HARMONIZED LANDSAT-SENTINEL SERVICE

API Documentation 2020

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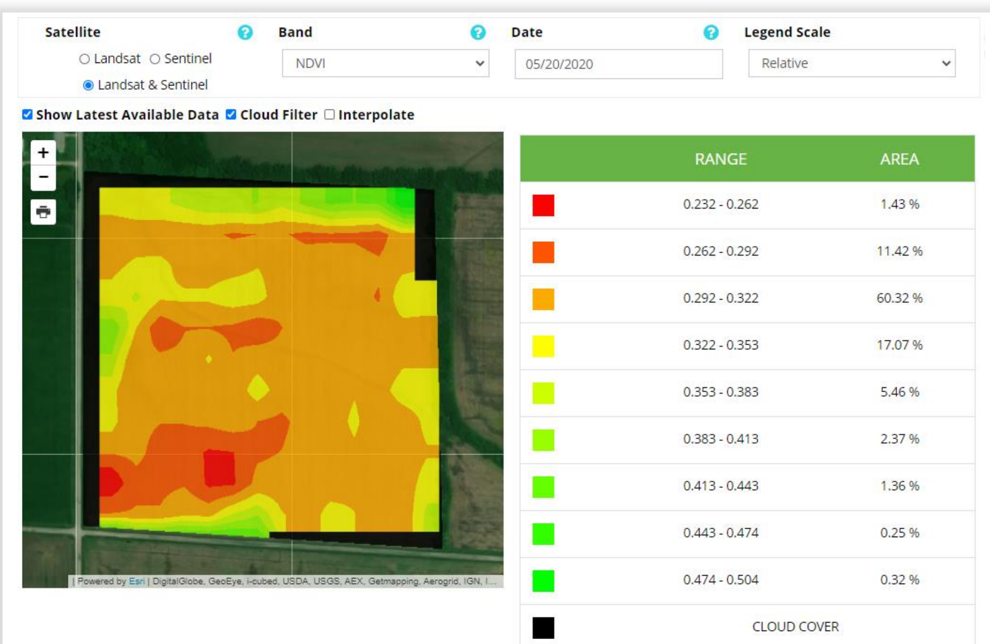
Service Overview

The Ag-Analytics® Harmonized Landsat-Sentinel Service (HLS) API provides the service in which a user can provide an area-of-interest (AOI) with additional customized options to retrieve the dynamics of their land at various times from the Landsat-8 (L30 Product) and Sentinel-2 (S30 Product) satellites. This service provides information on cloud cover, statistics, and Normalized Difference Vegetation Index in addition to MSI bands information.

The Harmonized Landsat-Sentinel (HLS) Project is a NASA initiative to produce a Virtual Constellation (VC) of surface reflectance (SR) data from the Operational Land Imager (OLI) and Multispectral Instrument (MSI) onboard the Landsat-8 and Sentinel-2 remote sensing satellites, respectively. The data from these satellites creates unprecedented opportunities for timely and accurate observation of Earth status and dynamics at moderate (<30 m) spatial resolution every 2-3 days.



HLS used in FarmScope

Service Information

Specifications for the HLS products used in the Ag-Analytics® Harmonized Landsat- Sentinel Service API are provided below (information from https://hls.gsfc.nasa.gov)

Product Name	S30	L30
Input sensor	Sentinel-2A/B MSI	Landsat-8 OLI/TIRS
Spatial Resolution	30 m	30 m
BRDF-Adjusted	Yes (except for bands 01, 05, 06, 07, 09, 10)	Yes
Bandpass-adjusted	Adjusted to OLI-like but no adjustment for Red Edge or water vapor	No
Projection	UTM	UTM
Tiling System	MGRS (110*110)	MGRS (110*110)

HLS Spectral Bands Nomenclature

HLS spectral band nomenclatures from the HLS User's guide.

Band Name	OLI band MSI number	MSI band number	HLS band code name Landsat8	HLS band code name Sentinel 2	L30** Subdataset number **	S30 **Subdataset number**	Wavelength (micrometers)
Coastal Aerosol	1	1	band01	B01	01	01	0.43 – 0.45*
Blue	2	2	band02	B02	02	02	0.45 – 0.51*
Green	3	3	band03	B03	03	03	0.53 – 0.59*
Red	4	4	band04	B04	04	04	0.64 – 0.67*
Red-Edge 1		5		B05		05	0.69 – 0.71**
Red-Edge 2		6		B06		06	0.73 – 0.75**
Red-Edge 3		7		B07		07	0.77 – 0.79**
NIR Broad		8		B08		08	0.78 –0.88**
NIR Narrow	5	8A	band05	B8A	05	09	0.85 – 0.88*
SWIR 1	6	11	band06	B11	06	10	1.57 – 1.65*
SWIR 2	7	12	band07	B12	07	11	2.11 – 2.29*
Water vapor		9		B09		12	0.93 – 0.95**

Cirrus	9	10	band09	B10	08	13	1.36 – 1.38*
Thermal Infrared 1	10		band10		09		10.60 – 11.19*
Thermal Infrared 2	11		band11		10		11.50 – 12.51*
QA					11	14	

General Flow of Service

When a user passes an area-of-interest (AOI) in the form of a shapefile, json, raster .tif, or geojson, the service finds the correct satellite imagery and clips each image to the AOI given. The service has the options to interpolate the result and to specify the imagery weeks that are returned.

General Algorithm Flow

1. Determine the AOI polygon given
2. Identify the corresponding satellite imageries based on the AOI, acquisition date, interpolation parameters, and other options passed by users.
3. The satellite imageries will then be clipped to the AOI. If the imageries from the same date overlay with each other on the AOI, the **mean** of the overlay area will be returned and **merged** with the area without overlay from each imagery.
4. The imageries of the AOI will then be mosaiced to get weekly average imageries.
5. If the interpolation option is chosen, the selected interpolation method and parameters will be applied to each weekly imagery where has cloud cover.

Interpolation Function

Due to cloud cover, the original satellite images may have many gaps and cannot fully cover the area-of-interest (AOI). The interest to solve this problem arose in 2003, and there have been many papers and methods developed for this problem since then. After comparing and testing multiple methods and algorithms that have been used in dealing with the missing data on remote sensing satellite images, we adopted a customized “inpainting” method - which means filling gaps in an image by extrapolating the existing parts of the image in our API service.

To take the spatial and temporal correlation of the images into consideration, our customized inpainting algorithm “inpaints” a sequence of images with cloud covered for the given AOI. Each missing part (multiple pixels) at a certain location is inpainted by linear transformation of the intensity of pixels at the same location of other images where the data of these pixels are available.

Interpolation Algorithm Flow

1. Identify the missing parts of the image and find the contours of each gap.
2. Find the best candidates from similar sequences of images which have non-missing pixels to fill the largest part of a given gap.
3. Define an outline – a thin curve around each gap, then used for obtaining the linear transformation of the pixel intensity between the two images for each of the best candidates. The candidate image with the best linear fit of the outline is chosen.
4. To better-fit the area close to the outline, an intensity correction mask is then created by blurring the patch-intensity difference image.
5. The mask is applied to the gap area on the best candidate and generates an inpainted patch.
6. Finally, this inpainted patch is used to fill the gap in the image.

POST Request

POST Request Example – form-data and urlencoded

form-data application/json

```
{
Band: "['NDVI']"
Enddate: "3/8/2019" Startdate: "3/2/2019"
aoi: {"type":"Feature", "geometry": {"type":"Polygon", "coordinates": [[[-
101.02684, 38.598114], [-101.026842, 38.597962], [-101.026956,38.59093], [-
101.028768,38.590943], [-101.029234, 38.590946], [-101.035523, 38.590991], [-
101.035526,38.590991], [-101.035564, 38.590991], [-101.035576, 38.590991], [-
101.035595,38.590991], [-101.035956, 38.590994], [-101.035974,38.591099],[-
101.035957,38.594349], [-101.036017, 38.598193], [-101.035203,38.598193],[-
101.033665,38.598182], [-101.031726, 38.598158], [-101.02684, 38.598114]]]},
"properties": {"OBJECTID":8091992, "CALCACRES":156.1000061, "CALCACRES2":null},
"id":8091992}
legendtype: "Relative"
satellite: "Landsat"
}
```

application/x-www-form-urlencoded

```
aoi=%7B%22type%22%3A%22Feature%22%2C%22geometry%22%3A%7B%22type%22%3A%22Polygon%22
%2C%22coordinates%22%3A%5B%5B%5B-101.02684%2C38.598114%5D%2C%5B-101.026842%2C38
.597962%5 D%2C%5B-101.026956%2C38.59093%5D%2C%5B-101.028768%2C38 .590943%5D%2C%5B-
101.029234%2C38.590946%5D%2C%5B-101.035523%2C38.590991%5D%2C%5B-101.035526%2C38.59
0991%5D%2C%5B-101.035564%2C38.590991%5D%2C%5B-101.035576%2C38.590991%5D%2C%5B-
101.035595%2C38.590991%5 D%2C%5B-101.035956%2C38.590994%5D%2C%5B-101.035974%2C38
.591099%5D%2C%5B-101.035957%2C38.594349%5D%2C%5B-101.036017%2C38.598193%5D%2C%5B-
101.035203%2C38.598193%5D%2C%5B-10 1.033665%2C38.598182%5D%2C%5B-101.031726%2C38.5
98158%5D%2C%5B-101.02684%2C38.598114%5D%5D%5D%7D%2C%22properties%22%3A%7B%22OBJE
```

Header Parameters

content-type: "application/x-www-form-urlencoded"

Request Parameters

Parameter	Data Type	Required?	Default	Options	Description
AOI	Geometry, file/text	Yes	-	JSON, GEOJSON, Shapefile, Raster	See Fig. 2 for further explanation.
Band	List	Yes	-	See Request Parameters - “Band” Options on page 7	Provide the list of HLS Spectral band names to retrieve for given AOI. See supplementary info tables.
Startdate	Date, mm / dd / yyyy	No	-	-	Landsat – data starts from **2013,** Sentinel – data starts from **2015**
Enddate	Date, mm / dd / yyyy	No	-	-	In the absence of startdate or enddate, or both, the service retrieves the latest information available on the land.
byweek	Int, boolean	No	1	1, 0	If set to 1, result raster will be the mosaic of all the tiles in a particular week for a given satellite
satellite	text	No	Landsat	Landsat, Sentinel	If set to both Landsat, Sentinel then the result raster will be the mosaic of both satellites for the given dates
showlatest	Int, boolean	No	1	-	If startdate or enddate is not given, shows the latest available tile.

filter	Int, boolean	No	0	0, 1	If set to 1, returns the response which is cloud-free after mosaic.
qafilter	Int, boolean	No	0	0, 1	If set to 1, continues to filter tiles until the invalid pixels are < **qacloudperc**
qacloudperc	float	No	100	0-100	This parameter comes to action with **qafilter**. If **qafilter** parameter is 1, then filters the tiles until the invalid pixels in those are < **qacloudperc**
displaynormalvalues	float	No	2000	-	This parameter is used to normalize the band values for display purposes. Used for bands like RGB, AGR, etc.
legendtype	text	No	Relative	Relative, Absolute	Legend type of display ranges of resulting response.
resolution	float	No	0.0001	-	Cellsize in meters.
flatten_data	Int, boolean	No	0	0, 1	Flatten data which has a list of Xcoord, Ycoord and Values for each band in the output. If 1, flatten_data is returned.
statistics	Int, boolean	No	1	0, 1	Returns statistical features of the output .tif file.
return_tif	int	No	1	0, 1	Returns the downloadable link to output raster. If 0, link will not be returned.
projection	text	No	Projection of AOI Given	**See projection example.**	Enter the desired projection for the result raster. See **projection example** for details.

Request Parameters - “Band” Options

The following bands, indices, and RGB insertions can be used for the “Band” parameter in the API request

Band Explanations

API Variable	Band Definition	Description
Red	Red (0.64-0.67µm)	Reflects reds, such as tropical soils or rust-like soils.
Green	Green (0.53-0.59µm)	Reflects greens, particularly leaf surfaces.
Blue	Blue (0.45-0.51µm)	Reflects blues, particularly helpful for deep waters.
NIR	Near Infrared (0.76-0.90µm)	Reflects healthy vegetation.
NIR_Broad	Near Infrared (.842 µm central)	Good for mapping shorelines and biomass content, as well as at detecting and analyzing vegetation.
Red_Edge_1	Red Edge (.69 - .71µm)	Can gauge foliage chlorophyll, canopy area, and water content. Applications include growth studies, precision ag, and vegetation productivity modeling.
Red_Edge_2	Red Edge (0.73 – 0.75 µm)	Can gauge foliage chlorophyll, canopy area, and water content
Red_edge_3	Red Edge (0.77 – 0.79 µm)	Can gauge foliage chlorophyll, canopy area, and water content
SWIR1	Short-wave Infrared (1.57-1.65µm)	Sensitive to moisture content. Assists in distinguishing between dry and wet soils and vegetation.
SWIR2	Short-wave Infrared 2 (2.08-2.35µm)	Used in imaging soil types, geological features, and minerals. Sensitive to vegetation and soil moisture variations.
Coastal Aerosol	Coastal Aerosol (0.43-0.45µm)	Reflects blues and violets.

QA	[Quality Assessment]	Provides useful information for optimizing the value of pixels, identifying which pixels may be affected by surface conditions, clouds, or sensor conditions.

Index Information

Index Name	API Variable	Formula	Description
Normalized Difference Vegetation Index (NDVI)	NDVI	NDVI = (NIR - Red) / (NIR + Red)	NDVI is derived from readily available satellite imagery which is positively correlated with green vegetation cover
Red-Green-Blue (RGB)	RGB	Composite of red, green, and blue bands.	Color imagery, how the human eye would view something.
Normalized Difference Water Index (NDWI)	NDWI	NDWI = (NIR - SWIR) / (NIR + SWIR)	NDWI uses the NIR and SWIR bands to determine changes in water content
Normalized Difference Buildup Index (NDBI)	NDBI	NDBI= (SWIR1 - NIR) / (SWIR1 + NIR)	NDBI uses SWIR1 and NIR bands to determine urban areas
Normalized difference Tillage Index (NDTI)	NDTI	NDTI= (SWIR1 - SWIR2) / (SWIR1 + SWIR2)	Similarly, NDTI is also derived from satellite imagery but calculated with different bands. It is positively correlated with crop residue cover
Urban Index (UI)	UI	UI= (SWIR2 - NIR) / (SWIR2 + NIR)	UI uses SWIR2 and NIR bands to determine urban density
Green Chlorophyll Vegetation Index (GCVI)	GCVI	GCVI = (NIR/GREEN) – 1	Used to estimate the content of leaf chlorophyll in various species of plants
MERIS-based Terrestrial Chlorophyll Index (MTCI)	MTCI	MTCI = (NIR_Broad - Red_Edge_1) / (NIR_Broad + Red)	MTCI can be used to gauge chlorophyll content.

Normalized Difference Red Edge (NDRE)	NDRE	NDRE = (NIR – Red_Edge_1) / (NIR + Red_Edge_1)	NDRE uses NIR and red edge bands to gauge late season plant health. Calculated using Red_Edge_1 based on wavelength used for NDRE calculation in this paper (Carisse et al 2010).

Band Insertion Into RGB

Features can be isolated to stand out by loading different combinations of bands into the red, green, and blue channels. Read more here.

Combo Name	API Variable	Formula (R-G-B)	Description
Traditional Color Infrared Image (CIR)	CIR	NIR - Red - Green	Combination of colors within the visible spectrum with addition of NIR light; useful for determining pigments in vegetation.
Urban Environment (UE)	UE	SWIR2 - SWIR1 - Red	False Color useful for visualizing urban environments.
Land and Water (LW)	LW	NIR - SWIR1 - Red	False Color good for picking out land from water.
Atmospheric Penetration (AP)	AP	SWIR2 - NIR - Green	False color image with good atmospheric penetration.
Agriculture (AGR)	AGR	SWIR1 - NIR - Blue	False color for visualizing agricultural activity.
Forest Fire Burn Scars (FFBS)	FFBS	SWIR2 - NIR - Blue	False color often used for visualizing forest fire burn scars
Bare Earth (BE)	BE	SWIR1 - Green - Blue	False color for distinguishing differences in bare earth.

Vegetation and Water (VW)	VW	NIR - SWIR2 - Coastal Aerosol	False color for visualizing vegetation and water.

POST Response

POST Response Example – application/json


```
[{

"tiledate": "09/23/2019-09/29/2019",
"band": "NDVI",
"download_url": "raster_bandNDVI_date2019266-2019272_20200611_141827_6340.tif",
"features": [{"attributes": {"OID": 0, "Extent": "-101.03596423533554, 38.591014376083464, -10
         1.02686423533554, 38.598114376083466", "Mean": 0.3157017763301112, "Max": 0.436977821
         1533957, "Min": 0.22988474901936115, "Std": 0.02079966053531458, "Percentile5": 0.289
         1595012773403, "Percentile95": 0.35072763128969403, "pngb64": "data:image/png;base64,
         iVBORw0KGgoAAAANSUhEUgAAAFsAAABHCAYAAABoIjt5AAAEvklEQVR4nO1cbbbjIAjFd7KjrCWzyNetTNaU+
         dHJK6GggGhMX+45PW3zgeaKgIpJ2wIbLACwAKwAMIMDD/J/8QjxYw2+38JBqWws68sgV8Yi/O6AaKKtMksNs6
         JPDNkAsPeOnqglOko2R/jMHJ8oQW5TQqCtrKesKJJLcrjzUn334xJ/KwBMAPCmkVIltMRYyGjRuBHyvMiVbTI
         jGhJbdm1O=",
"Legend": [{"color": "#ffaa00", "Min": 0.2759054317158133, "Max": 0.2989157730640393, "Mean":
         0.28741060238992633, "Area": "24.09 %", "Count": 852, "CountAllPixels": 6436},
         {"color": "#ffff00", "Min": 0.2989157730640393, "Max": 0.3219261144122654, "Mean": 0.
         310420943738152‌3, "Area": "54.1 %", "Count": 3482, "CountAllPixels": 6436}, {"color":
         "#ccff00 ", "Min": 0.3219261144122654, "Max": 0.3449364557604915, "Mean": 0.333431285
         0863784, "Area": "21.81 %", "Count": 1404, "CountAllPixels": 6436},
"CoordinateSystem": "GEOGCS[\"WGS 84\",DATUM[\"WGS_1984\",SPHEROID[\"WGS 84\",6378137,298.2572
         23563,AUTHORITY[\"EPSG\",\"7030\"]],AUTHORITY[\"EPSG\",\"6326\"]],PRIMEM[\"Greenwich\
         ",0,AUTHORITY[\"EPSG\",\"8901\"]],UNIT[\"degree\",0.0174532925199433,AUTHORITY[\"EPSG
         \",\"9122\"]],AUTHORITY[\"EPSG\",\"4326\"]]","CellSize": [0.00010000000000004023, -0.
         00010000000000001714], "Matrix": [71, 91]}}],
"Xcoordinates": "", "Ycoordinates": "", "Values": "", "error": "", "nodata_raster": false,
"dayoftiles": "2019266-2019272", "week": "38"

}]
```

Response Parameters

Parameter	Data Type	Description
download_url	URL	URL to download result raster (.tif) file
flattendtext	-	An array of Xcoords, Ycoords values from the .tif files.
tiledate	Date (mm/dd/yyyy)	The tile dates from where the band values are retrieved.
tilenames	-	List of the Blob names from the Azure Storage Container.
features	-	An array of features from the database.
features.attributes		
CellSize	Resolution	Resolution of result Geotiff file in meters.
CoordinateSystem	-	Coordinate system of the result raster.
Extent	-	Extents of the result raster.
Legend	List	Legend gives ranges of values for: ***Area:*** *Area covered in %* ***Count***: *# of pixels from the result raster in range* ***CountAllPixels***: *Total # of pixels in result* ***Max***: *Maximum value in range* ***Min***: *Minimum value in range* ***Mean***: *Mean value in range* ***Color***: *Hex color used for value ranges*
Matrix	List	Rows and Columns.
Max	Number	Maximum value from the result raster
Min	Number	Minimum value from the result raster
Mean	Number	Average value from the result raster
Percentile5	Number	5th percentile value from result raster
Percentile95	Number	95th percentile value from result raster
pngb64	URL	base64png image of the result raster with legend entries

GET Request

Request Example

The GET request to retrieve the tif image using the file name from the POST response.

```
https://ag-analytics.azure-api.net/harmonized-landsat-sentinel-service/?filename=
raster_bandNDVI_date2019203-2019209_20190807_174457_1233.tif
```

Request Parameters

Parameter	Data Type	Required?	Default	Options	Description
filename	text	Yes	--	.tif file	file name returned by POST request

Response Parameters

Parameter	Data Type	Description
file	.tif	Tiff file will be download to the computer of the caller with the name that was used to call the API.

Supplementary Information

Acronym Definitions

Parameter	Description
MSI	URL to download result raster (.tif) file
HLS	An array of Xcoords, Ycoords values from the .tif files.
HDF	The tile dates from where the band values are retrieved.
GLS	An array of features from the database.
BRDF	Bidirectional Reflectance Distribution Function
NBAR	Nadir BRDF-normalized Reflectance
OLI	Operational Land Imager

SDS	Scientific Data Sets
SR	Surface reflectance
SZA	Sun zenith angle
UTM	Universal Transverse Mercator
WRS	Worldwide Reference System

Coefficients of Linear Regression

Coefficients of linear regression used to adjust from Sentinel-2A,B/MSI to Landsat 8/OLI

			Sentinel-2A		Sentinel-2B	
HLS Band Name	**OLI Band Name**	**MSI Band Name**	**Slope**	**Offset**	**Slope**	**Offset**
Coastal Aerosol	1	1	0.9959	-0.0002	0.9959	-0.0002
Blue	2	2	0.9778	-0.004	0.9778	-0.004
Green	3	3	1.0053	-0.0009	1.0075	-0.0008
Red	4	4	0.9765	0.0009	0.9761	0.001
NIR	5	8A	0.9983	-0.0001	0.9966	0.000
SWIR 1	6	11	0.9987	-0.0011	1.000	-0.0003
SWIR 2	7	12	1.003	-0.0012	0.9867	0.0004

Projection Syntax Example

```
Projection Syntax:
projection: projection of a new resampled raster. It may take the
following forms:
   1. Well Known Text definition
   2. "EPSG:n"
   3. "EPSGA:n"
   4. "AUTO:proj_id,unit_id,lon0,lat0" - WMS auto projections
   5. "urn:ogc:def:crs:EPSG::n" - ogc urns
   6. PROJ.4 definitions
   7. well known name, such as NAD27, NAD83, WGS84 or WGS72
   8. "IGNF:xxxx", "ESRI:xxxx", etc. definitions from the PROJ database

Projection Example:

"urn:ogc:def:crs:EPSG::n"
```

Citations:

- NASA Landsat Information
- ESA Sentinel Information
  - Sentinel Band Descriptions
- NASA HLS Information
  - HLS User Guide
  - HLS Data Descriptions
- RGB Band Insertion Source
- Usage of Red_edge_1 for NDRE calculation
- Spatial Reference Information: Universal Transverse Mercator (UTM)

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