FEMC – Integrating field and Landsat data to Monitor Forest Conditions in the New York City Watershed

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Forest conditions within the two thousand square-mile New York City Watershed directly affect more than nine million people who depend on it for clean drinking water. For decades, the New York City Department of Environmental Protection (DEP) has maintained a large network of forest field plots, which serve as their primary means of monitoring forest changes due to land use, insects, droughts, and other disturbances. In this project, we integrated these plot data with historical and current Landsat-based vegetation indices within a custom Google Earth Engine (GEE) application that enables retrospective and near real-time assessments of changing forest conditions throughout the Watershed. This NYC-DEP Condition Monitoring Tool (LINK HERE; Figure 1) identifies and maps anomalies in canopy condition and allows DEP staff to efficiently relate the remotely sensed disturbances to observed field plot information. This integration adds tremendous value to both the remote sensing data and the field data.

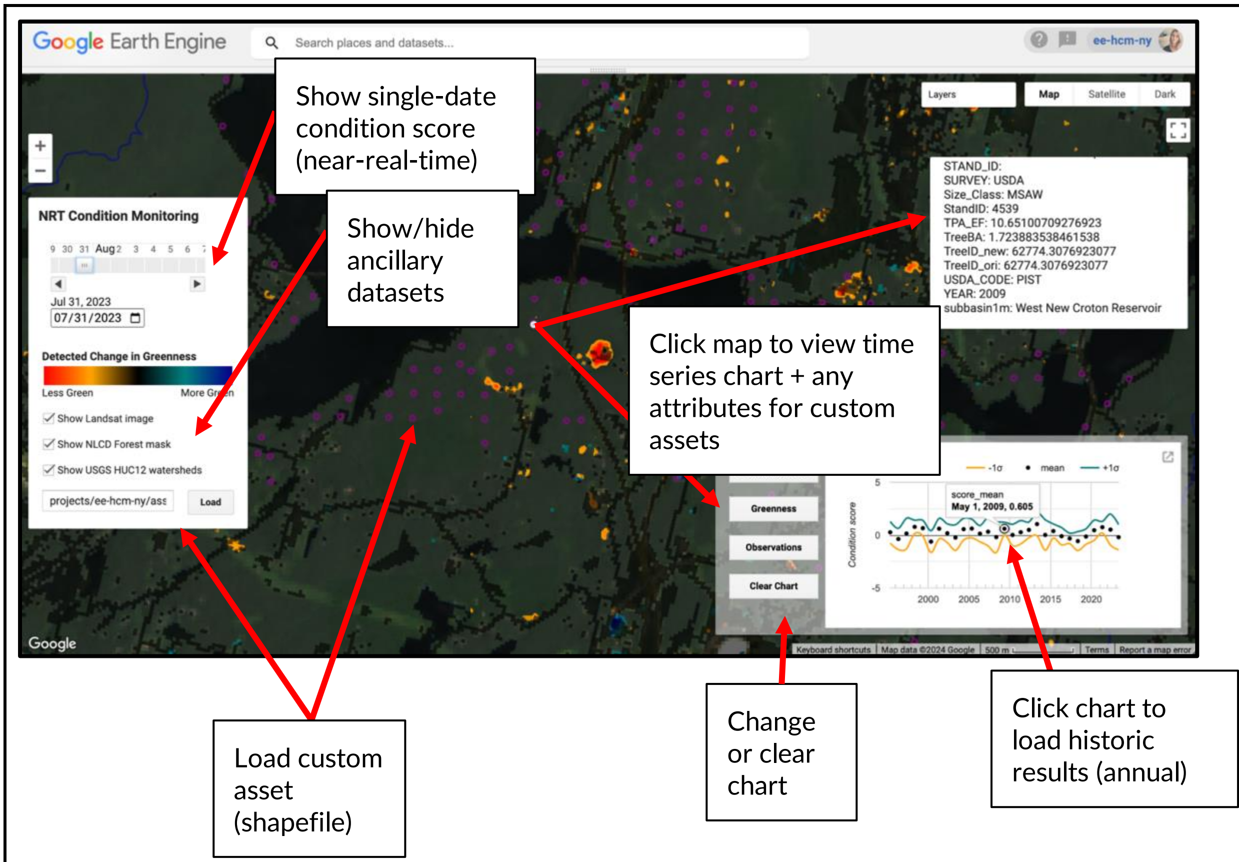


Figure 1. Screenshot of the custom Google Earth Engine (GEE) application that enables

retrospective and near real-time assessments of changing forest conditions throughout the New York city Watershed.

Milestones

Between 5/2022 and 4/2023, we co-designed and iteratively developed the tool and validated with existing and newly acquired DEP plot-scale data.

Major efforts during this period included:

- Identifying, collating, and processing relevant plot-scale data sources, with an initial set of data sources delivered in 8/2022.
- Drafting an initial design document for application functionality, including example user journeys and key implementation decision points, which was delivered to DEP in 12/2022.
- Coordinating DEP review on this initial design document, with initial input and feedback from major stakeholders delivered in 1/2023.
- Development of a prototype Earth Engine User Interface (UI) based on DEP's requests and specifications, including near-real-time monitoring functionality, historic charts, and custom layer display.
- Finalizing plans for surfacing Earth Engine application to DEP staff, including navigating privacy restrictions on key data sources and updates to GEE's government use policies. (See Appendix 1)
- Deployment of the Earth Engine UI code as an Earth Engine application for access by practitioners.

In 5/2023, we delivered a beta version of the tool and a User Guide (See Appendix 2) to DEP collaborators for broader testing and dissemination. The efficacy of the tool and approach were assessed by DEP, and results are summarized in an attached supplement (Supplement: FEMC User Report from DEP), which summarizes use cases and how these methods can be integrated into other ongoing monitoring efforts to inform other practitioners who are considering a similar approach.

By 6/2024, we delivered the code, tool access, and a report on the efficacy of the approach to the sponsors (this report). In turn, DEP developed a User Report describing their experience working with the tool (See Appendix 1)

Deliverables

- The deployed NYC-DEP Condition Monitoring app can be accessed at: https://ee-hcm-ny.projects.earthengine.app/view/condition-monitoring-tool
- Snapshot of the underlying app code (requires GEE account to run): https://code.earthengine.google.com/d8140aa3daae21547bbc53f604c372ae
- Snapshot of supplemental sampling script that can be used to extract condition scores for plot locations (requires GEE account to run): https://code.earthengine.google.com/77a323c8f3ff60e0ad632cfaaa1b2689

Key outcomes

- This project serves as an example for future efforts to integrate remote sensing and field data products into practitioners' workflow and operational decision making
- Through co-development of UI design, documentation, and data integration processes, we delivered a user-friendly code-free interface for exploring both historic and near-real-time changes in forest/vegetation condition, leveraging the power of Earth Engine compute and cloud-hosted datasets while also complying with platform and data access limitations.
- This effort also resulted in improved digitization and collation of DEP forest plot datasets.

Appendix 1: FEMC User Report to Researchers from from DEP

Monitoring forest conditions within the nearly 2,000 square mile NYC watershed protection forest is a cross-scale, interdisciplinary effort, and requires methods to detect and track impacts from potentially large-scale disturbances (forests pests, disease, blowdowns) as well as small-scale disturbances (encroachments, illegal harvests). DEP practitioners (involved in forest health, land use, invasive species) responsible for a range of forest cover and condition issues explored the tool and considered potential uses and limitations for their workflow and decision making. After exploring known disturbances based on field records (e.g. pest outbreaks, drought, harvests, blowdowns), DEP Foresters anticipate using the annual condition monitoring results for surveillance scans to detect change and target field visits for the next growing season. (Field data plots will be added to the tool when DEP is able to open a GEE account.) Foresters also envision using historic condition results together with field inventories to understand the disturbance history of forested parcels that NYC has newly acquired.

Following specific, known disturbance events, practitioners anticipate using near-real-time assessments to track the timing and scale of changes to forest condition to target sites for field visits. However, the variability in results between single-date assessments is a challenge when interpreting single-date near-real-time results for operational decision making. Practitioners expressed that the tool helps to feel prepared for more severe and frequent disturbances predicted under climate change. After exploring single-date results for known construction projects adjacent to NYC-owned land, practitioners who monitor encroachments anticipate using single-date results to verify the timing of large disturbances at specific, known locations. This information is expected to help decide where to target field visits to investigate significant encroachments (i.e. clearing for construction). A limitation to using the tool for this purpose is that a rapid land cover change (forest to grass) would not necessarily be apparent.

Practitioners involved in landscape-scale planning look forward to using the tool to extract scores to analyze change over time for given locations. The tool was developed to analyze change over time at the point-level. Moving forward, DEP practitioners expressed interest in aggregating scores at the forest block or sub-basin level.

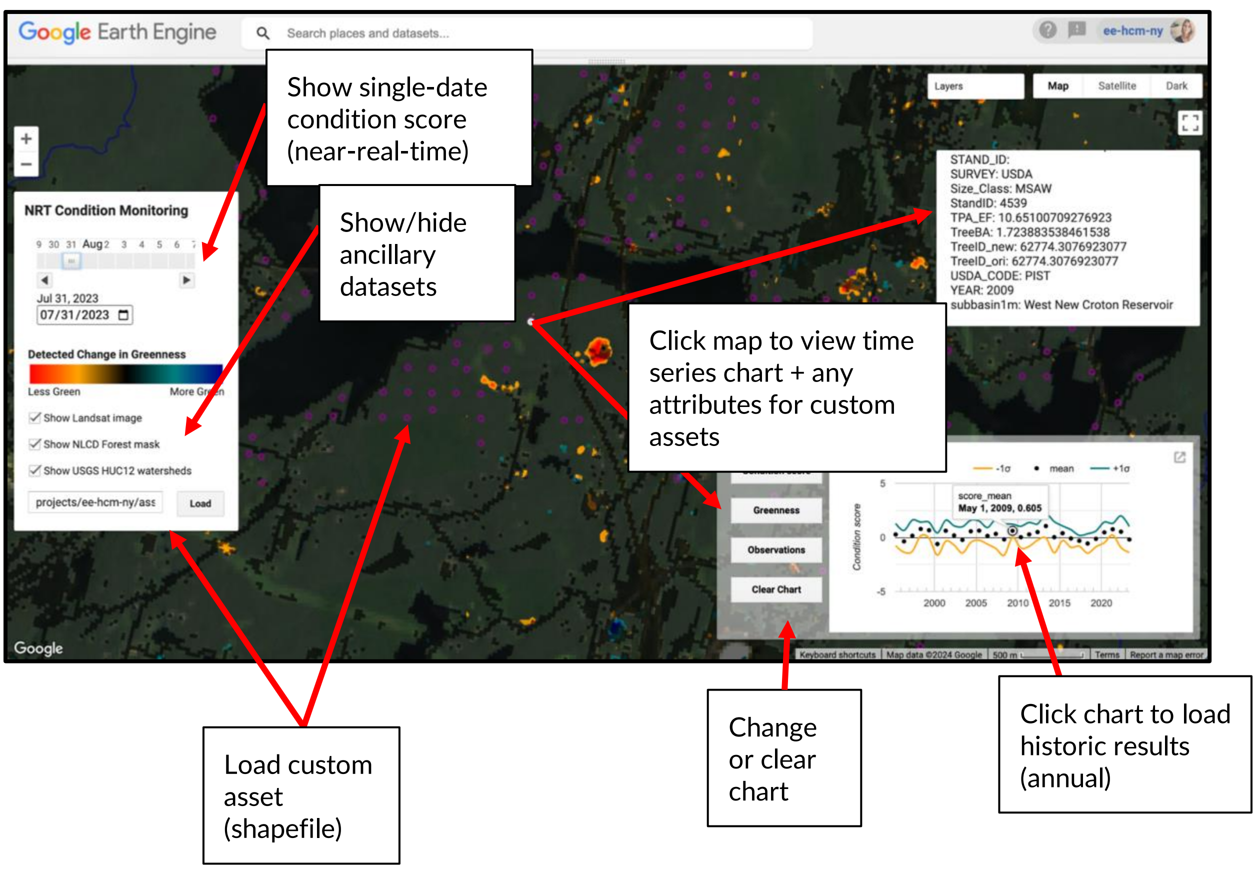
Appendix 2

FEMC– Integrating field and Landsat data to Monitor Forest Conditions in the New York City Watershed

HCM-NY Condition Monitoring App

USER GUIDE v1.0

The HCM-NY Harmonic Condition Monitoring tool allows the NYC Department of Environmental Protection (NYC DEP) to evaluate how forest conditions are changing throughout the watersheds they monitor and to relate Landsat-satellite observations to their existing network of field plots. The tool was developed using the Google Earth Engine platform and utilizes time series of all available Landsat imagery to establish baseline vegetation conditions and monitor for change (see https://valpasq.github.io/condition_monitoring/ for more on the harmonic condition monitoring approach). This user guide provides a basic overview of the core app functionality, including instructions on how to assess current and historic forest conditions and load and plot new dataset assets.

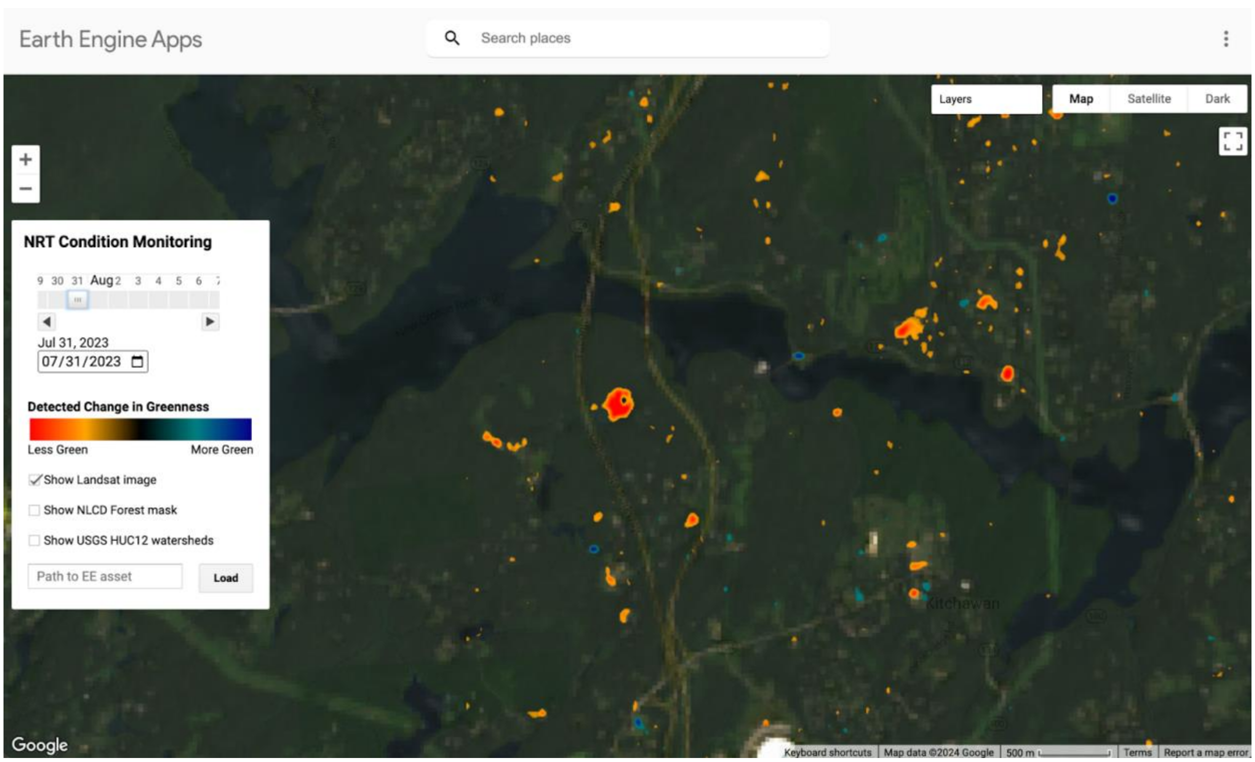


Quick Start Overview: HCM-NY Condition Monitoring Tool https://ee-hcm-ny.projects.earthengine.app/view/condition-monitoring-tool

Near-real-time monitoring

The near-real-time functionality of the app is designed to facilitate rapid assessment of changes in condition during the growing season (leaf-on conditions) for Landsat imagery intersecting NYC-DEP watersheds of interest. Use the time slider in the left-hand panel to select a date and if a Landsat image was acquired on that date, a single-date condition monitoring assessment will be displayed in the map panel. Landsat sensors have a 16-day revisit time with a minimum revisit of 8 days with two instruments in orbit (as is currently the case with the simultaneous operation of Landsats 8 and 9). That means that while there is not a result for every single day, you can expect to be able to view results at 8-day intervals.

The near-real-time monitoring protocol compares any single Landsat acquisition with historic baseline conditions from the last decade (as represented by an ensemble of five harmonic models, each fitted to five years of observed vegetation greenness). Single-date condition scores compare observed values with predictions from five five-year baseline models to calculate the average change in condition, as measured by the relative deviation in greenness from observed baseline conditions (Detected Change in Greeness). Scores are displayed such that more negative scores (less green vegetation) are shown in redder tones, while more positive scores (more green vegetation) are displayed in blues, as shown by the colorbar displayed in the app.



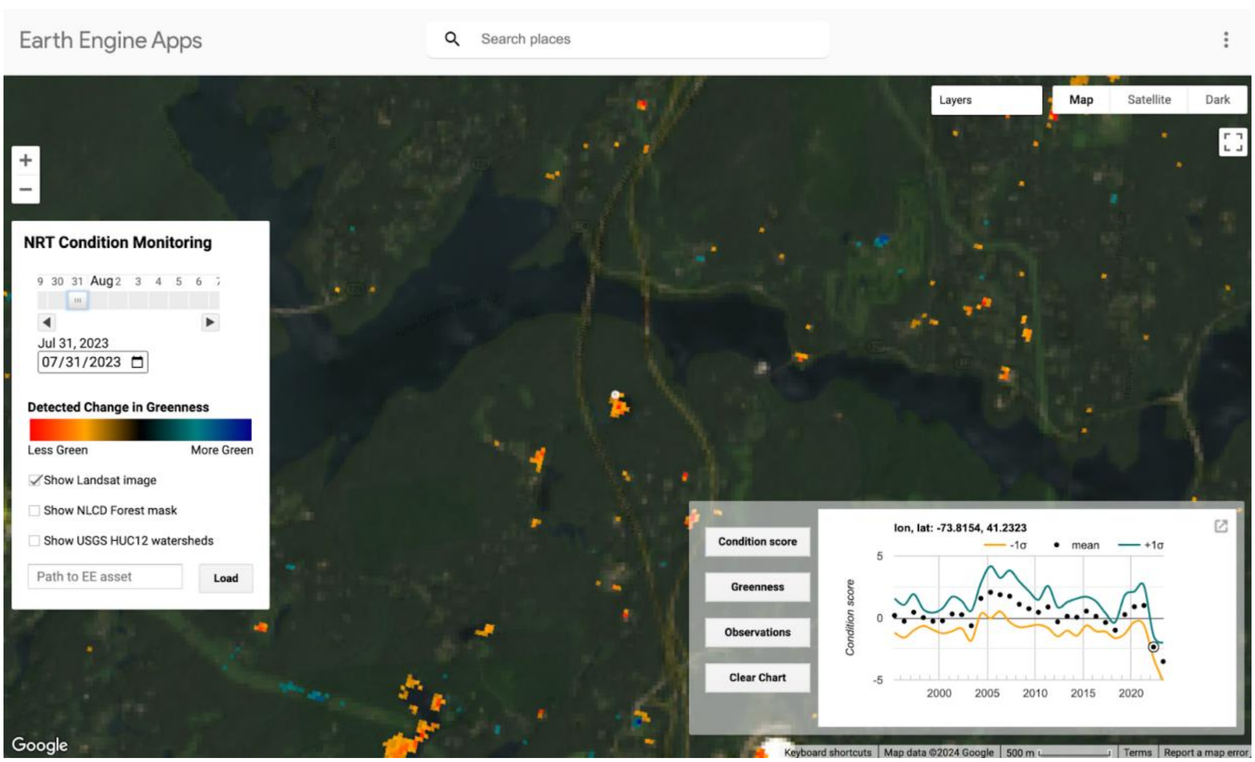
Single-date near-real-time assessment for July 31, 2023

Historic condition assessment

Historic condition assessment functionality is designed to help provide temporal context for near-real-time, single-date assessment results. Clicking a point on the map loads a time series chart with annual condition monitoring results (see [Pasquarella et al. 2023]() for more on these annual assessments).

The default “Conditions score” chart shows a time series of the mean (black dot) and +/-1 standard deviations (blue and orange lines) of condition monitoring scores for May through September of each year from 1995 to present. Clicking a mean observation (point) on the condition scores chart will display mapped results for that year. These results are overlaid on any already-loaded single-date results (and layer visibility can be controlled by checking/unchecking and adjusting transparency settings in the Layers list (near the top-right of the app interface; hover to display). The chart can also be viewed full-size in a new tab by clicking the arrow icon to the top-right of the chart panel.

In addition to a chart of condition scores through time, there is also a “Greenness” chart that can be used to inspect time series of the Tasseled Cap Greenness metric used to assess condition changes, and an “Observations” chart that allows you to view the number of observations used for monitoring. You can change between chart options using the buttons to the left-hand side of the chart panel, or if you want to remove the historic condition assessment chart panel from the map, simply click the “Clear Chart” button.



Time series of historic annual condition score assessments for a clicked point

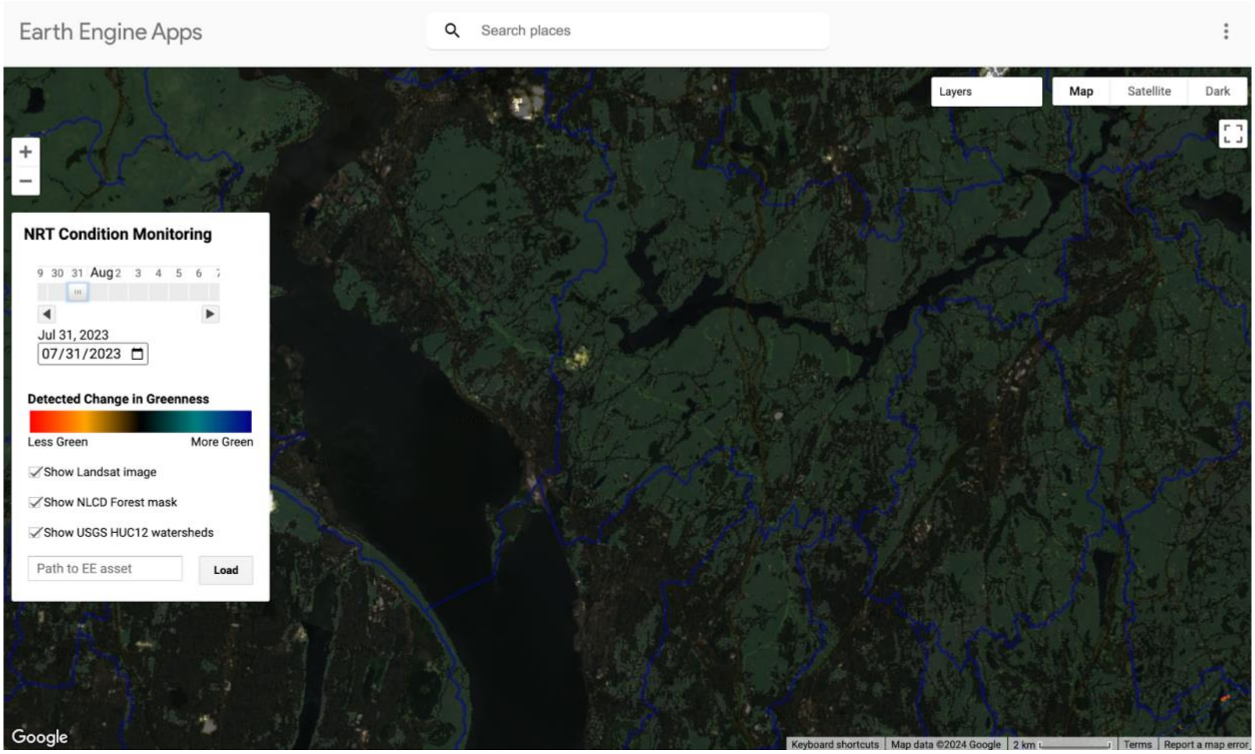
Ancillary Datasets

The HCM-NY app was developed specifically for NYC-DEP use cases and includes several ancillary layers requested to help facilitate visualization.

When viewing single-date near-real-time assessments, the Landsat image used to compute condition assessments is displayed as a true-color (RGB) image. Inspecting the input image can be helpful for understanding artifacts in the condition scores due cloud or cloud shadow interference or other ephemeral changes. Unchecking the “Show Landsat image” box will allow you to view the underlying Google Maps or Satellite basemaps or a simplified “Dark” mode basemap (use buttons to the top-right to switch between these basemaps).

In addition to Landsat imagery, you also have the option to display an NLCD forest mask (i.e., mask pixels not labeled *Deciduous forest*, *Evergreen forest*, *Mixed forest* or *Woody wetlands* in the NLCD 2019 release). Checking this option adds a binary forest/non-forest mask to the map display such that non-forested areas are more darkly shaded in semi-transparent black. This can be helpful for distinguishing between condition changes in forested areas versus those occurring in other vegetation types, e.g., wetlands, grasslands.

Finally, boundaries for the USGS HUC12 watersheds are displayed as an overlay (blue linework) that can be toggled on and off.

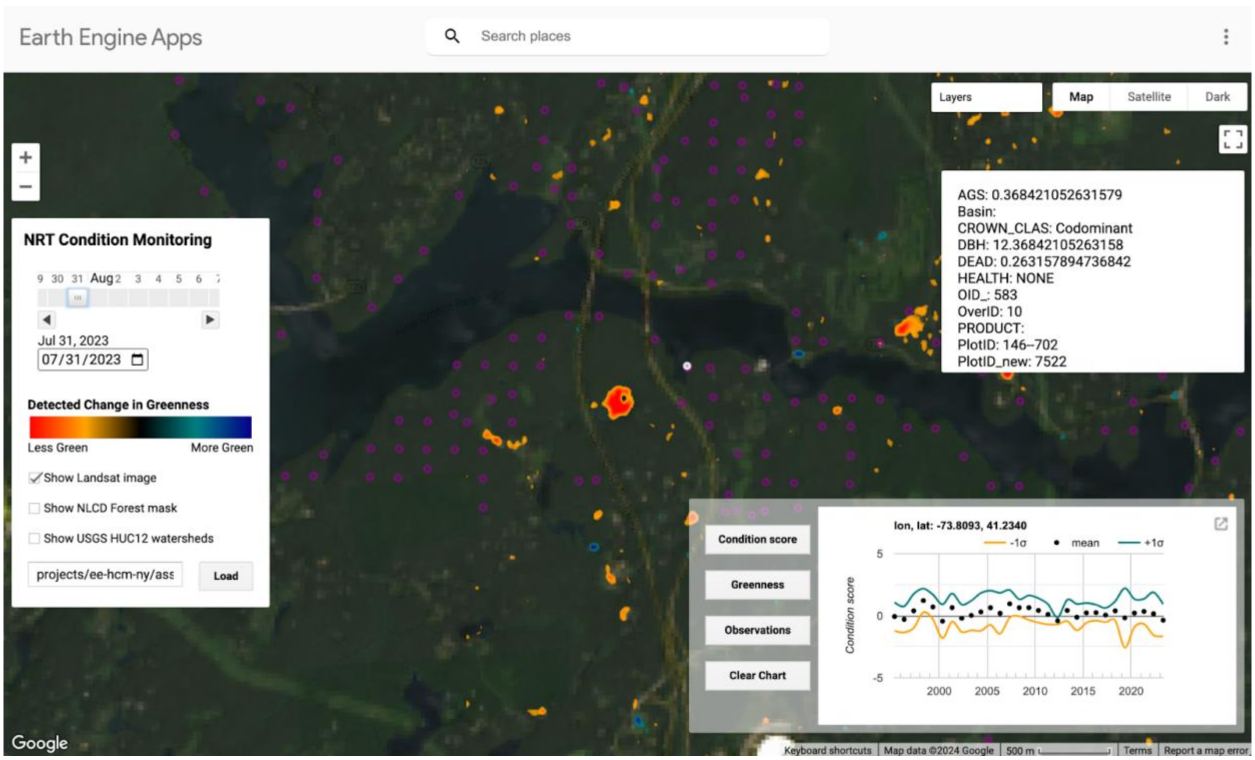


Overlay NLCD Forest mask and USGS HUC12 watersheds by checking the checkboxes for these layers

Add your own layers

To maximize utility of core near-real-time and historic harmonic condition monitoring functionality described above and provide the sort of flexibility needed to update and modify field-based datasets, the app allows you to display and inspect your own Earth Engine layers. For NYC-DEP, this could include field plot locations, parcel information or other areas of interest.

Layers are loaded using their Earth Engine Collection ID and must first be shared publicly or directly with the app (see section FAQ below for how to do this). Simply enter the layer's Collection ID in the text box at the bottom of the left-hand panel and click the Load button to display as an overlay on the map. Once a layer is loaded, clicking a feature in the layer will display that feature's attributes as a pop-up text box to the upper-right-hand side of the screen. For example, loading a plot dataset will display plot points on the map and the pop-up attribute box can be used to explore plot measurements and relate to condition changes.



Add and inspect a custom layer alongside near-real-time and historic condition monitoring results

FAQ

What if I see an error message?

Near-real-time condition monitoring results are computed on-the-fly, which means we are relying on Earth Engine to perform computations in real-time. Earth Engine's distributed computing means we can scale computations over larger areas than might be feasible on a local machine, but you may encounter variability in performance depending on caching (i.e, loading the same result again will be faster than an initial request) and demands on Earth Engine as a shared resource (i.e., sometimes you get errors and timeouts beyond your control simply because your calculation requests are running alongside other jobs). Sometimes computations time out or tiles fail to load. If this happens, you can retry your request by changing the selected date or clicking a new location, or reload the app link to refresh the entire page.

How do I upload my own datasets to Earth Engine?

To upload your own datasets to Earth Engine, you will first need a registered Earth Engine account. Once you have an account, you can follow the instructions for uploading a shapefile or uploading a CSV file in the Earth Engine Developers Guide. Datasets you upload or "ingest" into Earth Engine will be assigned a Collection ID that can be used to add them to the app (though note that the uploaded datasets or "assets" must first be share with the app or publicly to avoid permissions errors).

What if I want to extract historic condition scores for plot locations?

To use Earth Engine to exact historic harmonic condition score assessment for plot locations, you will need an Earth Engine account. You will also need to request access to the collection of historic harmonic condition monitoring results by joining this Google Group. Once you have access to the results collection, you can run this script to condition score values for point locations and generate an export task that will write results to your Google Drive.

Can you share the code for the app?

A snapshot of the source code for the generic version of the app (as of 2024-04-08) is available here: https://code.earthengine.google.com/799c705946e60886a1992cf69c67baf2

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