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Version

NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security-support Analysis Data (GFSAD) @ 30-m for Africa: Cropland Extent-Product (GFSAD30AFCE)

User Guide

Document History

Document Version	Publication Date	Description
1.0	September, 2017	Original
1.1		Modification made according to USGS reviewer comments

Contents

1.0 Dataset Overview

The goal of the Global Food Security-support Analysis Data @ 30-m (GFSAD30) project is to provide the highest resolution, objective cropland datasets to assist and address global food and water security issues in the twenty-first century. The project proposed developing cropland products using time-series Landsat and Sentinel satellite sensor data, machine learning algorithms, and cloud-based computing. The project is funded by the National Aeronautics and Space Administration (NASA) with supplemental funding from the United States Geological Survey (USGS). The project is led by USGS and carried out in collaboration with NASA AMES, University of New Hampshire (UNH), California State University Monterey Bay (CSUMB), University of Wisconsin (UW), NASA GSFC, and Northern Arizona University (NAU). There were a number of International partners, including The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

This user's guide provides information about the GFSAD30 cropland extent product for the African continent (GFSAD30AFCE) at nominal 30m resolution for 2015. The Coordinate Reference System (CRS) used for the GFSAD30AFCE is a geographic coordinate system (GCS) based on the World Geodetic System 84 (WGS84) reference ellipsoid. The legend is presented in Section 2. Datasets are provided as 10º x 10º tiles in GeoTIFF format. The year, resolution, tiling, and file name convention details are provided in section 2.0 of this document.

1.1 Background

Monitoring global croplands is imperative for ensuring sustainable water and food security for 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 nature 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; and/or (5) The absence of a dedicated Internet data portal for the dissemination of these cropland products. This project aims to address all these knowledge gaps.

Satellite-derived cropland extent maps at high spatial resolution are necessary for food and water security analysis. Therefore, the GFSAD30AFCE cropland extent product was produced at a resolution of 30-m for the entire continent of Africa for the nominal year 2015 using Sentinel-2 and Landsat-8 time-series data. These data are part of a global data release, whereby each continent will be made publically available. Global cropland extent data, indicating cropland and non-cropland areas, provide a working baseline data set to develop higher-level 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 the assessment of cropland productivity (productivity per unit of land), and crop water productivity (productivity per unit of water or “crop per drop”). Uncertainties associated with cropland extent data have a cascading effect on all these higher-level cropland datasets.

Cloud-based geo-spatial computing platforms and satellite imagery offer opportunities for producing precise and accurate data of cropland extent and area that meet the spatial and temporal requirements for a broad set of applications. Such data can be a significant improvement compared to existing products, which tend to be coarser resolution, are often not representative of regions with highly dynamic change, and have a fixed set of cover classes. Cloud-based computing platforms such as Google Earth Engine and new earth-observing satellites like those in the Sentinel constellation have brought significant improvements to land use/land cover (LULC) mapping and agriculture monitoring. Specifically, the production of standard static maps of the past will be shifted to dynamic creation of maps from massively large volumes of big data, crowd-sourcing of training and validation samples, and implementing machine learning algorithms on these computing clouds to better serve specific applications.

For a very detailed description of the satellite and reference data, processing schemes, approaches, methods, results, and conclusions of this project, please refer to the algorithm theoretical basis document (ATBD) of GFSAD30AFCE.

2.0 Dataset Characteristics

Global food security-support analysis data @ 30-m cropland extent for the African Continent (GFSAD30AFCE) datasets and characteristics are described below.

2.1 Global Food Security Support Analysis Data (GFSAD) 30-m V001

2.1.1 Collection Level

Short name	GFSAD30AFCE
Temporal Granularity	Static
Temporal Extent	2015, nominal
Spatial Extent	Africa
File size	~800 MB
Coordinate System	Geographic
Datum	WGS84
File Format	GeoTIFF

2.1.2 Granule Level

Number of Layers	1
Columns/Rows	307053 x 272312
Pixel Size	~30 m

2.1.3 Data Layer Characteristics

SDS Layer Name	Description	Units	Data Type	Fill Value	Valid Range	Scale Factor
Band 1	Crop Extent for African Continent	N/A	8-bit unsigned integer	N/A	0,1, 2	N/A

2.1.4 Data Layers Classification

Class Label	Class Name	Description
0	Water	Water bodies/ no-data
1	Non-Cropland	Non-Cropland areas
2	Cropland	Cropland areas

2.1.5 Filename Convention

GFSAD30AFCE_2015_N10E00_001_2017261090100.tif = File name
GFSAD30AFCE = Product Short name
30 = 30 m Spatial Resolution
AF = Africa
CE = Crop Extent
2015 = Nominal Year
N10E00 = 10 x 10 degree grid, starting at (N10, E00)
001 = Version
2017261090100 = Processing Date in YYYYJJJHHMMSS

3.0 Dataset Knowledge

The following questions address the user information regarding the GFSAD30AFCE collection.

3.1 Frequently Asked Questions

What is the accuracy of the GFSAD30AFCE product?
For the entire continent, the overall weighted accuracies were 94.5%, Fscore of 0.76, Producer's accuracy of 85.9% and user's accuracy of 68.5% (Table below). When considering 6 of the 7 zones (Figure 1 below), except zone 7, the overall accuracies ranged between 91-97% (rounded off to nearest integer), and producer's accuracies of croplands range between 61-95%, and user's accuracies range between 53-90% for

6 of the 7 zones where overwhelming proportion of the Africa's 313 Mha of total net cropland areas (TNCA's) exist. The producer's accuracy was 61% for the Zone with Madagascar where only 0.1% of the TNCA's of Africa exist. The user's accuracies ranged between 64-90% (rounded off to nearest integer) in 6 of the 7 zones. The user accuracy for zone 4 was only 53%. This zone has 6.2% of TNCA's of Africa. Zones with high % of the TNCA's had high overall, user's, and producer's accuracies (Table 1 below). These results clearly imply the high level of confidence in differentiating croplands from non-croplands for the African continent.

Table 1. Independent Accuracy Assessment of 30-m Cropland Extent Map for Africa. Accuracies were assessed for each of the 7 zones as well as for the entire continent.

Zone 1, % of TNCA* = 9.1%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	43	5	48	89.6%
	No-Crop	4	198	202	98.0%
Total		47	203	250	
Producer Accuracy		91.5%	97.5%		
Overall Accuracy		96.4%		Fscore	0.91

Zone 2, % of TNCA* = 26.4%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	21	8	29	72.4%
	No-Crop	8	213	221	96.4%
Total		29	221	250	
Producer Accuracy		72.4%	96.4%		
Overall Accuracy		93.6%		Fscore	0.72

Zone 3, % of TNCA* = 21.7%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	37	21	58	63.8%
	No-Crop	2	190	192	99.0%
Total		39	211	250	
Producer Accuracy		94.9%	90.0%		
Overall Accuracy		90.8%		Fscore	0.76

Zone 4, % of TNCA* = 6.2%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	8	7	15	53.3%
	No-Crop	1	234	235	99.6%
Total		9	241	250	
Producer Accuracy		88.9%	97.1%		
Overall Accuracy		96.8%		Fscore	0.67

Zone 5, % of TNCA* = 16.6%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	44	17	61	72.1%
	No-Crop	5	188	193	97.4%
Total		49	205	254	
Producer Accuracy		89.8%	91.7%		
Overall Accuracy		91.3%		Fscore	0.80

Zone 6, % of TNCA* = 19.9%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	22	9	31	71.0%
	No-Crop	4	215	219	98.2%
Total		26	224	250	
Producer Accuracy		84.6%	96.0%		
Overall Accuracy		94.8%		Fscore	0.77

Zone 7, % of TNCA* = 0.1%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	17	7	24	70.8%
	No-Crop	11	215	226	95.1%
Total		28	222	250	
Producer Accuracy		60.7%	96.8%		
Overall Accuracy		92.8%		Fscore	0.65

All Zones, % of TNCA*=100%		Reference Data			
		Crop	No-Crop	Total	User Accuracy
Map Data	Crop	176	81	257	68.5%
	No-Crop	29	1464	1493	98.1%
Total		205	1545	1750	
Producer Accuracy		85.9%	94.8%		
Overall Accuracy		93.7%		Fscore	0.76
Weighted Accuracy		94.5%			

Note: * TCA (Total Croplands Area) = 313 Mha

** The all-zones Weighted Accuracy is weighted by proportion of croplands in each zone

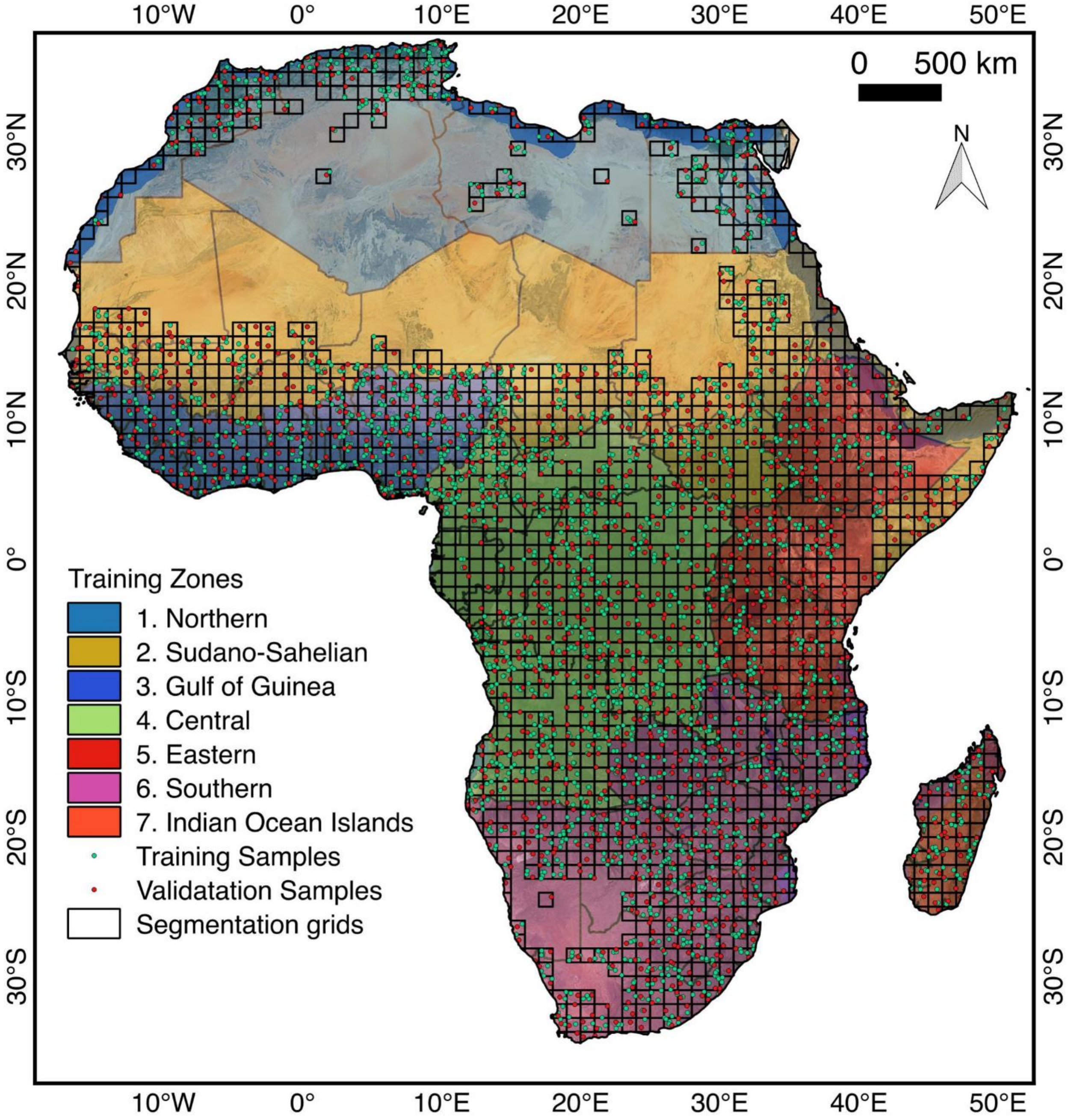

Figure 1. Stratification of the African continent into seven distinct refined FAO agro-ecological broad zones. The figure also shows the distribution of the reference training and validation data used in the machine learning algorithms.

What do GFSAD30AFCE product contain?

This product provides cropland extent for continental Africa at nominal 30-m. It covers all 55 African countries.

What's the definition of the crop extent?

For the entire Global Food Security-Support Analysis Data project at 30-m (GFSAD30) project, cropland extent was defined as: "*lands cultivated with plants harvested for food, feed, and fiber, include 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.

How can the dataset be obtained?

All the GFSAD30 products are downloadable through the Land Processes Distributed Active Archive Center (LP DAAC). GFSAD30AFCE, divided into 10x10 grids, is among them. You can also visualize these data @: croplands.org by going to the "products" drop-down menu there.

Can I obtain the dataset through Google Earth Engine (GEE)?

No. Currently, we are releasing our GFSAD30 cropland extent product only through LP DAAC. In future we may consider releasing it through GEE. For this contact project PI (Prasad S. Thenkabail).

4.0 Dataset Access (Applicable Data Tools)

The GFSAD30AFCE dataset is available through the LP DAAC Data Pool and NASA Earthdata Search. GFSAD data visualization and information can also be found at Global Croplands Website.

5.0 Contact Information

LP DAAC User Services
U.S. Geological Survey (USGS)
Center for Earth Resources Observation and Science (EROS)
47914 252nd Street
Sioux Falls, SD 57198-0001

Phone Number: 605-594-6116
Toll Free: 866-573-3222 (866-LPE-DAAC)
Fax: 605-594-6963

Email: lpdaac@usgs.gov
Web: https://lpdaac.usgs.gov

For the Principal Investigators, feel free to write to:

Prasad S. Thenkabail at pthenkabail@usgs.gov

For 30-m cropland product of Africa, please write to:
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Prasad S. Thenkabail at pthenkabail@usgs.gov
Pardhasaradhi Teluguntla at pteluguntla@usgs.gov

More details about the GFSAD project and products can be found at: globalcroplands.org

6.0 Citations

6.1 GFSAD30AFCE

Xiong, J., Thenkabail, P.S., Tilton, J.C., Gumma, M.K., Teluguntla, P., Congalton, R.G., Yadav, K., Dungan, J., Oliphant, A.J., Poehnelt, J., Smith, C., Massey, R. (2017). *NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security-support Analysis Data (GFSAD) Cropland Extent 2015 Africa 30 m V001* [Data set]. NASA EOSDIS Land Processes DAAC. doi: 10.5067/MEaSUREs/GFSAD/GFSAD30AFCE.001

7.0 Publications

The following publications are related to the development of the above croplands products:

7.1 Publications specific to this study

1) Xiong, J., Thenkabail, P. S., James C. T., Gumma, M. K., Teluguntla, P., Congalton, R. G., Poehnelt, J., Kamini Yadav., et al. (2017). A Nominal 30-m Cropland Extent of Continental Africa Using Sentinel-2 data and Landsat-8 by Integrating Random Forest (SVM) and Hierarchical Segmentation Approach on Google Earth Engine. In press.

2) Xiong, J., Thenkabail, P. S., Gumma, M. K., Teluguntla, P., Poehnelt, J., Congalton, R. G., et al. (2017). Automated cropland mapping of continental Africa using Google Earth Engine cloud computing. ISPRS Journal of Photogrammetry and Remote Sensing, 126, 225–244.

7.2 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-season 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

Massey, R., Sankey, T.T., Congalton, R.G., Yadav, K., Thenkabail, P.S., Ozdogan, M., Sánchez Meador, A.J. 2017. MODIS phenology-derived, multi-year distribution of conterminous U.S. crop types, Remote Sensing of Environment, Volume 198, 1 September 2017, Pages 490-503, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2017.06.033.

Phalke, A. R., Ozdogan, M., Thenkabail, P. S., Congalton, R. G., Yadav, K., & Massey, R. et al. (2017). A Nominal 30-m Cropland Extent and Areas of Europe, Middle-east, Russia and Central Asia for the Year 2015 by Landsat Data using Random Forest Algorithms on Google Earth Engine Cloud. (in preparation).

Teluguntla, P., Thenkabail, P.S., Xiong, J., Gumma, M.K., Congalton, R.G., Oliphant, A., Poehnelt, J., Yadav, K., Rao, M., and Massey, R. 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.IP-074181, http://dx.doi.org/10.1080/17538947.2016.1267269.

Teluguntla, P., Thenkabail, P., Xiong, J., Gumma, M.K., Giri, C., Milesi, C., Ozdogan, M., Congalton, R., Yadav, K., 2015. CHAPTER 6 - 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, in: Thenkabail, P.S. (Ed.), Remote Sensing Handbook (Volume II): Land Resources Monitoring, Modeling, and Mapping with Remote Sensing. CRC Press, Boca Raton, London, New York., pp. 131–160. Link.

Xiong, J., Thenkabail, P.S., Tilton, J.C., Gumma, M.K., Teluguntla, P., Oliphant, A., Congalton, R.G., Yadav, K. 2017. A Nominal 30-m Cropland Extent and Areas of Continental Africa for the Year 2015 by Integrating Sentinel-2 and Landsat-8 Data using Random Forest, Support Vector Machines and Hierarchical Segmentation Algorithms on Google Earth Engine Cloud. Remote Sensing Open Access Journal (in review).

Xiong, J., Thenkabail, P.S., Gumma, M.K., Teluguntla, P., Poehnelt, J., Congalton, R.G., Yadav, K., Thau, D. 2017. Automated cropland mapping of continental Africa using Google Earth Engine cloud computing, ISPRS Journal of Photogrammetry and Remote Sensing, Volume 126, April 2017, Pages 225-244, ISSN 0924-2716, https://doi.org/10.1016/j.isprsjprs.2017.01.019.

7.3 Web sites and Data portals:

http://croplands.org (30-m global croplands visualization tool)
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)
croplands.org (crowdsourcing global croplands data)

7.4 Other relevant past publications prior to GFSAD project

Biggs, T., Thenkabail, P.S., Krishna, M., GangadharaRao Rao, P., and Turral, H., 2006. Vegetation phenology and irrigated area mapping using combined MODIS time-series, ground surveys, and agricultural census data in Krishna River Basin, India. International Journal of Remote Sensing. 27(19):4245-4266.

Biradar, C.M., Thenkabail, P.S., Noojipady, P., Yuanjie, L., Dheeravath, V., Velpuri, M., Turral, H., Gumma, M.K., Reddy, O.G.P., Xueliang, L. C., Schull, M.A., Alankara, R.D., Gunasinghe, S., Mohideen, S., Xiao, X. 2009. A global map of rainfed cropland areas (GMRCA) at the end of last millennium using remote sensing. International Journal of Applied Earth Observation and Geoinformation. 11(2). 114-129. doi:10.1016/j.jag.2008.11.002. January, 2009.

Dheeravath, V., Thenkabail, P.S., Chandrakantha, G, Noojipady, P., Biradar, C.B., Turral. H., Gumma, M.1, Reddy, G.P.O., Velpuri, M. 2010. Irrigated areas of India derived using MODIS 500m data for years 2001-2003. ISPRS Journal of Photogrammetry and Remote Sensing. http://dx.doi.org/10.1016/j.isprsjprs.2009.08.004. 65(1): 42-59.

Thenkabail, P.S. 2012. Special Issue Foreword. Global Croplands special issue for the August 2012 special issue for Photogrammetric Engineering and Remote Sensing. PE&RS. 78(8): 787-788.Thenkabail, P.S. 2012. Guest Editor for Global Croplands Special Issue. Photogrammetric Engineering and Remote Sensing. PE&RS. 78(8).

Thenkabail, P.S., Biradar C.M., Noojipady, P., Cai, X.L., Dheeravath, V., Li, Y.J., Velpuri, M., Gumma, M., Pandey, S. 2007a. Sub-pixel irrigated area calculation methods. Sensors Journal (special issue: Remote Sensing of Natural Resources and the Environment (Remote Sensing SensorsEdited by Assefa M. Melesse). 7:2519-2538. http://www.mdpi.org/sensors/papers/s7112519.pdf.

Thenkabail, P.S., Biradar C.M., Noojipady, P., Dheeravath, V., Li, Y.J., Velpuri, M., Gumma, M., Reddy, G.P.O., Turral, H., Cai, X. L., Vithanage, J., Schull, M., and Dutta, R. 2009a. Global irrigated area map (GIAM), derived from remote sensing, for the end of the last millennium. International Journal of Remote Sensing. 30(14): 3679-3733. July, 20, 2009.

Thenkabail, P.S., Biradar, C.M., Turral, H., Noojipady, P., Li, Y.J., Vithanage, J., Dheeravath, V., Velpuri, M., Schull M., Cai, X. L., Dutta, R. 2006. An Irrigated Area Map of the World (1999) derived from Remote Sensing. Research Report # 105. International Water Management Institute. Pp. 74. Also, see under documents in: http://www.iwmigiam.org.

Thenkabail, P. S.; Dheeravath, V.; Biradar, C. M.; Gangalakunta, O. P.; Noojipady, P.; Gurappa, C.; Velpuri, M.; Gumma, M.; Li, Y. 2009b. Irrigated Area Maps and Statistics of India Using Remote Sensing and National Statistics. Journal Remote Sensing. 1:50-67. http://www.mdpi.com/2072-4292/1/2/50.

Thenkabail, P.S., GangadharaRao, P., Biggs, T., Krishna, M., and Turral, H., 2007b. Spectral Matching Techniques to Determine Historical Land use/Land cover (LULC) and Irrigated Areas using Time-series AVHRR Pathfinder Datasets in the Krishna River Basin, India. Photogrammetric Engineering and Remote Sensing. 73(9): 1029-1040. (Second Place Recipients of the 2008 John I. Davidson ASPRS President’s Award for Practical papers).

Thenkabail, P.S., Hanjra, M.A., Dheeravath, V., Gumma, M.K. 2010. A Holistic View of Global Croplands and Their Water Use for Ensuring Global Food Security in the 21st Century through Advanced Remote Sensing and Non-remote Sensing Approaches. Remote Sensing open access journal. 2(1):211-261. doi:10.3390/rs2010211. http://www.mdpi.com/2072-4292/2/1/211

Thenkabail P.S., Knox J.W., Ozdogan, M., Gumma, M.K., Congalton, R.G., Wu, Z., Milesi, C., Finkral, A., Marshall, M., Mariotto, I., You, S. Giri, C. and Nagler, P. 2012. Assessing future risks to agricultural productivity, water resources and food security: how can remote sensing help? Photogrammetric Engineering and Remote Sensing, August 2012 Special Issue on Global Croplands: Highlight Article. 78(8): 773-782.

Thenkabail, P.S., Schull, M., Turral, H. 2005. Ganges and Indus River Basin Land Use/Land Cover (LULC) and Irrigated Area Mapping using Continuous Streams of MODIS Data. Remote Sensing of Environment. Remote Sensing of Environment, 95(3): 317-341.

Velpuri, M., Thenkabail, P.S., Gumma, M.K., Biradar, C.B., Dheeravath, V., Noojipady, P., Yuanjie, L.,2009. Influence of Resolution or Scale in Irrigated Area Mapping and Area Estimations. Photogrammetric Engineering and Remote Sensing (PE&RS). 75(12): December 2009 issue.

7.5 Books and Book Chapters

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 (GFSAD1 km) 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. Press, Boca Raton, London, New York. ISBN 9781482217957 - CAT# K22130. Pp. 131-160

Biradar, C.M., Thenkabail. P.S., Noojipady, P., Li, Y.J., Dheeravath, V., Velpuri, M., Turral, H., Cai, X.L., Gumma, M., Gangalakunta, O.R.P., Schull, M., Alankara, R.D., Gunasinghe, S., and Xiao, X. 2009. Book Chapter 15: Global map of rainfed cropland areas (GMRCA) and stastistics using remote sensing. Pp. 357-392. In the book entitled: “Remote Sensing of Global Croplands for Food Security” (CRC Press- Taylor and Francis group, Boca Raton, London, New York. Pp. 475. Published in June, 2009. (Editors: Thenkabail. P., Lyon, G.J., Biradar, C.M., and Turral, H.).

Gangalakunta, O.R.P., Dheeravath, V., Thenkabail, P.S., Chandrakantha, G., Biradar, C.M., Noojipady, P., Velpuri, M., and Kumar, M.A. 2009. Book Chapter 5: Irrigated areas of India derived from satellite sensors and national statistics: A way forward from GIAM experience. Pp. 139-176. In the book entitled: “Remote Sensing of Global Croplands for Food Security” (CRC Press- Taylor and Francis group, Boca Raton, London, New York. Pp. 475. Published in June, 2009. (Editors: Thenkabail. P., Lyon, G.J., Biradar, C.M., and Turral, H.).

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