

## **GEE Timeseries Explorer: a user-friendly QGIS/EnMAP-Box plugin for planetary-scale visualization and temporal profile sampling of satellite imagery from the Earth Engine Data Catalog**

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Modern state-of-the-art analysis workflows require mass processing of satellite imagery, with data volumes easily exceeding several terabytes, even for relatively small areas of interest. This can scale up to multi-petabytes for a continental or planetary-scale analysis. Cloud processing platforms such as Google Earth Engine (GEE), Australian Geoscience Data Cube or CODE-DE leverage accessibility to satellite image archives and facilitate time series analysis workflows. Unfortunately, the support of instant visualization of spatio-temporal data is often limited, and usually require scripting language programming skills.

We here present the GEE Timeseries Explorer which provides instant access to multi-petabyte satellite imagery and geospatial datasets stored in the Earth Engine Data Catalog. The user-friendly interface gives direct access to the most popular satellite imagery collection like Sentinel, Landsat and MODIS. The user can apply pre-processing steps like i) filtering by date range and metadata properties, ii) cloud masking, and iii) application of band-wise spectral reflectance scale factors. Images from a (pre-processed) collection can be visualized individually or aggregated through compositing and mosaicking. Requested RGB data is delivered by the Earth Engine cloud computing service via a Web Map Service (WMS). The requested data is processed on-demand for the current map view extent and scale (using image pyramids), which allows fluid exploration of different spatial scales, ranging from local to regional to planetary. The GEE Timeseries Explorer also addresses the task of spectral-temporal profile sampling. It supports the extraction and interactive visualization of individual profiles. Via a batch downloader, the user can also sample multiple profiles for a list of points at once, which allows for a (offline) sample-based feasibility analysis, prior to any mass processing workflow.

Recently, the GEE Timeseries Explorer was used in the context of a sample-based mapping of land use in pivot irrigation plots across the Cerrado Biome in Brazil (ANA and INPE, 2021). In this study, time series data for 152,000 samples were downloaded and fed into a processing chain for deriving phenological information and ultimately classification of land use (Bendini et al., 2019). This workflow has been used for Brazil's irrigation atlas (ANA, 2021) and will contribute to an operational monitoring system to assess water consumption across Brazil.

Also, the GEE Timeseries Explorer was used for labelling reference samples to validate maps on long-term agricultural land use around the Aral Sea in Central Asia (Müller et al., 2021). A set of 2,187 validation samples was labelled at annual intervals across the period 1987 through 2019 by eight trained interpreters. The resulting dataset allowed for state-of-the-art accuracy assessment (Olofsson et al., 2014) and deriving unbiased area estimates of irrigated cropland in the region.

The here presented GEE Timeseries Explorer is carefully integrated into QGIS, one of the most popular and widely used open source GIS packages available. It can be used from within the QGIS main window and the EnMAP-Box, a QGIS plugin that has a strong focus on raster data processing and visualization. The EnMAP-Box introduces and improves some concepts in QGIS like i) freely arrangeable map views, ii) spectral and temporal annotations for raster bands, allowing for better spectral and temporal profile plotting, iii) a spectral library view for visualizing raster profiles and building libraries. Those extra features will improve data exploration even more.