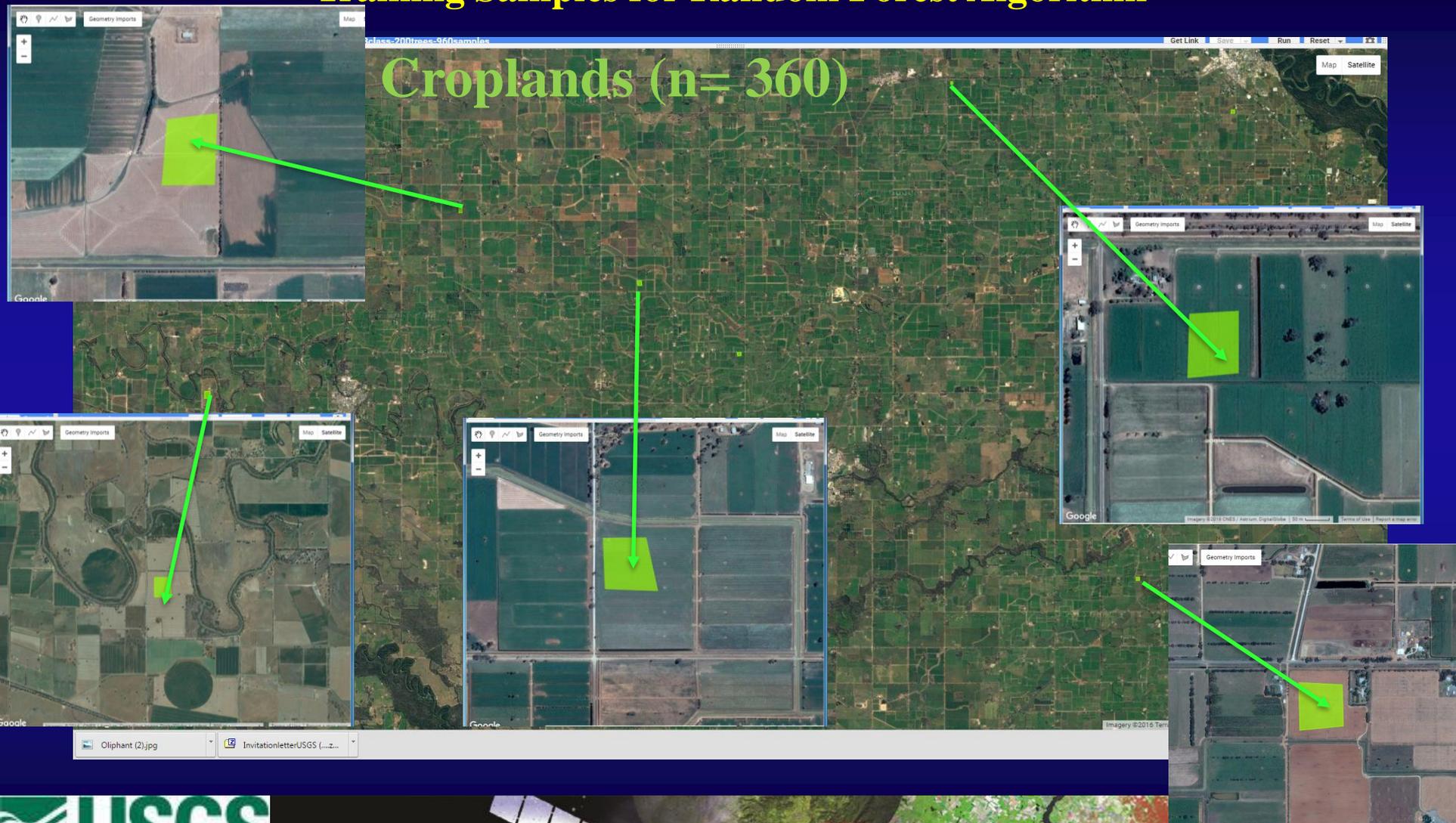
<https://www.croplands.org/>



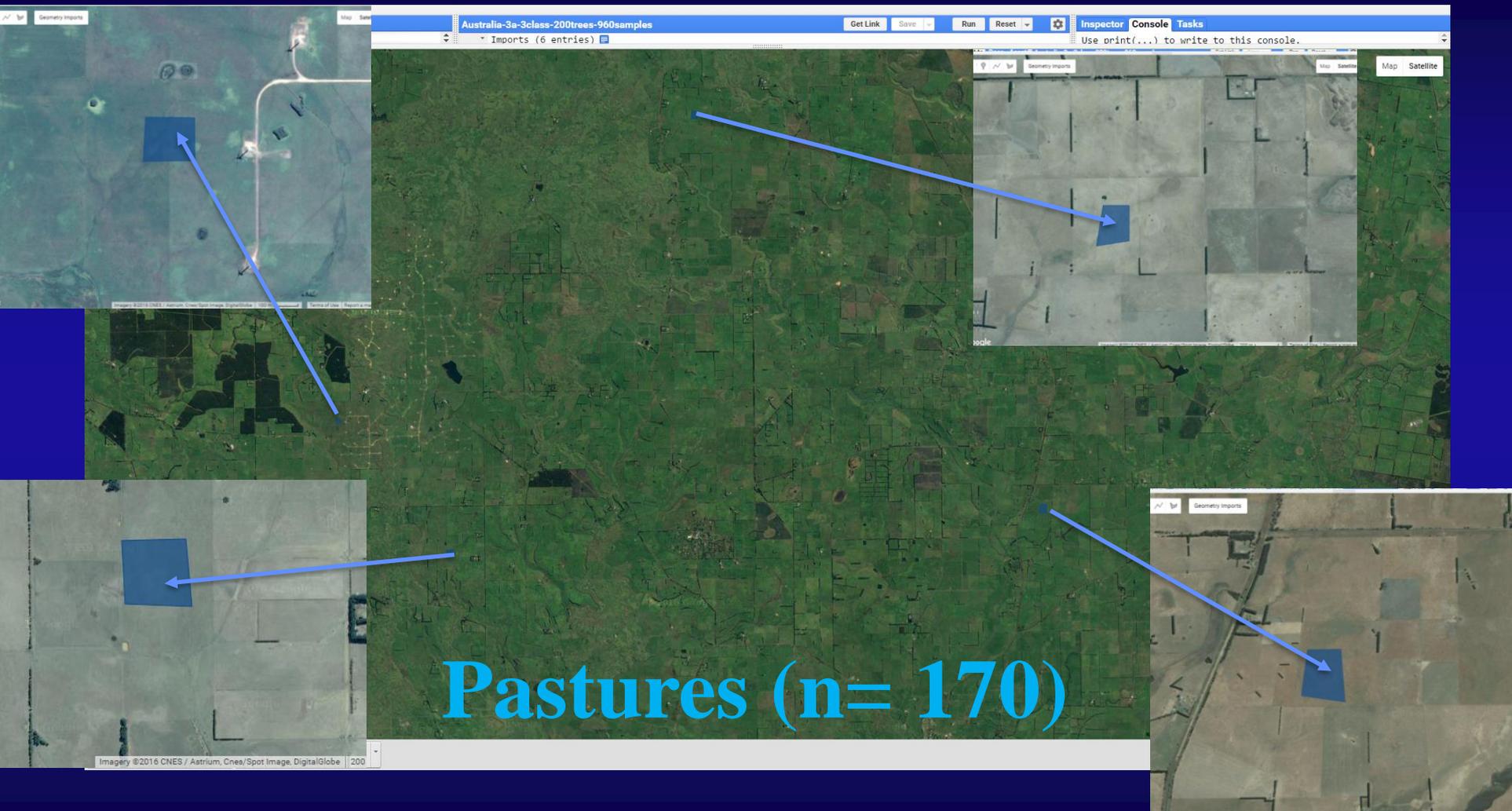
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Training Samples for Random Forest Algorithm



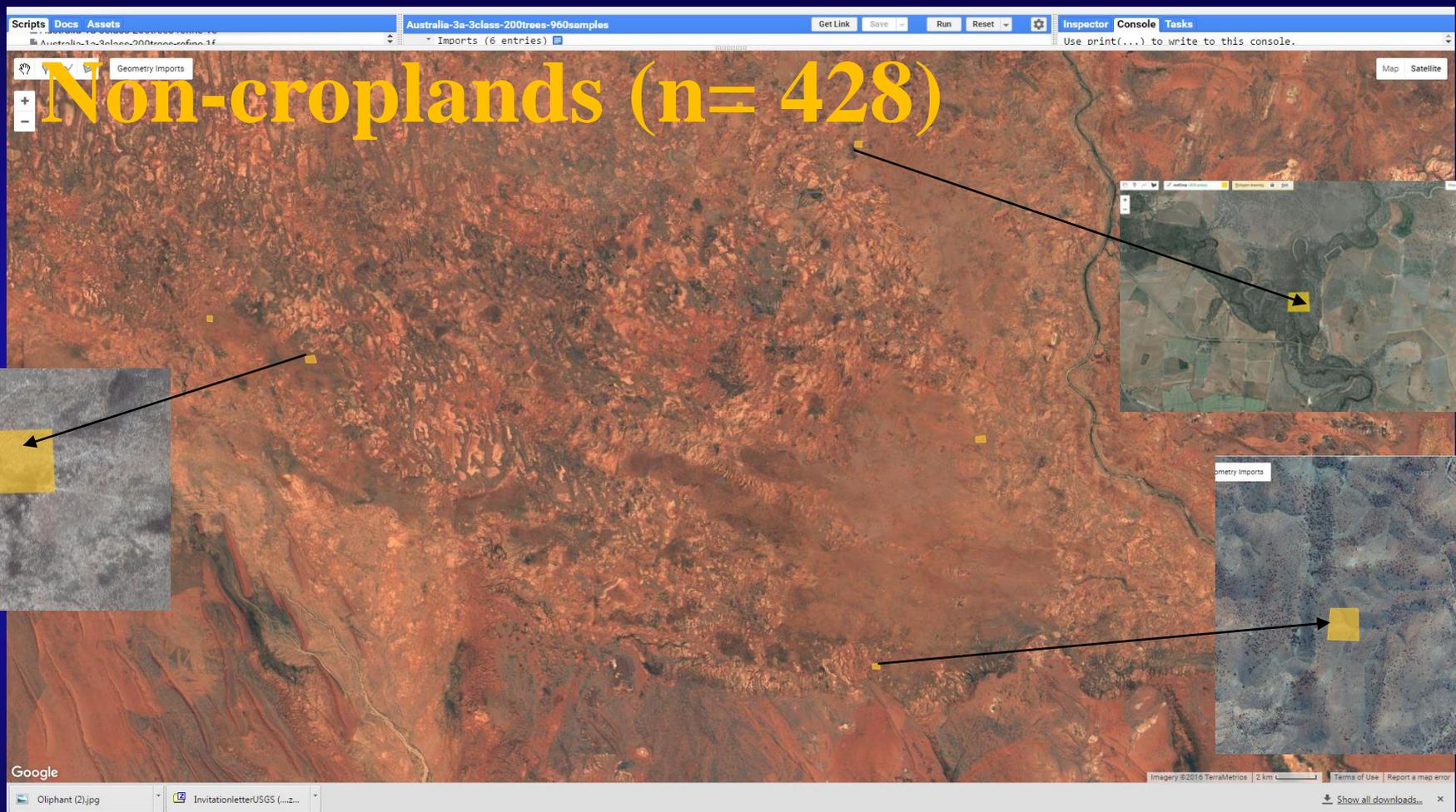
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Training Samples for Random Forest Algorithm



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Training Samples for Random Forest Algorithm



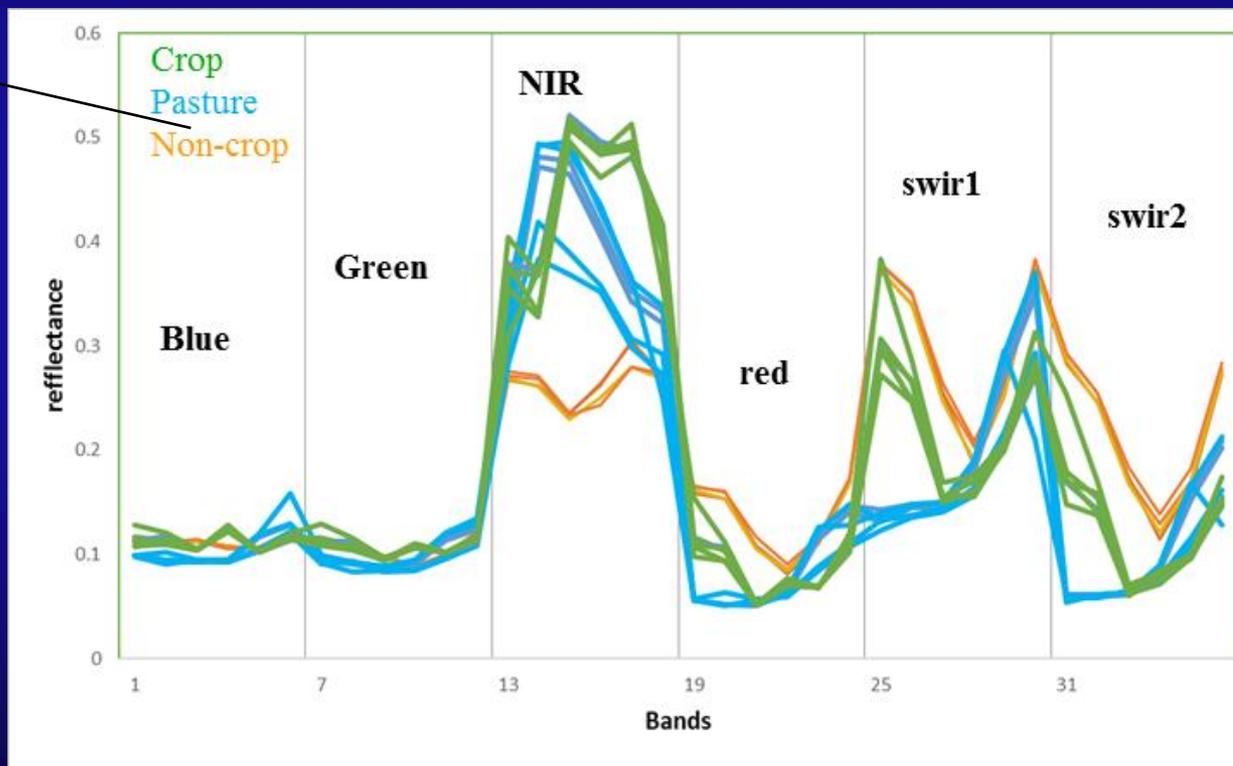
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Training Samples for Random Forest Algorithm



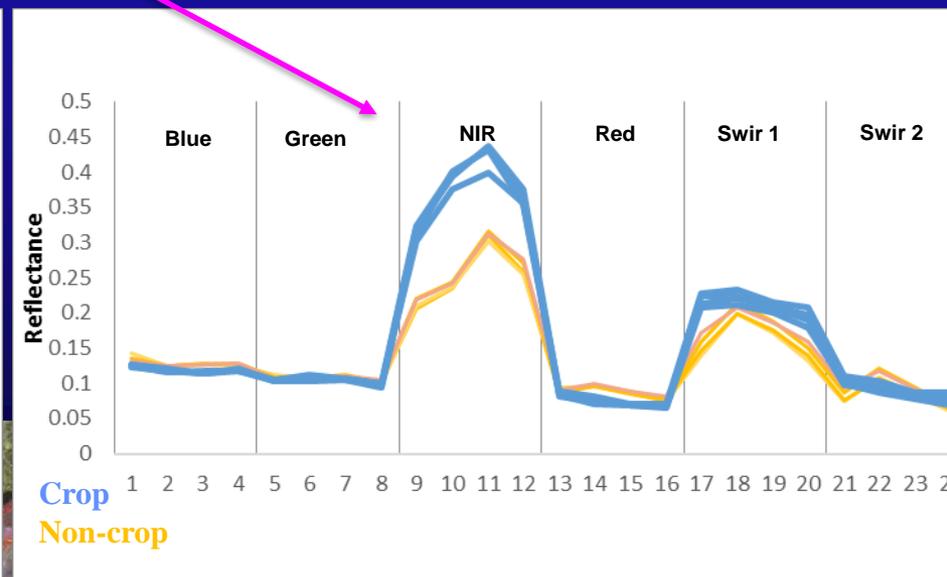
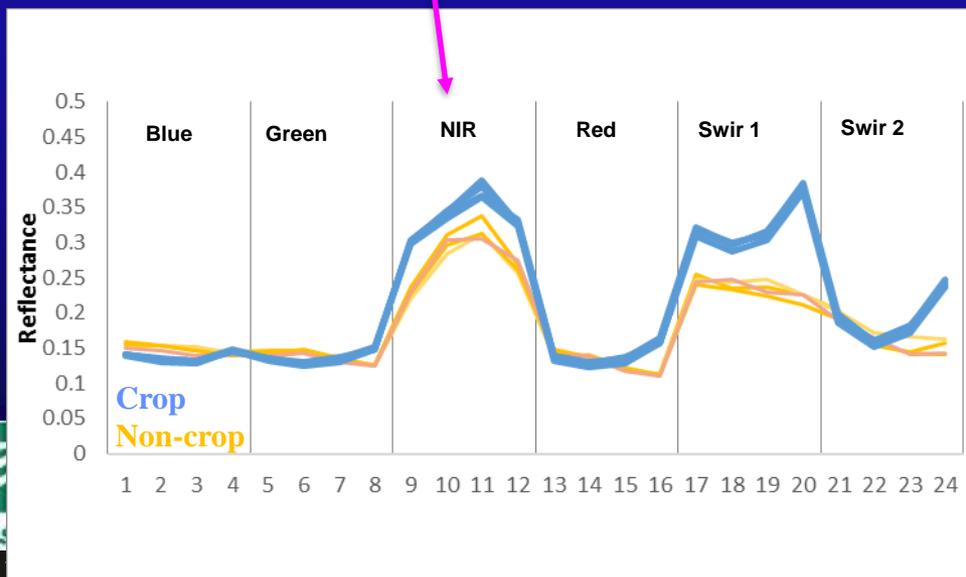
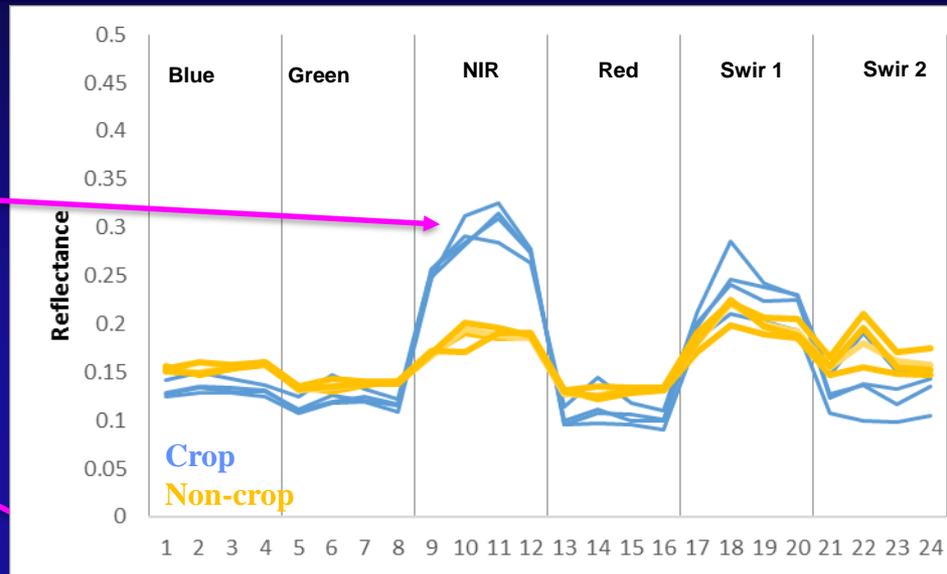
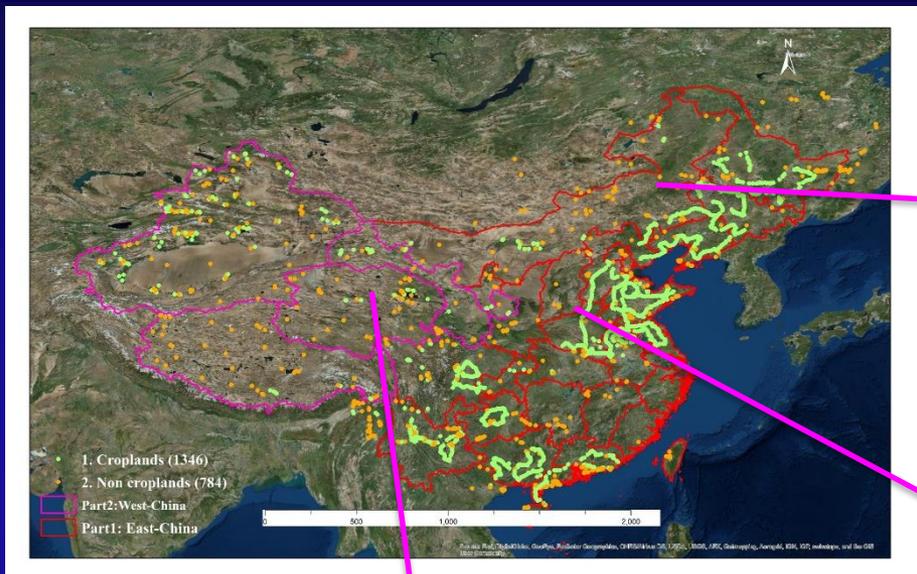
U.S. Geological Survey
U.S. Department of Interior



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Landsat 30-m Data

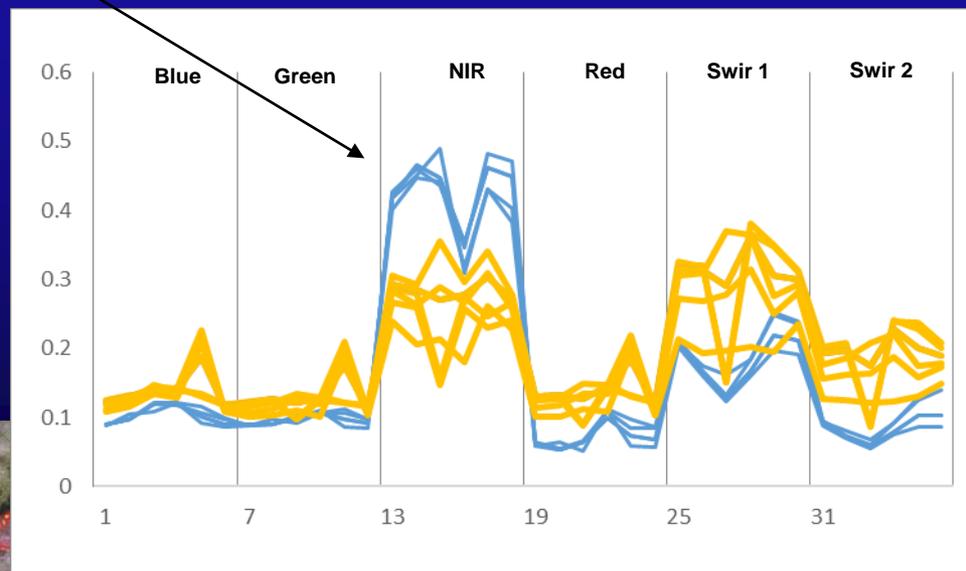
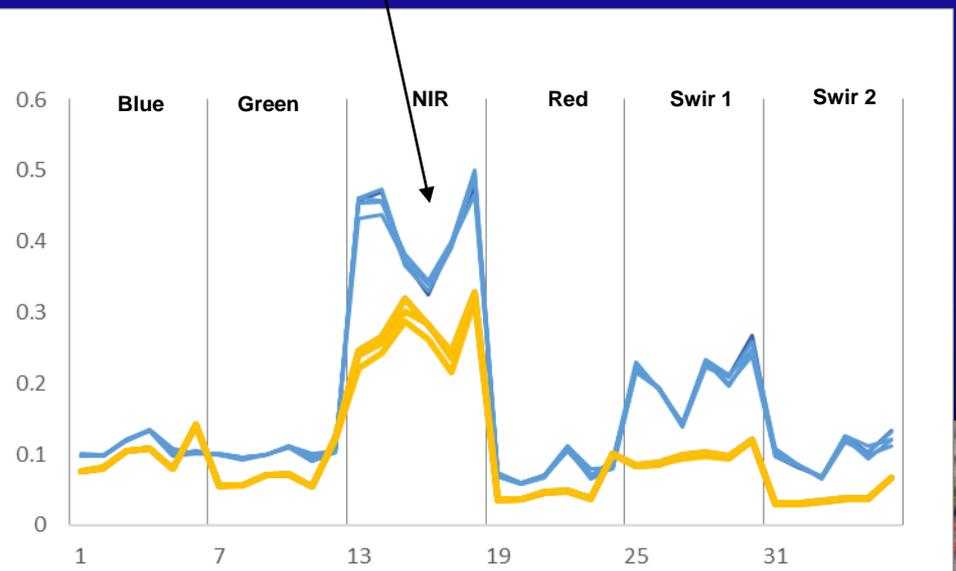
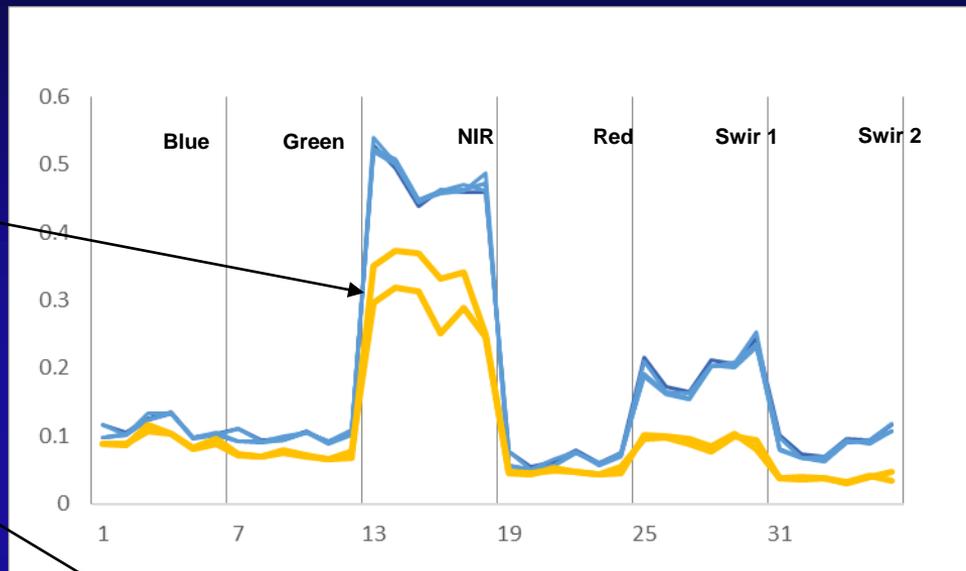
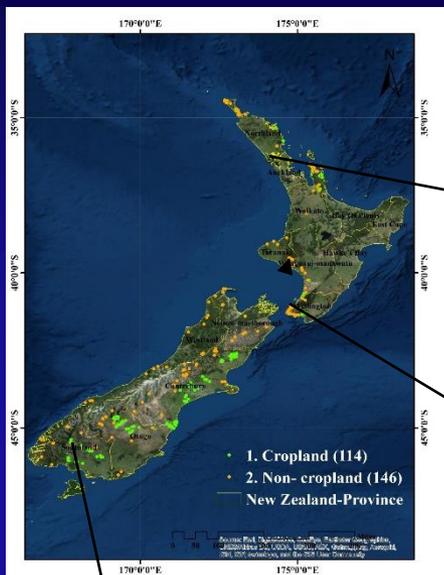


Cropland Products for China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Landsat 30-m Data

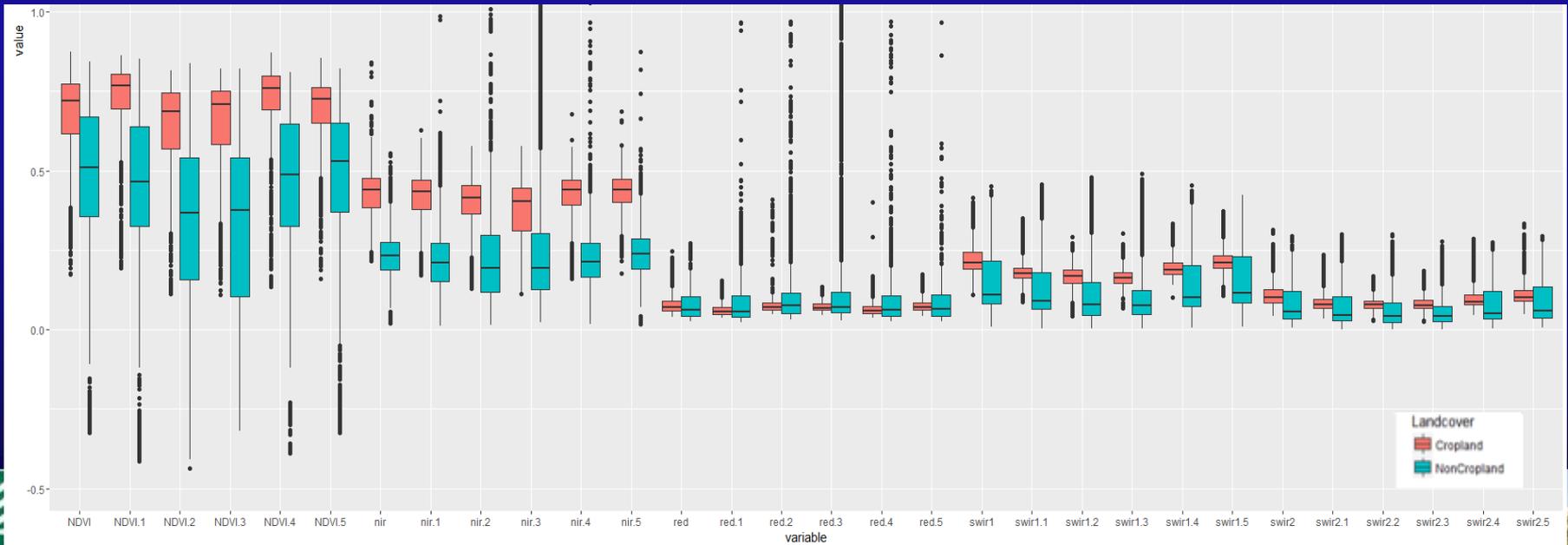
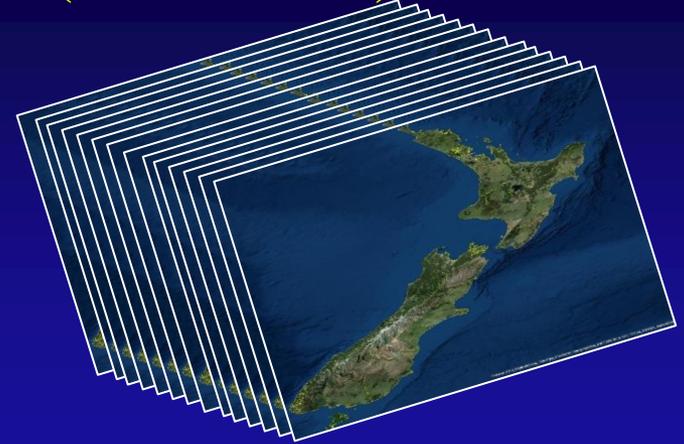
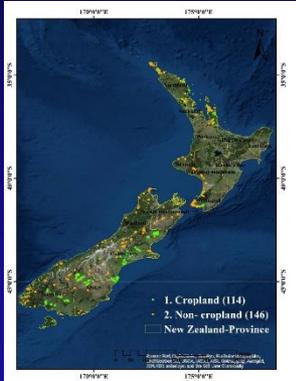


Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series

Characteristics of Landsat 30-m Data



Cropland Products Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Characteristics of Landsat 30-m Data (New Zealand)



Cropland Products

Nominal 30-m Cropland Extent Product

Results

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

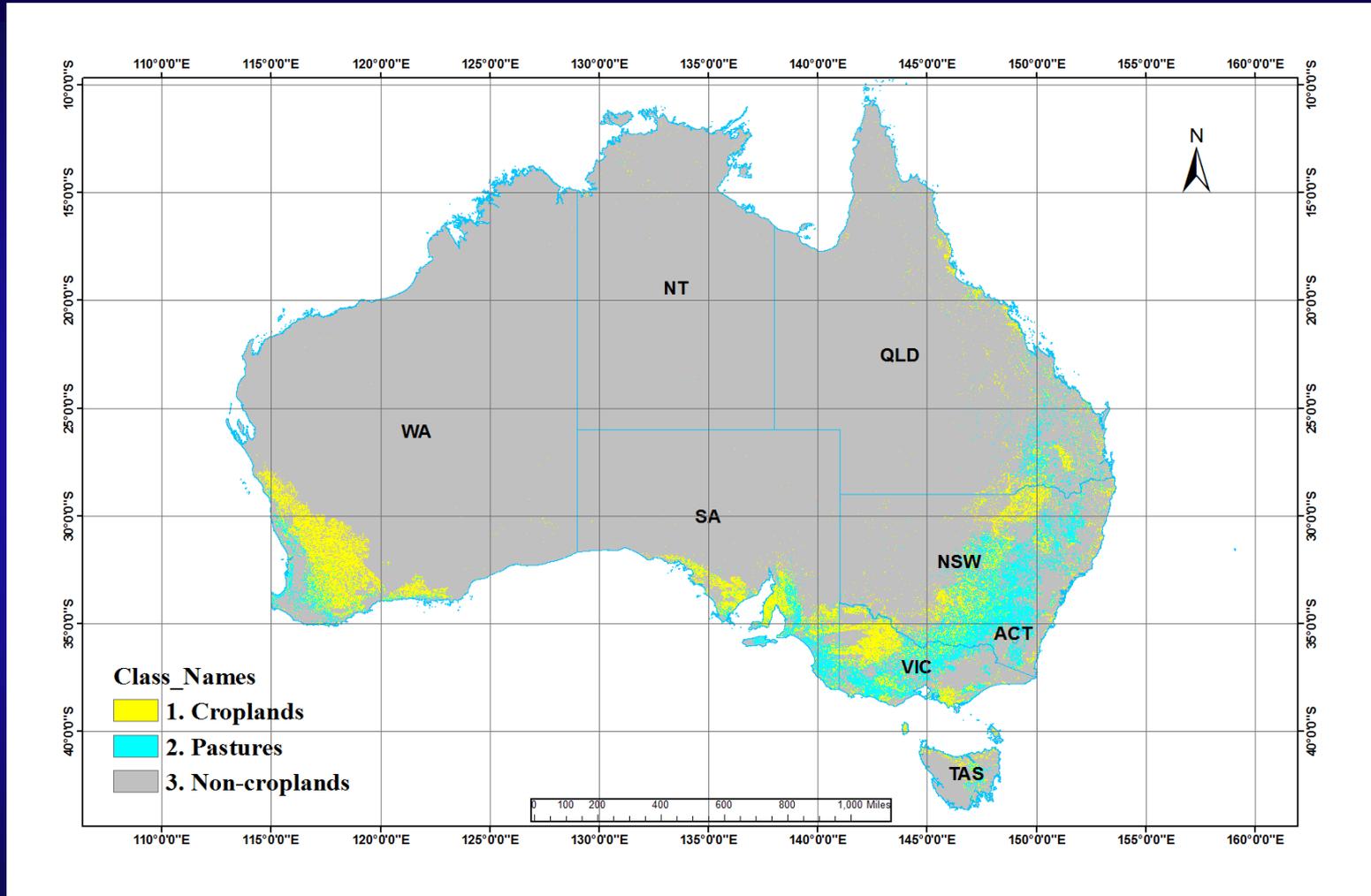
<https://www.croplands.org/>



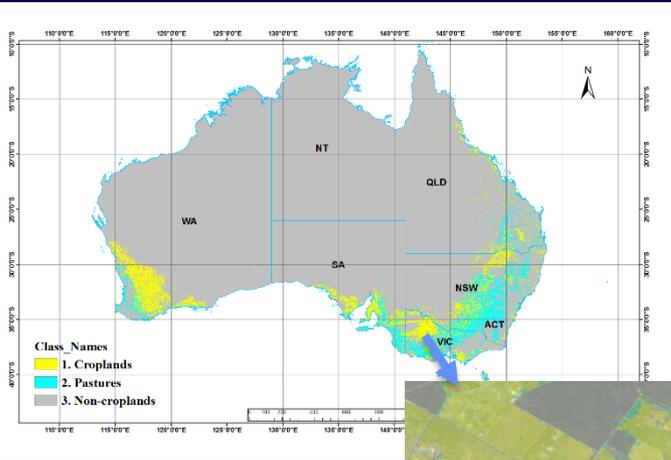
U.S. Geological Survey
U.S. Department of Interior



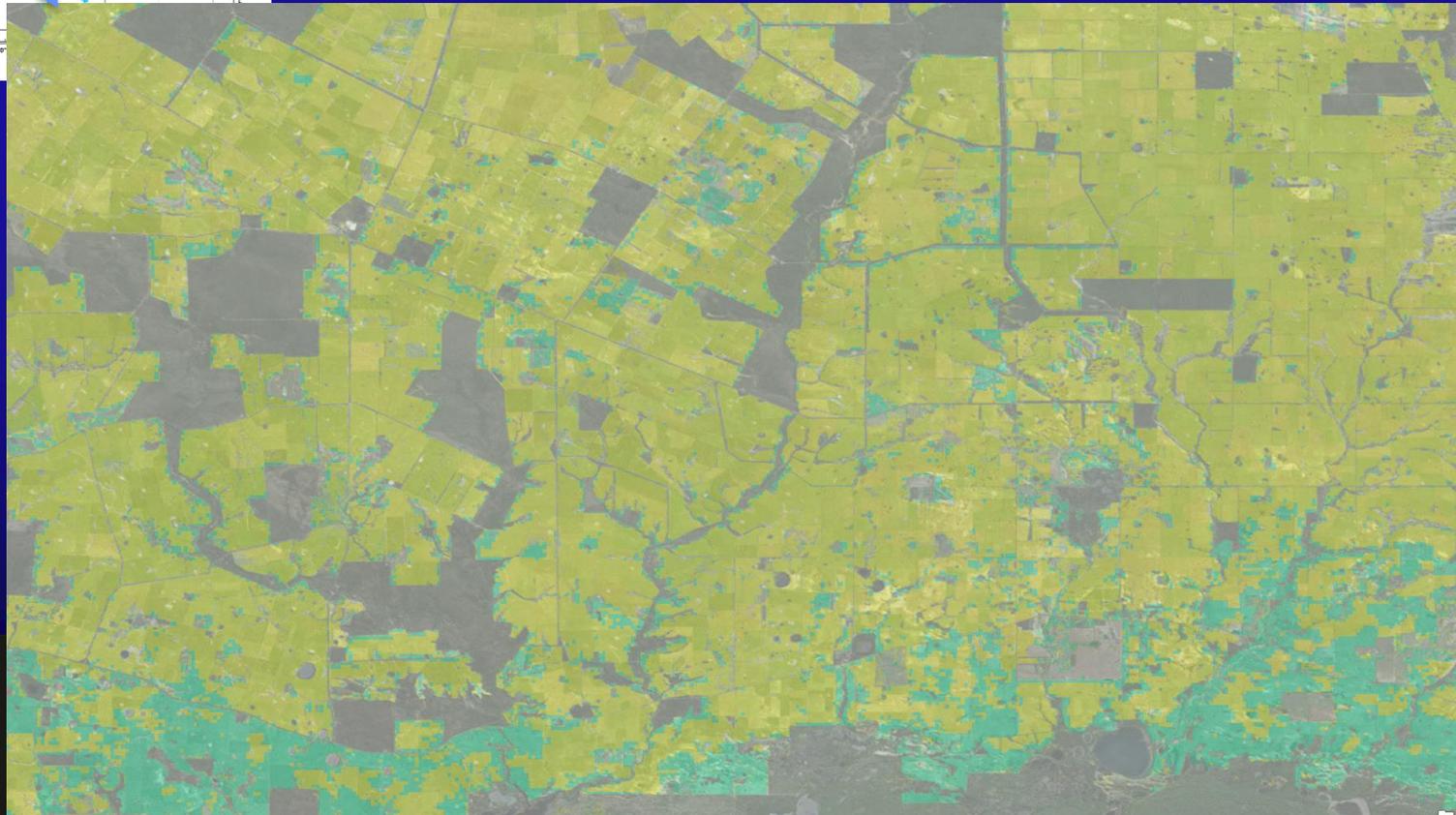
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series 3 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series 3 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing



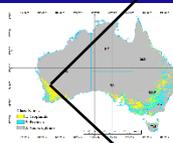
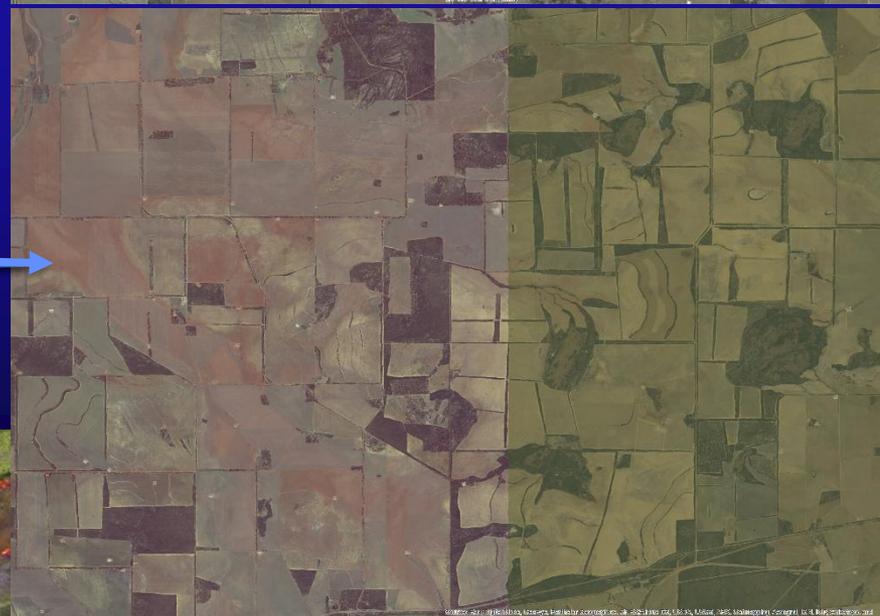
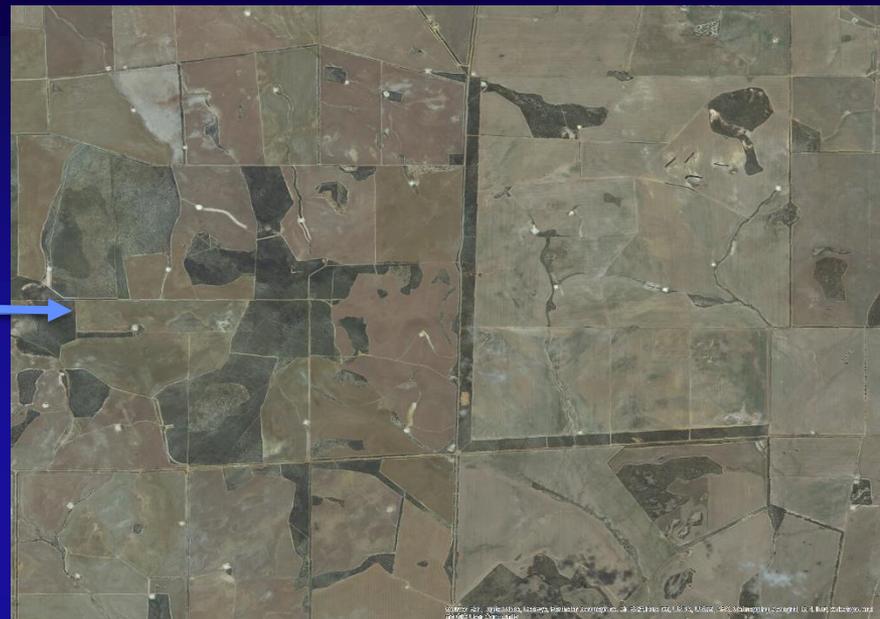
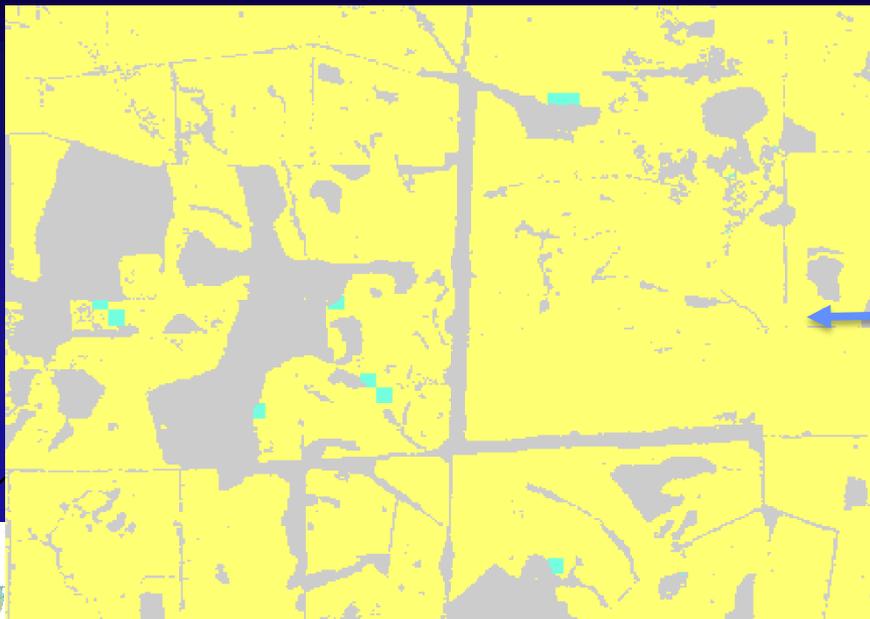
Zoom in View of croplands,
Pasture, and non-croplands @ 30-m



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

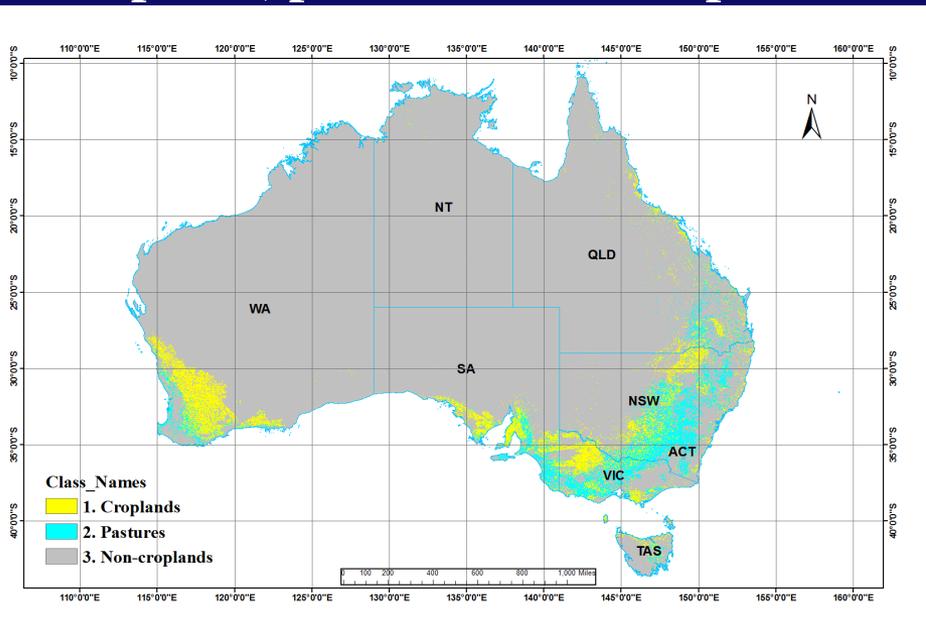
3 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing



U.S. Geological Survey
U.S. Department of the Interior

Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series 3 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing

Cropland, pasture & non cropland

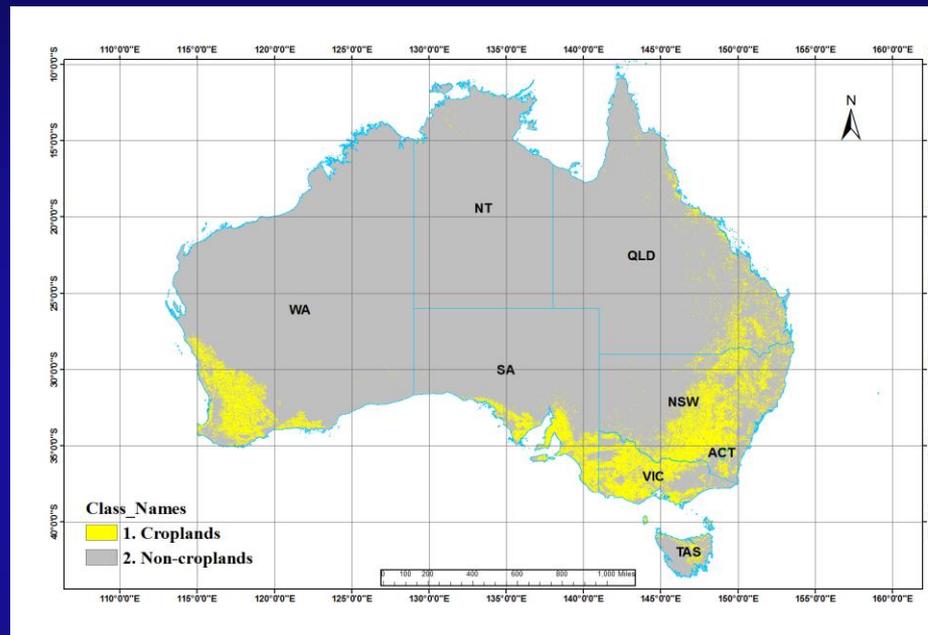


Total area of Croplands: 35.1 Mha (4.6%)

Total area of pastures: 30.1 Mha (3.9%)

Total non croplands: 703.5 Mha (91.5%)

Cropland & non cropland



Total area of Australia: 769 Mha

Total croplands: 65.2 Mha (8.5%)

(including pastures)

Total non croplands: 703.5 Mha (91.5%)



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 U.S. Department of Interior



Cropland Products
Nominal 30-m Cropland Extent Product
Accuracy Assessment
Australia

<http://geography.wr.usgs.gov/science/croplands/index.html>

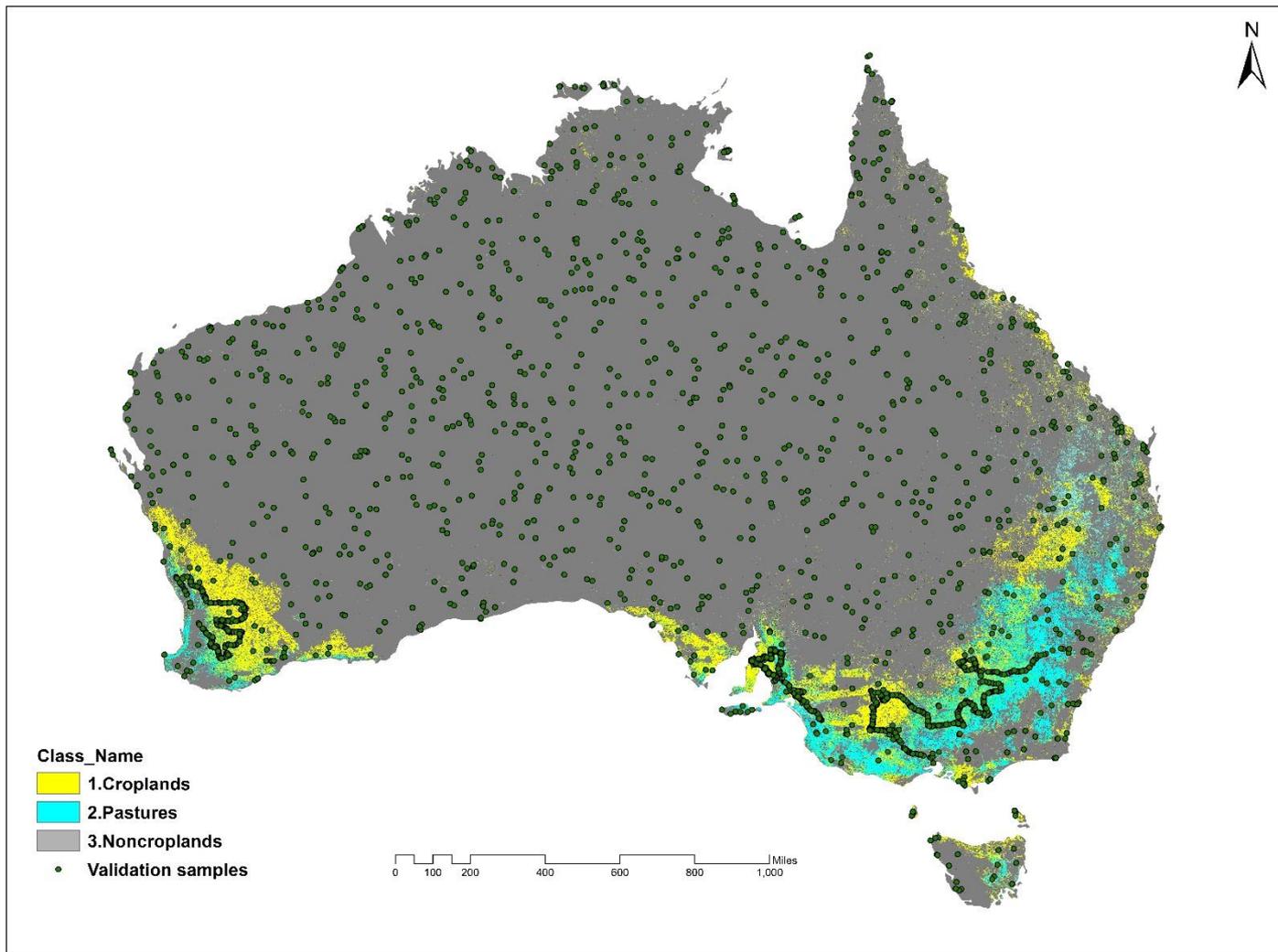
<https://croplands.org/app/map>

<https://www.croplands.org/>

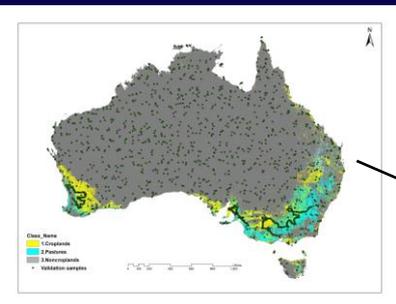


Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Distribution of validation samples for Accuracy Assessment

Ground Data and Sub-meter to 5 meter Very High Resolution Imagery (VHRI)



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Accuracy Assessment based on Available ground Data



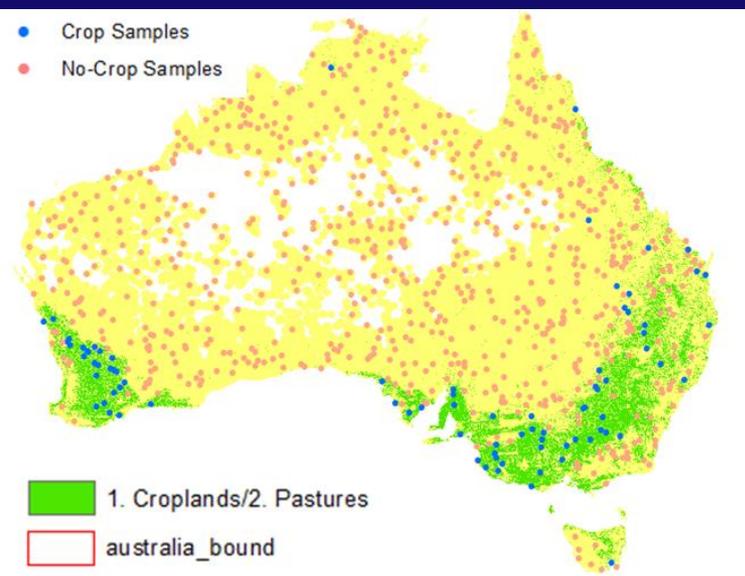
		Ground reference data			Commission error ⁵
		1. Cropland	2. Non cropland	Row total	
Map Data	1.Cropland	2261	112	2373	4.7%
	2. Non cropland	52	963	1015	5.1%
	Column total	2313	1075	3388	
	Omission error ⁶	2.2%	10.4%		
	Producer accuracy ¹	97.8%	89.6%		
	User accuracy ²	95.3%	94.9%		
	Overall accuracy ³				95.2%
				Kappa ⁴	0.89

Samples are un balanced (all available points from croplands.org which are not used for training)



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Accuracy Assessment based on Independent Ground Reference Data Set

Balanced Error Matrix in Crop/No-Crop



		Reference Data		Total	User Accuracy
		Cropland	No-Crop		
Map Data	Cropland	79	21	100	79.00%
	No-Crop	1	799	800	99.88%
Sum Points		80	820	900	
Producer Accuracy		98.75%	97.44%		97.56%

Kappa = 0.8 64383562

Samples are balanced (proportionate to % of area)
More details from Prof. Russ and Kamini's Presentation

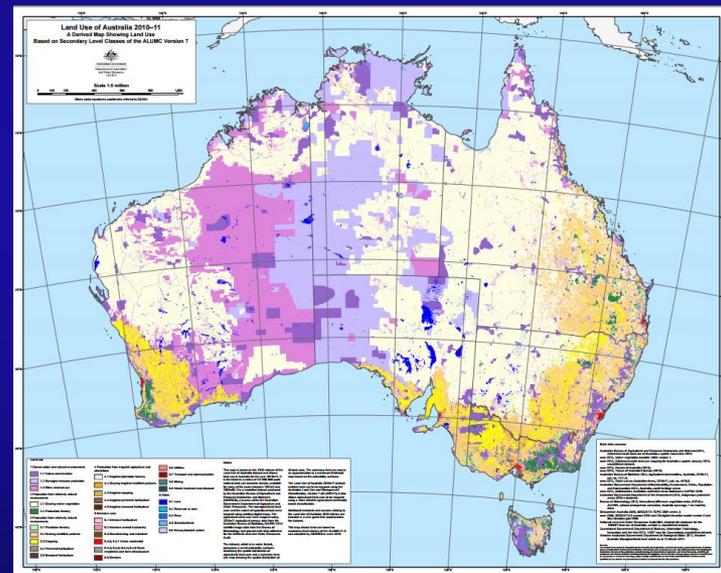


Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series

Area comparison

	GFSAD30 AU (Mha)	ACLUMP (Mha)
Croplands	35.1	36.9
Pastures	30.1	31.1
Total	65.2	68.0

Area	SECONDARY_V7
30.12	3.2 Grazing modified pastures Total
34.15	3.3 Cropping Total
0.10	3.4 Perennial horticulture Total
0.03	3.5 Seasonal horticulture Total
0.98	4.2 Grazing irrigated modified pastures Total
2.19	4.3 Irrigated cropping Total
0.37	4.4 Irrigated perennial horticulture Total
0.11	4.5 Irrigated seasonal horticulture Total
68.05	Grand Total



ACLUMP: Australian Collaborative Land Use and Management Program

<http://www.agriculture.gov.au/abares/aclump/about-aclump>

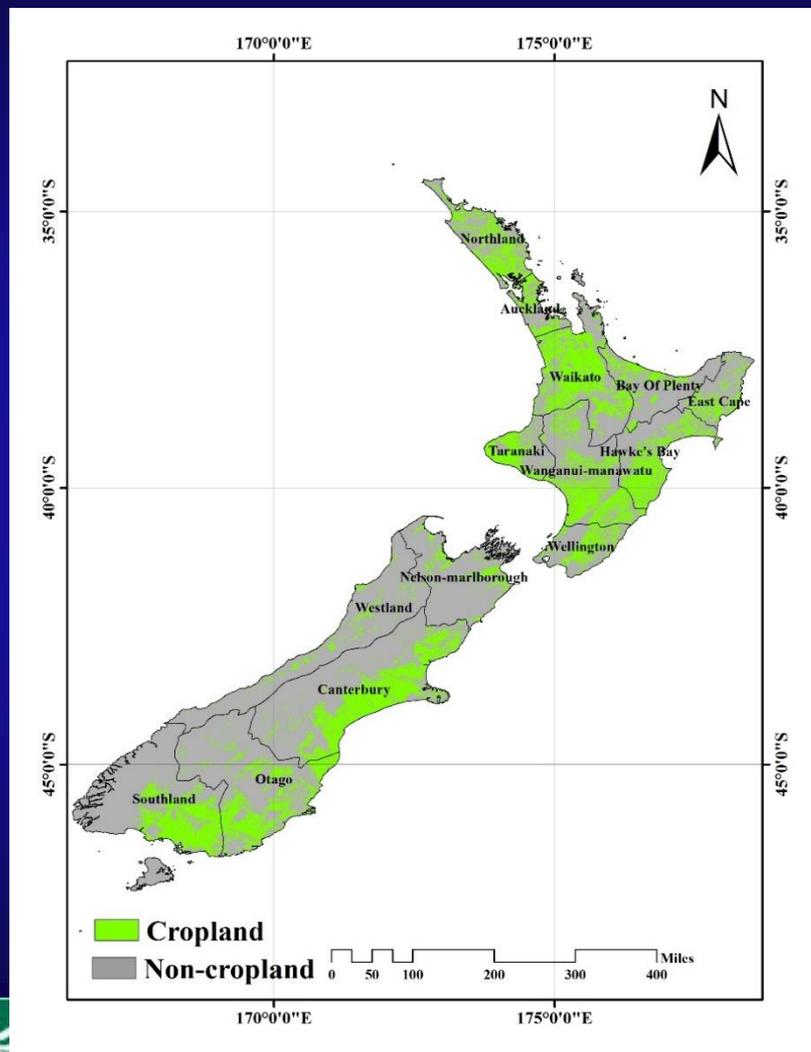
Date published: 2016-10-19T15:00:00



U.S. Geological Survey
U.S. Department of Interior



Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series 2 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing

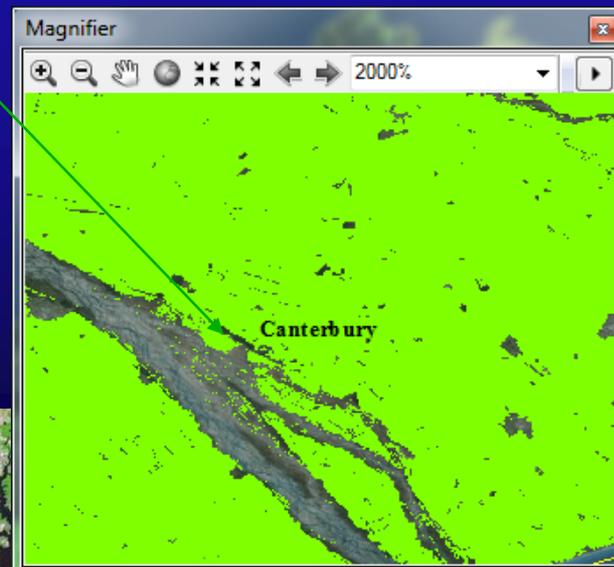
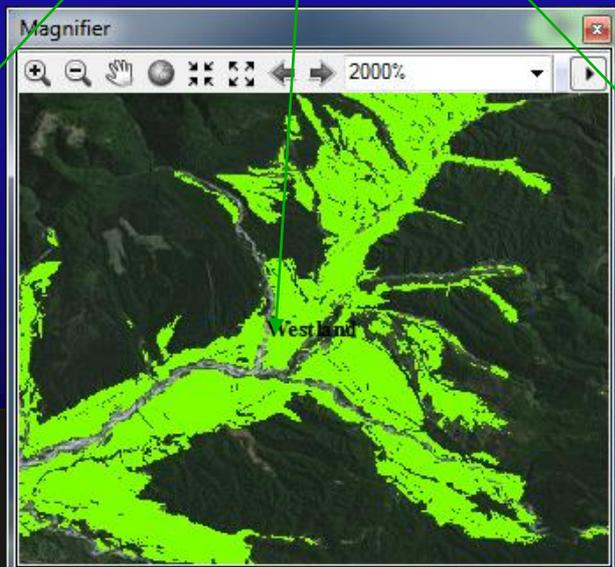
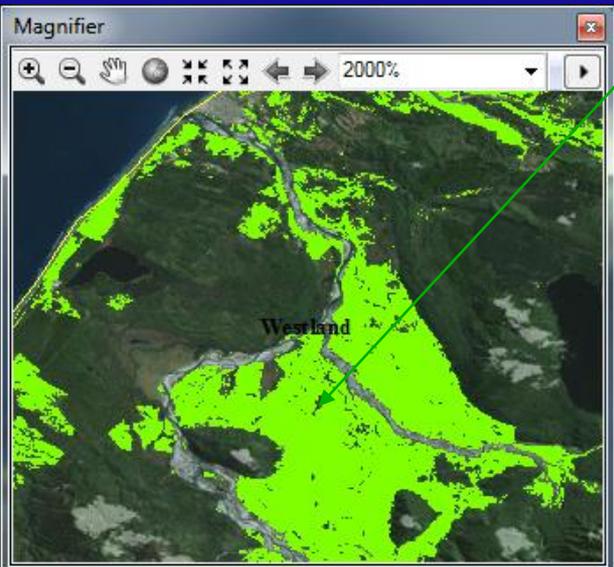
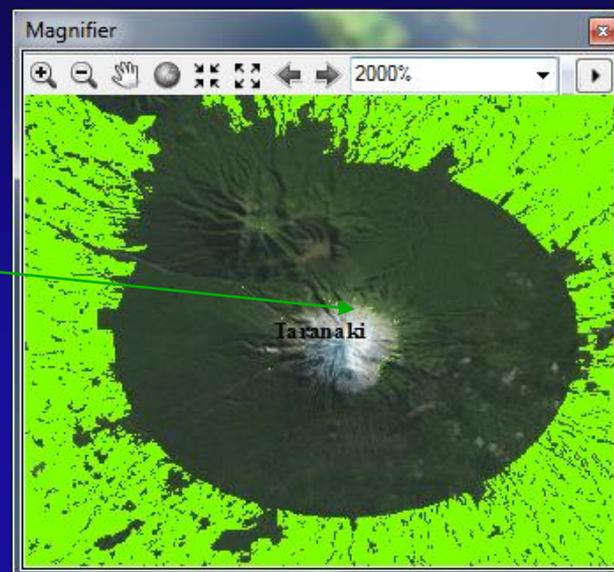
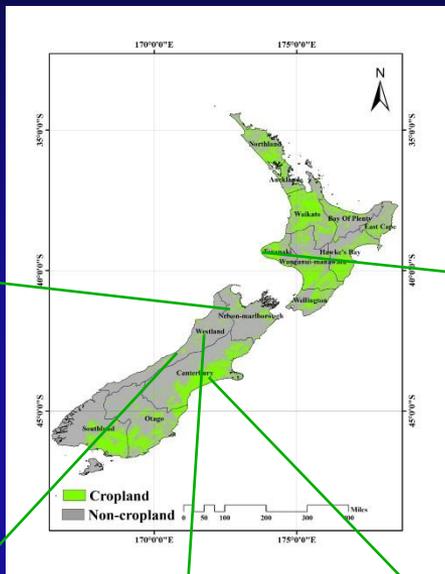
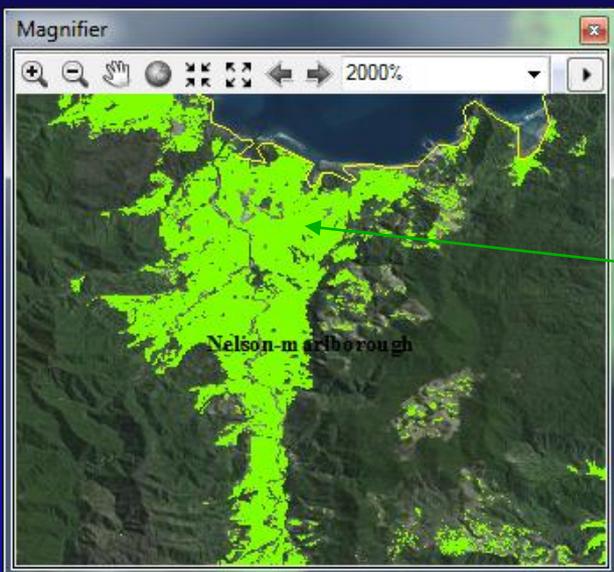


Total area of New Zealand: 26.7 Mha
Total croplands: 8.1 Mha (30.3%)
(including pastures)
Total non croplands: 18.6Mha (69.7%)

Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

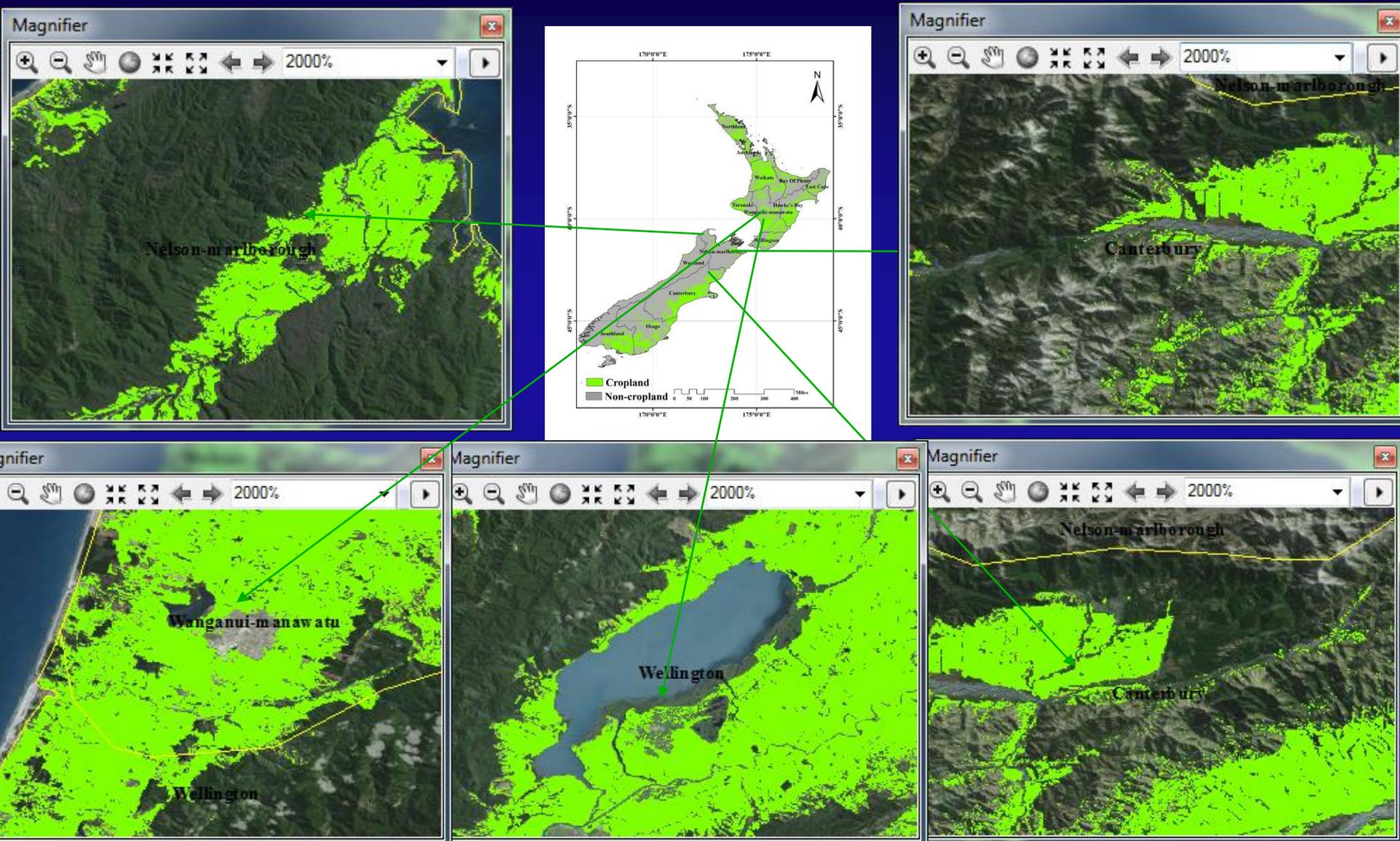
2 Classes @ 30-m derived from Random Forest Algorithm



Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

2 Classes @ 30-m derived from Random Forest Algorithm



Cropland Products
Nominal 30-m Cropland Extent Product
Accuracy Assessment
New Zealand

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



Cropland Products for New Zealand using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Accuracy Assessment based on Available ground Data

Samples are unbalanced (all available points from croplands.org which are not used for training)



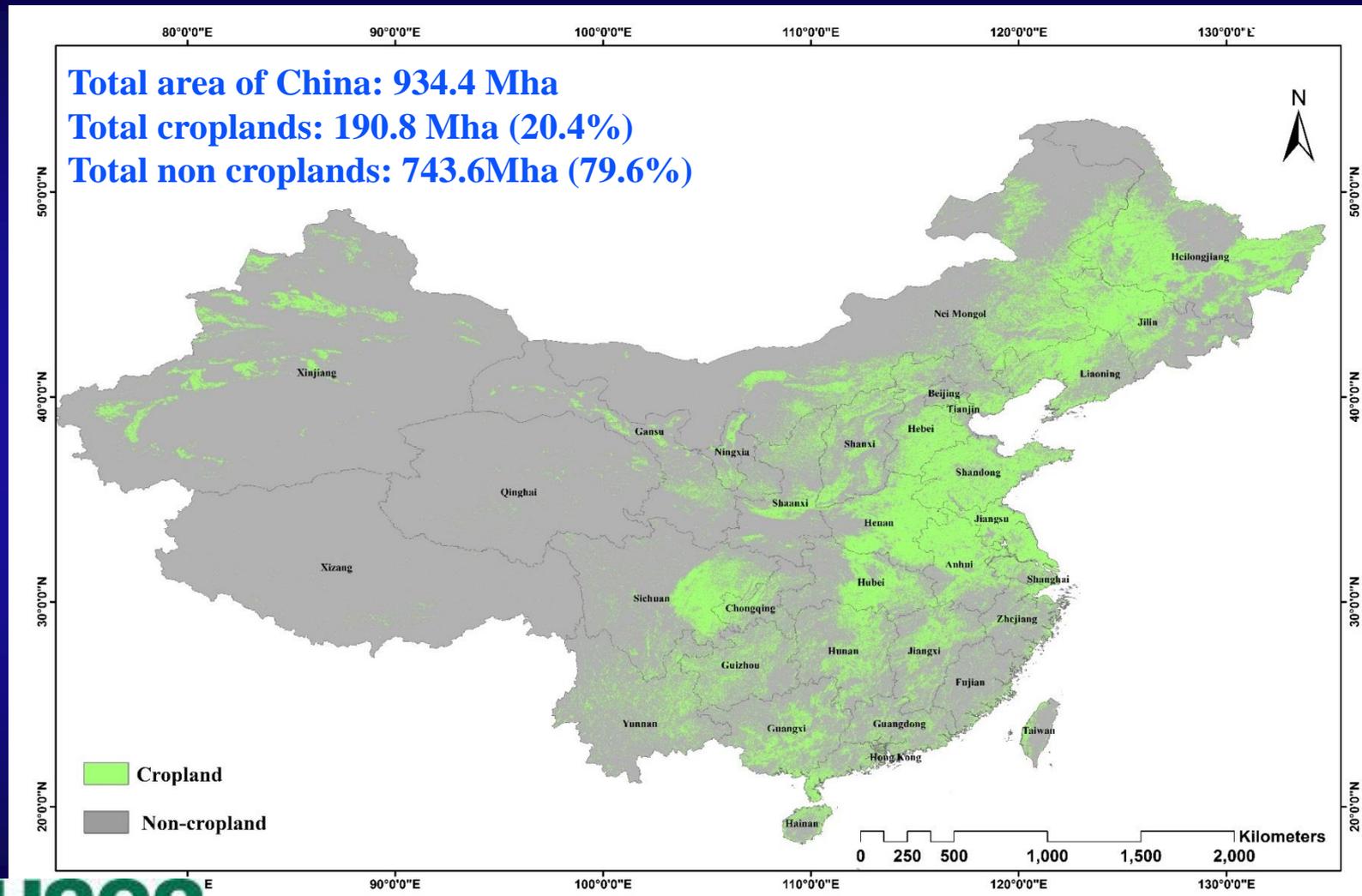
U.S. Geological Survey
U.S. Department of Interior



Cropland Products for China using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

2 Classes @ 30-m derived from Random Forest Algorithm on GEE Cloud Computing



Cropland Products
Nominal 30-m Cropland Extent Product
Accuracy Assessment
China

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



U.S. Geological Survey
U.S. Department of Interior



Cropland Products for China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Accuracy Assessment based on Available ground Data

		Reference Data			
		Cropland	Non cropland	Row Total	Commission error
Map Data	Cropland	195	52	247	21.1%
	Non cropland	63	1290	1353	4.7 %
	Column Total	258	1342	1600	
	Omission error	24.4%	3.9%		
	Producer accuracy	75.6%	96.1%		
	User accuracy	78.9%	95.3%		
	Overall accuracy				92.8%
				Kappa:	0.729

Samples are un balanced

Source: Interpreted from High resolution data by Bo et al 2016 ;



Cropland Products
Nominal 30-m Cropland Extent Product
Accuracy Assessment
Cropland Area Comparisons

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>

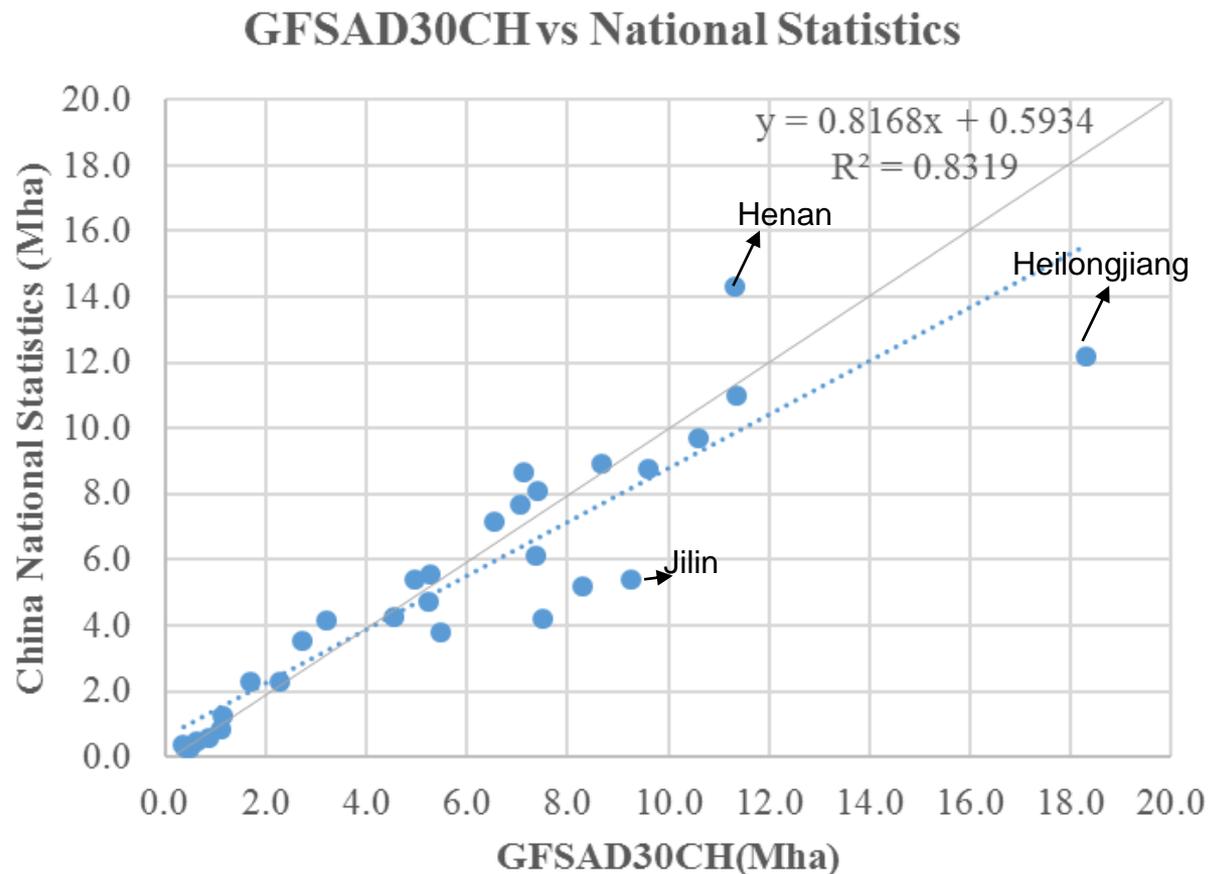


Cropland Products for China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Comparison of Cropland areas across Provinces

Total croplands:

**GFASD30CH :
190.8 Mha**

**China National Statistics:
164.6 Mh
(sown area)**



Data source:

<http://www.stats.gov.cn/tjsj/ndsj/2014/indexeh.htm>



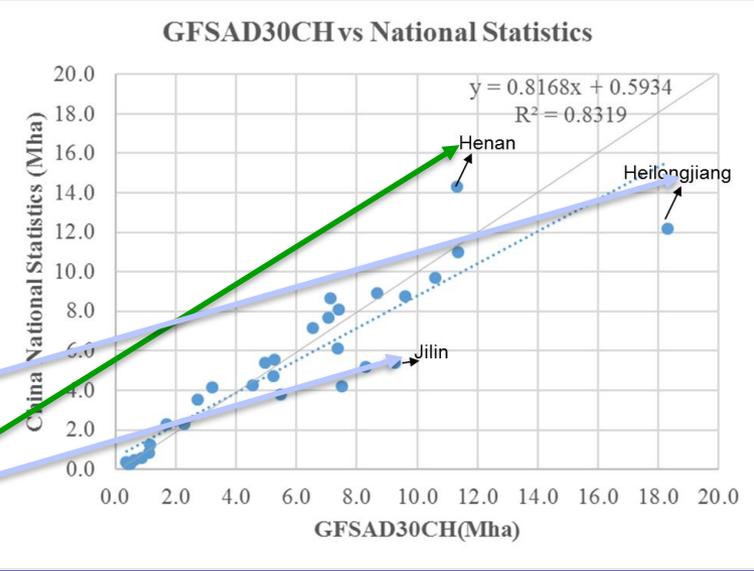
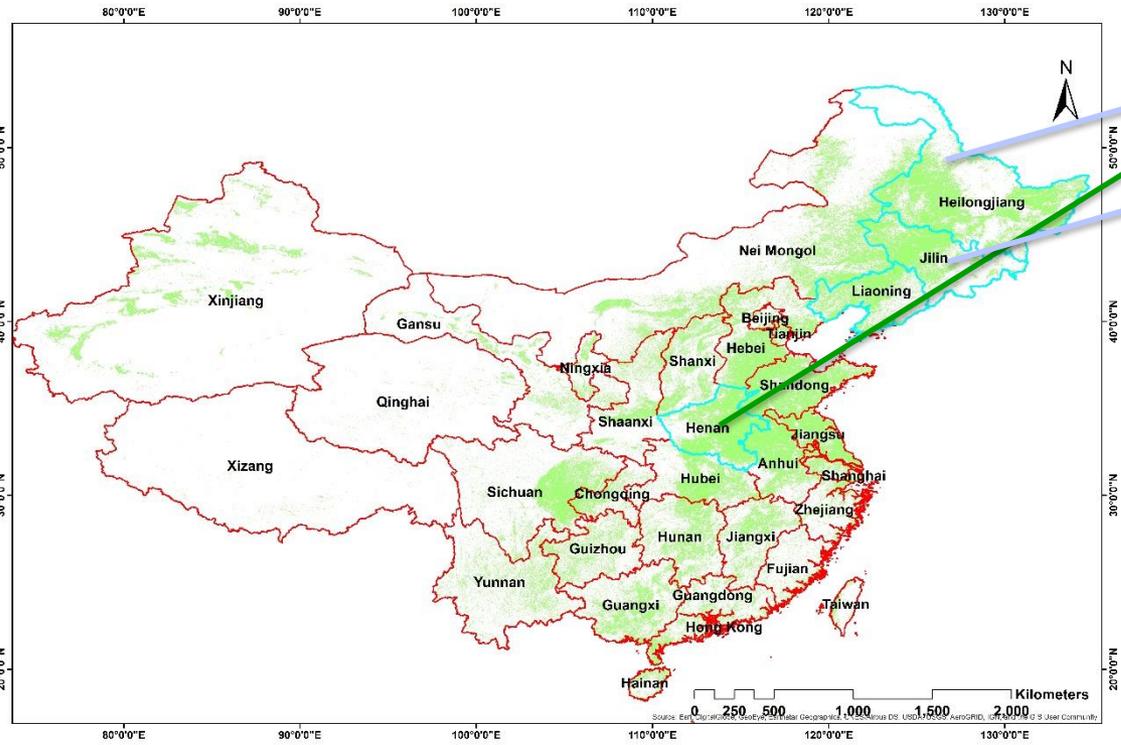
U.S. Geological Survey
U.S. Department of Interior



Cropland Products for China using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

Comparison of Cropland areas across Provinces

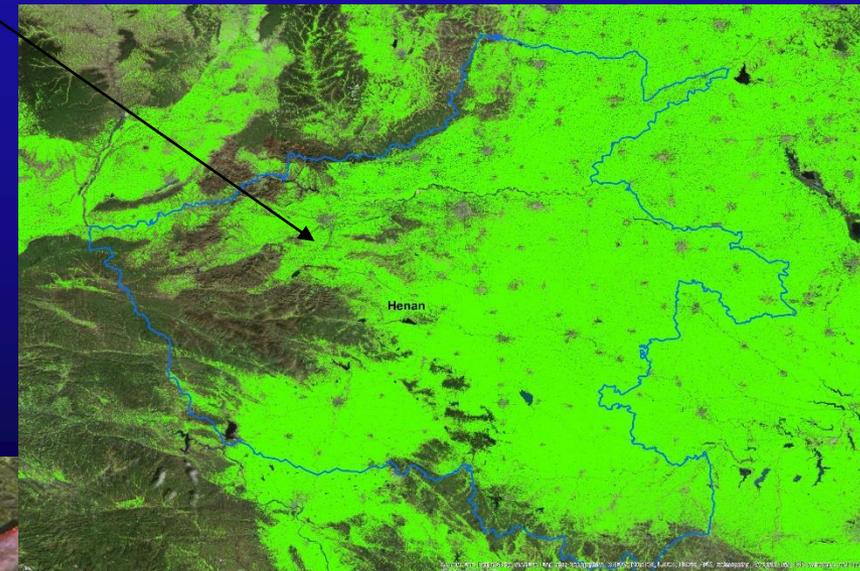
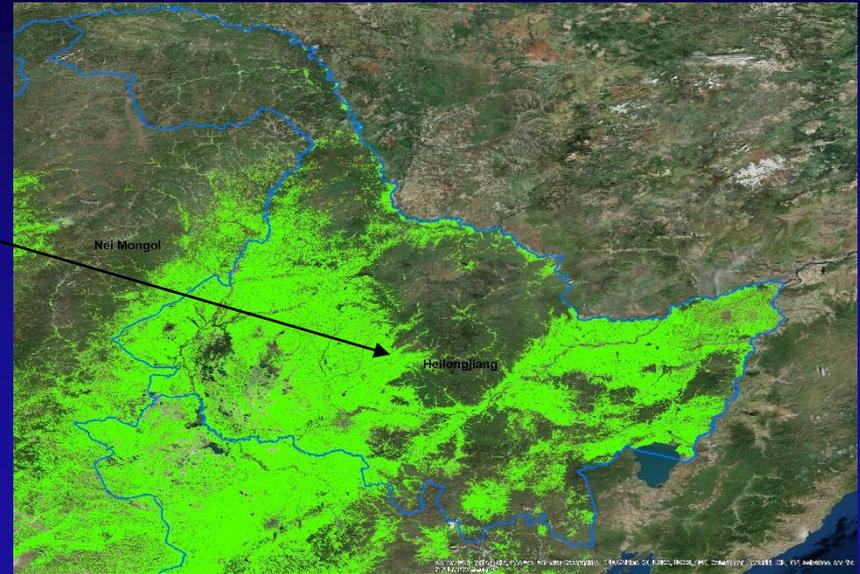
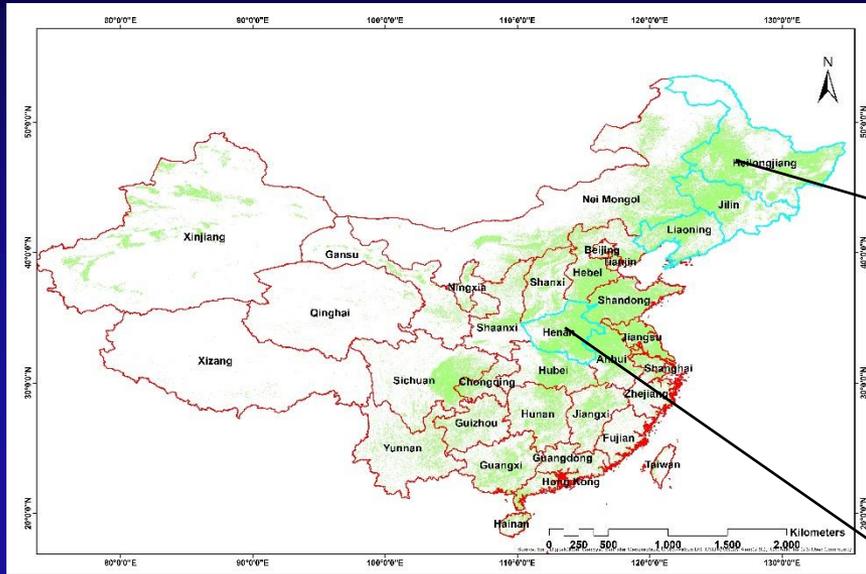


U.S. Geological Survey
U.S. Department of Interior

Data source:
<http://www.stats.gov.cn/tjsj/ndsj/2014/indexeh.htm>



Cropland Products for China using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Comparison of Cropland areas across Provinces



Cropland Products
Nominal 30-m Cropland Extent Product
Spatial Variability Comparisons: Across Resolutions
Australia

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>

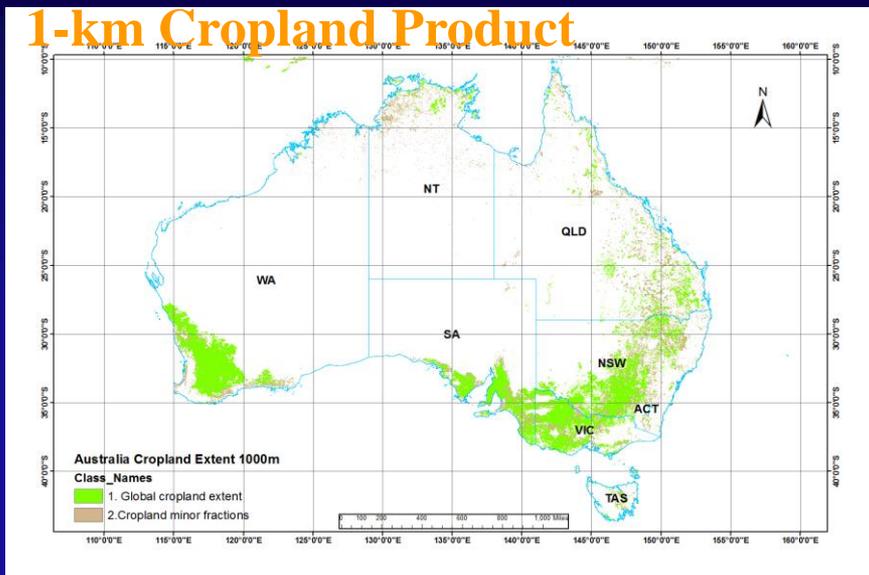


Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

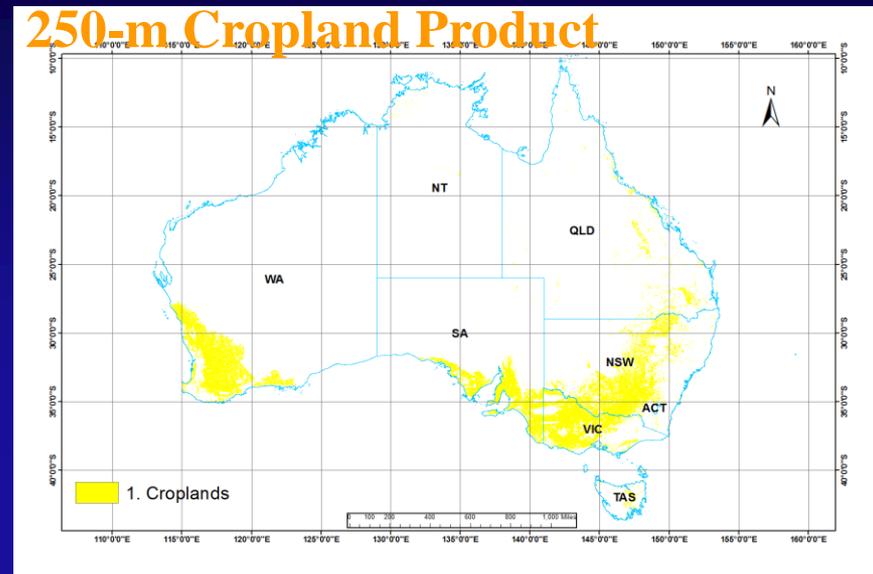
@ 30-m Resolution based on Landsat 16-day Time-Series

Comparisons of Products Across Resolutions

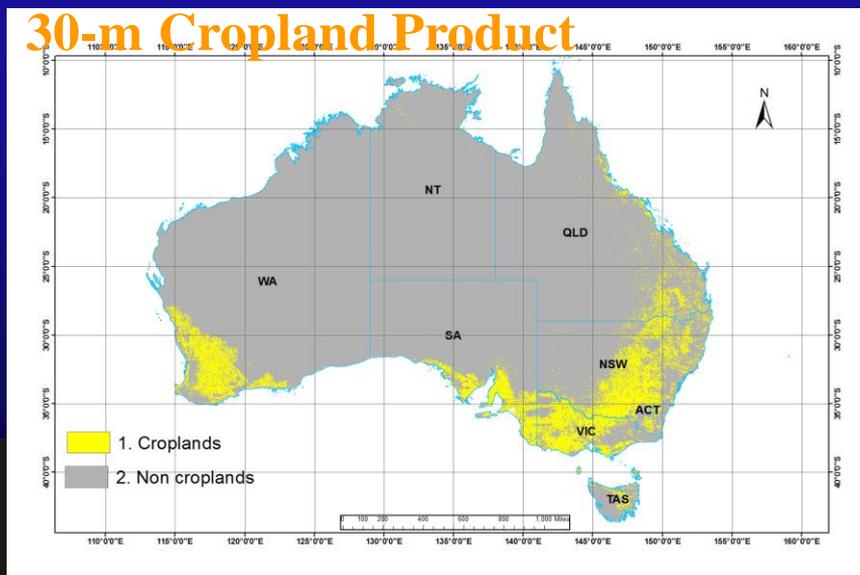
1-km Cropland Product



250-m Cropland Product



30-m Cropland Product



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

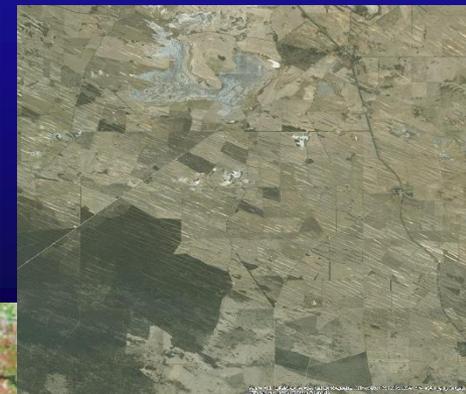
Comparisons of Products Across Resolutions

1-km Product

250-m Product

30-m Product

High resolution image



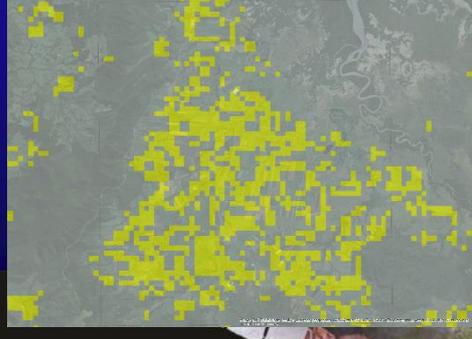
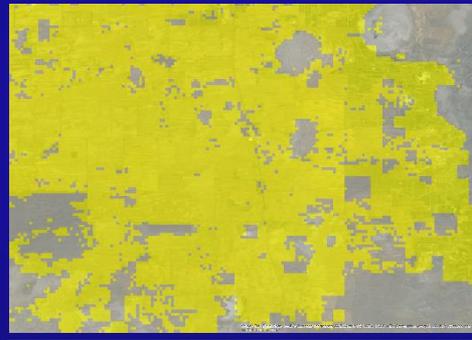
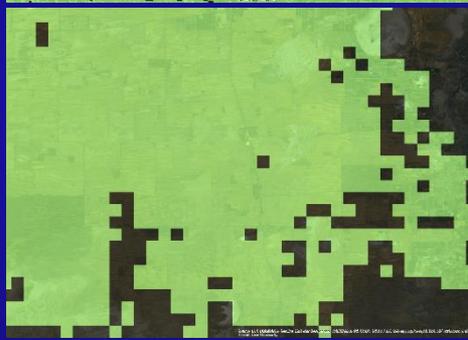
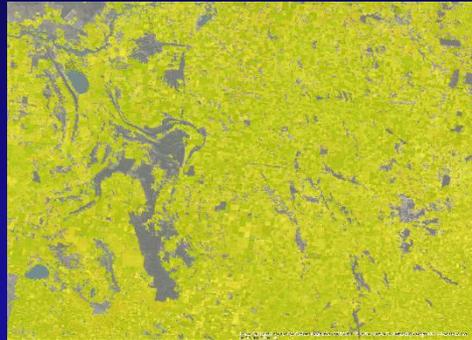
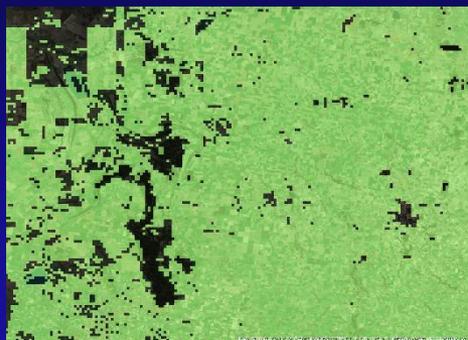
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Comparisons of Products Across Resolutions

1-km Product

250-m

30-m Product

High resolution image



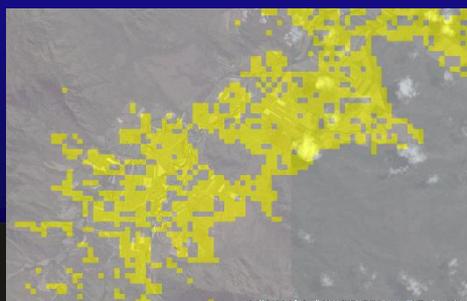
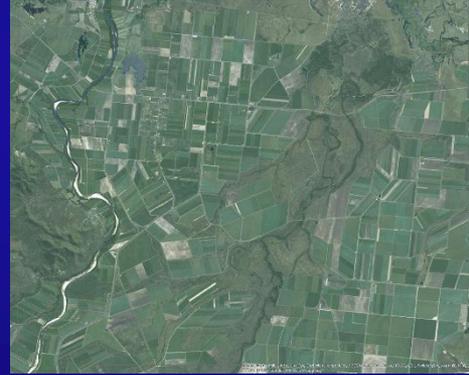
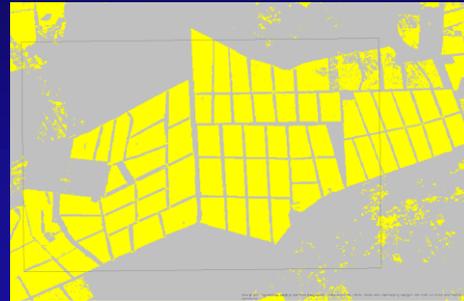
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing @ 30-m Resolution based on Landsat 16-day Time-Series Comparisons of Products Across Resolutions

1-km Product

250-m Product

30-m Product

High resolution image



Cropland Products nominal30-m for 2014

Conclusions

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



U.S. Geological Survey
U.S. Department of Interior



**Cropland Products for Australia , NewZealand and China using
Google Earth Engine (GEE) Cloud Computing
@ 30-m Resolution based on Landsat 16-day Time-Series**

Conclusions

1. Cropland products are produced at three levels\resolutions:

1 km (past work; only overview; Products released earlier; write up published)

250 m (recent work summary; short presentation; published in IJDE)

30 m (current work; upto date presentation)

**2. Detailed presentations are made for Landsat 30m products of Australia,
NewZealand and China**

3. Currently products released through

<https://croplands.org/app/map>

We will soon release products on LP DAAC :

4. Manuscript is under preparation



Conclusions

- 1. Random forest was applied to Landsat 30m data to create Crop extent for Australia, New Zealand and China on Google Earth Engine;**
- 2. The acceptable results depend on the size and quality of sample data used to train the classifier;**
- 3. Accuracies are assessed for Australia, China;**
- 4. An Independent accuracy assessment was conducted by our accuracy team for Australia;**
- 5. Province wise Cop area compared with China National Statistics;**
- 6. Compared cropland maps across 3 different spatial resolutions for Australia region**



Cropland Products
Nominal 30-m Cropland Extent Product

Dissemination

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

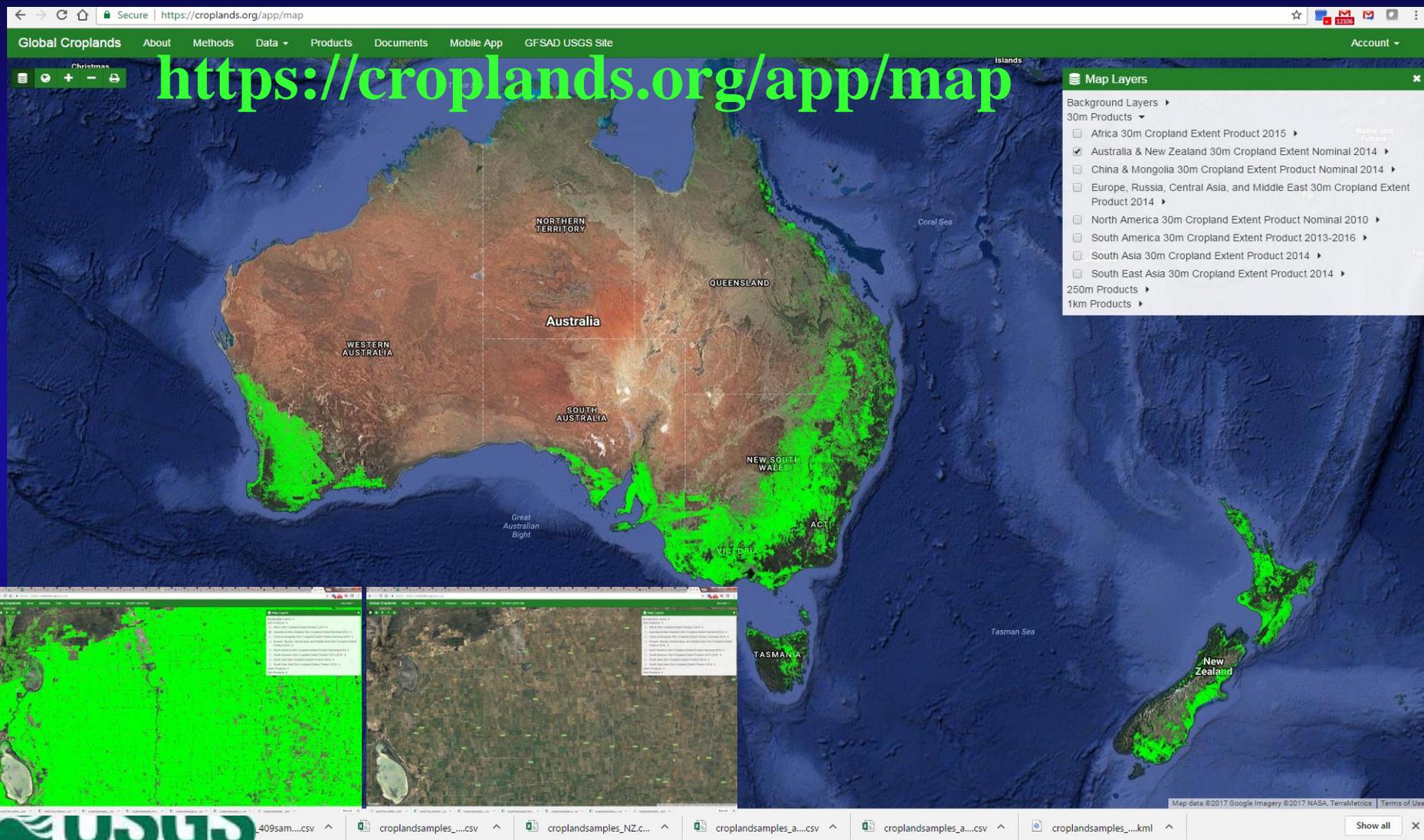
<https://www.croplands.org/>



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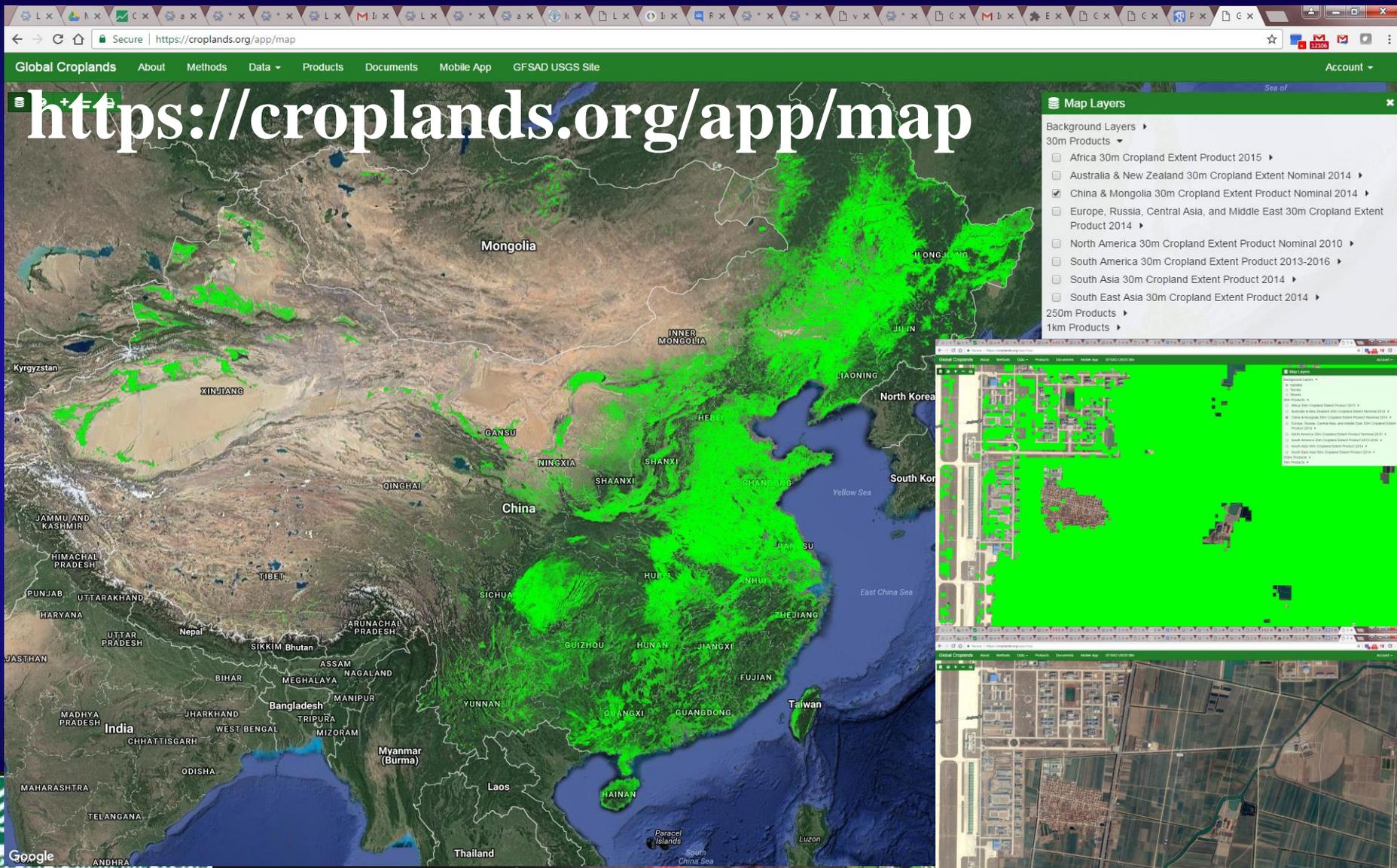
Australia Cropland Mapping @ Landsat 30-m using Random Forest Algorithm in Google Earth Engine (GEE) Cloud Computing Dissemination



U.S. Geological Survey
U.S. Department of Interior

<https://croplands.org/app/map>

Australia Cropland Mapping @ Landsat 30-m using Random Forest Algorithm in Google Earth Engine (GEE) Cloud Computing Dissemination



Cropland Products
Nominal 30-m Cropland Extent Product
Going Forward: Upcoming
Products

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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Australia
Cropland Products
~30-m for 2014

Irrigated *versus* Rainfed

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

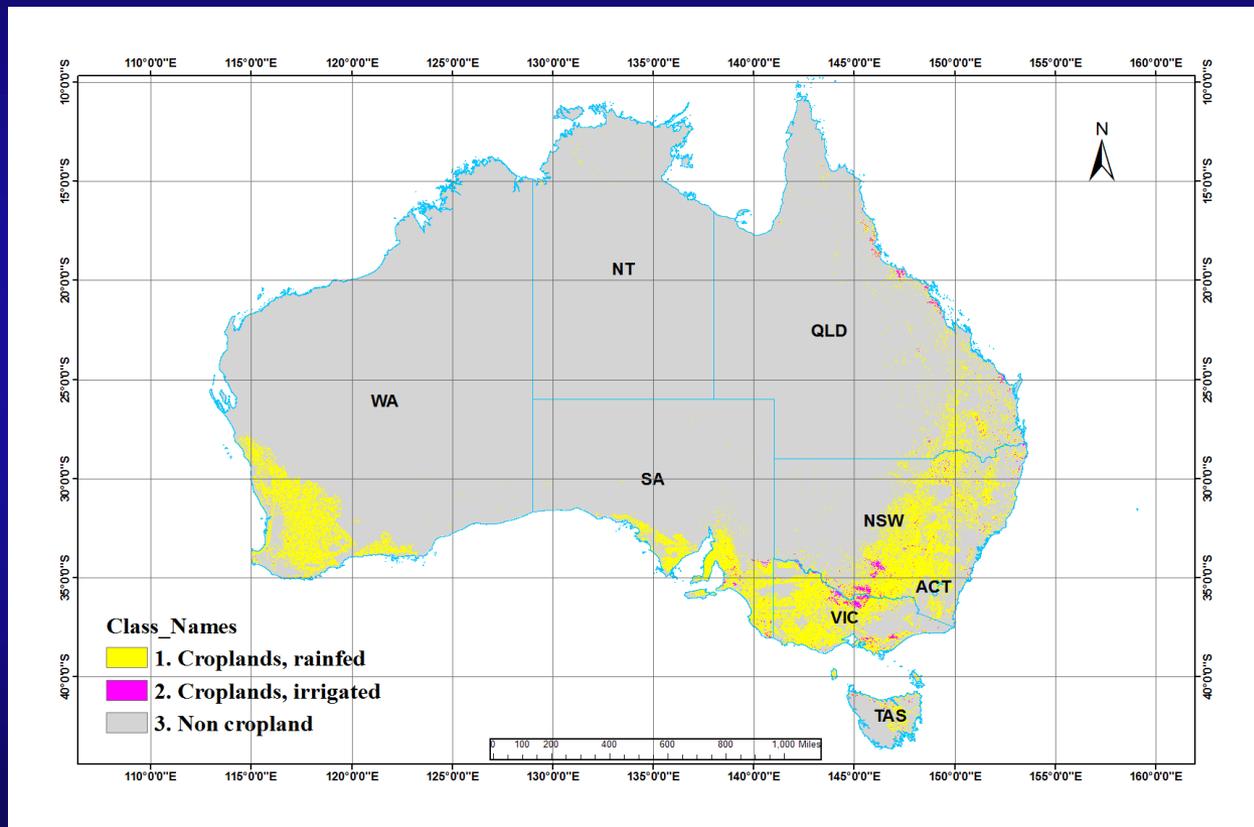
Product 2: Irrigated *versus* Rainfed

Note: We have retained irrigated areas as in MODIS 250-m product. Changing this will make little difference and not worth the effort.

Total Cropland: 65.2 Mha

Rainfed : 63.0 Mha (96.6%)

Irrigated : 2.2 Mha (3.4%)



Australia
Cropland Products
~30-m for 2014
Cropping Intensity

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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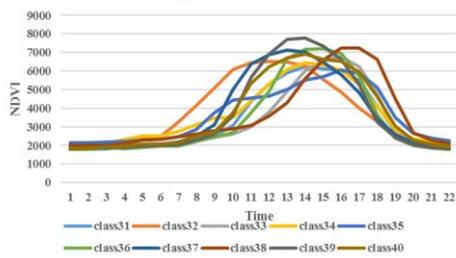
Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

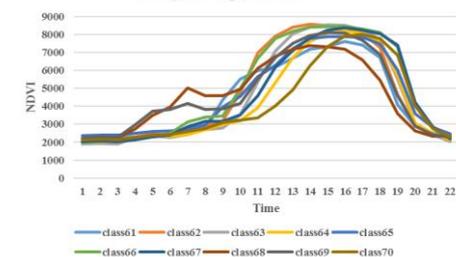
Product 3: Cropping Intensity

Approach: The Landsat 30-m cropland product was fused with MODIS 16-day NDVI time series to derive intensity @ 30-m

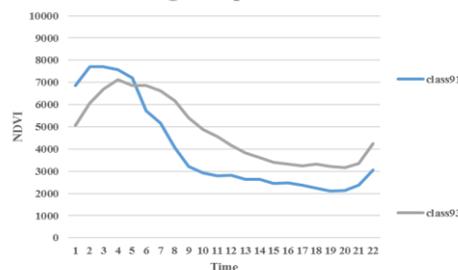
Single crop, season1



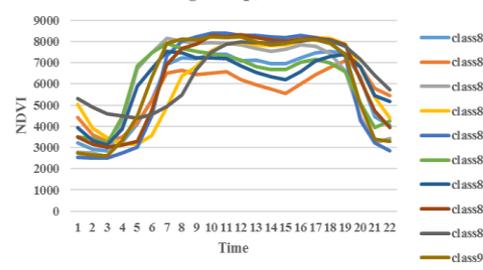
Singlecrop, season1



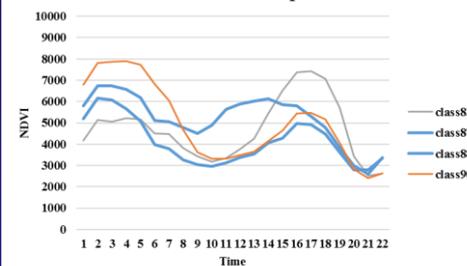
Single crop-Season2



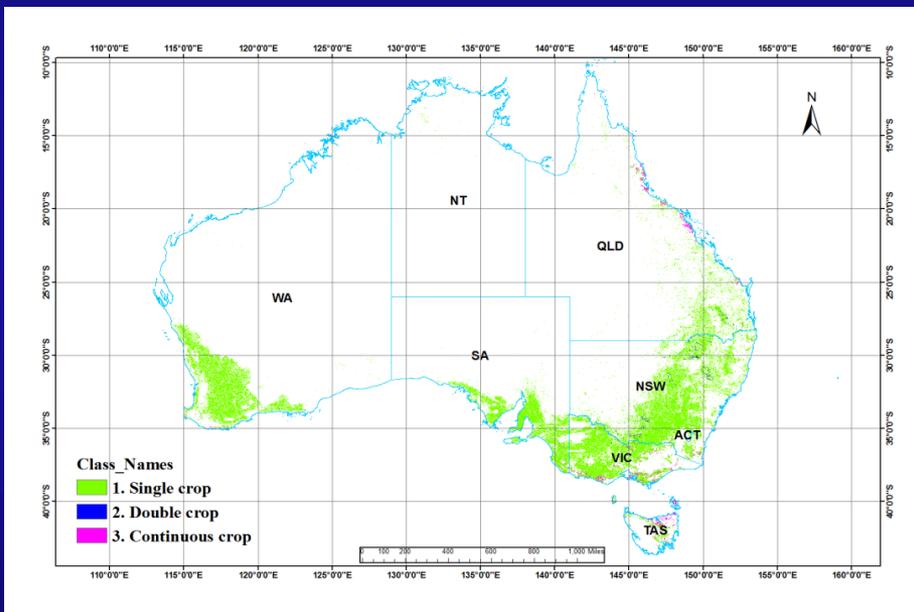
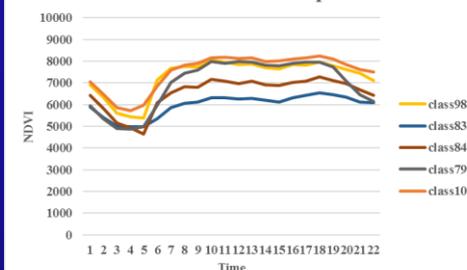
Single crop, Pastures



Double crop



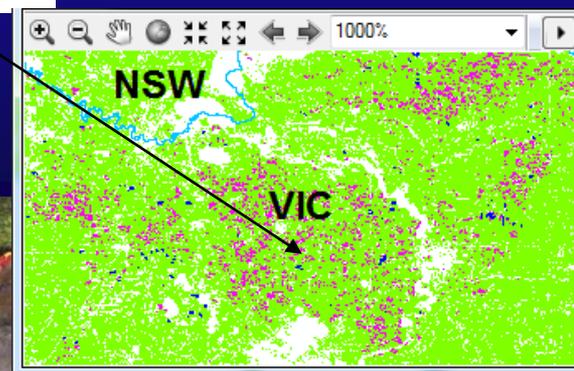
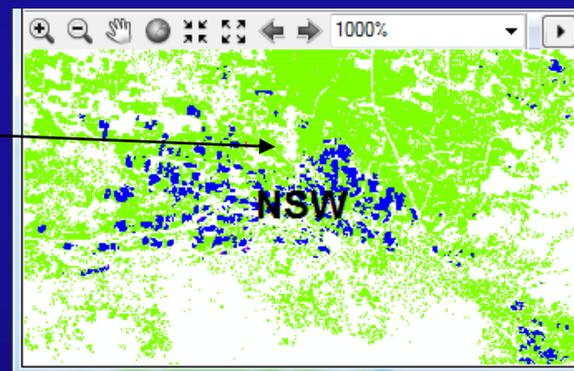
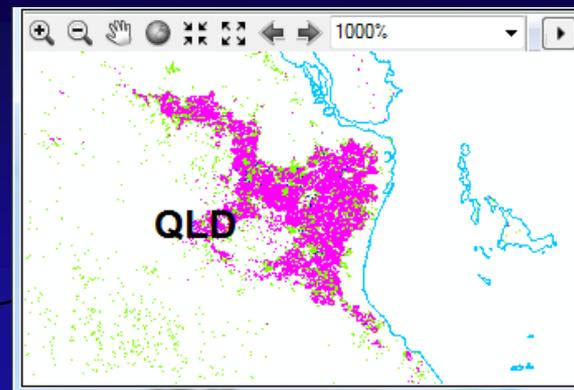
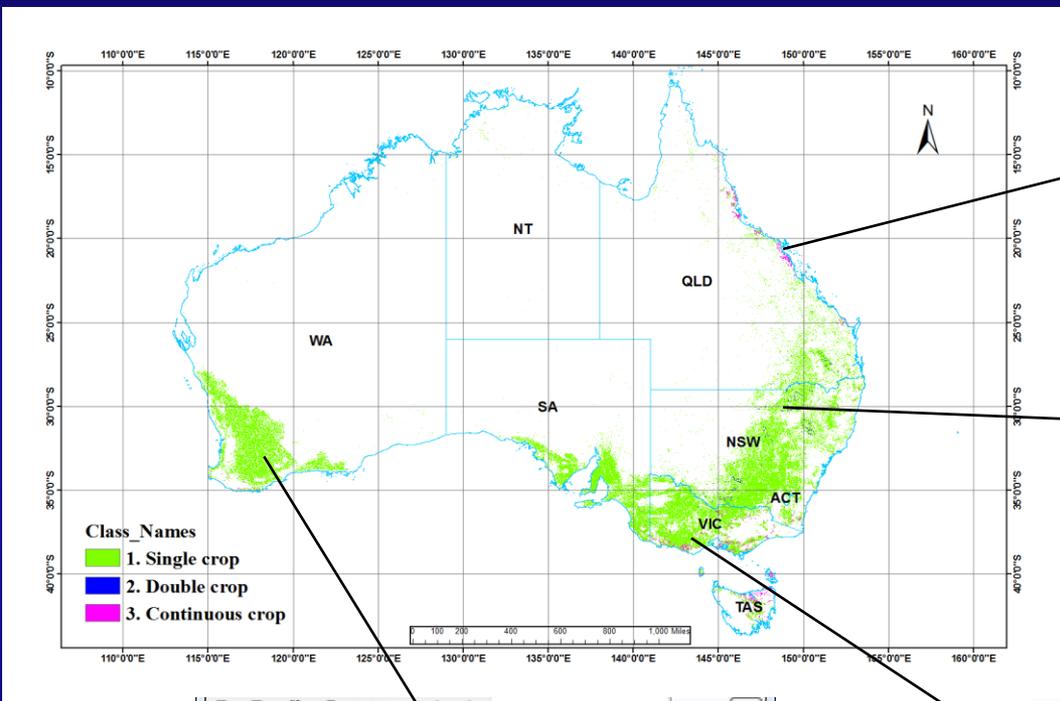
Continuous crop



Cropland Products for Australia using Google Earth Engine (GEE) Cloud Computing

@ 30-m Resolution based on Landsat 16-day Time-Series

Product 3: Cropping Intensity



Australia
Cropland Products
~30-m for 2014
Crop Type

<http://geography.wr.usgs.gov/science/croplands/index.html>

<https://croplands.org/app/map>

<https://www.croplands.org/>



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Thank you



Cropland Products of Australia @ Nominal 250 m

Approach for Producing Cropland Products from Years 2000 through 2015

.....Three Step Approach

1. Produce Cropland products for a base year 2014 using MODIS time-series data and Spectral Matching Techniques (SMTs)

Cropland Products are produced based on **MODIS time-series data and Spectral Matching Techniques (SMTs)** using extensive field knowledge (ground data) of a baseline year 2014. Classes are tested for accuracy using independent ground data;

2. Develop automated cropland classification algorithms (ACCA) using knowledge base of classes from the base year 2014

Capture knowledge of Cropland Classes produced for baseline year 2014 **by a decision tree automated cropland classification algorithm (ACCA)**;

3. Apply ACCA algorithm for other independent years using MODIS time series data for those years

ACCA algorithm is applied on MODIS time-series data from 2000 through 2013 and 2015 **to reproduce cropland classes similar to the baseline year 2014, automatically.** ACCA derived classes are compared with SMT derived classes for 2014. For other years, ACCA derived classes are tested for accuracy using independent data.

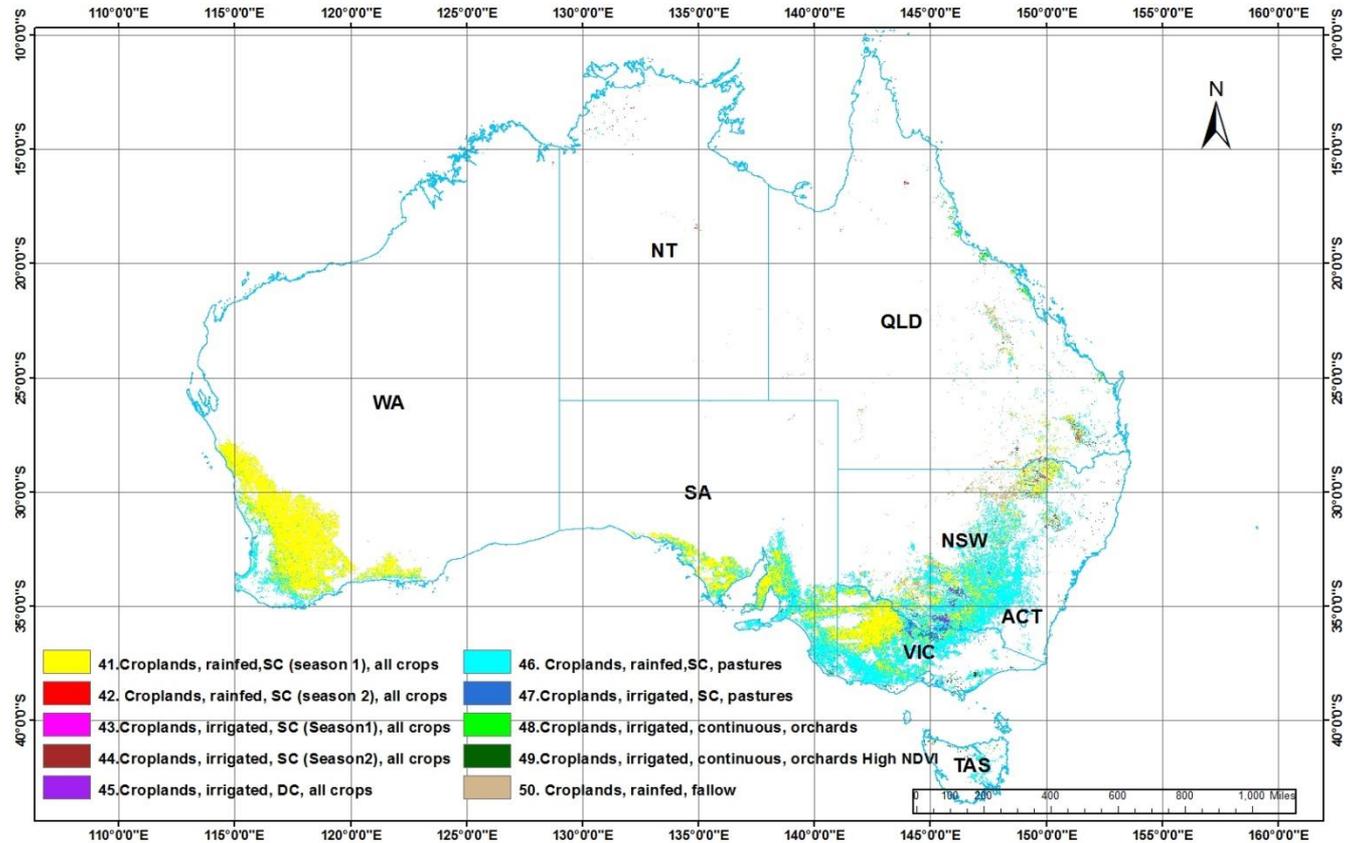


Cropland Classes of Australia using MODIS 250m, Year 2014

Total 10 Unique Classes from 3 Mask Areas: Rainfed, Pasture, Irrigated

Based on Spectral Matching Techniques (SMTs);
Projection: Geographic, Datum: WGS84

Total area of Croplands of Australia: ~ 58.5 Mha



Ground Sample Data: Crop Types

Data Collected during September- October 2014 (peak crop growing period)

(Total Sample Size : 4431)

Note:

The total ground data points,

N= 4411, was divided into 3 blocks.

One Reference /training dataset

N1= 1458

two validation datasets:

N2= 1488 and

N3= 1465

Code	Crop Description	Samples for or training	Samples for testing	Samples for Validation	Samples Total number
		N1	N2	N3	N
#	Name	#	#	#	#
1	Alfafa	4	3	4	11
2	Barley	154	153	154	461
3	Beans	30	29	29	88
4	Canola	186	185	186	557
5	Lentils	65	65	65	195
6	Lupin	34	33	35	102
7	Oats	73	72	73	218
8	Peas	27	26	26	79
9	Wheat	283	283	284	850
10	Orchards	55	60	54	169
11	Sown-pasture	95	98	96	289
12	Season2 Crops	20	16	18	54
13	Crop-harvested	9	9	10	28
14	Vegetables	1	1	1	3
15	Plantation	4	3	3	10
16	Cropland,others	30	29	25	84
20	Grazing/pastures	118	117	117	352
30	Non croplands	145	165	155	465
40	Fallow	125	141	130	396
	Total	1458	1488	1465	4411

Producing Reference Cropland Products for Australia @ 250-m based on MODIS 16-day Time-Series Using Spectral Matching Techniques (SMTs)

