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NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security-support Analysis Data (GFSAD) @ 30-m: Cropland Extent Validation (GFSAD30VAL)

Algorithm Theoretical Basis Document (ATBD)

USGS EROS
Sioux Falls, South Dakota

Document History

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1.0	September, 2017	Original
1.1		Modification made according to USGS reviewer's comments

Contents

I. Members of the team

This Global Food Security-support Analysis Data 30-m (GFSAD30) Cropland Extent Validation (GFSAD30VAL) was produced independent of the crop extent mapping teams by the following members. Their specific role is mentioned.

Dr. Russell G. Congalton, Professor of Remote Sensing and GIS at the University of New Hampshire, led the independent accuracy assessment/validation of the entire GFSAD30 project.

Ms. Kamini Yadav, PhD student at the University of New Hampshire was a lead member of the independent accuracy assessment team led by Prof. Russell G. Congalton.

Ms. Kelley McDonnell, undergraduate at the University of New Hampshire collected reference data for this project.

Mr. Justin Poehnelt, former member of the GFSAD30 team, helped initial conceptualization and development of the croplands.org website.

Mr. Bo Stevens, former member of the GFSAD30 team, contributed significantly to the interpretation of very high resolution imagery (VHRI) to provide independent reference samples used by the accuracy assessment/validation team.

Dr. Murali Krishna Gumma, Senior Scientist at the International Crops Research Institute for the Semi-Arid Tropics (**ICRISAT**), helped collect reference data for the project.

Dr. Pardhasaradhi Teluguntla, Research Scientist, Bay Area Environmental Research Institute (BAERI) at the United States Geological Survey (USGS), helped collect reference data for the project..

Dr. Prasad S. Thenkabail, Research Geographer, United States Geological Survey, is the Principal Investigator (PI) of the entire GFSAD30 project.

II. Historical Context and Background Information

Monitoring global croplands 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) The absence of precise spatial location of the cropped areas; (2) The coarse resolution of the map products with significant uncertainties in areas, locations, and detail; (3) The uncertainties in differentiating irrigated areas from rainfed areas; (4) The absence of crop types and cropping intensities; (5) The absence of a dedicated Internet data portal for the dissemination of cropland products; and/or (6) poor or invalid accuracies of these cropland maps. Therefore, the overall goal of our project is to close these gaps through a Global Food Security Support-Analysis Data @ 30-m (GFSAD30) product. The specific goal of the validation/accuracy assessment component of the GFSAD30 team is to provide a thorough, complete, and independent accuracy assessment/validation of the mapping products produced by rest of the team.

This algorithm theoretical basis document (ATBD) provides a detailed account of the GFSAD30 cropland extent accuracy assessment/validation product for the globe (GFSAD30VAL, Table 1). This document is organized into four broad sections. Section 1 introduces the rationale of generating the product. Section 2 provides an overview and the technical background information and algorithms employed in the generation of the product. Section 3 presents and discusses the results. Section 4 describes the validation activities of the product.

Table 1. Basic information of the Global Food Security support-Analysis Data @ 30-m cropland extent accuracy assessment/validation product for the globe (GFSAD30VAL).

Product Name	Short Name	Spatial Resolution	Temporal Resolution
GFSAD 30-m Cropland Extent Accuracy Assessment/Validation Product for the Globe	GFSAD30VAL	3x3 30-m pixels forming 90 m homogeneous samples	nominal 2015

III. Rationale for Development of the Algorithms

Mapping the precise location of croplands enables the extent and area of agricultural lands to be more effectively captured, which is of great importance for managing food production systems and to study their interrelationships with water, geo-political, socio-economic, health, environmental, and ecological issues (Thenkabail et al., 2010). Further, accurate development of all higher-level cropland products such as crop watering method (irrigated or rainfed), cropping intensities (e.g., single, double, or continuous cropping), crop type mapping, cropland fallow, as well as assessment of cropland productivity (i.e., productivity per unit of land), and crop water productivity (i.e., productivity per unit of water) are all highly dependent on availability of precise and accurate cropland extent maps. Uncertainties associated with cropland extent maps effect the quality of all higher-level cropland products reliant on an accurate base map. However, precise and accurate cropland extent maps are mostly nonexistent at the continental scale at a high spatial resolution (30-m or better). By mapping croplands at a high-resolution at the continental scale, the GFSAD30 project has resolved many of the shortcomings and uncertainties of other cropland mapping efforts. In addition, the thorough and valid accuracy assessment/validation of these cropland extent maps makes them even more valuable and is a critical component of any mapping project (Congalton and Green 2009).

The most widely accepted approach to perform a quantitative accuracy assessment is generating an error matrix (Congalton, 1991). The error matrix is a cross tabulation of the class labels predicted by the image classification against that observed from a validation dataset. A global validation dataset was developed in this project that covers only a sample of the cropland mapping area using an appropriate sample size, sample unit, and sampling design (Congalton and Green, 2009). The sampling design, based on the inclusion probability of occurrence of each mapped class in the region or the continent, is required to provide a statistically valid accuracy assessment procedure (Strahler et. al., 2006). If the inclusion probabilities of crop and no-crop mapping area (i.e., crop extent) are ignored in assessing the thematic maps, a significant bias is likely to occur. Unless the validation samples represent the entire proportion of cropland distribution, the accuracy estimates are subject to uncertainty. However, while individual measures of accuracy are well established in literature (e.g., Congalton 2015, Congalton and Green, 1999; Stehman, 1997; Congalton, 1991), considerable ambiguity remains about the implementation and interpretation of large area thematic map accuracy assessment. Therefore, this project investigated a variety of sampling methods to produce an effective and valid sampling and assessment methodology for the globe (see an overview of this methodology in Figure 1).

IV. Algorithm Description

An overview of the algorithm used to conduct the accuracy assessment is shown in Figure 1. An overview of this process is briefly described in this paragraph and presented in detail in subsequent sections of this ATBD document. The accuracy assessment was conducted for each continental region separately. Table 1 shows the breakdown of these continental regions. Each continental region was further divided (stratification) into either Agro-Ecological Zones (AEZs) or a buffer zone to facilitate more homogeneous mapping and assessment (Table 1). Reference data were collected for each continental region from a variety of sources. If reference data existed for an area and were deemed acceptable, then these data were used. Where possible, ground reference data were collected. Finally, interpretation of very high resolution imagery (VHRI) was employed to produce reference samples. These data were produced either by Bo Stevens who was trained for this purpose by the GFSAD30 team and placed in the Croplands.org database or by the validation team (see Table 3). Sufficient reference data at an appropriate sample unit size were collected for each continental region. Once the reference data were compiled, an error matrix was generated for each AEZ or buffer zone. Descriptive statistics including overall, producer's, and user's accuracies were then generated for each matrix. Finally, overall accuracy was computed for each continental region and then for the entire globe.

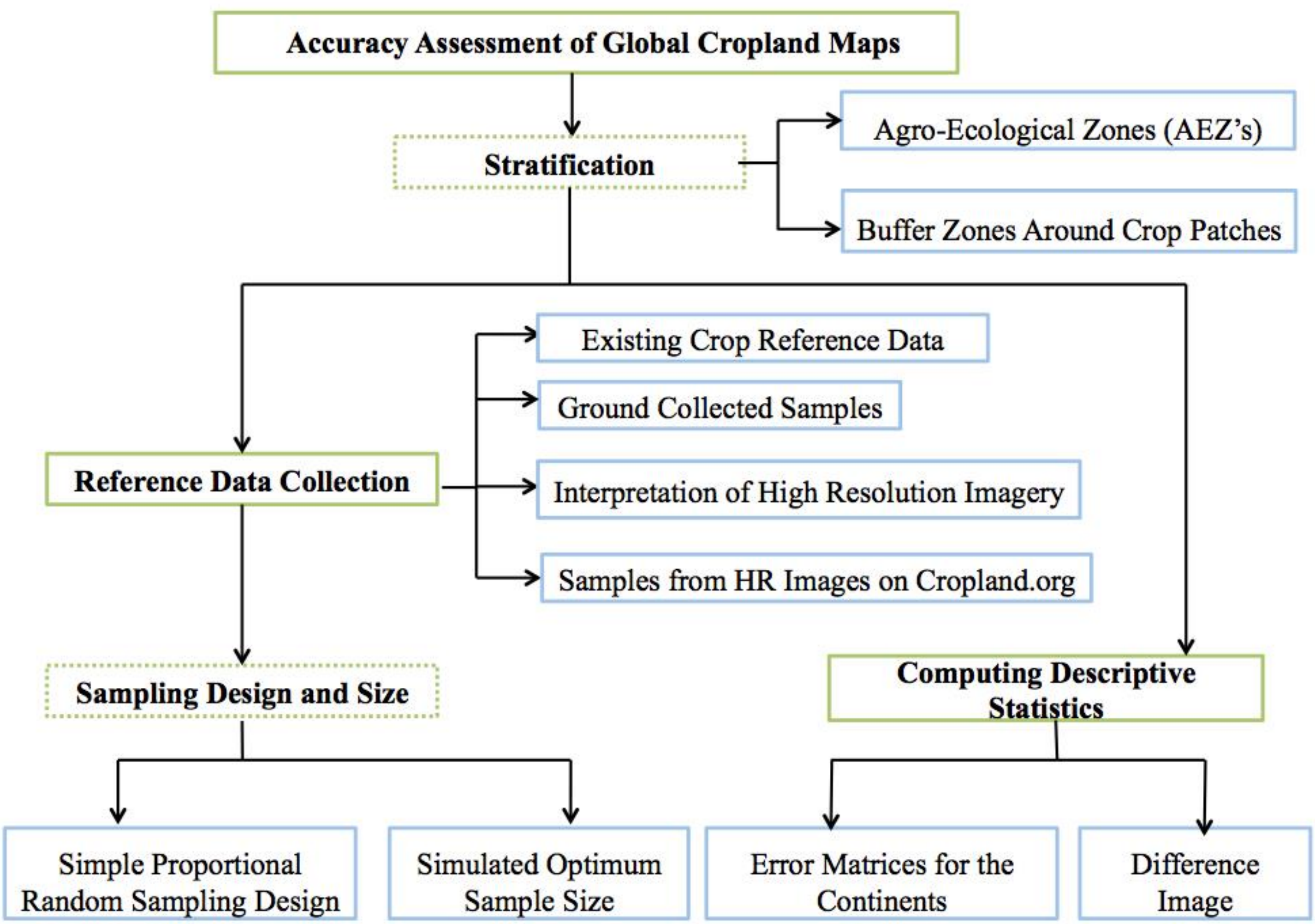

Figure 1. Flowchart of the process used to conduct the independent accuracy assessment of the GFSAD30 mapping products.

Table 1. Area, number of zones, and total reference samples used for each continental region.

Continent	Area (Mha)	Zones	Samples
North America including US, Canada, Mexico, and Central America, Cuba, Caribbean. Is., DR Haiti	2,190.7	25	
❖ United States	13.35	9	2250
❖ Canada	10.86	3	750
❖ Mexico	2.36	6	1463
❖ Central America	0.68	2	496
❖ Cuba, Caribbean. Is., DR Haiti, Alaska, and Hawaii	64.67	5	1240
❖ Iceland	0.17	1	250
South America	20.60	5	1250
South East Asia	6.21	7	1750
Africa	33.31	7	1750
Mongolia	2.28	3	300
New Zealand	26.3	2	500
China	14.86	3	1972
Europe, Russia, and Mid East	3,076	12	3000
South Asia	861.64	6	1500
Australia (Only Crop Buffer 1)	768.7	1	700
Total	7,000.60	72	19,171

Table 2. Sources of reference data used in the generation of the error matrices.

	Continent	Source of Validation Dataset
	Africa	Independent generated samples along with cropland.org samples
	Canada	Samples from AAFC cropland reference layer
	United States	Samples from CDL cropland reference layer
	Mexico	Independent generated samples
	Central America	Independent generated samples
	Cuba, DR Haiti, Caribbean Islands, Alaska, and Hawaii	Independent generated samples
	Iceland	Independent generated samples
	Mongolia	Independent generated samples
	China	Independent generated samples combined with cropland.org samples
	Australia	Independent generated samples and Ground collected samples
	New Zealand	Independent generated samples
	South Asia	Independent generated samples
	South East Asia	Only Cropland.org samples
	Europe, Russia, and Mid East	Independent generated samples
	South America	Only Cropland.org samples

a. Input data

1. Reference Data

In order to assess the accuracy of the maps generated by the GFSAD30 mapping teams, a reference data set collected independently from any reference data used for training or testing by the mapping teams was required. In total, 19,171 reference samples (see Table 1), gathered as described in the following paragraph, were used to validate the maps. The assessment was performed individually for each AEZ or buffer zone (72 in total, Figure 2) and reported as an error matrix for each of these zones. The results were then compiled into an error matrix for each continental region (15 regions, see Table 1) and then compiled into a single global error matrix.

The independent reference data were obtained in the following ways. First, a search was conducted to determine if any country, region, or continent had readily available data that could be used as reference data. Both the United States and Canada collect annual information that provides excellent reference data. The National

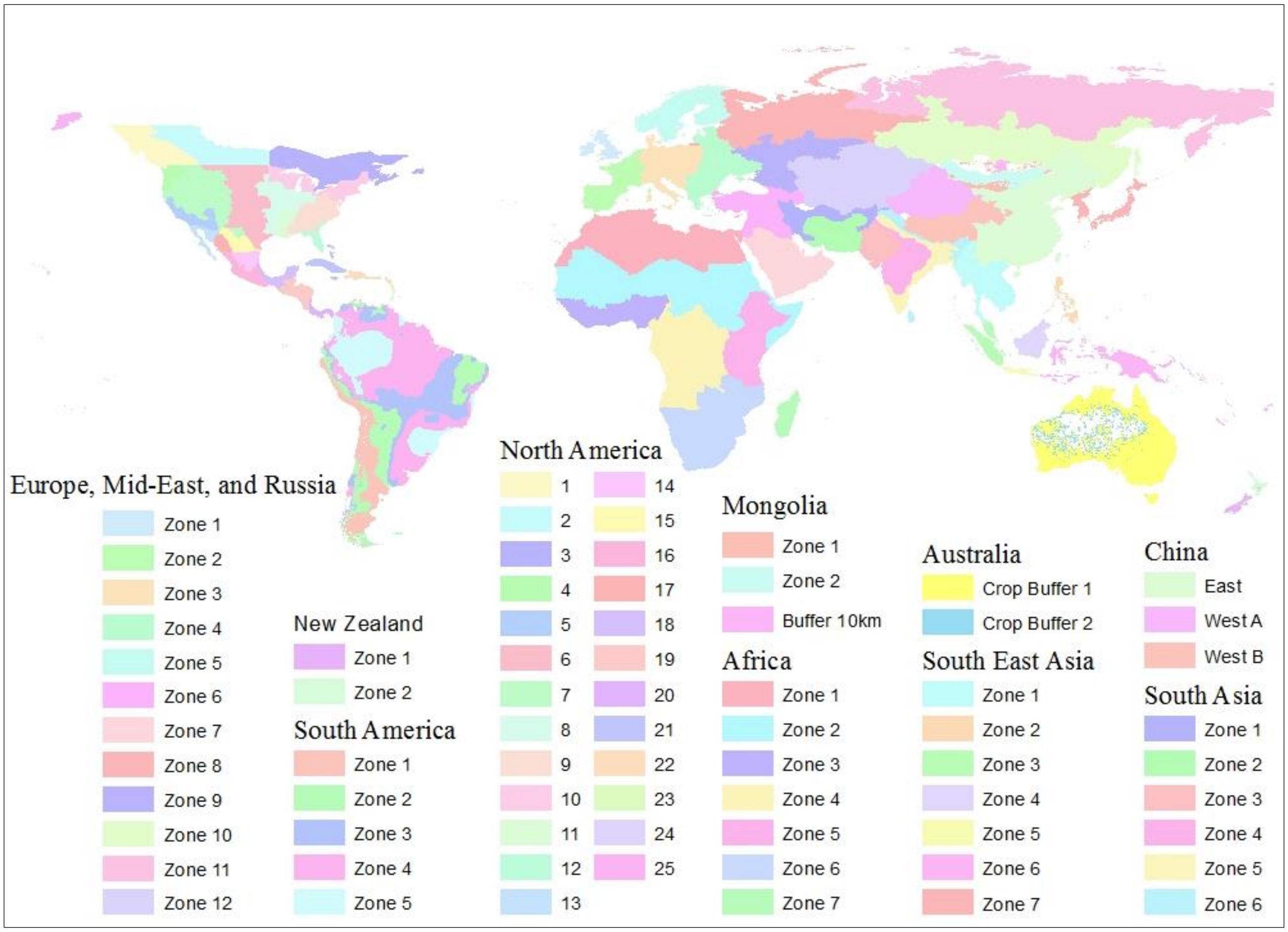

Figure 2. Representing stratified zones for different continents selected to assess the cropland extent maps

Agricultural Statistics Service (NASS) of the US Department of Agriculture (USDA) developed the Cropland Data Layer (CDL) product for the entire United States (Boryan et al. 2011). The CDL product is a comprehensive, raster-formatted, geo-referenced, and crop-specific land cover map that utilizes ortho-rectified imagery to identify field crop types accurately and geospatially (Han et al. 2012). Since 2009, CDL is available at 30m spatial resolution for all 48 conterminous states in the United States. The Agriculture and Agri-Food Canada's (AAFC) Annual Space-Based Crop Inventory for Canada provides high quality information at 30m spatial resolution for the location, extent and changes of Canadian crops (Fissette et al. 2013). Starting in 2009, AAFC began generating annual crop type digital maps using satellite imagery. Since 2011, AAFC has consistently delivered an annual crop inventory for all the Canadian provinces. As part of the Canadian federal government commitment to open data, the entire datasets is uploaded to http://data.gc.ca.

Second, field campaigns were conducted by some mapping team members to collect reference data not only on crop extent (cropland vs. no cropland), but also on crop type, irrigated vs. rainfed, and crop intensity (single, double crop per year). Finally, the vast majority of reference data were collected by image interpretation of very high resolution imagery (VHRI). This collection occurred in two ways. First, Mr. Bo Stevens, trained by the GFSAD30 team interpreted a great deal of VHRI imagery to be used by the entire GFSAD30 team. These data were spit 60/40 with 60 percent of the data being used by the mapping teams for training and testing of their classification algorithms. Forty percent was set aside and hidden from the mapping teams and made available only to our accuracy assessment team. All of this reference data was housed in a database (Cropland.org). Second, the accuracy assessment team used the 40 percent of the reference data in croplands.org, but only after reviewing each sample and confirming the interpretation. If both interpretations agreed, then the sample was selected for use. Additionally, the accuracy assessment team interpreted a supplemental sample of reference data from VHRI. Again here, two interpreters were used to insure high accuracy in the reference data.

The distribution and source of reference data by AEZ/buffer zone are shown in Table 2. In every case, the best data available was used to generate the error matrices and conduct the assessment. Figure 3 shows the distribution of reference samples broken into the four different sources of data: existing reference data, ground collected data, cropland.org data, and accuracy assessment team data.

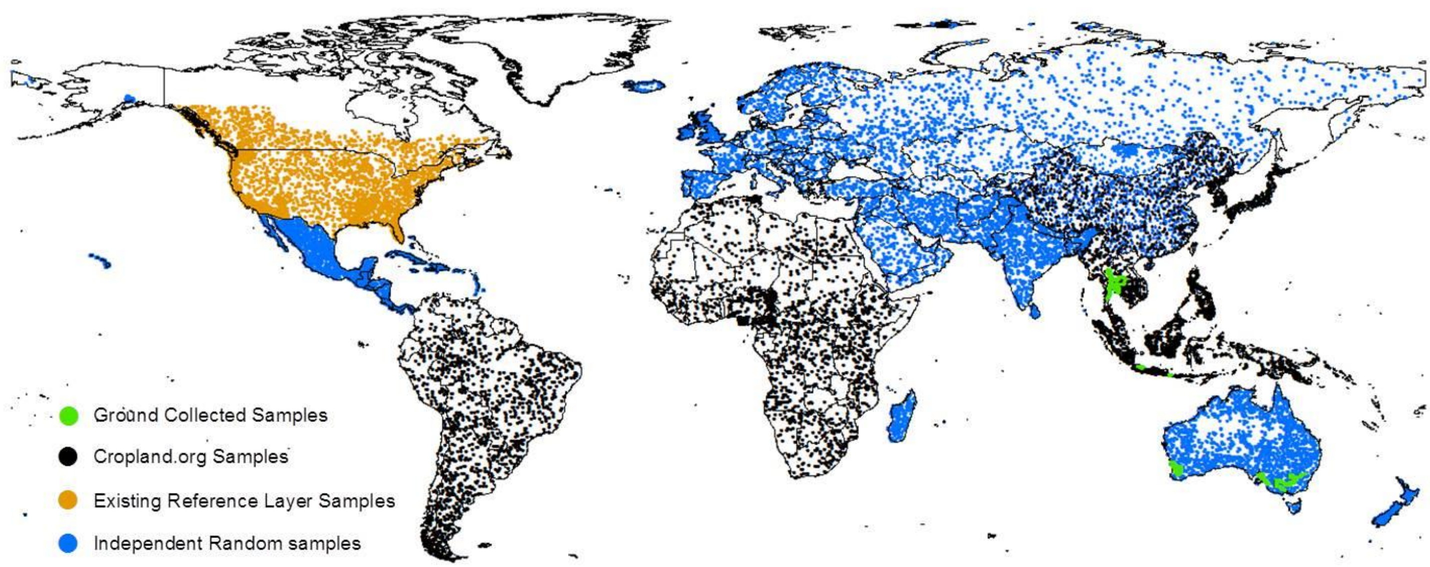

Figure 3. The distribution of independent reference data samples by type used to assess the accuracy of the GFSAD30 crop extent map product.

2. GFSAD30 Cropland Extent Maps

In order to generate error matrices to assess the accuracy of the GFSAD30 cropland extent maps, the maps provided by each mapping team were compared to the reference data as described above. The methods and algorithms used to create each continental region map are described in separate reports for each region as part of this GFSAD30 project.

b. Theoretical description

1. Definition of Croplands

The Global Food Security-Support Analysis Data at 30-m (GFSAD30) project used the following definition for cropland extent for both the maps and the reference data used to assess these maps: "lands cultivated with plants harvested for food, feed, and fiber, including both seasonal crops (e.g., wheat, rice, corn, soybeans, cotton) and continuous plantations (e.g., coffee, tea, rubber, cocoa, oil palms). Cropland fallow are lands uncultivated during a season or a year but are farmlands and are equipped for cultivation, including plantations (e.g., orchards, vineyards, coffee, tea, rubber" (Teluguntla et al., 2015). Cropland extent includes all planted crops and fallow lands. Non-croplands include all other land cover classes other than croplands and cropland fallow (Figure 4).

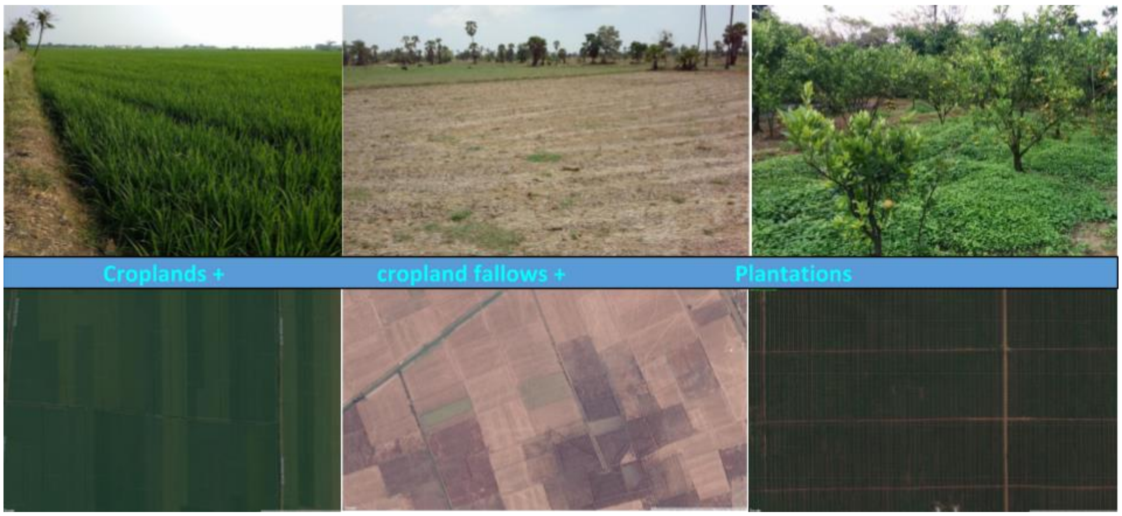

Figure 4. Illustration of definition of cropland used for both the cropland extent maps and the reference data. Croplands included: (a) standing crop, (b) cropland fallows, and (c) permanent plantation crops.

ii. Algorithms

This study used four processes, outlined below, to produce the accuracy assessment/validation for the cropland extent maps. These processes include: stratification, sampling of the reference data, generation of the error matrices, and creation of the difference images.

c. Practical description

1. Stratification

Stratification (i.e., dividing an area into homogeneous regions based on some relevant factor) was used prior to collecting reference data and generating accuracy measures for different continents. Implementing a stratification method prior to the actual assessment was necessary to rationalize effectively validating the cropland extent maps to account for diverse cropping patterns with different continental regions (Waldner et. al., 2015). Two different stratification methods were employed to divide the world.

- Agro-Ecological Zones (AEZ's)

The choice of an appropriate stratification method was decided based on the length of the growing period days of different crops in homogenous climatic and topographic conditions or regions known as Agro-Ecological Zones (AEZ's) (Source: Food and Agriculture Organization-Global Agro-Ecological Zones) for different continental regions. A different number of zones were selected for each continental region based on the variable distribution of cropland throughout the zones in that area. Most of the world was divided using AEZ's.

- Buffer Zones

In a few continental regions, it was difficult to stratify areas using the AEZ approach because of the very low proportion of cropland in some areas. Theses continental regions showed a more clustered cropland pattern in which cropland did not exist at all in some areas. Therefore, a more effective stratification method (i.e., buffering approach) was used to define an appropriate sampling area around the cropland patches instead (for example, Australia, Alaska, Iceland, and Mongolia). The buffers around the cropland patches were derived by calculating Euclidean distance between crop and no-crop pixels using Arc GIS tools. Sampling then occurred only within the buffer zone excluding sampling in areas where there was extremely low probability of finding cropland.

In total 72 AEZ's and crop buffers were used to divide the entire globe into homogeneous regions to perform the accuracy assessment for the different continental regions (Figure 2.)

2. Sampling Design

The sampling design used in this assessment includes the sampling scheme, sample unit, and sample size (i.e., appropriate number of samples used to perform the assessment of cropland maps). The sampling scheme was implemented within each of the stratified homogeneous zones (AEZ's or buffer zones) for the different continental regions. A simple random sampling design was implemented in ArcGIS resulting in a sample reflecting the proportion of the cropland and non-cropland map classes. Each sample in crop and no-crop class had an equal and independent chance of being selected (Congalton and Green, 2009). This sampling design is capable of accounting for the proportions of high and low map categories such as crop and no-crop distribution in the different continental regions (Card 1982, van Genderen et al. 1978). A homogeneous cluster of 3 × 3 pixels was selected as the sampling unit for the assessment to account for positional error in the maps derived from 30m Landsat satellite imagery (Congalton and Green, 2009). The use of this sampling unit ensured that only thematic error was measured in the error matrix analysis and not error due to mis-registration or positional accuracy.

The most challenging component of assessing the thematic map accuracy was collecting a sufficient and appropriate number of samples to be used as the reference data. Early in the analysis, a sample simulation was performed to determine the number of cropland samples needed to generate a valid error matrix. It was determined that 250 samples per zone would provide sufficient samples for the analysis.

3. Error Matrix

The error matrix is a cross tabulation of the class labels predicted by the image classification against that observed from the reference dataset (Congalton and Green, 2009). The process of creating the error matrix using the tools and algorithms described here is shown in Figure 6. The steps are as follows:

1. Stratify the continental regions into zones using either the AEZ or buffer approaches as described above.
2. Within each zone select random samples (a total of 250 per zone).
3. Extract the map label for the random samples from the cropland extent map.
4. Extract or generate reference data (using one of the four approaches described in this document) for each of the random sample.
5. Output an attribute table using ArcGIS that lists the map label and the reference data label for each random sample.
6. Generate the error matrix (R Code available to do this).

Once an error matrix is properly generated, it is used to calculate various measures of accuracy including overall, producer's, and user's accuracies. Overall accuracy is computed by summing the major diagonal of the matrix and dividing by the total number of samples. The matrix is also indicative of omission error and commission error in the map. A commission error is defined as including an area into a thematic class when it doesn't belong to that class while an omission error is excluding that area from the thematic map when it does belong to that class. Omission errors are calculated by dividing the total number of correctly classified sample units in a category by the total number of sample units in that category from the reference data (the column total) (Congalton 1991, Story and Congalton 1986). This measure is often called the "producer's accuracy," because from this measurement the producer of the classification will know how well a certain area was classified (Congalton 1991). Commission errors, on the other hand, were calculated by dividing the number of correctly classified sample units for a category by the total number of sample units that were classified in that category (Story and Congalton 1986; Congalton 1991; Congalton and Green 1999). This measure is also called "user's accuracy," indicating to the users of the map the probability that a sample unit classified on the map represents that category on the ground (Story and Congalton 1986; Congalton and Green 1999).

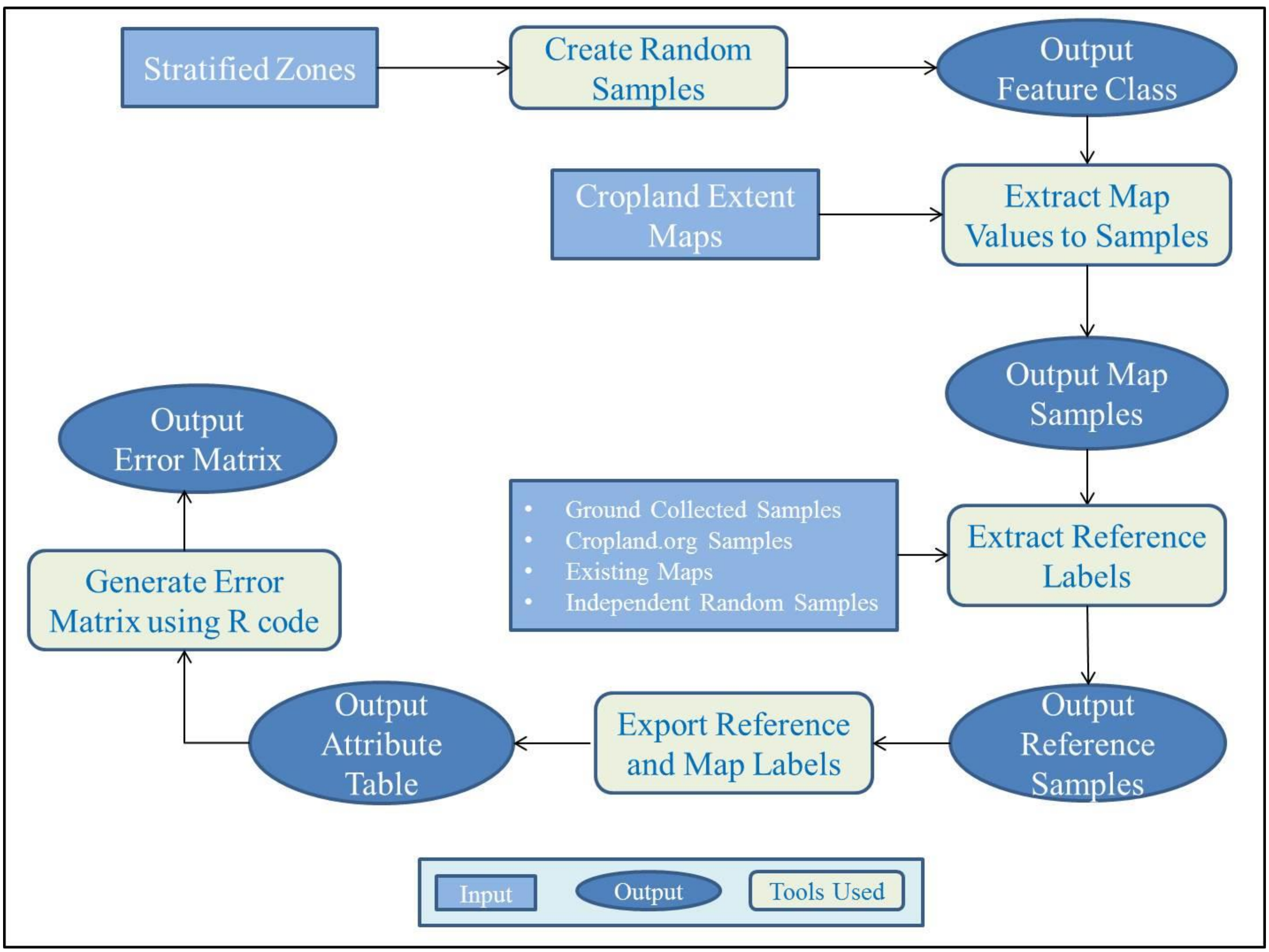

Figure 6. The overall workflow of the accuracy assessment process (error matrix generation) as implemented in ArcGIS and R.

4. Difference Image

A difference image is a map that results from comparing a thematic map with another thematic map (sometimes a reference map) and noting the agreement and disagreement. The difference image is used to depict the omission and commission errors that occurred between the two cropland maps. This image can only be generated when there is another thematic map available. In some cases, such as in the US and Canada, there are reference data sets that cover the entire study area. In most areas of the world, these reference maps do not exist and only limited reference data samples are available. Therefore, to create a difference image using reference data, this process could only be performed in the United States or in Canada using the reference data previously described above. However, GFSAD30 mapping teams did create difference images by comparing the GFSAD30 cropland extent map for their continental region with other global cropland maps produced by other researchers. The difference image clearly demonstrated the spatial distribution of agreement and disagreement between the two thematic maps. This process is performed using the ArcGIS software. Once the difference image is created, the results can also be shown in a similarity matrix which is generated in the same way as an error matrix. Unless the analysis is being conducted using a reference map, the matrix demonstrates similarity between the two thematic maps and not error.

5. Programming and codes

The algorithms used to create the stratification, conduct the sampling, generate the error matrices, and produce the difference images were coded in ArcGIS (Esri). These processes are outlined above. Code was also created in R to generate the error matrices and is provided in a zip file that is available for download along with this ATBD.

6. Results

The results of the accuracy assessment/validation of the GFSAD30 cropland extent maps are represented by error matrices. An error matrix was generated for each continental region AEZ or buffer zone (total of 72 error matrices, see Table 1). These matrices are presented in each continental region ATBD produced by the mapping teams in this project. The results reported here show the ten error matrices produced only for the continental regions and then an overall global error matrix (Figures 7 and 8).

North America

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	962	307	1,269	75.8%
	No-Crop	141	4,789	4,930	97.1%
Total		1,103	5,096	6,199	
Producer Accuracy		87.2%	94.0%		**92.8%**

South America

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	128	39	167	76.7%
	No-Crop	27	1,056	1,083	97.5%
Total		155	1,095	1,250	
Producer Accuracy		82.6%	96.4%		**94.7%**

South East Asia

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	376	114	490	76.7%
	No-Crop	85	1175	1260	93.3%
Total		461	1289	1750	
Producer Accuracy		81.6%	91.2%		**88.6%**

Africa

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	176	81	257	68.5%
	No-Crop	29	1,464	1,493	98.1%
Total		205	1,545	1,750	
Producer Accuracy		85.9%	94.8%		**93.7%**

Mongolia

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	12	1	13	92.3%
	No-Crop	4	283	287	98.6%
Total		16	284	300	
Producer Accuracy		75.0%	99.7%		**98.3%**

New Zealand

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	110	23	133	82.7%
	No-Crop	10	357	367	97.3%
Total		120	380	500	
Producer Accuracy		91.7%	94.0%		**93.4%**

China

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	272	51	323	84.2%
	No-Crop	68	1,581	1,649	95.9%
Total		340	1,632	1,972	
Producer Accuracy		80.0 %	96.9 %		**94.0%**

Europe_Mid-East_Russia

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	857	143	1,000	85.7%
	No-Crop	134	1,866	2,000	93.3%
Total		991	2,009	3,000	
Producer Accuracy		86.5%	92.9%		**90.8%**

South Asia

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	418	92	510	82.0%
	No-Crop	141	849	990	85.8%
Total		559	941	1,500	
Producer Accuracy		74.8%	90.2%		**84.5%**

Australia

		Reference Data			
		Cropland	No-Crop	Total	User Accuracy
Map Data	Cropland	50	28	78	64.1%
	No-Crop	20	602	622	96.8%
Total		70	630	700	
Producer Accuracy		71.4%	95.6%		**93.1%**

Figure 7. The 10 error matrices for the continental regions of the GFSAD30 cropland extent maps.

Entire World Overall Accuracy

		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	3,339	924	4,263	78.3%
	No-Crop	666	14,242	14,908	95.5%
Total		4,005	15,166	19,171	
Producer Accuracy		83.4%	93.9%		**91.7%**

Figure 8. The global overall error matrix for the GFSAD30 cropland extent map.

V. Calibration Needs/Validation Activities

GFSAD30VAL is in itself the accuracy assessment/validation process for the other GFSAD30 mapping teams which produced the cropland extent maps. However, this assessment process included some additional validation of its own. First, all reference data collected from VHRI was checked by two different interpreters. Only those samples in which both interpreters agreed with the map label were used. Any data in which the two interpreters disagreed was rejected. Second, the process of creating a difference image/similarity matrix as described above was also used as a means of validation. Where other maps or data sources existed for different areas of the world, the GFSAD30 cropland extent map was directly compared to this other source to spatially observe where there was agreement and disagreement between the two. In addition, a similarity matrix was generated to graphically represent this agreement and disagreement.

VI. Constraints and Limitations

Any accuracy assessment/validation is limited by the amount of reference data available to conduct the assessment. However, this project has used a very large amount of reference data to assess the accuracy of each zone for each continental region (total of 19,171 samples). Still, more reference data would allow for more detailed assessment of even smaller zones resulting in more localized information. The reference data sets here are available on croplands.org for use by anyone needing to use them.

VII. Publications

The following publications are related to the development of the above croplands products and the validation/accuracy assessment:

a. Peer-reviewed publications within GFSAD project

Congalton, R.G., Gu, J., Yadav, K., Thenkabail, P.S., and Ozdogan, M. 2014. Global Land Cover Mapping: A Review and Uncertainty Analysis. Remote Sensing Open Access Journal. Remote Sens. 2014, 6, 12070-12093; http://dx.doi.org/10.3390/rs61212070.

Congalton, R.G, 2015. Assessing Positional and Thematic Accuracies of Maps Generated from Remotely Sensed Data. Chapter 29, In Thenkabail, P.S., (Editor-in-Chief), 2015. "Remote Sensing Handbook" Volume I: Volume I: Data Characterization, Classification, and Accuracies: Advances of Last 50 Years and a Vision for the Future. Taylor and Francis Inc.\CRC Press, Boca Raton, London, New York. Pp. 900+. In Thenkabail, P.S., (Editor-in-Chief), 2015. "Remote Sensing Handbook" Volume I: **): Remotely Sensed Data Characterization, Classification, and Accuracies**. Taylor and Francis Inc.\CRC Press, Boca Raton, London, New York. ISBN 9781482217865 - CAT# K22125. Print ISBN: 978-1-4822-1786-5; eBook ISBN: 978-1-4822-1787-2. Pp. 678.

Gumma, M.K., Thenkabail, P.S.,Teluguntla, P., Rao, M.N., Mohammed, I.A., and Whitbread, A.M. 2016. Mapping rice-fallow cropland areas for short-period grain legumes intensification in South Asia using MODIS 250 m time-series data. International Journal of Digital Earth, http://dx.doi.org/10.1080/17538947.2016.1168489

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http://geography.wr.usgs.gov/science/croplands/index.html (GFSAD30 web portal and dissemination)
http://geography.wr.usgs.gov/science/croplands/products.html#LPDAAC (dissemination on LP DAAC)
http://geography.wr.usgs.gov/science/croplands/products.html (global croplands on Google Earth Engine)
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