# Landscape characterization with Google Earth Engine: functionality supporting high resolution spatiotemporal analyses utilizing satellite imagery

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## 1. Introduction

Assessing pesticide fate in the environment requires assumptions or empirical information regarding the landscape in which pesticides are used and areas in proximity. Regulatory exposure scenarios have defined environmental factors allowing consistent and transparent use for all stakeholders. Spatially explicit exposure studies incorporate locally-relevant information on a specific environment, quantitatively selected to be placed into a larger regional context. The effort and cost of these landscape-based studies have steadily decreased as more and better data and tools become available.

This presentation will introduce functionality in Google Earth Engine that increases efficiency and transparency in landscape characterization studies while reducing time and effort needed. Earth Engine includes access to a wealth of historic and real-time satellite imagery suitable for immediate use, as well as numerous image analysis functions that can be applied directly to this imagery. Demonstrations using high temporal (5 to 7 day revisit), high spectral (13 bands), and moderate spatial resolution (10m) from the European Space Agency's Sentinel constellation will be presented.

## 2. Materials and methods

Earth Engine is a platform developed by Google that brings together geospatial datasets, satellite imagery, and image analysis functions to create a robust platform that can be accessed through the web. In the past, image pre-processing was a time-intensive activity that needed to be completed before any analysis could begin. Earth Engine's extensive library of satellite, climate, weather, and geophysical datasets are already suited for direct analysis. This analysis is executed through JavaScript in a web-based code editor where datasets can be imported and functions such as vegetation indices, charting, land cover classifications, time-series comparisons, and user-defined methods can be coded. While basic knowledge of JavaScript is necessary, Earth Engine provides guides on getting started and detailed documentation on each of the available functions. Once a foundational knowledge of JavaScript is established, implementing image and dataset processing functions is simple and many common operations have available user guides. Figure 1 shows an example of the web inteface used to develop Earth Engine applications. Earth Engine's large pre-processed image collections, simple coding interface, and readily available analysis functions make it an inexpensive and user-friendly tool for landscape-based studies.

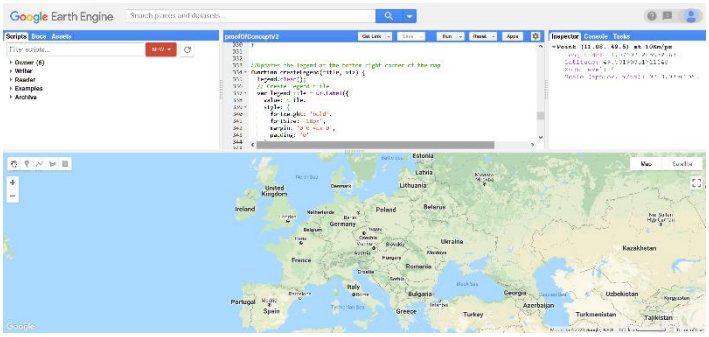



***Figure 1: Earth Engine JavaScript web interface***

Machine learning functions are some of Earth Engine's cutting-edge features, including classifiers such as Naive Bayes, Support Vector Machine, CART, and Random Tree, which can be used in conjunction with training data to quickly create land cover maps from satellite imagery acquired as recently as a week ago.

## 3. Examples

Figure 2 shows an example of the Normalized Difference Vegetation Index (NDVI) applied to a Sentinel-2 image. A single function call computes the index and the result can be displayed on the web application's map. The NDVI function was applied to two images from different dates (Figure 2, left) in the same location. With

only one line of code, the change in vegetation vigor between these two dates was calculated and a second line displayed the map with a custom color palette (Figure 2, right). With Sentinel's 5-7 day revisit period and Earth Engine's pre-processed image library, selecting a location to examine from anywhere in the world is a quick process and analysis can be done within a few lines of code.

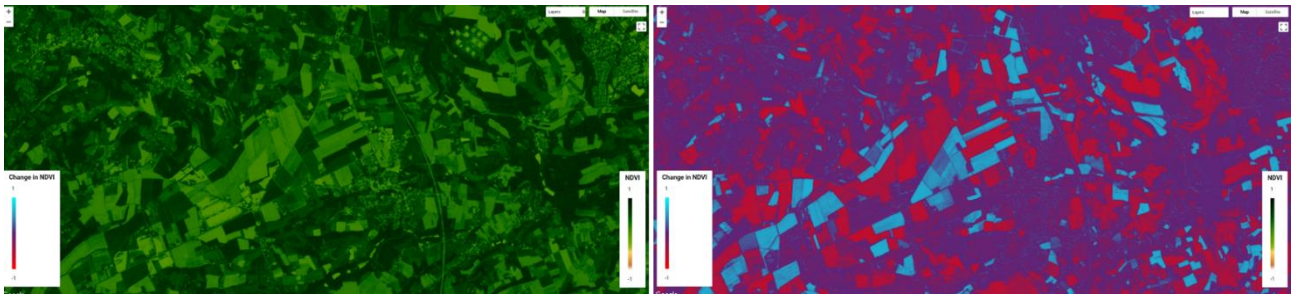
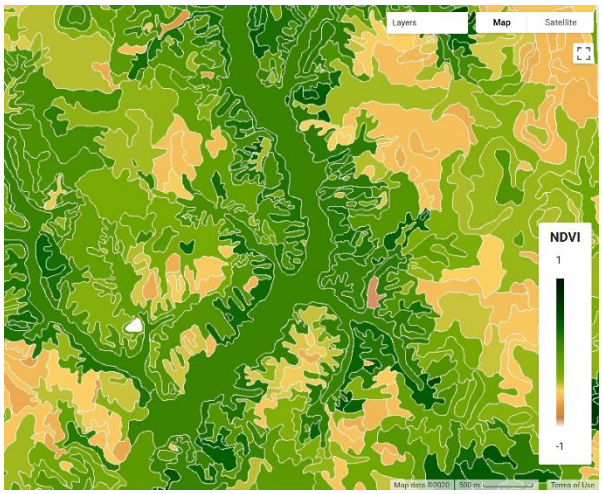
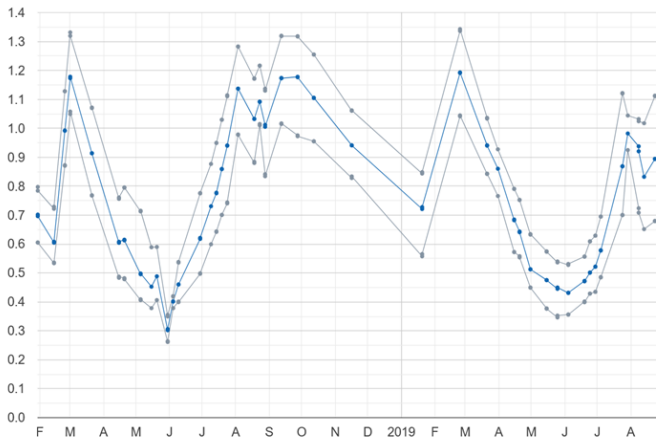


***Figure 2: A satellite image displayed using NDVI values (left) and NDVI change compared to a second date (right)***




User created assets such as images or spatial datasets can be uploaded to Earth Engine for analysis. Users can also define polygons interactively through the web application. These polygons can be used to specify areas of interest within which information can be summarized. This is especially useful for spatial data representing field boundaries, soils (Figure 3), or catchment boundaries that may be relatively homogenous; it reduces data volume and provides image-based results at the spatial unit relevant to the user.

***Figure 3: NDVI summarized by soil polygons in Illinois***




Earth Engine also provides built-in functionality to chart data obtained from images, while data can also be exported as a table for use in other charting software. Figure 4 shows a time series of NDVI values of a user-selected polygon over time, plotting the mean, 10$^{th}$ percentile, and 90$^{th}$ percentile of the polygon pixels. Individual data series can also be charted. For example, individual land cover classes in an image can be plotted as a different series in one chart. This lets the user explore how different land covers change over time in comparison with other land cover types.

***Figure 4: NDVI values of a user-selected field over time: mean, 10$^{th}$, and 90$^{th}$ percentile***

## 4. Summary

Collaboration between Earth Engine users is encouraged vis-à-vis the Developers Forum, a community where users can ask and answer questions alongside developers of the platform. While a Google Earth Engine account is required to develop code, apps can be published that allow shareable tools to be created that can demonstrate capabilities in an interactive way without requiring an account. User data uploads to Earth Engine along with any code that is written can be shared with other Earth Engine users, increasing transparency and collaboration among team members. Computations are performed on Google's servers removing processing requirements often needed by traditional analysis methods and desktop software.

Expansive data and efficient functionality available in Earth Engine allow for easier access to the latest satellite data and modern image processing methods to support modeling and environmental characterization. The outcomes can provide timely and detailed information to support landscape-scale pesticide exposure assessments.