Impact Observatory

Global Scale Automated Near Real-Time Landcover Maps Using Deep Learning

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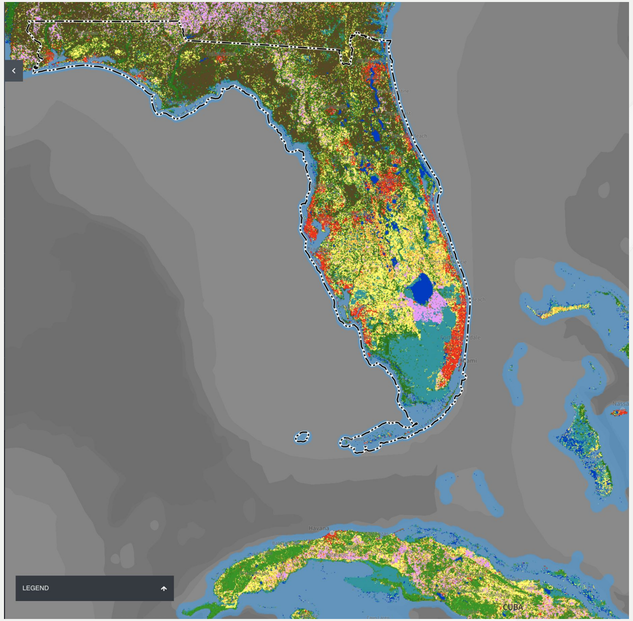
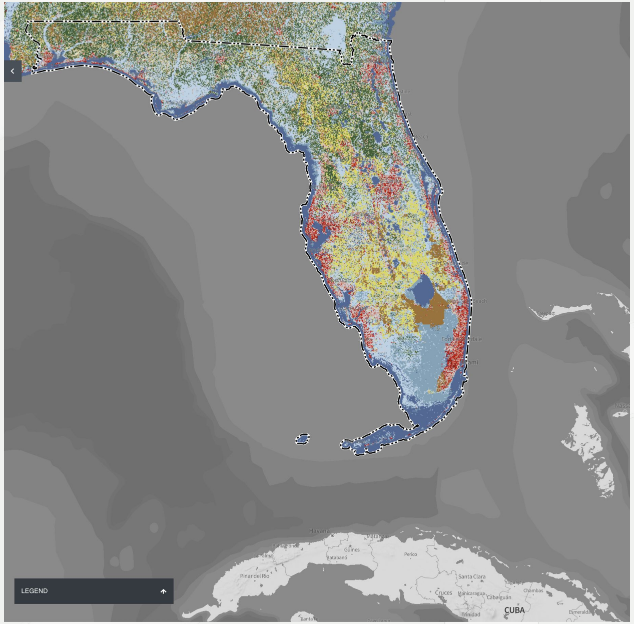
Traditional approaches to mapping and monitoring at national to global scale can be expensive, complex, and slow



EU Copernicus CGLS-LC100 100m 2019



USGS NLCD Landsat 30m 2019 - USA

Traditional state-of-the-art maps are produced by a few national governments using semi-manual methods, and published with a delay of at least one year. Global maps are lower resolution (>100m ground sample distance). Example: Left: CGLS-LC100 Global 100m 2019. Right: USGS NLCD US-only 30m 2019.

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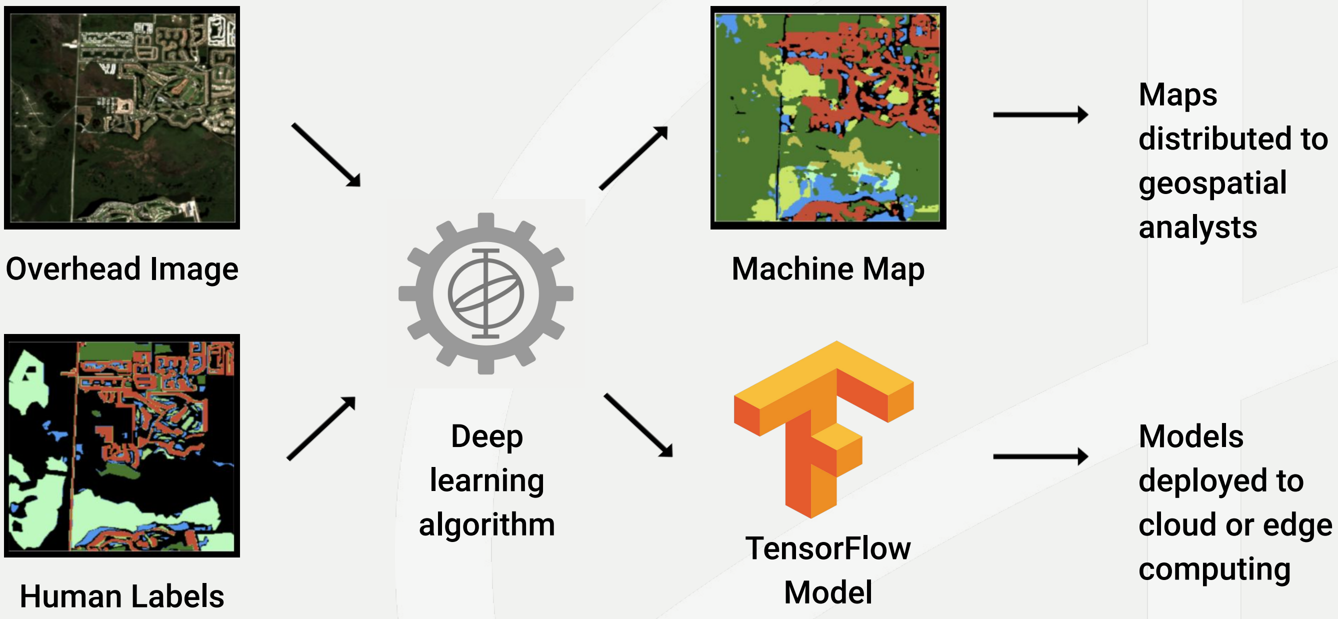
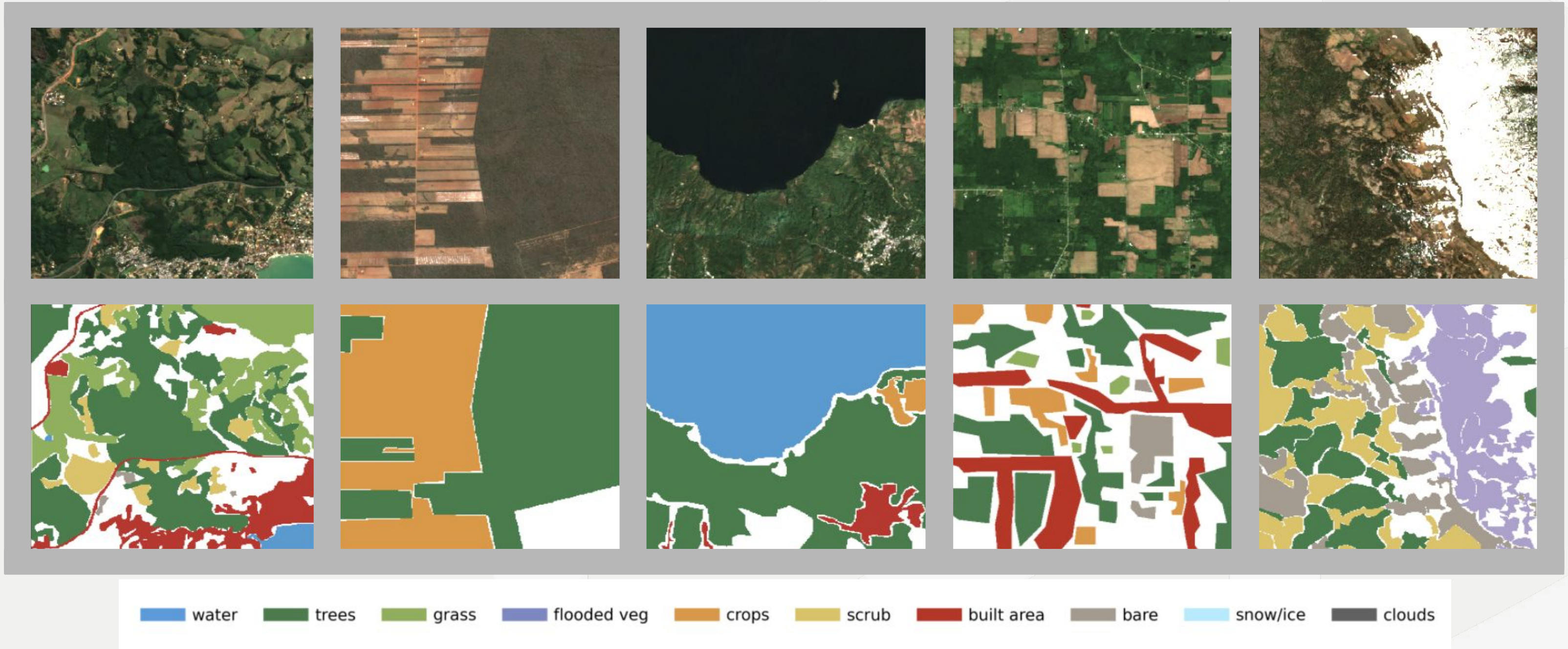
New approach: Landcover mapping using deep learning applied to satellite imagery time series can be formulated as a supervised segmentation problem



Deep learning algorithms take in image tiles and matching human-labelled data and learn models that process images into maps. The models can be deployed to cloud or edge computing systems.

Producing deep learning models that generalize well to global scale requires many well-sampled training labels



National Geographic Society's Geographic Visualization Lab produced a dataset of over **5 billion human-labeled pixels** for Copernicus Sentinel-2 10m imagery in 2020 with stratified sampling across over 25,000 locations distributed across all continents and all major biomes [**Brown, Brumby, et al., Sci Data 2022**]

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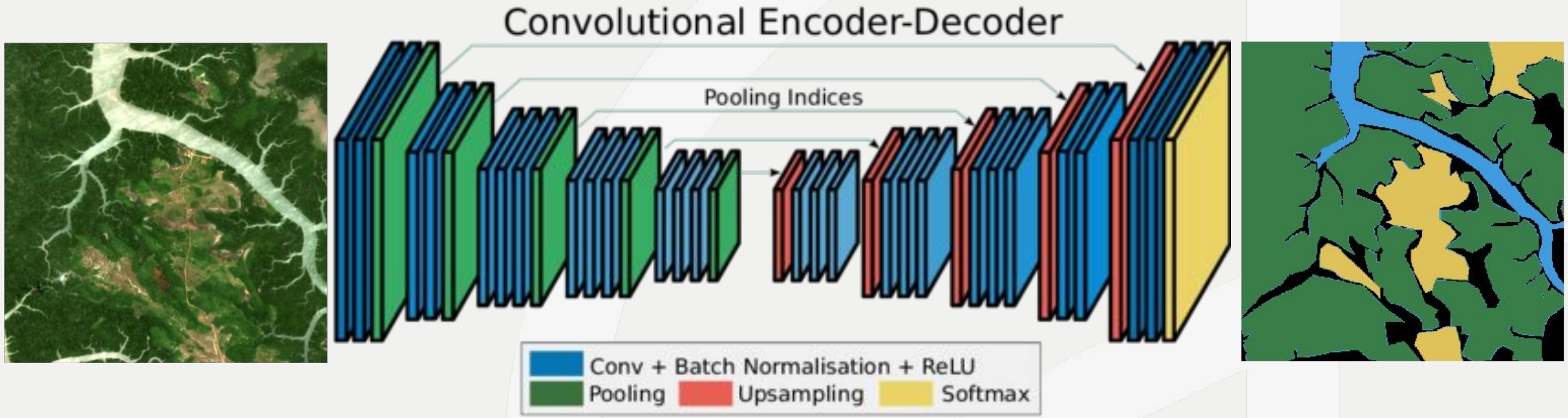
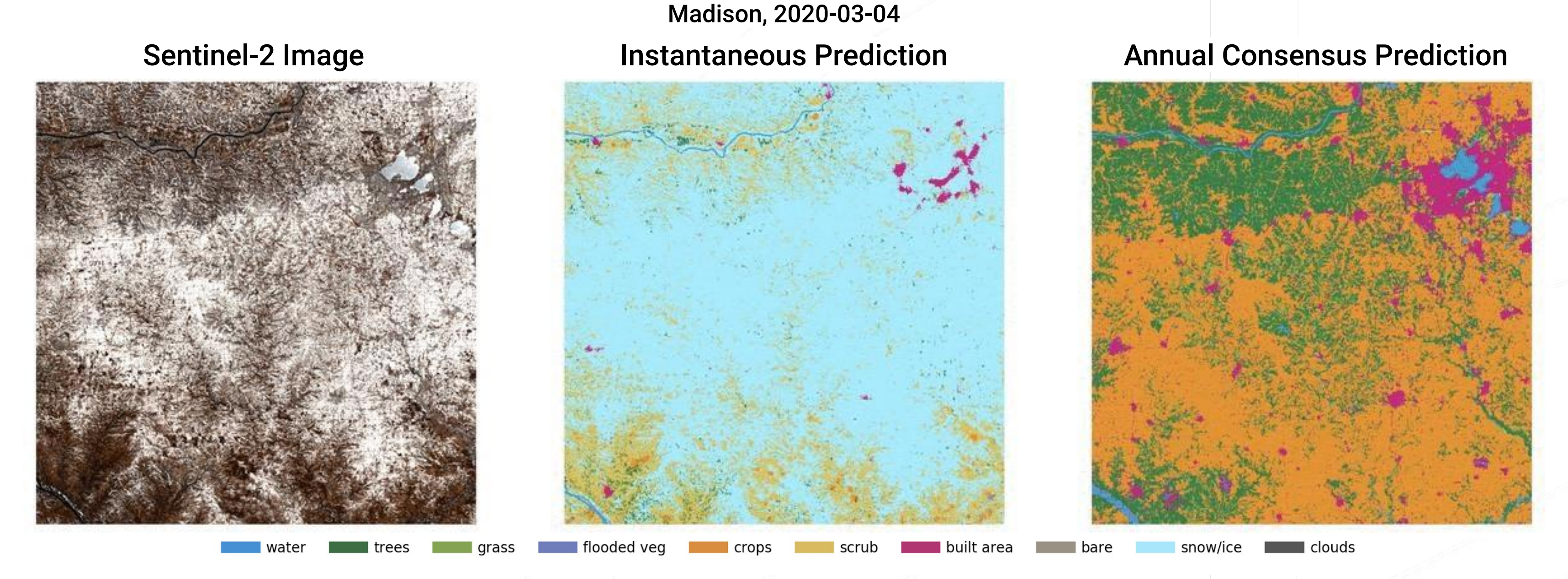
Standard approach for deep learning model architecture is U-Net semantic segmentation originally proposed for medical imagery.



Impact Observatory implemented a deep learning U-Net system [**Ronneberger, et al., MICCAI 2015**] for Copernicus Sentinel-2 10m Level 2A surface reflectance visible/infrared satellite imagery in COG format, using commercial cloud compute and the public imagery STAC service on Microsoft Azure Planetary Computer [**Karra, et al., IEEE IGARSS 2021**]

The trained model outputs inferences from individual satellite observations across time which are then combined using additional processing to produce a consensus annual map



Impact Observatory's U-Net model takes in daily Sentinel-2 satellite observations (left), producing maps for each observation (center), that estimate change and produce annual consensus maps (right).

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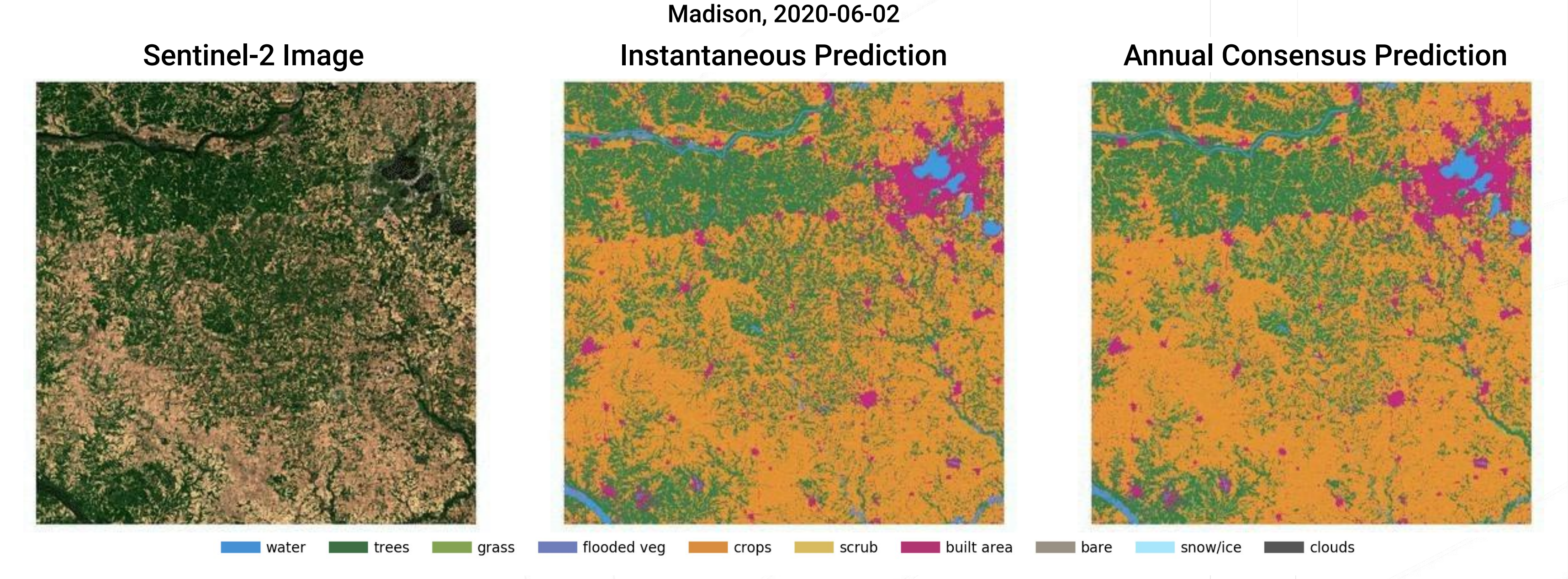

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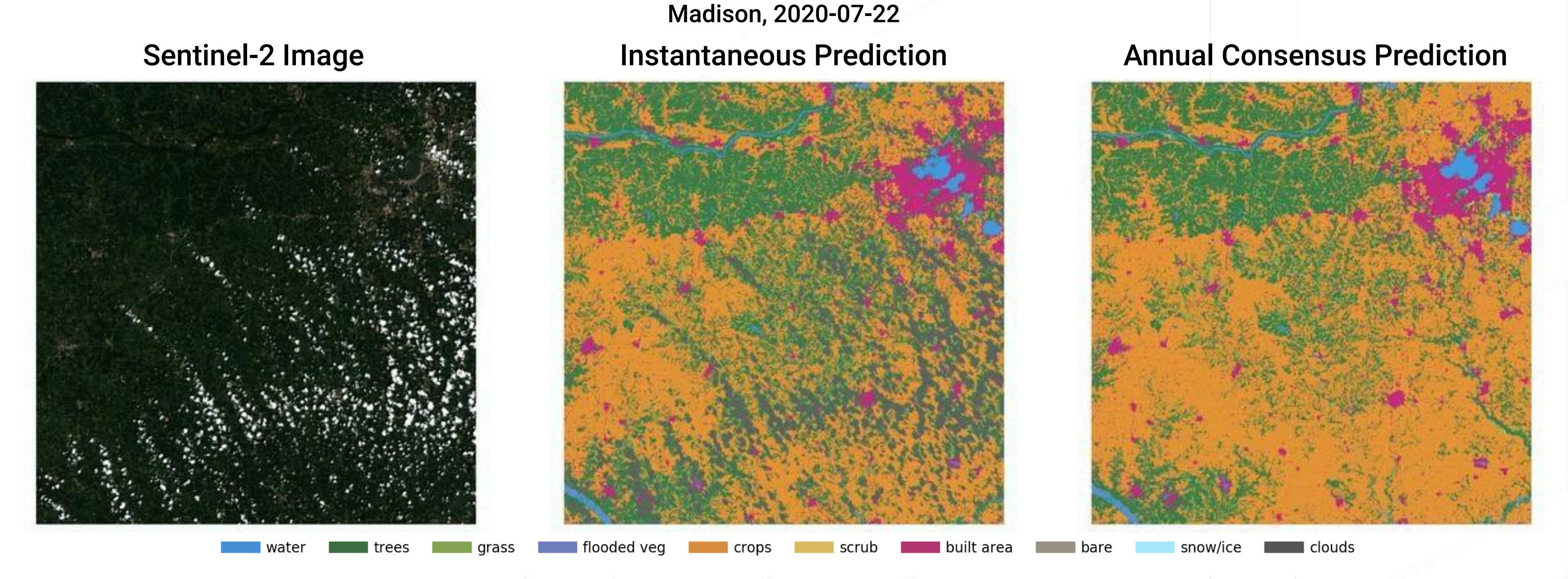

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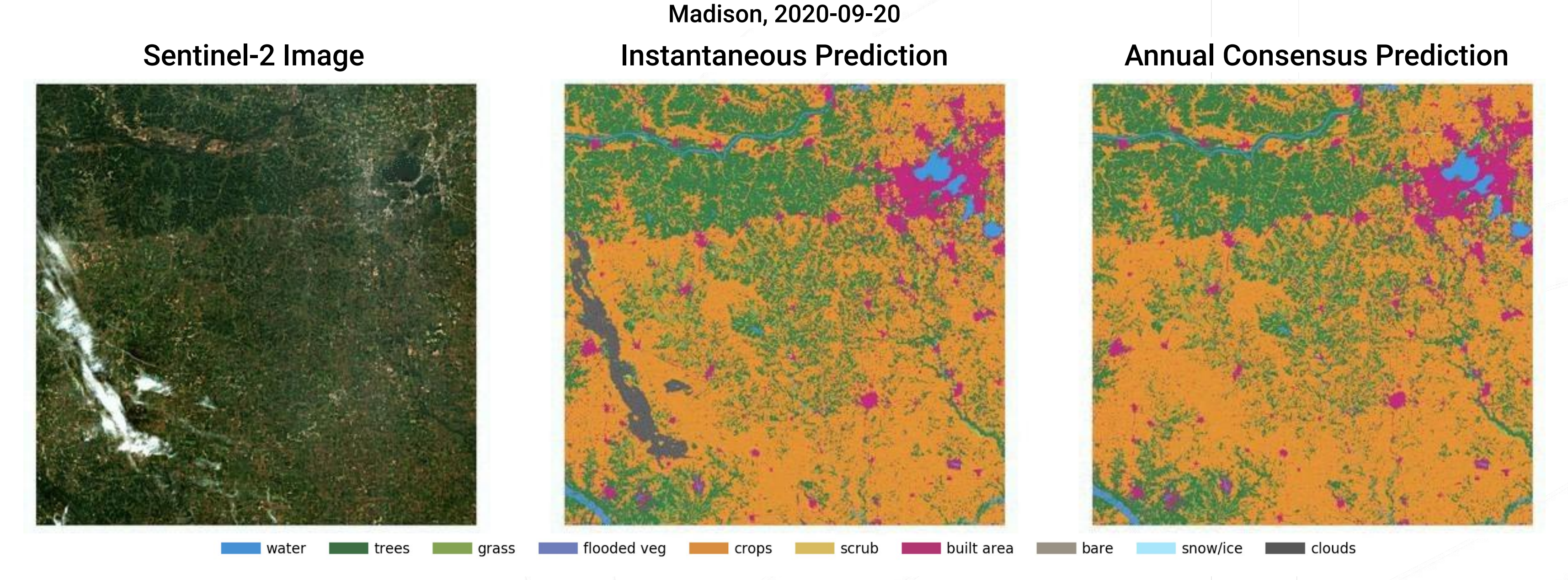

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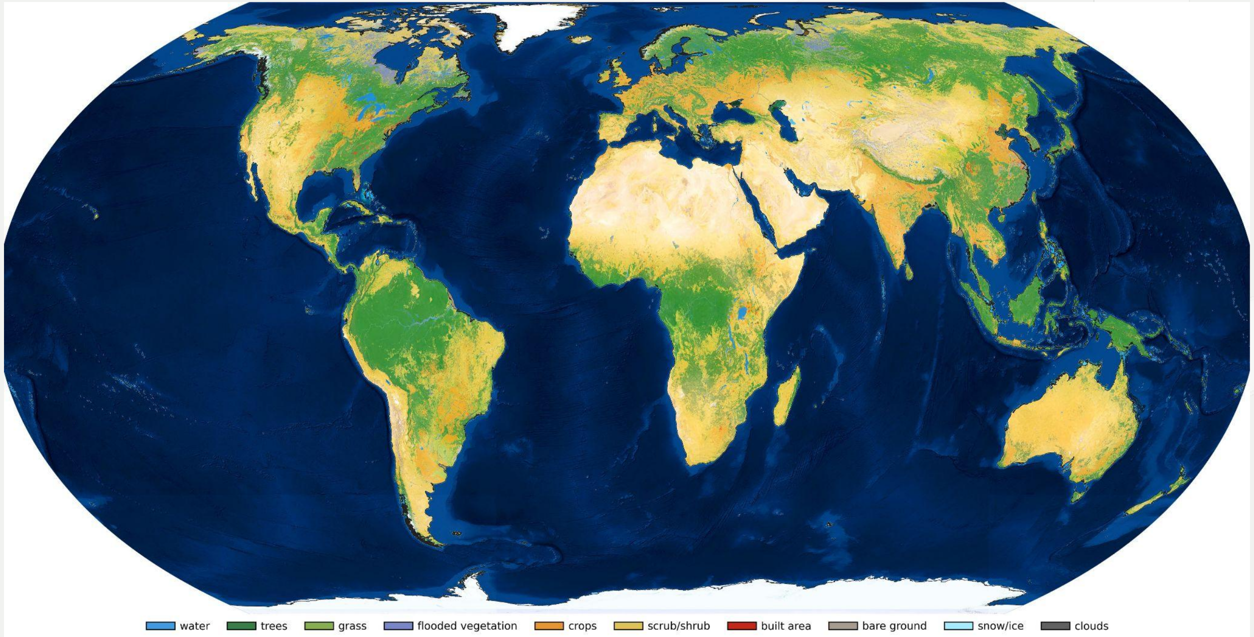
A combination of innovative new open tools and standards made it possible to generate the world's first 10m global landcover map

Enabling ideas: *scaling, discoverability, interoperability*

Azure Machine Learning Studio | Microsoft Planetary Computer | Cloud Optimized GeoTIFF | Azure Batch | Tensorflow

- Open Geospatial Standards:
    - SpatioTemporal Asset Catalog (STAC)
    - Cloud Optimized Geotiff (COG)
- Azure Batch
    - flexible, dynamically reconfigurable cluster system
- Microsoft Planetary Computer
- Azure Blob Storage
    - house, write, and read intermediate LULC predictions
- Widespread Python adoption for machine learning and geospatial data

The "Esri 2020 Land Cover" map (June 2021) required processing over 400,000 Sentinel-2 images using 10,000 cpus and taking 1 week, achieving analysis that is *faster than collection*



Impact Observatory's "Esri 2020 Land Cover" 10m resolution global map produced using 400,000 Copernicus Sentinel-2 satellite images in 1 week using 10,000 compute nodes (Intel Xeon D4v2 Virtual Machines) on Microsoft Azure Planetary Computer [BBC News, June 2021]. Independent peer-reviewed analysis has determined this map to have the best overall accuracy, achieving a **global accuracy of 75%** [**Venter, et al., 2022**].

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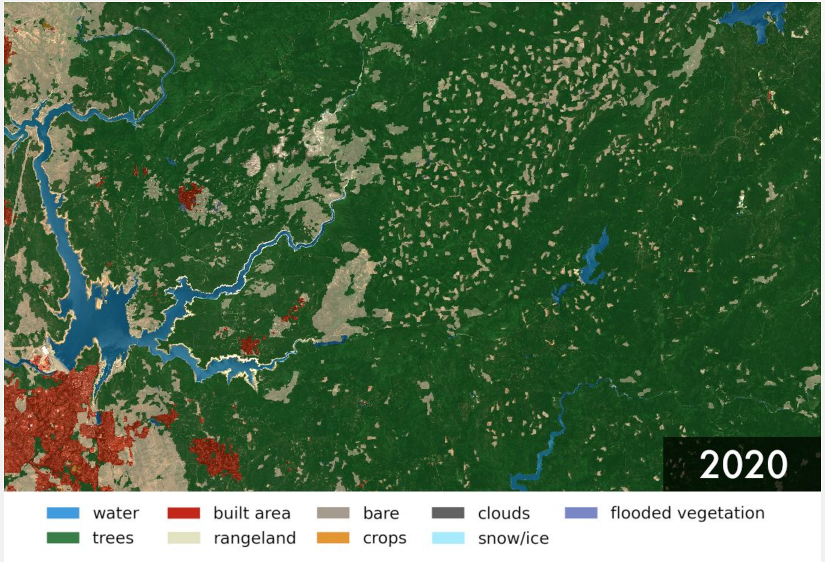
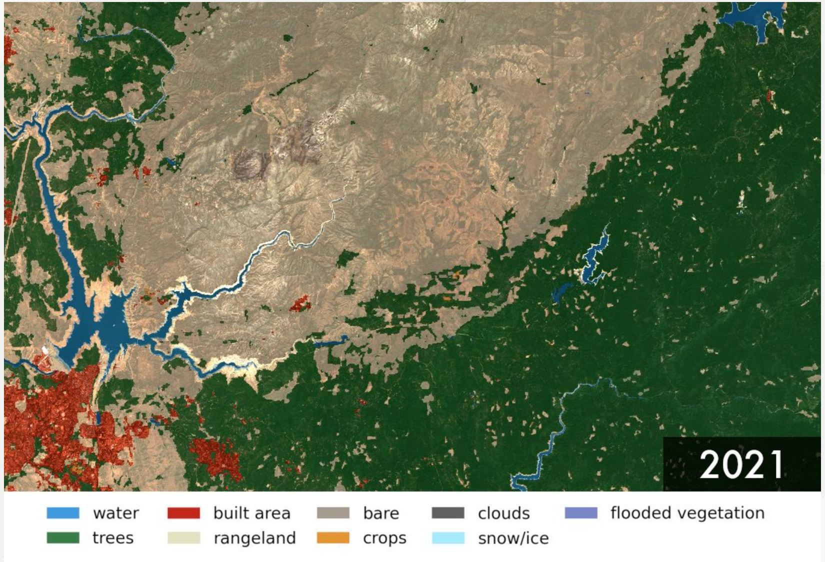
Annual maps for 2017-2021 (March 2022) required processing >2,000,000 Sentinel-2 images in <1 week for each year, reveal multi-year patterns of land cover change due to human impact and the climate crisis





Forest fires in 2020 ravaged Butte County, California, resulting in significant tree loss in the 2021 land cover.

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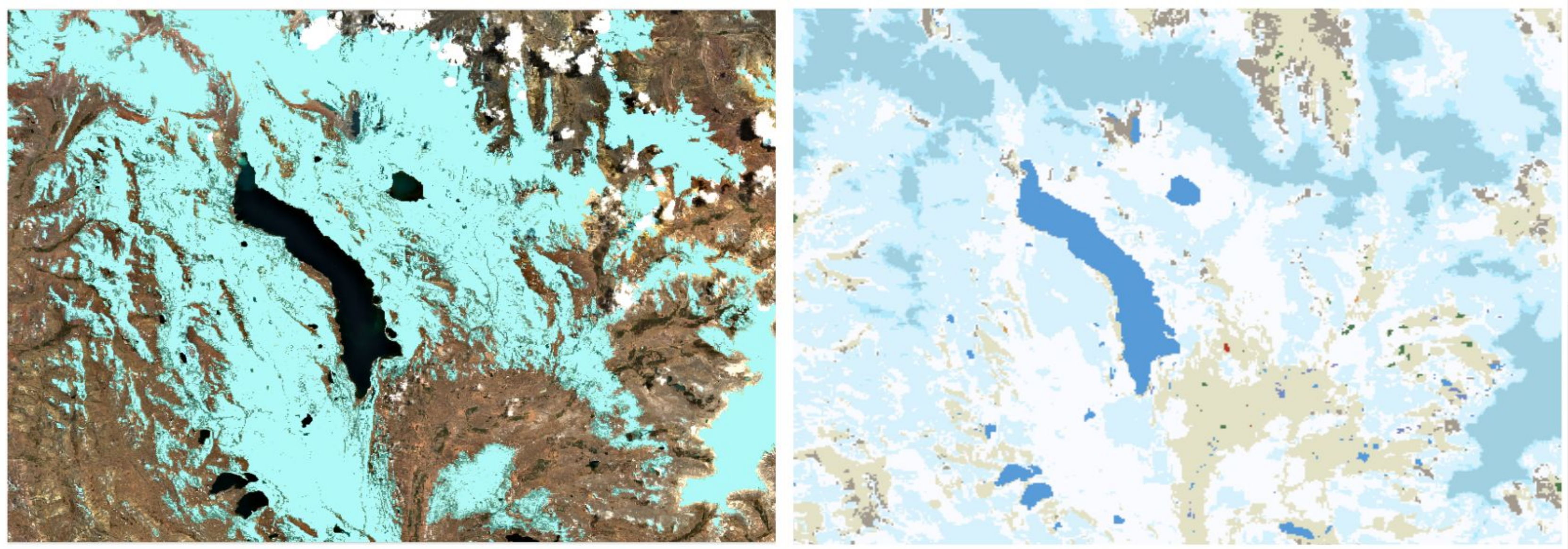
Seasonal and permanent snow & ice in Cordillera Vilcanota Peru, 2021



Left: Sentinel-2 satellite image from Sep 26 showing extensive seasonal snowfall
Right: map of surface water and snow

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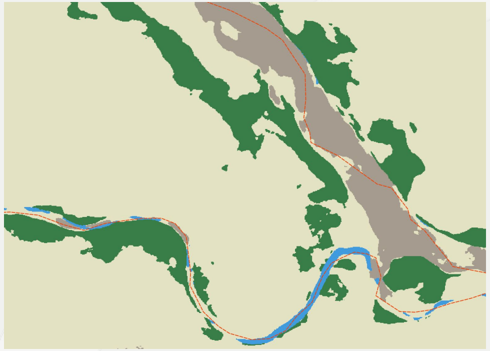
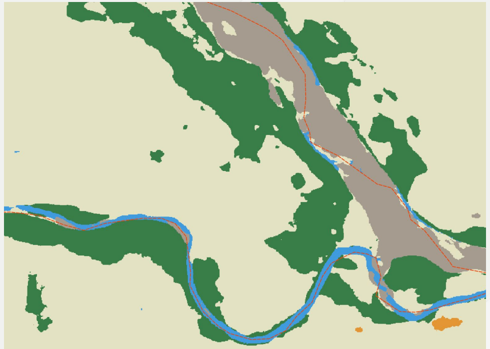
Sub-annual results reveal seasonal changes of Tuli, Botswana

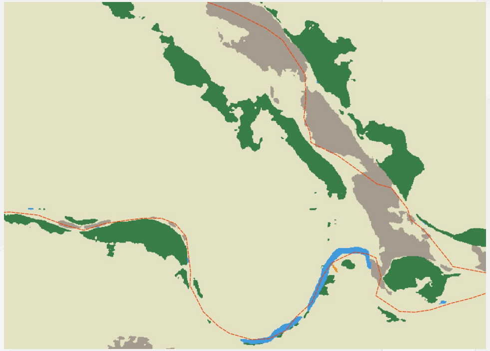
Basemap Image

Annual composite 2018





Wet Season Composite



Dry Season Composite

water | trees | grass | flooded veg | crops | scrub | built area | bare | snow/ice | clouds

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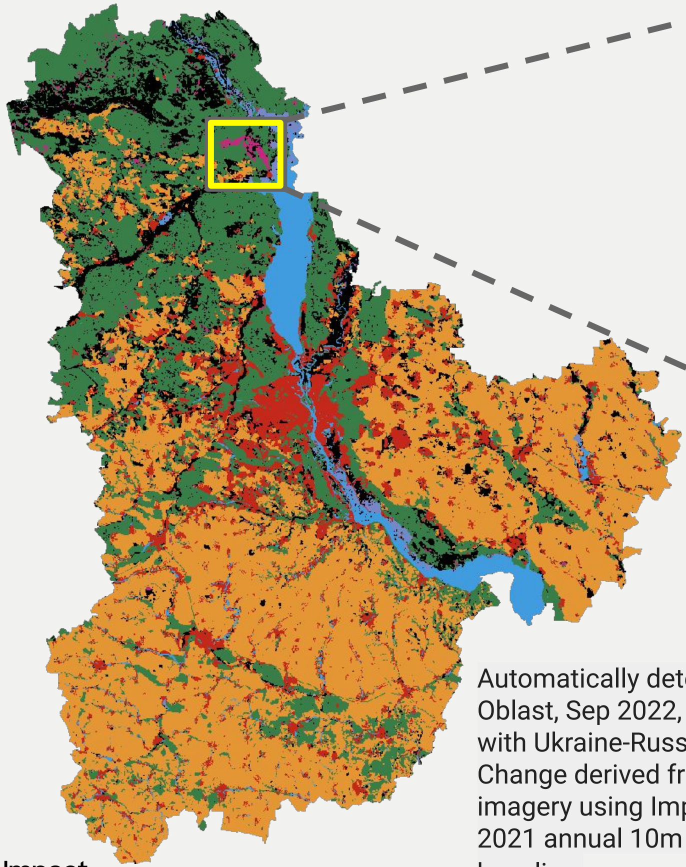
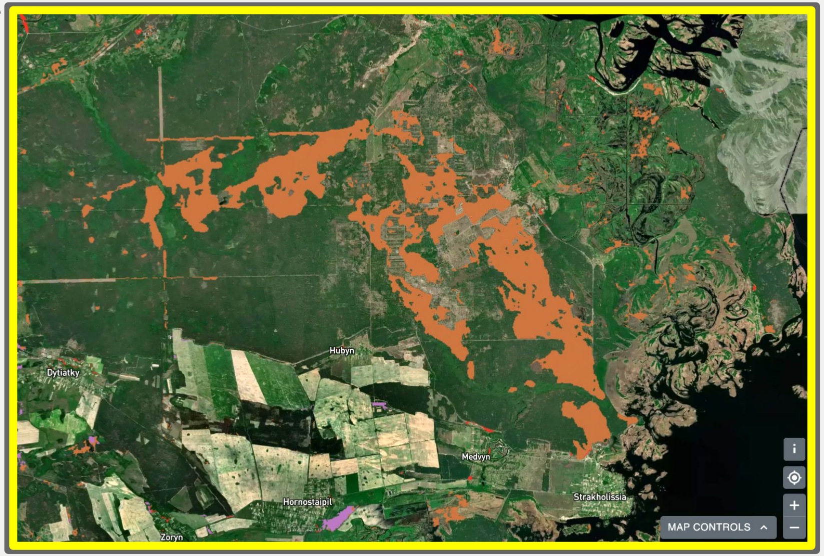
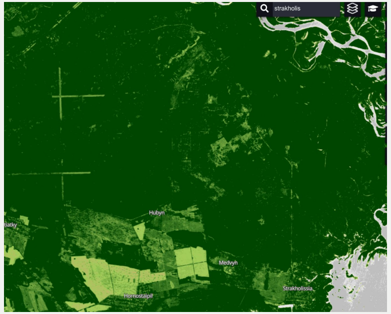
Deforestation during conflict in Kyiv Oblast, Feb - Sep 2022

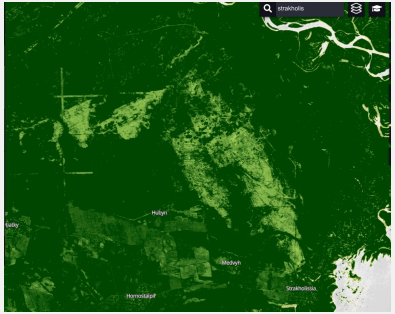




Automatically detected tree loss in Kyiv Oblast, Sep 2022, possibly associated with Ukraine-Russia conflict. Change derived from Sentinel-2 imagery using Impact Observatory 2021 annual 10m LULC map as baseline.



Sentinel-2 NDVI 9/9/2021



Sentinel-2 NDVI 8/25/2022

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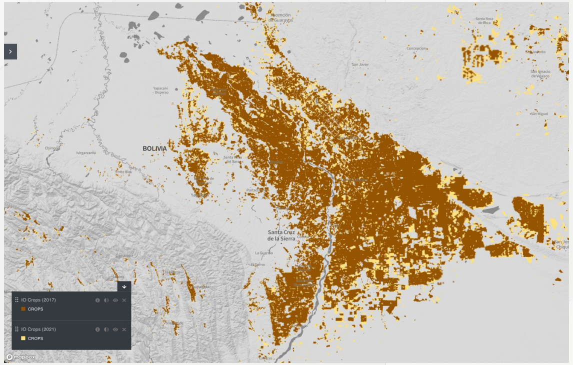
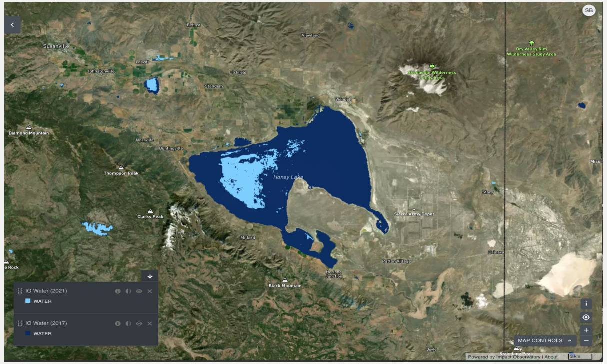
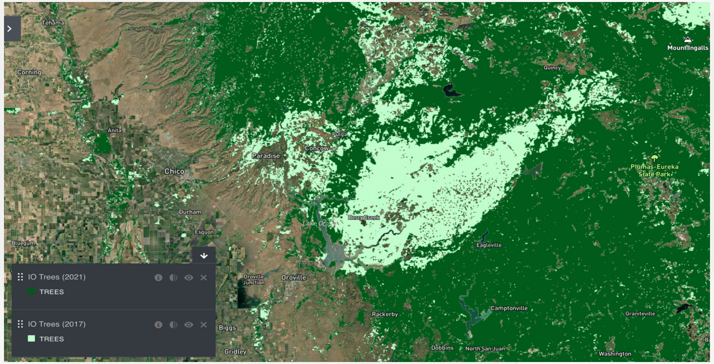
The new maps enable single-category explorations of key changes, e.g., changes to the built environment, agriculture, and key natural resources including surface water and forests







Upper left: **New construction** in Spratly Islands. Upper right: Commercial **agricultural expansion** in Bolivia
Lower Left: **Seasonal lake** in Honey Lake Valley, California. Lower right: Extensive **wildfire forest loss** in California.

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Our public annual 10m maps are now helping other organizations to discover important changes

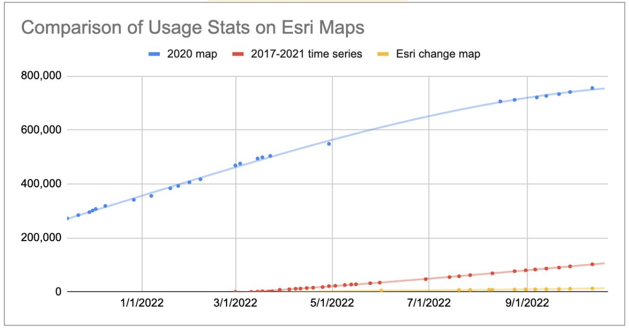
NY Times (Sep 2022) used Impact Observatory's 2021 land cover map for Pakistan to report on the large-scale impact to devastating floods to agricultural land.

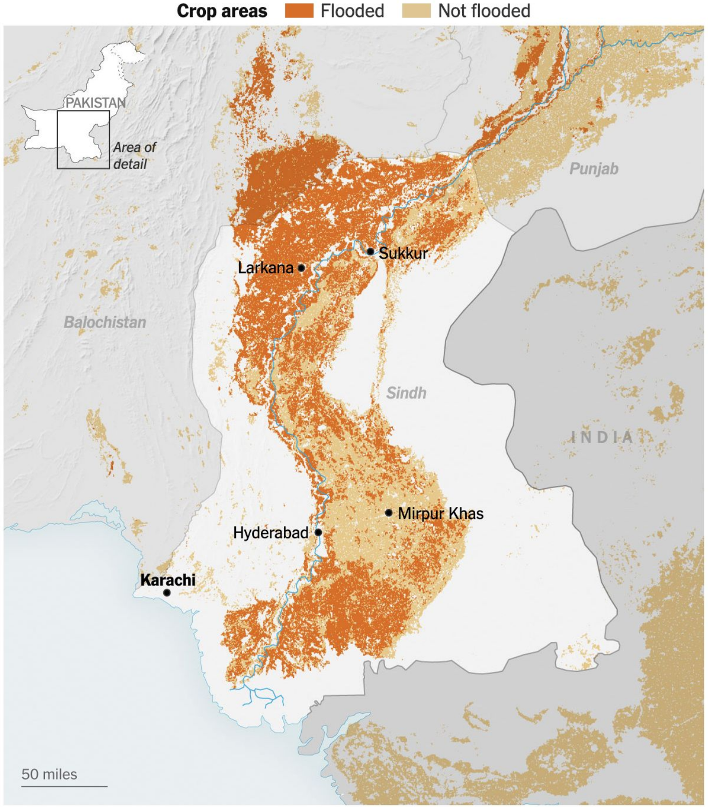
Impact Observatory's global maps for 2017-2021 were released in March 2022 on Esri Living Atlas, Microsoft Azure Planetary Computer, and in UN Biodiversity Lab.

LINK https://www.nytimes.com/2022/09/11/world/asia/pakistan-floods-food-crisis.html

IO Map Usage Stats from Esri Living Atlas

	Total views	~Views/Day
2020 Map	755,417	1485
Time Series	102,397	442
Change Map	12,840	95
Total	**870,654**	





Sources: 2017-21 crop areas from Impact Observatory analysis of Sentinel-2 imagery; flood extent from UNOSAT • By Agnes Chang

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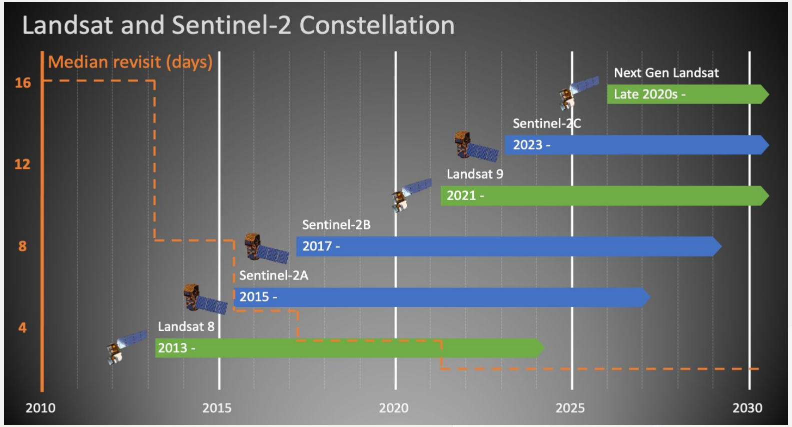
Celebrating 50 YEARS Landsat 1972-2022

Harmonized Landsat and Sentinel-2 (HLS) provides higher cadence and will be beneficial for our future landcover maps

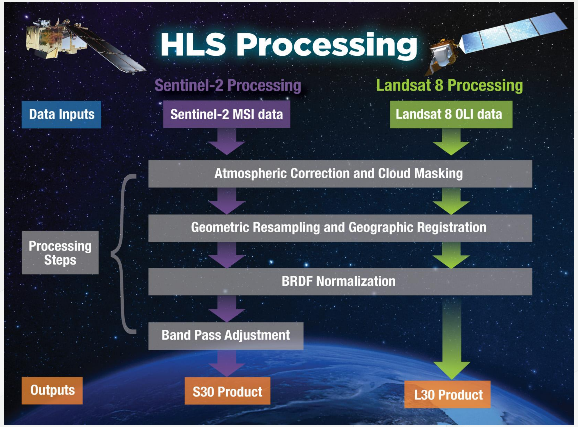
Observations every **2 to 3 days**

We can now **leverage STAC+COG** for HLS to access imagery and distribute results across USGS, NASA, NGO, and commercial repositories

HLS refactored for cloud optimization (COG) by HLS science team at NASA Goddard Space Flight Center (GSFC) and available in Azure and AWS



Credit: HLS Science Team



Credit: HLS Science Team

Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J.-C., Skakun, S. V., & Justice, C. (2018). The Harmonized Landsat and Sentinel-2 surface reflectance data set. *Remote Sensing of Environment*, 219, 145-161.

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Thank you! … any questions?

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