UNESCO/IHA research project on the

GHG status of freshwater reservoirs

The GHG Reservoir Tool (G-res)

User guidelines for the Earth Engine functionality

iha
international hydropower association

United Nations
Educational, Scientific and
Cultural Organization

UNESCO Chair in
Global environmental
change

In cooperation with:

With financial support from:

Recommended citation:
Prairie YT, Alm J, Harby A, Mercier-Blais S, Nahas R. 2017. User guidelines for the Earth Engine functionality, UNESCO/IHA research project on the GHG status of freshwater reservoirs. Joint publication of the UNESCO Chair in Global Environmental Change and the International Hydropower Association. 24 pages.

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Introduction

In order to provide useful estimates of net GHG emissions from reservoirs, the G-res tool requires a lot of information concerning the physical, geographical, climatic, soil and land cover attributes of the reservoir itself as well as its catchment. In the embedded database of the current G-res tool version, this information has already been extracted from globally consistent sources and calculated for approximately 7000 reservoirs worldwide. However, for new projects or for existing reservoirs not currently in the G-res tool database, this information needs to be obtained from the same sources and entered manually within the tool. This process can be arduous and prone to error or inconsistencies. To facilitate this process, the G-res tool provides an additional functionality to help the user extract the information in a globally consistent manner and import it within the G-res tool. This functionality was developed using Earth Engine platform of Google and it thus termed the Earth Engine (EE) functionality in the G-res tool. The information thus obtained can then be saved locally for future use.

The reservoir specific information that can be derived directly from the EE functionality are:

For the catchment:

- Catchment area (in square kilometres)
- Catchment perimeter (in kilometres)
- Mean runoff (in millimeters per year)
- Mean slope (in degrees)
- Population density (person per square kilometre)
- Population (person)
- Land cover by soil type (in percentage)
- Annual mean precipitation (in millimetres per year)

For the reservoir:

- Dam coordinates (in degrees, WGS84)
- Reservoir area (in square kilometres)
- Reservoir perimeter (in kilometres)
- Maximum depth (in meters)
- Mean depth (in meters)
- Climate zone
- Monthly mean temperature (in degree Celsius)
- Mean annual Global Horizontal Radiance (GHR) (in kilowatt hour per square meter per day)
- Mean annual global horizontal Radiance (GHR) for the months of May to September (in kilowatt hour per square meter per day)
- Mean annual Global Horizontal Radiance (GHR) for the months of November to March (in kilowatt hour per square meter per day)
- Land cover by soil type (in percentage)
- Mean soil carbon content (kilogram of carbon per square meters)
- Wind at 50 meters above ground (meters per second)

BEFORE TO START TO USE EARTH ENGINE

WARNINGS concerning data output:

Catchment Annual Runoff vs Annual Discharge from the reservoir

The catchment annual runoff (catchment mean runoff in mm/year) is given by Earth Engine and asked in the G-res tool. Although, if the Annual Discharge (m^3/s) is available, please provide this value first and do not type in the Earth Engine value for Runoff.

Reservoir Mean Global Horizontal Radiance (GHR)

Please choose one of the options:

- If 40 > Latitude > -40:

  Mean annual GHR (kWh/m2/day)

- If Latitude > 40

  Mean GHR May to September (kWh/m2/day)

- If Latitude < -40

  Mean GHR November to March (kWh/m2/day)

Wind Speed

The wind speed value outputted in Earth Engine is at 50 meters above the surface. It needs to be at 10 meters. The following equation will make the conversion:

$$\text{Annual Wind Speed at 10 m} =$$

$$\text{Reservoir Mean Wind Speed at 50 m} * \left(1 - \left(\frac{CD^{0.5}}{0.4}\right) * \text{Log10}\left(\frac{10}{50}\right)\right)^{-1}$$

Where

$$CD = 0.001\ ;\ \text{If Reservoir Mean Wind Speed} < 5$$

Or

$$CD = 0.000015\ ;\ \text{If Reservoir Mean Wind Speed} > 5$$

River Area Before Impoundment vs Reservoir Water Bodies from Land Coverage categories

If the natural water body present before the impoundment of the reservoir is a **river**, please use the River Area before Impoundment percent.

If the natural water body present before the impoundment of the reservoir is a **lake**, please use the Water Bodies from the land coverage of the reservoir area before impoundment percent.

Parameters name in the G-res tool compared to the Earth Engine tool

G-res parameters name	Earth Engine parameters name
Catchment Area (km²)	catchment area (km2)
Population in the Catchment (persons)	catchment population (persons)
Catchment Annual Runoff (mm/yr)	catchment mean runoff (mm/year)
Land cover in the Catchment Area	catchment land cover by soil type (%)
Croplands	Croplands - Non-Organic Soil + Croplands - Organic Soil
Bare Areas	Bare Areas - Non-Organic Soil + Bare Areas - Organic Soil
Wetlands	Wetlands - Non-Organic Soil + Wetlands - Organic Soil
Wetlands	Wetlands - Non-Organic Soil + Wetlands - Organic Soil
Grassland/Shrubland	Grassland/Shrubland - Non-Organic Soil + Grassland/Shrubland - Organic Soil
Permanent Snow/Ice	Permanent Snow/Ice - Non-Organic Soil + Permanent Snow/Ice - Organic Soil
Settlements	Settlements - Non-Organic Soil + Settlements - Organic Soil
Water Bodies	Water Bodies - Non-Organic Soil + Water Bodies - Organic Soil
Drained Peatlands	Drained Peatlands - Non-Organic Soil + Drained Peatlands - Organic Soil
Longitude of Dam (DD)	dam latitude (° , WGS84)
Latitude of Dam (DD)	dam longitude (° , WGS84)
Reservoir Area (km²)	reservoir area (km2)
Maximum Depth (m)	reservoir max depth (m)
Mean Depth (m)	reservoir mean depth (m)
Climate Zone (Reservoir Area)	Climate
Mean Temperature per Month (°C)	reservoir mean temperature [Month] (°C)
Mean Global Horizontal Radiance (kWh/m²/d)	Mean annual GHR (kWh/m2/day)
	Mean GHR May to September (kWh/m2/day)
	Mean GHR November to March (kWh/m2/day)
Pre-Impoundment Land cover at the Reservoir Area	reservoir land cover by soil type (%)
Soil Carbon Content Under Impounded Area (kgC/m²)	Soil C (kgC/m2)
Annual Wind Speed at 10 m (m/s)	reservoir wind at 50m (m/s)

Below is a step-by-step guide describing how to use the EE functionality and how to link the information obtained with the appropriate fields of the G-res tool itself.

STEP 1: CREATING A GOOGLE ACCOUNT AND ENABLING THE ACCESS TO EARTH ENGINE

Step 1.1: Creating a Google account

If you already have a Google account, jump to **Step 1.2**. If you do not already have a Google account, you will have to create one. Go on https://accounts.google.com/signup and follow these steps to create your account.

1) Enter your first and last names
2) Choose your username. This will be your Gmail address.
3) Create a password.
4) Confirm your password.
5) Enter your birthday.
6) Choose your gender (Female, Male, or Other).
7) This step is optional. Enter a mobile phone number or a current Email address to reset your password in case it is lost.
8) Type the text that appears in the image. It will be different each time. You may not have the same text as in this example.
9) Select your country.
10) Check the box "I agree to the Google Terms of Service and Privacy Policy" after reading them by clicking on the links.
11) Click on the "Next step" button to create your Google account.

Step 1.2: Enabling the access to Earth Engine

Once you have your Google account, you will have to enable your access to Earth Engine. Go on https://earthengine.google.com/ and click on "SIGN UP" on the upper right corner.

You will then be asked to fill the following form.

1) Your Gmail address should appear here automatically. If not, Sign in.
2) Enter your full name.
3) Enter your affiliation or the name of the institution that employs you.
4) Select your country or your region.
5) Write a brief description on what you would like to accomplish with Earth Engine e.g. "Evaluate the GHG emissions from a reservoir".
6) Click on "I agree that my use of the Earth Engine services and related APIs is subject to my compliance with the applicable Terms of Service" after reading the Terms and Service by clicking on the link. You can access the Terms of Service again at all time on https://earthengine.google.com/terms/.
7) Click on the "SUBMIT" button.

Soon (it can take up to one week), you will receive a confirmation email in the inbox of your Gmail account. Once you have the confirmation that you now have access to Earth Engine, you can continue to **Note 1**.

NOTE 1: UNDERSTANDING THE INTERFACE OF EARTH ENGINE

1) Geometry Tools: The polygon drawing tool (far right) may be used to delineate catchment. The point tool (second from the left) will be used to input the location of the dam.
2) Zoom: To zoom in and out the map. The wheel on the computer mouse can also be used.
3) Geometry Imports: List of the drawn polygon and point. Check the box to see them on the map, uncheck to hide. It will only appear once a geometry is drawn.
4) Map: Draw the polygon and point here. The land cover map and imported catchment will also appear on this map.
5) List of the layers used or created. Check the box to see them on the map, uncheck to hide. You may use the sliders to adjust the transparency of the layers.
6) Outputs: The data will appear in the “Console” tab. The “Tasks” tab is used to export the data to a CSV file.
7) Code window: Some information will be inputted in the code window.

NOTE 2: "CATCHMENT" DEFINITION

Before we begin the steps to get the catchment and reservoir data, we need to understand what a catchment is in order to delineate the zone accordingly.

A catchment, also called a watershed, "is the geographical area drained by a watercourse." (Food and Agriculture Organization of the United Nations 2016) It is delineated by the ridges of the surrounding topography.

In this Google Earth image, the catchment of the Oberrar reservoir (Switwerland) is delineated in red.

STEP 2: GET CATCHMENT AND RESERVOIR DATA FOR NEW PROJECTS

Step 2.1: From an Imported Catchment Vector File

In the G-res tool app, go in the Earth Engine tab and click on the "New Reservoir and Catchment Data from an Imported Catchment Vector File (Between 60N and 60S)" button (if your study site is between 60°N or 60°S) or on the "New Reservoir and Catchment Data from an Imported Catchment Vector File (Between 60N and 60S)" button (if your study site is between 60°N and 90°N or 60°S and 90°S) to open the code in Earth Engine on your web browser.

WARNING: Make sure to always import your vector file before to place the point at the dam site.

1. Click on "Show Code"
2. Zoom on your study site using the + and – zoom buttons or the wheel on the computer mouse. For this user guide, the Pwalugu dam project in the Republic of Ghana will be used as an example.
3. You may use the sliders in the "Layers" menu to adjust the transparency of the "Hillshade" and "Landsat" layers. These layers (along with the terrain map that appears on the map automatically) may be used to verify that the obtained reservoir make sense.

Once these preliminary steps are done, we need to import the vector file of the catchment in the KML format to transform from vector data to a Fusion Table:

1. Make sure to be log into your Earth Engine account first, then create a Fusion Table using the following link https://fusiontables.google.com/data?dsrcid=implicit.
   *More information about fusion table can be found at: https://support.google.com/fusiontables#topic=1652595
2. In the "From this Computer" tab of the 'Import new table' window, click **Choose File** and choose the vector file stored as a .kml file on your computer.
   *(For simple geometries (e.g. points), a two-column location in tabular data can be used. (Note: two-column locations are not supported in the Earth Engine Explorer interface). For complex geometries, KML is usually preferable.

3. Click **Next** and check the table obtained if the format is ok.
4. If the data are correctly imported, click **Next** again, fill in the relevant metadata fields, then click **Finish**. The imported Fusion Table will be created in your Google Drive account and you will be taken to the Fusion Table page.
5. Go to the **File** menu and select **About this table**.
6. In the 'About this table' dialog, find the **Id** and copy it [...].

   More information can be found here: https://developers.google.com/earth-engine/importing#importing-vector-data-with-fusion-tables.

Alternatively, the website shpescape.com can create a Fusion Table directly from a shapefile.

If you use shpescape.com to create a Fusion Table directly from a shapefile, be careful to leave the "Advance Options" unchecked.

The Fusion Table and its ID are stored in Google Drive and can be used again or copied into the code later.

4. In the 26th line of the code, replace [YOUR TABLE FUSION ID HERE] (the hard brackets also need to be removed) by pasting the ID you copied after ft:.

```
8    style: {position: 'bottom-right', width: '350px', height:  '300px'}
9  }).add(ui.Label('INSTRUCTIONS:'))
10 .add(ui.Label('please execute the following in order'))
11 .add(ui.Label('1) Import the catchment by writting the Table Fusion ID at the line 26'))
12 .add(ui.Label('2) Place a point at the dam site location using the point drawing tool'))
13 .add(ui.Label('3) Write the water surface elevation in meters at the line 48 (replace the default "0"
14 .add(ui.Label('for a step-by-step guide, please consult the user guide'));
15 ui.root.add(panelInst);
16
17 // Inputs
18 Map.setOptions('TERRAIN');
19
20 var image = ee.Image("LE7_TOA_1YEAR/2014");
21 Map.addLayer(image, {min:0, max: 100, bands: ["B3", "B2", "B1"]},'Landsat');
22 var hillshade = ee.Terrain.hillshade(ee.Image("srtm90_v4"));
23 image = image.add(hillshade.int().subtract(180));
24 Map.addLayer(image, {min:0, max: 100, bands: ["B3", "B2", "B1"]},'Hillshade');
25
26 var ft = ee.FeatureCollection("ft:[YOUR TABLE FUSION ID HERE]");
27 var studyArea = ft.geometry();
28 Map.addLayer(studyArea,{},'My Imported Catchment');
29
30 ////////////////////////////////////////////////////////////////////////////////
31
```

5. Place a point at the dam site location using the point tool.

6. Write the water surface elevation in meters at the line 48 (replace the default "0" value). In the case of the Pwalugu dam project, we used 171 meters above mean sea level (amsl).

```
38  // elevation at head of the dam
39  var min = SRTM.reduceRegion({
40    reducer:ee.Reducer.min(),
41    geometry: geometry,
42    scale: 300
43  });
44
45  var waterOrigin = ee.Number(min.get('elevation'));
46
47  // water surface elevation (m)
48  var riseLevel = 0;
49
50  // potential inundation areas
51  var possible_Zone = srtmArea.lte(riseLevel);
52
53  // masking areas not affected by rise
54  var inundationAreas = possible_Zone.updateMask(possible_Zone);
55
56  // painting the source polygon - needs to be an image for the cumulativeCost method
57  var sourceImage = ee.Image(0).uint8().paint(geometry, 1).eq(1).select(['constant'],['max']);
58
59  // using the cumulative cost to determine inundated Areas
60  var cc = inundationAreas.cumulativeCost({
61      source: sourceImage,
62
```

```
38  // elevation at head of the dam
39  var min = SRTM.reduceRegion({
40    reducer:ee.Reducer.min(),
41    geometry: geometry,
42    scale: 300
43  });
44
45  var waterOrigin = ee.Number(min.get('elevation'));
46
47  // water surface elevation (m)
48  var riseLevel = 171;
49
50  // potential inundation areas
51  var possible_Zone = srtmArea.lte(riseLevel);
52
53  // masking areas not affected by rise
54  var inundationAreas = possible_Zone.updateMask(possible_Zone);
55
56  // painting the source polygon - needs to be an image for the cumulativeCost method
57  var sourceImage = ee.Image(0).uint8().paint(geometry, 1).eq(1).select(['constant'],['max']);
58
59  // using the cumulative cost to determine inundated Areas
60  var cc = inundationAreas.cumulativeCost({
61      source: sourceImage,
62
```

7. Click on the “Run” button to see the land cover inside the catchment and the flooded area.
8. The data needed to run the G-res tool also appear in he “Console” tab.
9. To export the data in a CSV text file, click on the “Tasks” tab.

10. In the “Task” tab, click on “RUN” (for each file)

11. In the new window that appears, click on “RUN” once again to export the data to your Google Drive (https://www.google.com/drive/) in CSV text format (for each file). You can connect to Google Drive with your Google account.

Step 2.2: From a Hand-Drawn Catchment

In the G-res tool app, go in the Earth Engine tab and click on the "New Reservoir and Catchment Data from a Hand-Drawn Catchment (Between 60N and 60S) (Between 60N and 60S)" button (if your study site is between 60°N or 60°S) or on the "New Reservoir and Catchment Data from a Hand-Drawn Catchment (Between 60N-90N or 60S-90S)" button (if your study site is between 60°N and 90°N or 60°S and 90°S) to open the code in Earth Engine on your web browser.

WARNING: Make sure to always draw the catchment polygon before to place the point at the dam site.

1) Click on "Show Code"
2) Zoom on your study site using the + and – zoom buttons or the wheel on the computer mouse. For this user guide, the Pwalugu dam project in the Republic of Ghana will be used as an example.
3) Using the terrain map (it appears on the map automatically), the different catchment layers (different scales), and the "Hillshade" and the "Landsat" layers in the "Layers" toolbar, delineate the catchment of the future reservoir (see step 4). You may use the sliders to adjust the transparency of these layers. In the case of the Pwalugu dam project, "Catchment Guide scale 3" is the most appropriate.

4) Use the polygon drawing tool (far right in the Geometry Tools toolbox) to trace on the map the catchment of the future reservoir. To draw, click on the map to input each vertex of the polygon. Double-click on the last one to finish the drawing.

   To keep a copy of the drawn polygon, click on the "Show generated code" button and copy the code of the variable called "geometry". If you want to reuse this polygon in another code, simply paste this part at the beginning of the new code.

5) Geometry Imports will appear with only one item listed: "geometry (1 poly)". Click on "Exit" to exit the Polygon drawing mode. If you want to erase the drawn polygon, click on the gear icon beside "geometry (1 poly)" and then on the trash can icon.

6) Click on "+ new layer" under "Geometry Imports" and select the point tool. Place a point at the dam site. Please make sure that the point of the dam site is in contact with the polygon of the catchment area.

6

6

7) Write the water surface elevation in meters at the line 51 (replace the default "0" value). In the case of the Pwalugu dam project, we used 171 meters above the mean sea level (amsl).

```
41  // elevation at head of the dam
42  var min = SRTM.reduceRegion({
43    reducer:ee.Reducer.min(),
44    geometry: geometry2,
45    scale: 300
46  });
47
48  var waterOrigin = ee.Number(min.get('elevation'));
49
50  // water surface elevation (m)
51  var riseLevel = 0;
52
53  // potential inundation areas
54  var possible_Zone = srtmArea.lte(riseLevel);
55
56  // masking areas not affected by rise
57  var inundationAreas = possible_Zone.updateMask(possible_Zone);
58
59  // painting the source polygon - needs to be an image for the cumulativeCost method
60  var sourceImage = ee.Image(0).uint8().paint(geometry2, 1).eq(1).select(['constant'],['max']);
61
62  // using the cumulative cost to determine inundated Areas
63  var cc = inundationAreas.cumulativeCost({
64      source: sourceImage,
65      maxDistance: 100000
66      });
67
68
```

```
41  // elevation at head of the dam
42  var min = SRTM.reduceRegion({
43    reducer:ee.Reducer.min(),
44    geometry: geometry2,
45    scale: 300
46  });
47
48  var waterOrigin = ee.Number(min.get('elevation'));
49
50  // water surface elevation (m)
51  var riseLevel = 171;
52
53  // potential inundation areas
54  var possible_Zone = srtmArea.lte(riseLevel);
55
56  // masking areas not affected by rise
57  var inundationAreas = possible_Zone.updateMask(possible_Zone);
58
59  // painting the source polygon - needs to be an image for the cumulativeCost method
60  var sourceImage = ee.Image(0).uint8().paint(geometry2, 1).eq(1).select(['constant'],['max']);
61
62  // using the cumulative cost to determine inundated Areas
63  var cc = inundationAreas.cumulativeCost({
64      source: sourceImage,
65      maxDistance: 100000
66      });
67
68
```

8) Click on the "Run" button to see the land cover inside the catchment and the flooded area.
9) The data needed to run the G-res tool also appear in the "Console" tab.
10) To export the data in a CSV text file, click on the "Tasks" tab

11) In the “Task” tab, click on “RUN” (for each file)

12) In the new window that appears, click on "RUN" once again to export the data to your Google Drive (https://www.google.com/drive/) in CSV text format (for each file). You can connect to Google Drive with your Google account.

ACKNOWLEDGEMENTS

I would like to acknowledge the help of the Google Earth Engine Developers forum in the writing of these codes. David Weekley (david.weekley@ku.edu) provided the base of the code to the cumulative cost method for delineating flood areas.

REFERENCES

Food and Agriculture Organization of the United Nations. (2016). Sustainable Forest Management (SFM) Toolbox. Available at http://www.fao.org/sustainable-forest-management/toolbox/modules/watershed-management/basic-knowledge/en/ (consulted on 2016-04-25)