The terraPulse land monitoring system

Location intelligence for land managers—Know the land.

Summary

TerraPulse is a cloud-based, end-to-end software platform for analyzing and monitoring large land areas. The system comprises three parts: terraPulse data, the terraView monitoring dashboard, and terraServe—the geospatial API for data scientists. TerraPulse data are digital maps of ecosystem cover, structure, and function, as well as their dynamics over time. TerraView displays the current value of each map layer and allows users to retrieve historical values for selected points and areas. The terraServe API allows automated, big-data access to terraPulse for analysts, modelers, and data scientists.

Land changes—so should your maps.

Based on streaming satellite imagery, calibrated to high-quality reference data, and built on the Amazon Web Services cloud platform for round-the-clock data storage, backup, and delivery, terraPulse enables access to the highest-quality information on land cover and its changes over time. Customized for each user, terraView displays a user-defined selection of map layers from terraPulse and other sources. Subset to a user's geographic area at either pixel- or parcel-resolution, these datasets describe the history, status, and potential of each piece of land—from an individual parcel up to the entire globe—with global consistency and cutting-edge scientific accuracy.

Contents

terraPulse Data Products

The terraPulse data cube is an empirical record of Earth's biosphere. Mined from satellite measurements with machine learning, terraPulse datasets are gridded maps of the cover, structure, and function of ecosystems. The data are provided by location, from pixels and parcels up to the entire globe, and successive map layers depict changes over time. Spatial resolution ranges from 1 to 500 meters, at extents ranging from individual forest stands or property parcels up to the entire globe. Measurements are updated daily or annually, depending on the variable, and extend from 1984 to the present.

TerraPulse data products quantify the state and changes of forest-, rangeland, cropland, wildlife habitat, and urban development. These spatio-temporal data records fill a critical gap in natural resource information, increasing the liquidity of land information and improving the transparency and efficiency of land governance, insurance, purchase, and management. Relied upon by NASA, World Bank, US Forest Service, and the US Bureau of Land Management, the terraPulse algorithms apply decades of expertise in satellite image analysis to automate the provision of actionable, near real time, and cost-effective decision-making tools.

TerraPulse data are delivered through the terraView dashboard for fast access and monitoring, as well as through the terraView API in GeoJSON, CSV, SHP, or TIFF format.

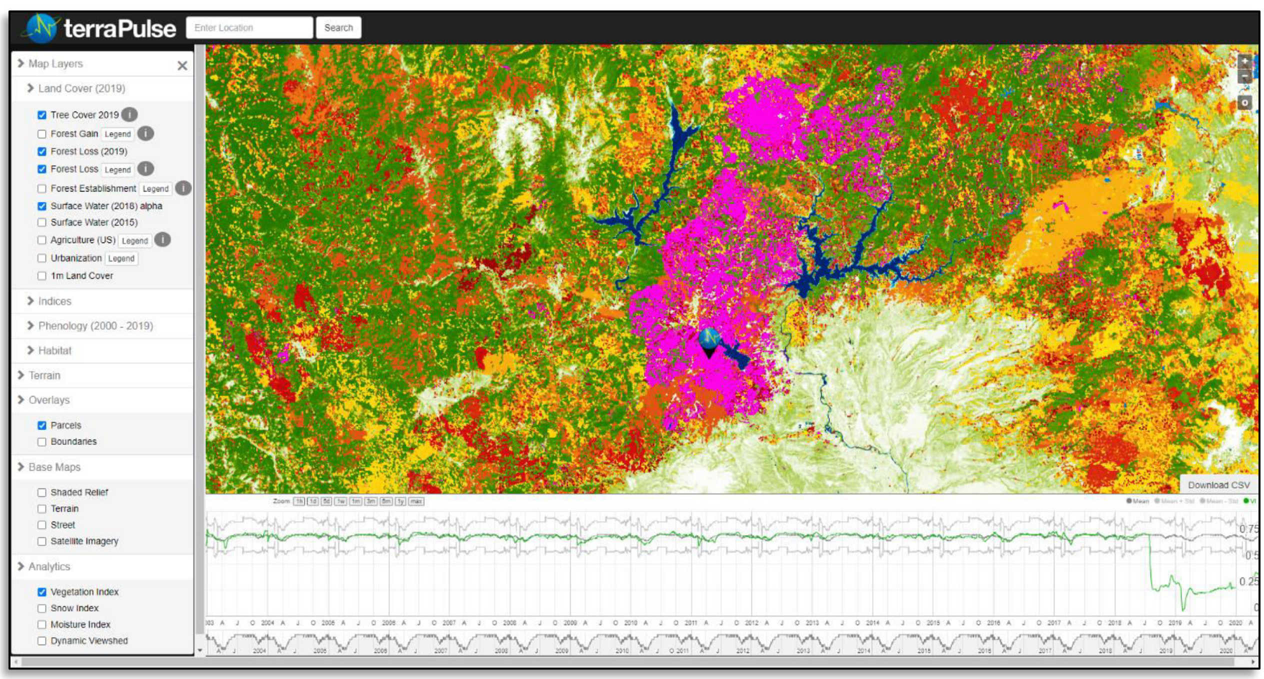


Figure 1. The terraView dashboard showing three terraPulse Forest Cover & Change data products and time-serial NDVI over the area of the Carr Fire, 2019, in California. Tree Canopy Cover is shown in the map as shades of green, Forest Loss (year) is mapped in yellow-red heatmap, and 2019 Forest Loss is highlighted in magenta. Time-serial NDVI is shown in the chart below.

Land Cover & Change

TerraPulse Land Cover & Change data represent the state and changes of ecosystems as percentages of different land cover types, including tree, building, pavement, grass/herb, bare, and water. At the highest (~1-meter) resolution, these types are represented as single categories. At coarser resolutions (e.g., 10-meter or 30-meter pixels) and across larger areas (e.g., property parcels, regions, or countries), cover is summarized as areas or areal percentages. Changes over time are detected using both the estimate and the uncertainty of the value in each pixel.

Land-cover type

The terraPulse Land Cover dataset is a categorical description of Earth's terrestrial ecosystems. At its highest, 1-meter resolution, the data record one of five categories—building, pavement, tree, grass/herb, bare, water—in each pixel. At coarser resolution, the pixels are resampled as class-percentages.

Unit:	*categorical (building, pavement, tree, grass/herb, bare, water)*
Scale:	
	***Spatial**: 1-m resolution, global extent*
	***Temporal**: variable*
Latency:	*previous year*
Source:	*terraPulse*

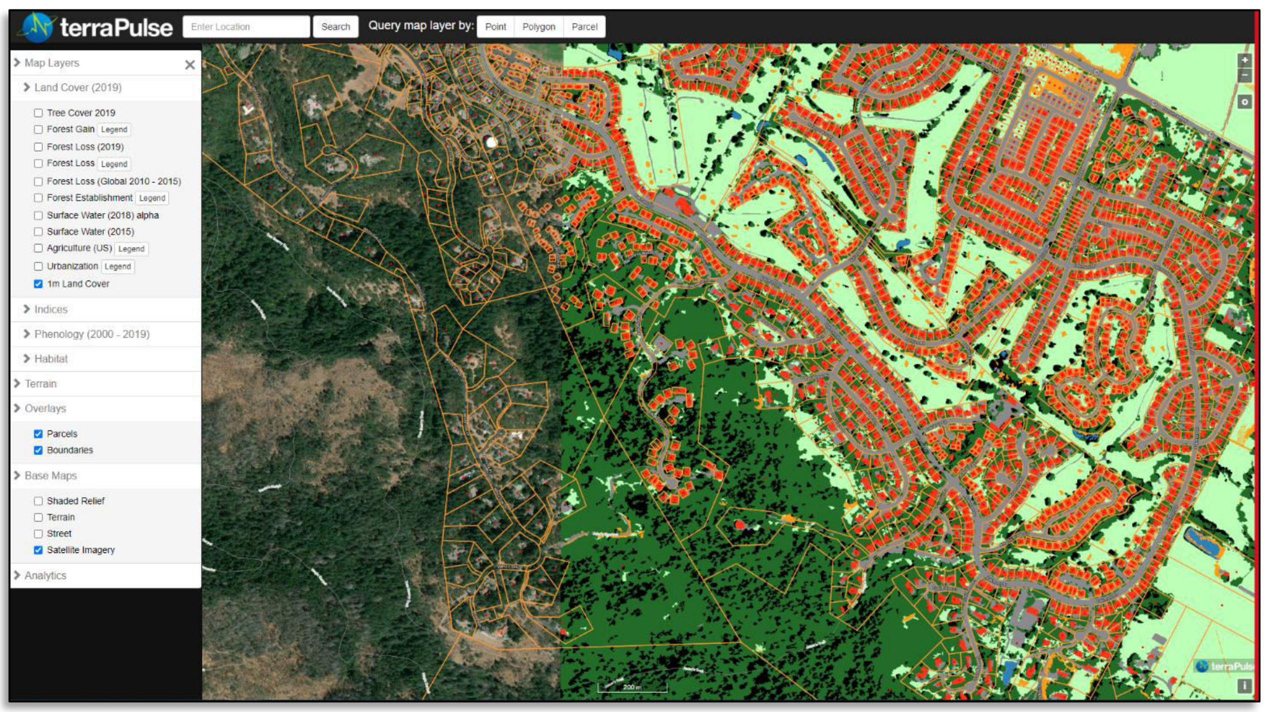


Figure 2. The terraView dashboard showing the terraPulse Land Cover Type layer over a wildland-urban interface in Sonoma County, California. Cover types are: building (red), pavement (gray), tree (dark green), grass/herb (light green), water (blue).

Forest

Tree cover, the primary measurable attribute of forests, correlates to timber volume, habitat quality and movement of wildlife, as well as residential property value and other forestland values. Mapping forests as percentages of tree cover over time enables informed detection and monitoring of clearing, harvest, degradation, and growth, and it enables monitoring and retrieval of site-specific histories of forest change.

The terraPulse forest product suite is based on time-serial maps estimating the percentage of horizontal area in each pixel covered by woody vegetation taller than 3 to 5 meters from current and historical satellite imagery. The dataset is available from 1984 to 2020 at 30-meter resolution for any region resolution, as well as derived categories of forest cover and change detection. Through the terraPulse Land Cover Dataset, the tree-cover layer is also available as a binary measurement at 1-meter resolution, with historical coverage depending on availability of high-resolution imagery.

Standard Layers

Tree Canopy Cover

Unit: *percent of area*
Scale:
Spatial*: 30-m resolution, global extent*
Temporal*: annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Deciduous Canopy Fraction

Unit: *percent of area*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Evergreen Canopy Fraction

Unit: *percent of area*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Forest cover

Unit: *binary (forest/nonforest)*
Scale:
Spatial*: up to 30-m resolution, global extent*
Temporal*: up to annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Forest loss

Unit: *binary, significance (probability)*

Scale:

***Spatial**:* *30-m resolution, global extent*

***Temporal**:* *annual resolution from 1984 – present*

Latency: *previous year*

Source: *terraPulse*

Forest gain

Unit: *binary, significance (probability)*

Scale:

***Spatial**:* *30-m resolution, global extent*

***Temporal**:* *annual resolution from 1984 – present*

Latency: *previous year*

Source: *terraPulse*

Forest stand age

Unit: *years since establishment/detection (forest gain)*

Scale:

Spatial: *30-m resolution, global extent*

Temporal: *annual resolution from 1984 – present*

Latency: *previous year*

Source: *terraPulse*

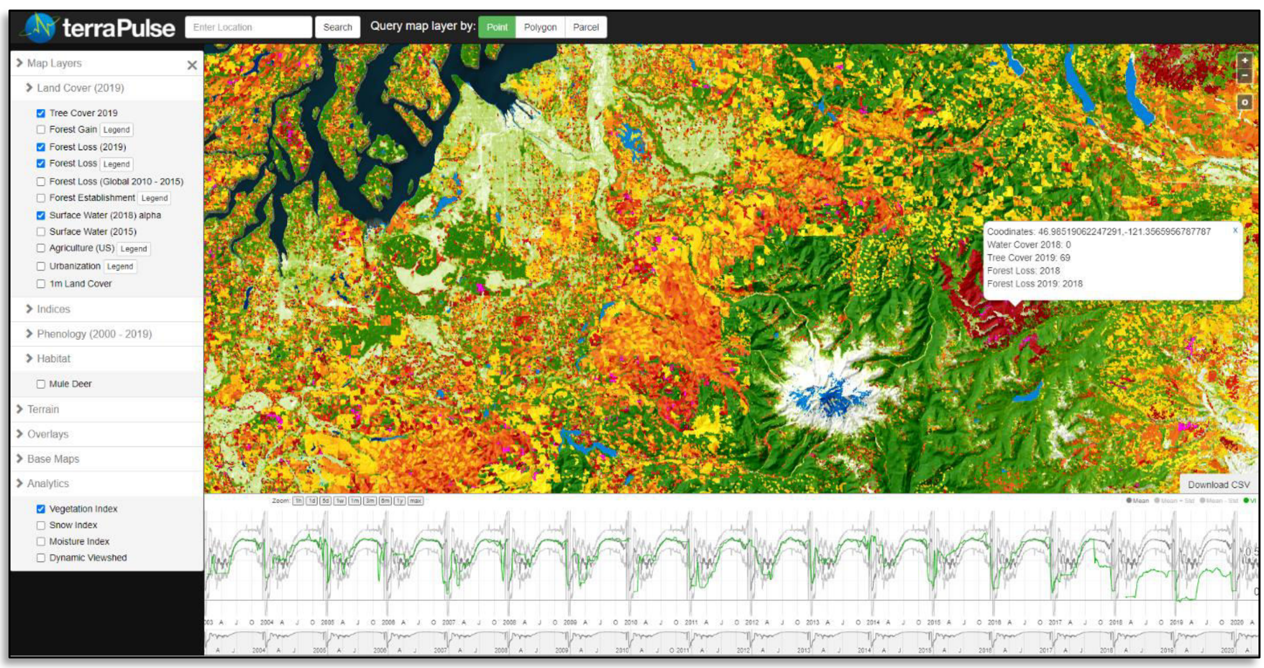


Figure 3. terraView displaying terraPulse Tree Cover (2019) and Forest Loss (1984 – 2019) at 30m resolution over Washington's Olympic Peninsula in green and orange-red heatmaps. The time-series chart shows the Normalized Difference Vegetation Index at daily, 500-meter resolution from 2000 to 2019 at the pinned location.

Water

The spatial distribution of water and its changes over time indicate exposure to flood risk, detect aquaculture and paddy agriculture, and identify wetland habitats for waterfowl and other wildlife. The terraPulse suite of surface-water layers represent inundation of the ground surface of each pixel by water—either categorically at any point in time or probabilistically over longer intervals—and are available globally at 30-m resolution from 1984 to 2020. Through the terraPulse Land Cover Layer, the Surface Water layer is also available as a binary measurement at 1-meter resolution, with historical coverage depending on availability of high-resolution imagery.

Standard Layers

Surface Water Cover

Unit: *percent of area*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

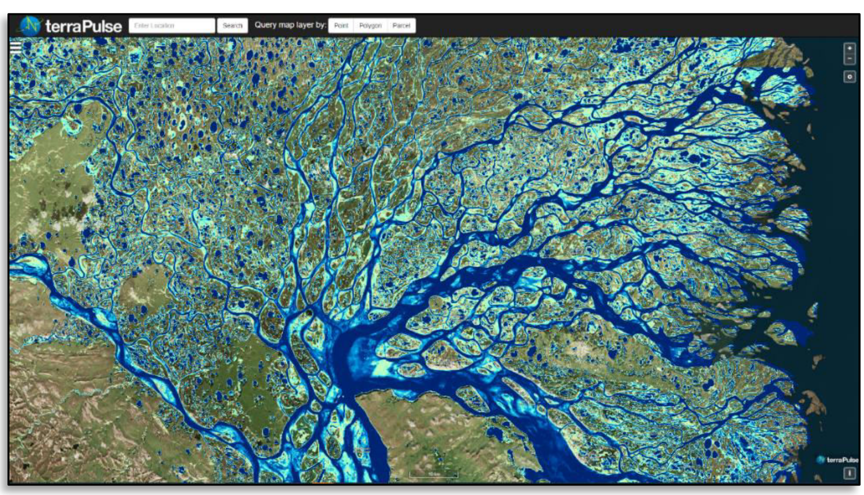
Hydroperiod & inundation frequency

Unit: *percent of observations detected as inundated*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Inundation year & age

Unit: *years since most recent inundation*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

The terraView dashboard showing the terraPulse hydroperiod layer (2020) over the Lena River Delta in Russia. The background image is a high-resolution satellite image. The yellow-blue colors are the percentage of the year each pixel was inundated with (liquid) water.



Urban & Developed

Urban impervious surfaces—defined as artificial materials through which water does not penetrate (e.g., concrete and asphalt roads, sidewalks, and buildings)—impact energetic, chemical, and hydrological fluxes, as well as biodiversity, economies, and even human health. Impervious surfaces are indicators of economic development and are the causes of increased surface and air temperatures, as well as hydroperiod variability, streamwater temperature, sediment load, and levels of heavy metals, nitrogen, phosphorous, and fecal coliform bacteria.

The terraPulse urbanization data products map urban cover and change through spatio-temporal measurements of impervious surface cover. The data are based on high-resolution satellite estimates of building and pavement cover, interpolated to 30-meter, annual resolution using Landsat, Sentinel, and other data sources. Through the terraPulse Land Cover Dataset, the Impervious Surface Cover layer is also available as a binary measurement at 1-meter resolution, with historical coverage depending on availability of high-resolution imagery.

Standard Layers

Impervious Surface Cover

Unit: *percent of area*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Urban Cover

Unit: *binary (urban/nonurban)*
Scale:
Spatial*: up to 30-m resolution, global extent*
Temporal*: up to annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Urban Change (loss and gain)

Unit: *direction (gain/loss), significance (probability)*
Scale:
Spatial*:* *30-m resolution, global extent*
Temporal*:* *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Development Year & Age

Unit: *years since development/detection (urban gain)*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *annual resolution from 1984 – present*
Latency: *previous year*
Source: *terraPulse*

Figure 4. The terraView dashboard showing the 1-meter resolution terraPulse Land Cover Type map over College Park, Maryland. The dataset has six categories: building (red), pavement (gray), tree (dark green), grass/herb (light green), water (blue), and bare (orange).Property parcels are outlined in orange. Note the large patches of bare soil detected during commercial development of large site in the center of the map.

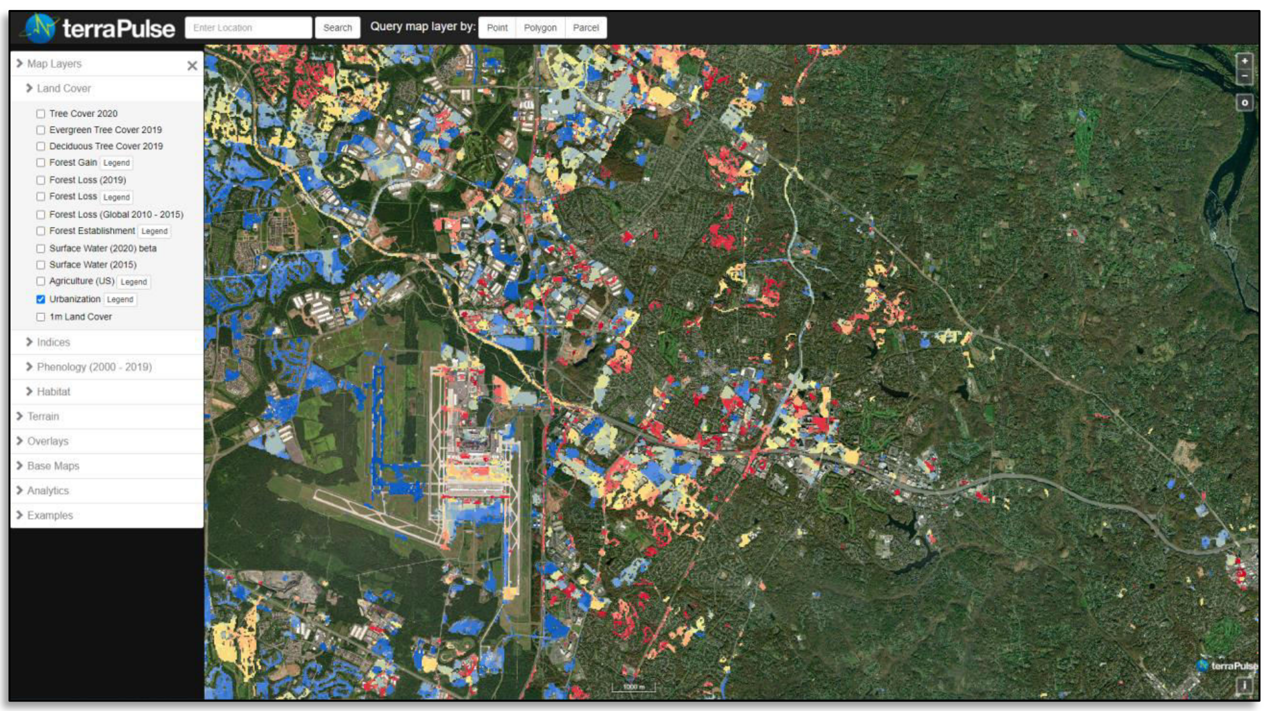


Figure 5.The terraView dashboard showing terraPulse Development Year dataset over the area around Dulles-Washington International Airport. The heatmap represents year of urban growth from 1985 (blue) to 2010 (red).

Cropland

TerraPulse hosts the US Department of Agriculture Cropland Data Layer for visualization on terraView and download through terraServe. The data cover the conterminous US at a resolution of 30 meters from 2008 to the previous year. Coverage may be greater or lesser depending on regional agricultural intensity. The data represent 107 agricultural crop species and types, as well as seven non-agricultural types.

Standard Layers

Crop Type

Unit: *categorical*

Scale:

- ***Spatial:*** *30-m resolution, continental US*
- ***Temporal:*** *2008 – present (additional years vary by state)*

Latency: *previous year*

Source: *USDA NASS Cropland Data Layer*

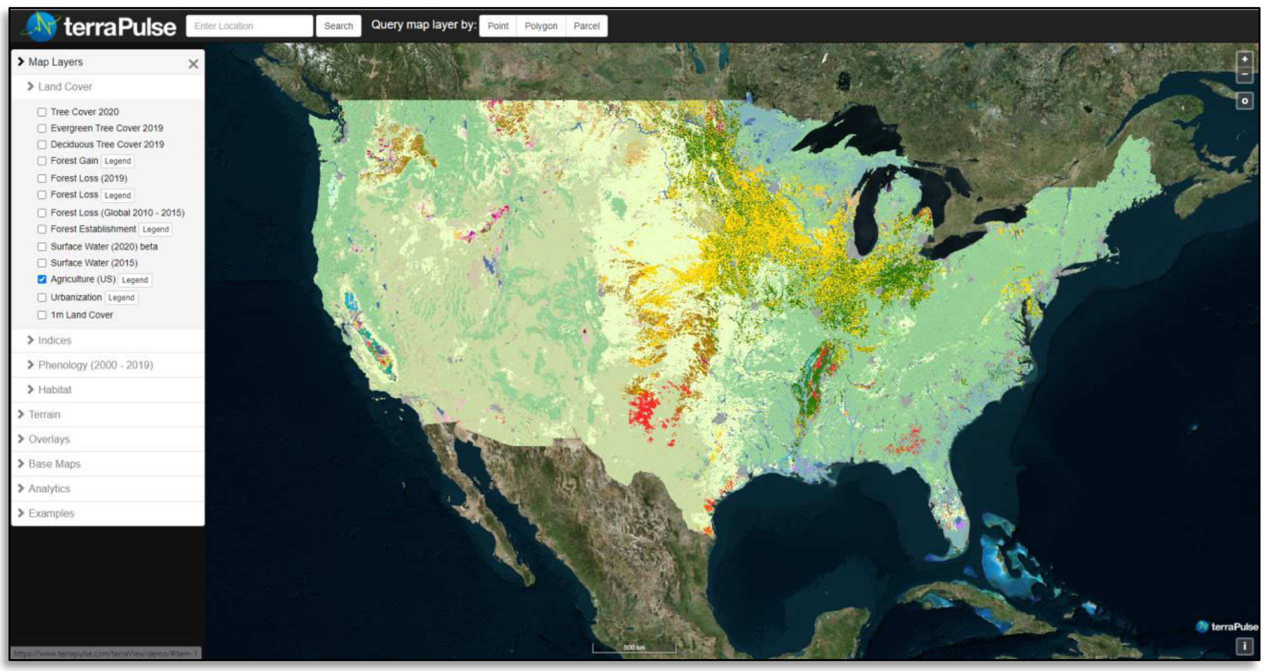


Figure 6. The terraView dashboard showing the USDA Cropland Data Layer over the conterminous US in 2020. The USDA CDL dataset is available at 30-meter, annual resolution over the conterminous US from 2008 to 2020.

Indices

Crop-, range-, and wildland systems require frequently updated data for monitoring plant health and condition, surface moisture, and snow. TerraPulse produces a variety of satellite-based indices at up to 30-m, daily resolution, as well as longer-term summaries of historical conditions and their variability.

Standard Layers

Normalized Difference Vegetation Index (NDVI)

Unit: *unitless ratio*

Scale:

Mapping: *30-meter globally, interpolated to daily resolution from 1985 – present*

or

Time-series: *500-meter, daily resolution at global extent from 2001 – present*

Latency: *~10 days*

Source: *terraPulse*

Normalized Difference Wetness Index (NDWI)

Unit: *unitless ratio*

Scale:

Mapping: *30-meter globally interpolated to daily resolution from 1985 – present*

or

Time-series: *500-meter, daily resolution at global extent from 2001 – present*

Latency: ~10 days

Source: *terraPulse*

Normalized Difference Snow Index (NDSI)

Unit: *unitless ratio*

Scale:

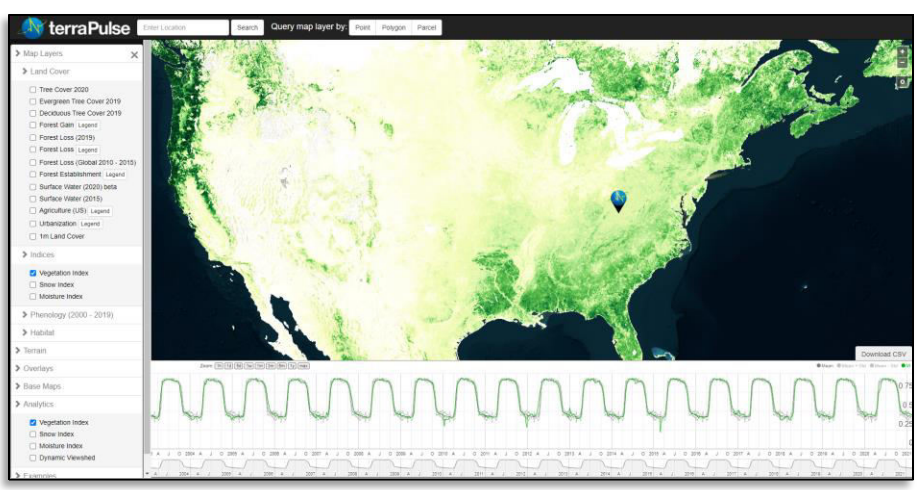
Mapping: *30-meter globally interpolated to daily resolution from 1985 – present*

or

Time-series: *500-meter, daily resolution at global extent from 2001 – present*

Latency: ~10 days

Source: *terraPulse*



TerraView showing the most recent daily acquisition of Normalized Difference Vegetation Index (NDVI) in the map window and the complete time-series for the pinned location in the charting window.

Phenology

Phenology is the study of inter-annual biotic cycles. Phenological processes in plants are driven mainly by climate. In turn, plant phenology affects cycling of energy, water, and nutrients, as well as seasonal animal behavior. The terraPulse suite of phenology datasets are derived from time-serial measurements of the Normalized Difference Vegetation Index (NDVI) in each pixel. To improve representation in temperate, boreal, and arctic regions, data can be masked for snow upon request.

Standard layers

Start of Growing Season (SOS)

Unit: *day, NDVI*
Scale:
 Spatial: *30-m resolution, global extent*
 Temporal: *annual resolution from 2001 – present*
Latency: *previous year*
Source: *terraPulse*

Peak of Growing Season (POS)

Unit: *day, NDVI*
Scale:
 Spatial: *30-m resolution, global extent*
 Temporal: *annual resolution from 2001 – present*
Latency: *previous year*
Source: *terraPulse*

End of Growing Season (EOS)

Unit: *day, NDVI*
Scale:
 Spatial: *30-m resolution, global extent*
 Temporal: *annual resolution from 2001 – present*
Latency: *previous year*
Source: *terraPulse*

Length of Growing Season (LOS)

Unit: *days*
Scale:
 Spatial: *30-m resolution, global extent*
 Temporal: *annual resolution from 2001 – present*
Latency: *previous year*
Source: *terraPulse*

Total of Growing Season (TOS)

Unit: *NDVI*
Scale:
 Spatial: *30-m resolution, global extent*
 Temporal: *annual resolution from 2001 – present*
Latency: *previous year*
Source: *terraPulse*

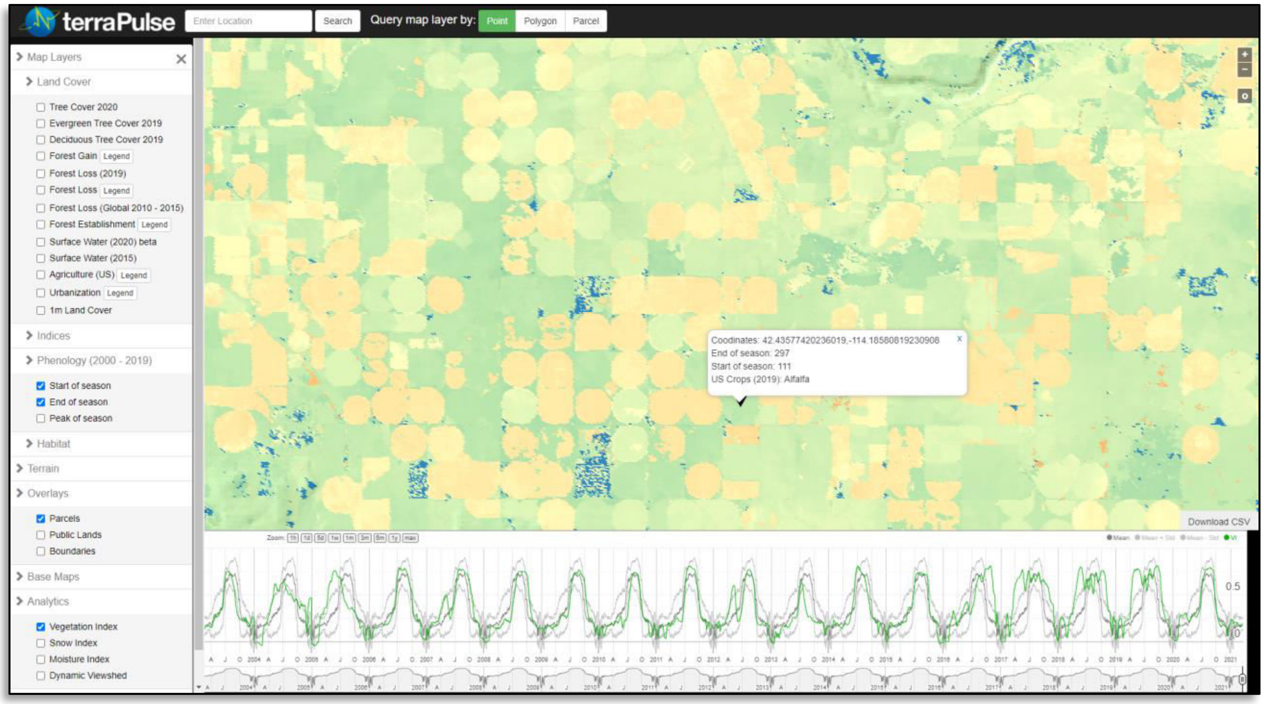


Figure 7. The terraView dashboard showing terraPulse Phenology Start of Season (day of year) over an agricultural region in southern Idaho, USA and historical NDVI of an alfalfa field at the pinned location in the time-series chart. Corresponding to crop establishment, the pinned location shows SOS on day 111 (April 21) in 2020.

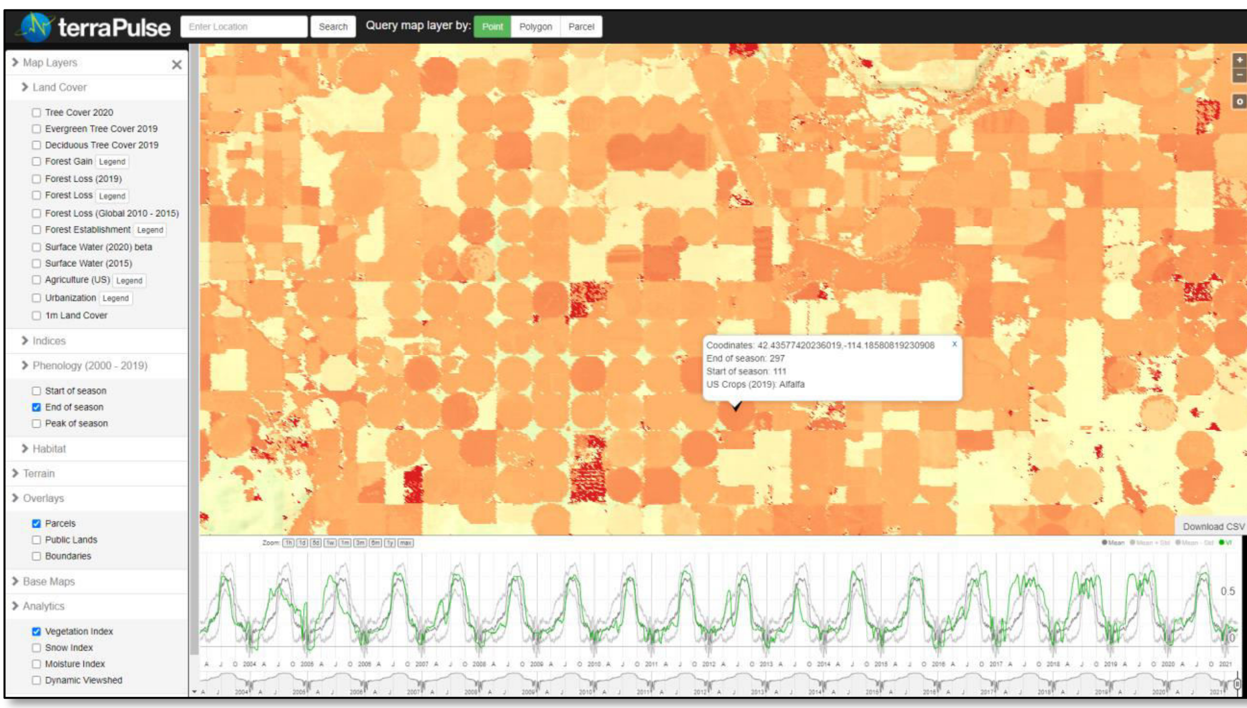


Figure 8. The terraView dashboard showing terraPulse Phenology End of Season (day of year) over an agricultural region in southern Idaho, USA and historical NDVI of an alfalfa field at the pinned location in the time-series chart. The pinned location shows EOS on day 111 (October 23) in 2020, corresponding to crop harvest.

Terrain

The terraPulse terrain product suite is derived from gridded measurements of elevation captured by optical and radar sensors aboard a variety of Earth-orbiting satellites. These layers are static over time and aid interpretation of dynamic, satellite-based variables to inform decisions such as site selection for agricultural and forest uses, habitat improvement, and energy development.

Elevation

Unit: *feet or meters*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *static*
Source: *USGS*

Slope

Unit: *degrees or percent*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *static*
Source: *USGS*

Aspect

Unit: *azimuth degrees*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *static*
Source: *USGS*

Topographic Moisture Index

Unit: *watershed catchment area divided by tan(slope)*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *static*
Source: *USGS*

ViewScore topographic visibility index

Unit: *visible area (sq. km.)*
Scale:
Spatial: *30-m resolution, global extent*
Temporal: *static*
Source: *USGS*

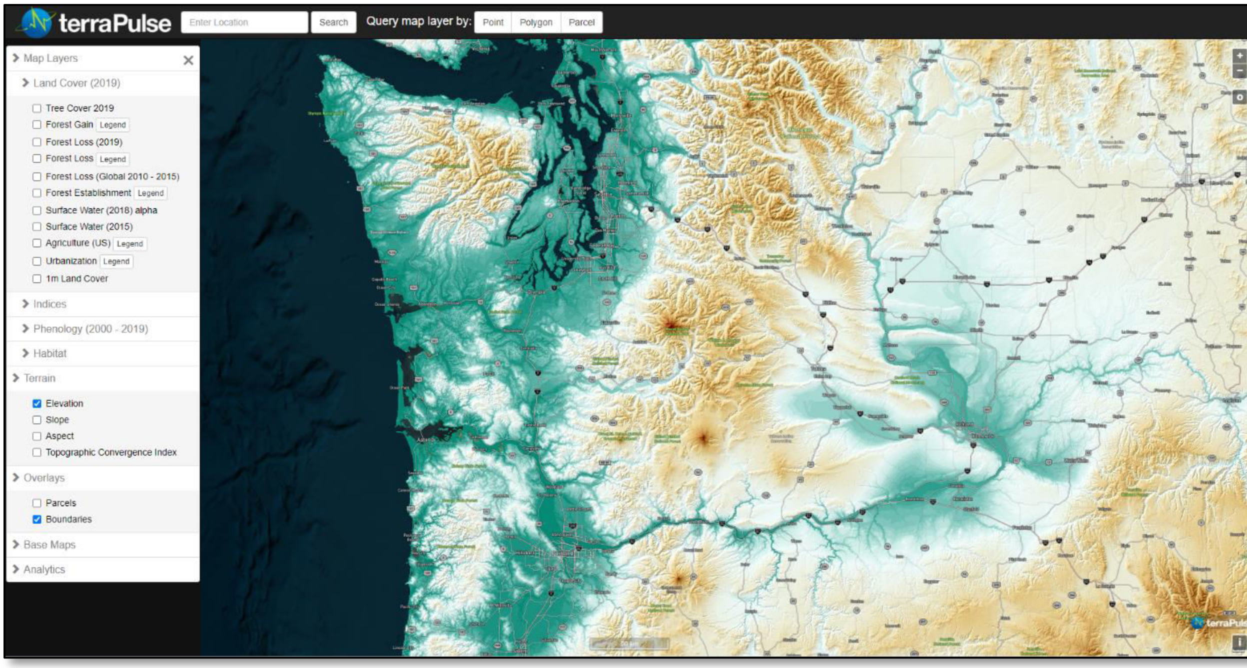


Figure 9. The terraView dashboard showing the terraPulse Elevation layer over the Pacific Northwestern United States. Note the steep relief of the Olympic Peninsula and the volcanoes of the central Cascades Mountain Range.

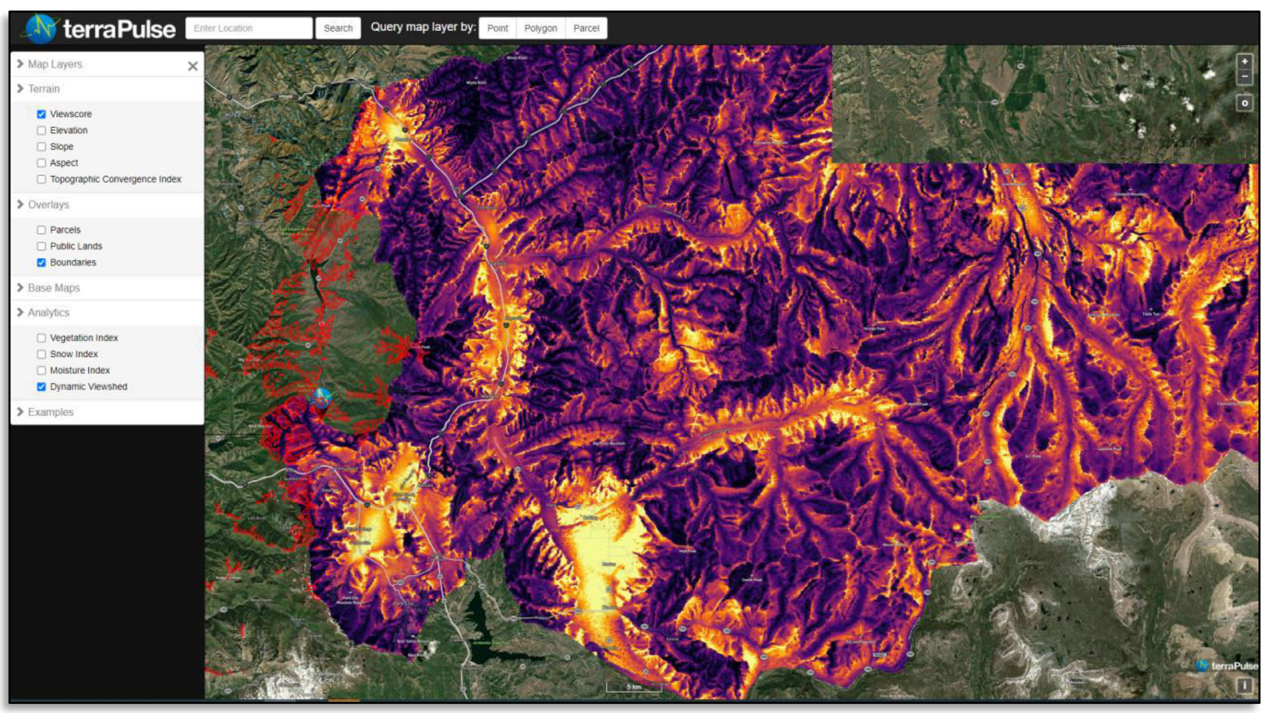


Figure 10. The terraView dashboard showing the terraPulse ViewScore layer over Summit County, Utah. In units of visible viewshed area, the heatmap ranges from zero (dark purple) to thousands in yellow. The area visible to the pinned location is outlined in red.

Ownership

TerraPulse offers a custom public lands layer derived from the Protected Areas Database of the US (PAD-US). This layer covers the continental US at a resolution of 30 meters and is available for visualization on terraView and download through terraServe. The data represent seven categories: National Parks; National Forests; Military Lands; BLM/BLR Lands; Tribal Lands; State Parks (including related state-managed protected areas); and State Forests/Wildlife Management Areas. Easements and global public lands can be added at request.

US Public Lands

Unit:	*categorical (National Parks; National Forests; Military Lands; BLM/BLR Lands; Tribal Lands; State Parks; State Forests/Wildlife Management Areas)*
Scale:	
	Spatial: *30-m resolution, global extent*
	Temporal: *static*
Source:	*Protected Areas Database of the US (PAD-US), supplemented by state data*

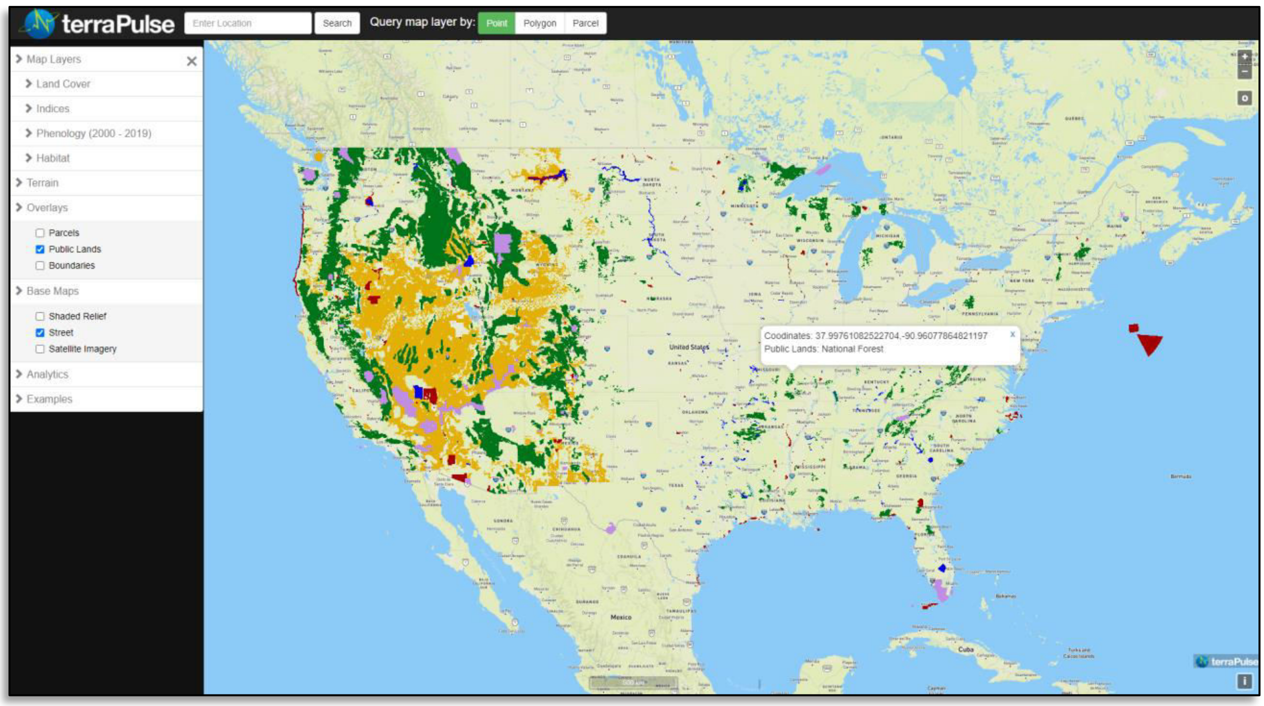


Figure 11. The terraView dashboard showing the terraPulse Public Lands map over the continental United States. The pinned location shows management by the US Forest Service.

terraView Dashboard

Map layers

Most current value of each terraPulse map layer

Vector overlays

- Roads & Boundaries
- Custom AOI's (e.g., management units, supplied by user)

Map functions

- Map Pan & Zoom
- GPS & text location search
- Graphical ad numerical point- and polygon summary
- Time-series index charts

Security

Private accounts and data access

Browser

Chrome preferred

terraServe

Application Programming Interface (API)

The terraPulse data cube is a high-dimensional record of ecosystem dynamics. Individual terraPulse data layers may be accessed through the terraServe Application Programming Interface (API). The terraServe API is available as a subscription service to developers and data scientists.

MapTiles

Any terraPulse map layer can be visualized on mapping platforms such as ArcGIS, QGIS, Google Maps, MapBox, Leaflet, and OpenLayers. The map tiles are exposed using XYZ tiles, where each tile is a 256 x 256 PNG using a EPSG: 3857 projection.