rgee: An R package for interacting with Google Earth Engine

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Summary

Google Earth Engine (Gorelick et al. 2017) is a cloud-based platform designed for planetary-scale environmental data analysis. Its multi-petabyte data catalog and computation services are accessed via an Internet-accessible API. The API is exposed through JavaScript and Python client libraries. Google provides a browser-based IDE for the JavaScript API, and while convenient and useful for rapid data exploration and script development, it does not allow third-party package integration, relying solely on Google Maps and Google Charts for data visualization, and proprietary systems for metadata viewing and asset management. By contrast, the Python and Node.js distributions offer much flexibility for developers to integrate with third-party libraries, but without the structure of a dedicated IDE, casual users can be left directionless and daunted. A significant gap exists between these two offerings (Google-supported JavaScript IDE and base client libraries) where convenience and flexibility meet. We propose to fill this gap with an R package that wraps the Earth Engine Python API to provide R users with a familiar interface, rapid development features, and flexibility to analyze data using open-source, third-party packages.

rgee is an Earth Engine (EE) client library for R that allows users to leverage the strengths of the R spatial ecosystem and Google Earth Engine in the same workflow. All of the Earth Engine Python API classes, modules, and functions are made available through the reticulate package, which embeds a Python session within an R session, enabling seamless interoperability. Additionally, rgee adds several new features such as (i) new I/O design, (ii) multiple user support, (iii) interactive map display, (iv) easy extraction of time series, (iv) asset manage interface, and (v) metadata display, also with rgee is possible the execution of Earth Engine Python code from within R which make the translation of large Python projects unnecessary.

Features

I/O Enhanced

`rgee` implements several functions to support download/upload of spatial objects (Table 1 and Table 2). For instance, to download vector (image) files you might use `ee_as_sf` (`ee_as_raster` or `ee_as_stars`). In `rgee` all the functions from server to local side have the option to fetch data using an intermediate container (Google Drive or Google Cloud Storage) or through a REST call ("$getInfo"). Although the last option permits users a quick download, there is a limitation by request of 262144 pixels for ee.Image and 5000 elements for ee.FeatureCollection which makes it not recommendable for large objects. The others download functions, from server-side to others (see Table 1), are implemented to enable more customized download workflows. For example, using `ee_image_to_drive` and `ee_drive_to_local` users could create scripts which save results in a `.TFRecord` rather than a `.GeoTIFF` format. The upload process follows the same logic (Table 2). In `rgee` we implement `raster_as_ee`, `stars_as_ee` for upload images and `sf_as_ee` for vector data. Large uploads are just possible with an active Google Cloud Storage account.

		FROM	TO	RETURN

Table 1: Download functions provided by package rgee.

		FROM	TO	RETURN
Image	ee_image_to_drive	EE server	Drive	Unstarted task
	ee_image_to_gcs	EE server	Cloud Storage	Unstarted task
	ee_image_to_asset	EE server	EE asset	Unstarted task
	ee_as_raster	EE server	Local	RasterStack object
	ee_as_stars	EE server	Local	Proxy-stars object
Table	ee_table_to_drive	EE server	Drive	Unstarted task
	ee_table_to_gcs	EE server	Cloud Storage	Unstarted task
	ee_table_to_asset	EE server	EE asset	Unstarted task
	ee_as_sf	EE server	Local	sf object
Generic	ee_drive_to_local	Drive	Local	object filename
	ee_gcs_to_local	Cloud Storage	Local	GCS filename

Table 2: Upload functions provided by package rgee.

		FROM	TO	RETURN
Image	gcs_to_ee_image	Cloud Storage	EE asset	EE Asset ID
	raster_as_ee	Local	EE asset	EE Asset ID
	stars_as_ee	Local	EE asset	EE Asset ID
Table	gcs_to_ee_table	Cloud Storage	EE asset	EE Asset ID
	sf_as_ee	Local	EE asset	EE Asset ID
Generic	local_to_gcs	Local	Cloud Storage	GCS filename

The next example illustrates how to integrate the `rgee` I/O module and ggplot2 (Wickham 2011) to download and visualize metadata for the BLM AIM TerrestrialAIM dataset.

```r
library(tidyverse)
library(rgee)
library(sf)

ee_Initialize()

# Define a Region of interest
roi <- ee$Geometry$Point(-120.06227, 40.64189)$buffer(25000)

# Load TerrADat TerrestrialAIM Dataset
blocks <- ee$FeatureCollection("BLM/AIM/v1/TerrADat/TerrestrialAIM")
subset <- blocks$filterBounds(roi)

# Move an Earth Engine FeatureCollection to their local env
sf_subset <- ee_as_sf(x = subset)

# Create a boxplot with ggplot2
gapPct <- c("_25_50" = "GapPct_25_50","_51_100"="GapPct_51_100",
            "101_200" = "GapPct_101_200","200_>" = "GapPct_200_plus")

sf_subset[gapPct] %>%
  st_set_geometry(NULL) %>%
  as_tibble() %>%
  rename(!!gapPct) %>%
  pivot_longer(seq_along(gapPct), names_to = "Range") %>%
  ggplot(aes(x = Range, y = value, fill = Range)) +
  geom_boxplot() +
  xlab("") + ylab("% of the plot's soil surface") +
  theme_minimal()
```

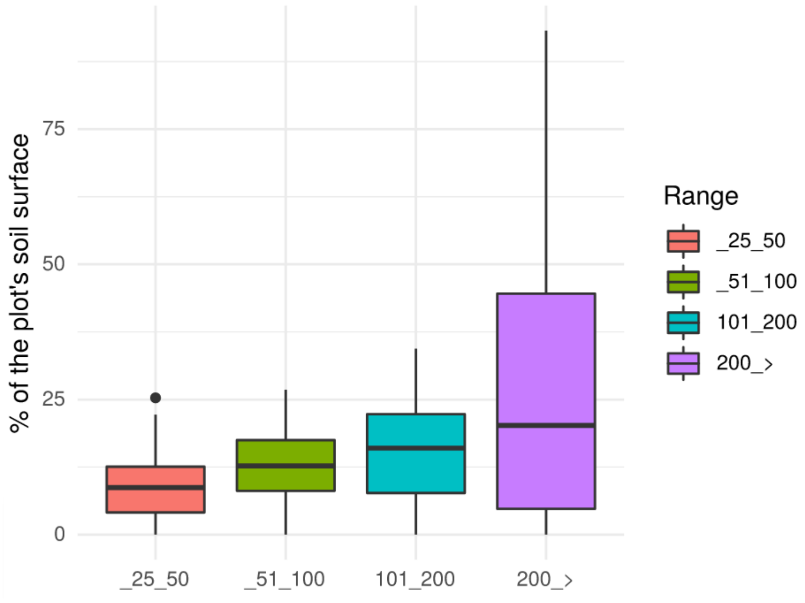


Figure 1: Gaps percentage between plant canopies of different sizes in a place near to Carson City, Nevada, USA

Authentication of multiple users

`rgee` makes the grant of permission only necessary once per user through `ee_Initialize` (a wrapper around `ee$Initialize`) a function which use a file folder system in the path: `~/.config/earthengine/` to arrange multiple credentials (Google Earth Engine, Google Drive, and Google Cloud Storage) for multiple users. The principal advantage of it is the possibility to distribute requests by accounts (in other words, parallelize in the client-side). For instance, if a research group want to analyze the deforestation, a code like the one bellow will permit them to obtain results three-times faster:

```r
library(foreach)
library(rgee)

ee_users()
ee_user_info()
google_account <- c("csaybar", "ryali93", "lbautista")

foreach(account = google_account, .combine = "c") %dopar% {
  ee_Initialize(gmail)
  ic_results <- deforestation_analysis(split_by = google_account)
  ee_imagecollection_to_local(ic_results)
} -> results
```

Interactive Map Display

rgee offers interactive map display through “Map$addLayer”, an R function which mimics the mapping module of the Earth Engine code editor. Map$addLayer takes advantage of the `getMapId` EE method to fetch and return a ID dictionary which is used to create layers into a mapview (Appelhans et al. 2016) object. Users can provide visualization parameters to Map$addLayer by using the argument visParams, as we can see here:

```r
library(rgee)
ee_Initialize()

# Load an ee.Image
image <- ee$Image("LANDSAT/LC08/C01/T1/LC08_044034_20140318")

# Centers the map view
Map$centerObject(image)

# Display the ee.Image
Map$addLayer(
  eeObject = image,
  visParams = list(bands = c("B4", "B3", "B2"), max = 10000),
  name = "SF"
)
```

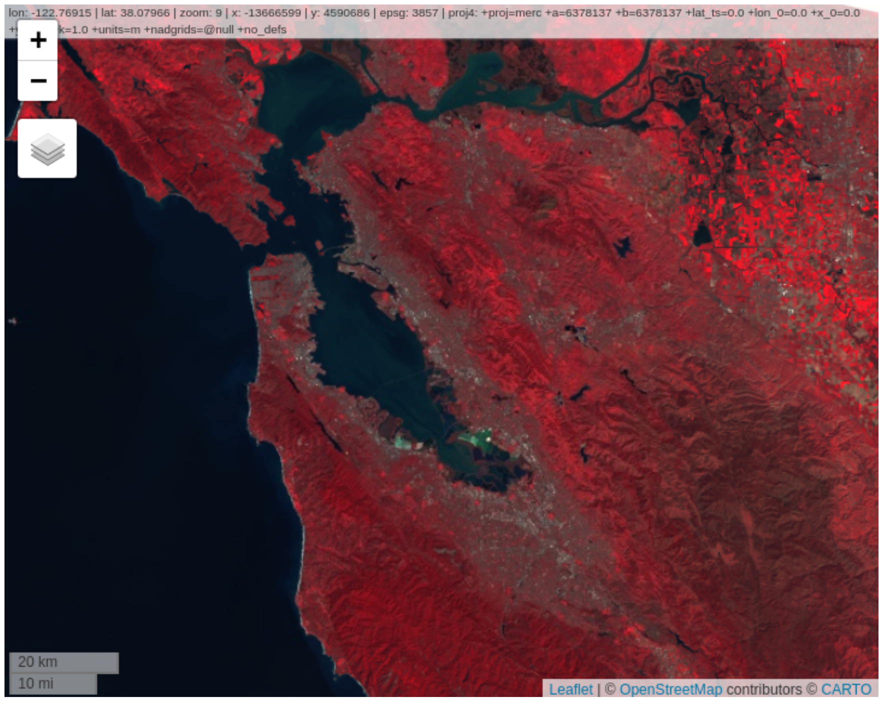

lon: -122.76915 | lat: 38.07966 | zoom: 9 | x: -13666599 | y: 4590686 | epsg: 3857 | proj4: +proj=merc +a=6378137 +b=6378137 +lat_ts=0.0 +lon_0=0.0 +x_0=0.0
k=1.0 +units=m +nadgrids=@null +no_defs
+
−
20 km
10 mi
Leaflet | © OpenStreetMap contributors © CARTO

Figure 2: Landsat 8 false color composite of San Francisco bay area, California, USA

Extraction of time series

`rgee` can extract values from `ee.Image` and `ee.ImageCollection` at the location of `ee.Geometry`, `ee.Feature`, `ee.FeatureCollection` and `sf` objects. If the geometry is a polygon, users can summarize the values considering a built-in Earth Engine reducer function. The code below explains how to extract the average areal rainfall from the TerraClimate (Abatzoglou et al. 2018) precipitation dataset in 2011 for North

Carolina counties.

```r
library(tidyverse)
library(rgee)
library(sf)

ee_Initialize()

# Image or ImageCollection (mean composite)
terraclimate <- ee$ImageCollection("IDAHO_EPSCOR/TERRACLIMATE")$
  filterDate("2001-01-01", "2002-01-01")$
  map(function(x) x$select("pr"))

# Define a geometry
nc <- st_read(system.file("shape/nc.shp", package = "sf"))

# Extract the average areal rainfall
ee_nc_rain <- ee_extract(terraclimate, nc, sf = FALSE)
colnames(ee_nc_rain) <- sprintf("%02d", 1:12)
ee_nc_rain$name <- nc$NAME

ee_nc_rain %>%
  pivot_longer(-name, names_to = "month", values_to = "pr") %>%
  ggplot(aes(x = month, y = pr, group = name, color = pr)) +
  geom_line(alpha = 0.4) +
  xlab("Month") +
  ylab("Precipitation (mm)") +
  theme_minimal()
```

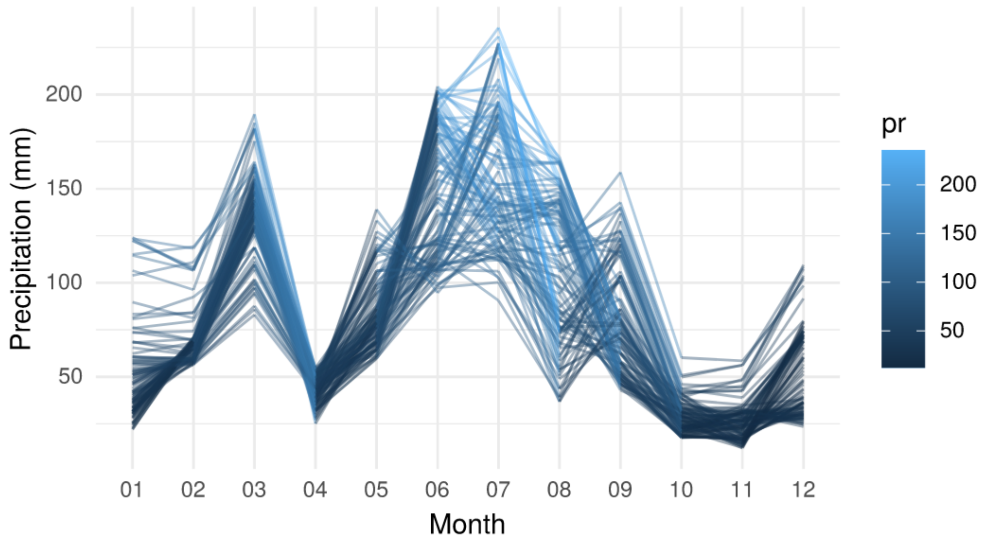


Figure 3: Average areal rainfall from the North Carolina counties in 2011 according to TerraClimate

Asset Manage Interface

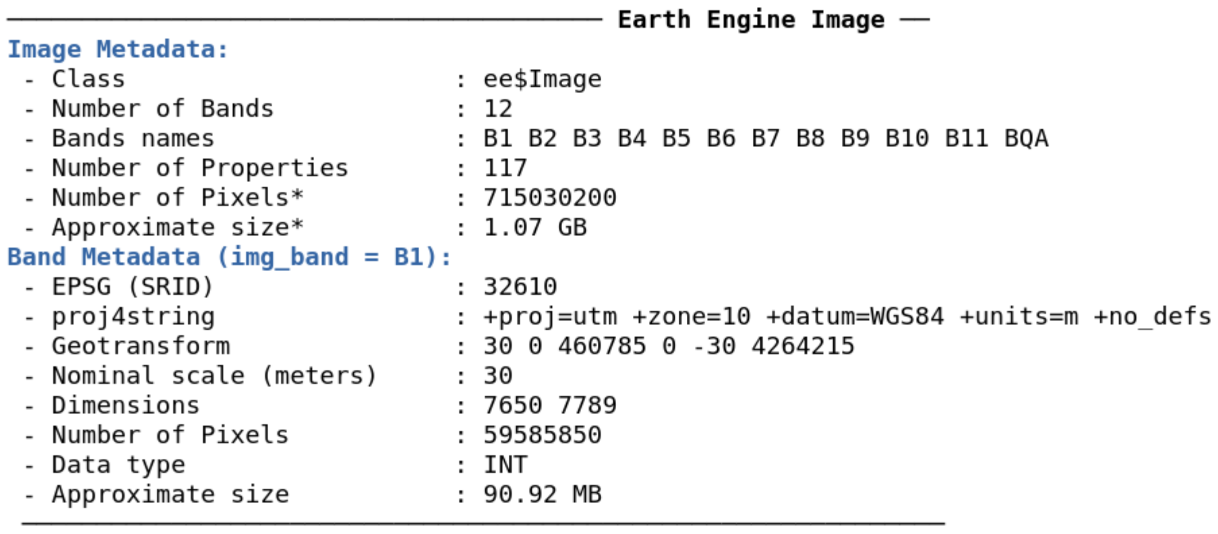
`rgee` implement an interface to batch actions on assets extending capabilities of the existing GEE data module (ee.data.*). The interface is composed for a series of functions, and users can identify them by the prefix ee_manage_*. Between the actions that the Asset Manage Interface enables we have: creation and elimination of folders, moving and copy assets, set and delete properties, handle the access control lists, and to manage or cancel tasks. For example, users could move a Landsat 8 image to their personal EE asset as follow:

```r
library(rgee)
ee_Initialize()

server_path <- "LANDSAT/LC08/C01/T1/"
user_asset_path <- ee_get_assethome()

ee_manage_copy(
  path_asset = paste0(server_path,"/LC08_044034_20140318"),
  final_path = paste0(user_asset_path,"/LC08_044034_20140318")
)
```

Metadata display

`rgee` through `ee_print` can fetch and return metadata (Fig .2) about spatial Earth Engine objects. With `ee_print` the acquire of information about the number of images or features, number of bands or geometries, number of pixels, geotransform, datatype, properties and aproximate size of the object can be made with a single line of code. `ee_print` was designed to be used inside debugging pipelines (e.g. inside the ee.Image.aside function).

```r
library(rgee)

ee_Initialize()
l8 <- ee$Image("LANDSAT/LC08/C01/T1/LC08_044034_20140318")
ee_print(l8)
```



```
──────────────────────────────────────── Earth Engine Image ──
Image Metadata:
 - Class                      : ee$Image
 - Number of Bands            : 12
 - Bands names                : B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 BQA
 - Number of Properties       : 117
 - Number of Pixels*          : 715030200
 - Approximate size*          : 1.07 GB
Band Metadata (img_band = B1):
 - EPSG (SRID)                : 32610
 - proj4string                : +proj=utm +zone=10 +datum=WGS84 +units=m +no_defs
 - Geotransform               : 30 0 460785 0 -30 4264215
 - Nominal scale (meters)     : 30
 - Dimensions                 : 7650 7789
 - Number of Pixels           : 59585850
 - Data type                  : INT
 - Approximate size           : 90.92 MB
 ──────────────────────────────────────────────────────────────
```

Figure 4: ee.Image metadata for a Landsat 8 Image

Availability

`rgee` is open source software made available under the Apache 2.0 license. It can be installed through CRAN (——) using: install.packages("——"). `rgee` can also be installed from its GitHub repository using the remotes package: remotes::install_github("r-spatial/rgee"). A serie of examples about the use of `rgee` are available here.

References

Abatzoglou, John T, Solomon Z Dobrowski, Sean A Parks, and Katherine C Hegewisch. 2018. “TerraClimate, a High-Resolution Global Dataset of Monthly Climate and Climatic Water Balance from 1958–2015.” *Scientific Data* 5. Nature Publishing Group: 170191.

Appelhans, Tim, Florian Detsch, Cristoph Reudenbach, and Stefan Woellauer. 2016. “Mapview-Interactive Viewing of Spatial Data in R.” In *EGU General Assembly Conference Abstracts*. Vol. 18.

Gorelick, Noel, Matt Hancher, Mike Dixon, Simon Ilyushchenko, David Thau, and Rebecca Moore. 2017. “Google Earth Engine: Planetary-Scale Geospatial Analysis for Everyone.” *Remote Sensing of Environment* 202. Elsevier: 18–27.

Wickham, Hadley. 2011. “Ggplot2.” *Wiley Interdisciplinary Reviews: Computational Statistics* 3 (2). Wiley Online Library: 180–85.