Landsat Time-series Derived 30-m Cropland Extent Product in Support of Food and Water Security

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Global Food Security-support Analysis Data @ 30 m (GFSAD30) Project
PI, co-Is, and Project Team

PI and co-Is who wrote the proposal (original team that wrote the proposal):
Dr. Prasad S. Thenkabail, PI, U.S. Geological Survey, Flagstaff, AZ;
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Dr. Mutlu Ozdogan, co-I, University of Wisconsin, Madison, WI;
Dr. Russell G. Congalton, University of New Hampshire, Durham, NH;
Dr. Chandra Giri, co-I, United States Environmental Protection Agency (USEPA);
Dr. James C. Tilton, NASA Goddard Space Flight Center, Greenbelt, MD;

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Three Main Contributors to today’s presentation:
Dr. Pardasaradhi Teluguntla, BAERI\USGS Scientist
Dr. Jun Xiong, BAERI\NASA AMES Scientist
Mr. Adam Oliphant, USGS Geographer

Complete team and their profiles @:
www.croplands.org
Importance of Global Food and Water Security

Thoughts for this Talk

“Civilization as it is known today could not have evolved, nor can it survive, without an adequate food supply” - Norman Borlaug, Father of the Green Revolution and Nobel Laureate

To meet food and nutritional demand of 10+ billion people by the end of the century

“When the well is dry, we know the worth of water.” Benjamin Franklin, one of the Founding Father of the United States
GFSAD30 Project
Goals and Objectives

https://web.croplands.org/app/map
croplands.org
Monitoring global croplands (GCs) is imperative for ensuring sustainable water and food security to the people of the world in the Twenty-first Century. However, the currently available cropland products suffer from major limitations such as: (1) Absence of precise spatial location of the cropped areas; (b) Coarse resolution nature of the map products with significant uncertainties in areas, locations, and detail; (b) Uncertainties in differentiating irrigated areas from rainfed areas; (c) Absence of crop types and cropping intensities; and (e) Absence of a dedicated web\data portal for the dissemination of cropland products.

The overarching goal of this project is to produce consistent and unbiased estimates of global agricultural cropland areas, crop types, crop watering method, cropping intensities, & Cropland Fallows using Multi-sensor, Multi-date Remote Sensing and mature cropland mapping algorithms (CMAs).
Rice crop in India: Year 2000

Global Cropland Products @ 30-m

1. Cropland extent/areas;
2. Watering method (e.g., Irrigated versus rainfed);
3. Cropping intensity (e.g., single, double, triple, continuous);
4. Crop types (e.g., Major 8);
5. Croplands versus cropland fallows.

...the above products will lead to other higher level cropland products such as:

A. Crop productivity (kg/m²);
B. Crop water use (m³/m²);
C. Crop water productivity ("crop per drop": kg/m³).
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

30-m Cropland Extent Product of the World

Landsat derived global food security-support analysis
cropland areas @ 30-m (GFSAD30) =1.873 billion hectares
Global Croplands @ 30-m

Definition: How Croplands are defined and mapped

https://web.croplands.org/app/map
croplands.org
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Understanding Cropland Extent

Definitions: Net Cropland Extent Includes

- Croplands +
- Cropland fallows +
- Plantations

All croplands cultivated for food, feed, and fiber, including plantations (e.g., orchards, vineyards, coffee, tea, rubber) or croplands that are left fallow
Understanding Cropland Extent

Definitions: Agricultural Systems, Part of the Croplands

Aquaculture, fish ponds, often adjoin rice fields

Three areas of difficulty:
1. Aquaculture;
2. Green houses;
3. Managed pasture

Managed Rangelands are large part of agricultural systems of many countries (e.g., Australia, New Zealand, Brazil, Argentina, and Kazakhstan), we should map them, but keep them as a separate class NOT included in croplands

We should include aquaculture\fish ponds because they often adjoin rice fields and/or often part of heavily cultivated deltas and hence included in croplands

Rangelands, often adjoin croplands
Global Croplands @ 30-m

Methods:
Machine Learning Algorithms (MLA’s)

https://web.croplands.org/app/map
croplands.org
Pixel-based supervised machine learning algorithms (MLAs) along with Object-based hierarchical segmentation (HSEG) have been used extensively in generating global cropland products. In many cases we have also successfully in automated them to apply year after year with ability to: 1. hind-cast (e.g., past years), 2. now-cast (present year), and 3. future-cast (e.g., future years):

A. Random forest algorithms (Tatsumi et al., 2015, Gislason et al., 2006);
B. Support vector machines (Mountrakis et al., 2011);
C. Automated cropland classification algorithms (Thenkabail et al., 2010, Teluguntla et al., 2017);
D. Spectral matching techniques (Thenkabail et al., 2007, Teluguntla et al., 2017)
E. Decision Tree algorithms (Friedl and Brodley, 1997, Defries et al., 1998, Waldner et al., 2015);
F. Linear discriminant analysis (Imani and Ghassemian, 2015);
G. Principal component analysis, change detection analysis (Jensen, 2000);
H. kMeans, Isoclass clustering (Duveiller et al., 2015, Jensen et al., 2000);
I. Classification and Regression Tree (CART) (Egotov et al., 2015, Deng and Wu, 2013);
J. Tree-based regression algorithm (Ozdogan and Gutman, 2008);
K. Phenology based methods (Dong et al., 2015);
L. Fourier harmonic analysis (Zhang, 2015, Geerken et al., 2005);
M. Hierarchical segmentation (HSEG; Tilton et al., 2011, 2015).
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Accessing and Computing Massively Large Big Data (e.g., on GEE Cloud Computing)
Normalized data, Code Sharing, Parallel Computing, Massively Big Data, Rapid Results

72 AEZ’s

Landsat 2013-2016
### South East and North East Asia AEZs, Training Samples for Machine Learning Algorithms

<table>
<thead>
<tr>
<th>Zone</th>
<th>Region</th>
<th>Cropland Training Samples</th>
<th>Non Cropland Training Samples</th>
<th>Total Training Samples</th>
<th>Land Area</th>
<th>Area per Sample</th>
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<td>683</td>
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<td>Total</td>
<td>3,610</td>
<td>4,239</td>
<td>7,849</td>
<td>5,573,883</td>
<td>710</td>
</tr>
</tbody>
</table>
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Reference Data used for Training and Validation

~120,000 sub-meter to 5-m Very High Resolution Data (VHRI) Locations

Training and Validation Samples from VHRI (~130,000 samples worldwide)

Each sample is 90m x 90m

Roughly, 60% for Training & 40% for Validation
Reference Data for Training and Validation

Croplands versus Non-croplands
Ground Data for Training, Class Identification, and Validation
Recent (August, 2016) Field Data in Indonesia (Adam Oliphant & Prasad Thenkabail)

Java
Double crop irrigated rice

Indonesia

Bali
Double crop irrigated rice followed by short season crop
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Knowledge Generation for Machine Learning Algorithms: Some Examples
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies
Knowledge Generation for Random Forest Algorithm to Derive
Croplands versus Non-croplands @ 30-m

1. Take zone

2. Create a 30-m Landsat data cube

3. Create Training samples

4. Generate Distinct Knowledge

<table>
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Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies
Knowledge Generation for Machine Learning Algorithms: Some Examples
Global Croplands @ 30-m

Results:
30-m Global Cropland Extent

https://web.croplands.org/app/map
croplands.org
Landsat Satellite 16-day Time-Series Data for Deriving Global Croplands
Global Cropland Extent (GCE30) Product, nominal 2015

Landsat derived global food security-support analysis
cropland areas @ 30-m (GFSAD30) = 1.873 billion hectares

Net cropland Areas
Landsat Satellite 16-day Time-Series Data for Deriving Global Croplands GCE30 Product for South and South East Asia, nominal 2015

www.croplands.org
Landsat Satellite 16-day Time-Series Data for Deriving Global Croplands GCE30 Product for South and South East Asia, nominal 2015

www.croplands.org
Global Croplands @ 30-m

Results:

30-m Global Cropland Extent Accuracies

https://web.croplands.org/app/map
croplands.org
Global Cropland Extent @ 30-m (GCE30) Product Derived using Landsat Data

Validation of GCE30

Total Number of Samples: 19,171
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Accuracy Error matrices: Zone-by-Zone Error Matrices

For the entire world, the global cropland extent product had an overall accuracy of 91.7%. For the cropland class, the producer’s accuracy was 83.4% (errors of omission of 16.6%) and user’s accuracies of 78.3% (errors of commissions of 21.7%).
Global Cropland Extent @ 30-m Derived from Landsat Time-series Data

Accuracies: SE Asia
Whole SE Asia

Total land area of all zones (TLAall): 546.83 Mha
Cropland as % of TLAall: 23.4%
total net cropland area of SE Asia = 128 Mha

Reference Data

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<tr>
<th>Map Data</th>
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<th>No-Crop</th>
<th>Total</th>
<th>User Accuracy</th>
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<td>Total</td>
<td>461</td>
<td>1289</td>
<td>1750</td>
<td>88.63%</td>
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</table>

Producer Accuracy: 81.56%  91.16%  88.63%
Myanmar, Thailand, Laos, Cambodia, & Vietnam

<table>
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<th>Total</th>
<th>User Accuracy</th>
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<td>16</td>
<td>134</td>
<td>150</td>
<td>89.33%</td>
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<tr>
<td><strong>Total</strong></td>
<td>96</td>
<td>154</td>
<td>250</td>
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<tr>
<td><strong>Producer Accuracy</strong></td>
<td>83.33%</td>
<td>87.01%</td>
<td><strong>85.60%</strong></td>
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Reference Data

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<th>No-Crop</th>
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<th>User Accuracy</th>
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<td><strong>Map Data</strong></td>
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<tr>
<td>Crop</td>
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<td>158</td>
<td>88.61%</td>
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<tr>
<td>No-Crop</td>
<td>24</td>
<td>67</td>
<td>91</td>
<td>73.63%</td>
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<tr>
<td><strong>Total</strong></td>
<td>164</td>
<td>85</td>
<td>249</td>
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</table>

Producer Accuracy 85.37% 78.82% 83.13%

Global Cropland Extent @ 30-m Derived from Landsat Time-series Data

Accuracies for Zone 4: South Asia

Total land area of Zone 4 (TLAZ4): 174.87 Mha
Cropland as % of TLAZ4: 57.49%
Total net cropland area of SAsia (TCASA) = 262.47 Mha
Cropland as % of TCASA: 38.30%
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Producer’s Accuracies of Cropland Class (measures errors of omissions)

https://croplands.org/app/map/accuracyMap
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

User’s Accuracies of Cropland Class (measures errors of commissions)

https://croplands.org/app/map/accuracyMap
Global Croplands @ 30-m Results:
30-m Global Cropland Extent Areas

https://web.croplands.org/app/map
croplands.org
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

30-m Net Cropland Area as % of Geographic Area of the Country

Moldova: 87.1%
San Marino: 86.8%
Hungary: 80.6%

Denmark: 76.8%
Ukraine: 74.8%
Ireland: 74.7%
Bangladesh: 73.4%
Uruguay: 67%

UK: 64% (15.4 Mha)
France: 58% (31.8) Mha
Italy: 61% (17.9) Mha

https://croplands.org/app/map/statsMap
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Leading 4 Countries with 155-180 Mha of Net Cropland Areas

- India: 179.7 Mha
- USA: 167.8 Mha
- China: 165.3 Mha
- Russia: 155.8 Mha

www.croplands.org
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

30-m Cropland Area as ha\per person per Country

Landsat derived global food security-support analysis

cropland areas @ 30-m (GFSAD30) = 1.873 billion hectares
<table>
<thead>
<tr>
<th>Rank</th>
<th>Continent Name</th>
<th>Country Name</th>
<th>Gaul Admn Code</th>
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<td>GFSAD30³</td>
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Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Area Comparisons of Countries: GFSAD30 Vs. FAO (2015)

\[ \text{GFSAD30 crop area (Mha)} = 0.8928 \times \text{FAO crop area (Mha)} + 2.0577 \]

\[ R^2 = 0.9278 \]
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies

Area Comparisons of Countries: GFSAD30 Vs. FAO (2015)

Irrigated area in Pakistan

\[ y = 1.5487x \]
\[ R^2 = 0.8594 \]

Irrigated area in Sri Lanka

\[ y = 0.4951x \]
\[ R^2 = 0.8436 \]

Irrigated area in Bangladesh

\[ y = 0.6539x \]
\[ R^2 = 0.6632 \]

Irrigated area in Nepal

\[ y = 1.0171x \]
\[ R^2 = 0.8834 \]
Global Croplands @ 30-m Dissemination

https://web.croplands.org/app/map
croplands.org
Global 30-m Landsat-derived Cropland Extent, Areas, and Accuracies
DATA Access\Dissemination through LP DAAC
Data, Products, ATBD’s, User Guide’s, Manuscripts

Data Download:
https://lpdaac.usgs.gov/about/news_archive/release_gfsad_30_meter_cropland_extent_products

Data Browse:
www.croplands.org

Project Sites:
www.croplands.org
globalcroplands.org

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Release of GFSAD 30 meter Cropland Extent Products

The Land Processes Distributed Active Archive Center (LP DAAC) is pleased to announce the availability of the The NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security-support Analysis Data 30 meter (GFSAD30) Cropland Extent data product. The monitoring of global cropland extent is critical for policymaking and provides important baseline data that are used in many agricultural cropland studies pertaining to water sustainability and food security. The GFSAD30 collection provides cropland extent data across the globe, divided and distributed into 7 separate regional datasets, for nominal year 2015 (2010 for North America) at 30 meter resolution. Additionally, the validation dataset used to conduct an independent accuracy assessment of global cropland extent is available.

The Digital Object Identifier (DOI) for each dataset is given below to provide users with a persistent link to the product information.

GFSAD30 Cropland Extent 2015 Africa 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30AFCE_001

GFSAD30 Cropland Extent 2015 30 m Australia, New Zealand, China, Mongolia 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30AUNZCNMOC_001

GFSAD30 Cropland Extent 2015 Europe, Central Asia, Russia, Middle East 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30EUCERAME_001

GFSAD30 Cropland Extent 2015 North America 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30NAFC_001

GFSAD30 Cropland Extent 2015 South Asia, Afghanistan, Iran 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SAIFIR_001

GFSAD30 Cropland Extent 2015 South America 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SAFC_001

GFSAD30 Cropland Extent 2015 Southeast and Northeast Asia 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SEACF_001
GFSAD30 Cropland Extent 2015 Africa 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30AFCE.001

GFSAD30 Cropland Extent 2015 30 m Australia, New Zealand, China, Mongolia 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30AUNZCNMOCE.001

GFSAD30 Cropland Extent 2015 Europe, Central Asia, Russia, Middle East 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30EUCARUMECE.001

GFSAD30 Cropland Extent 2015 North America 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30NACE.001

GFSAD30 Cropland Extent 2015 South Asia, Afghanistan, Iran 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SAAFGIRCE.001

GFSAD30 Cropland Extent 2015 South America 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SACE.001

GFSAD30 Cropland Extent 2015 Southeast and Northeast Asia 30 m
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30SEACE.001

GFSAD30 Cropland Extent 2015 Global Validation
DOI: https://doi.org/10.5067/MEaSUREs/GFSAD/GFSAD30VAL.001

