PROJECT TECHNICAL REPORT

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GOOGLE EARTH ENGINE JAVASCRIPT OPEN CODE FOR THE SCRUTINY, VISUALISATION, AND ANALYSIS OF THE USGS LANDSAT MISSIONS HISTORICAL DATA FOR AN AREA OF INTEREST: THE CASE OF MOUNTAINOUS AND CLOUD-PRONE AREAS IN CENTRAL COLOMBIA

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1. EXECUTIVE SUMMARY

1.1. OVERVIEW OF THE PROJECT

The project comprised the development of an open access script that allows the user to access, visualize, browse, and retrieve a customized view of the best available historic data for a given area.

The developed script is intended to provide users of Google Earth Engine (GEE) JavaScript Code Editor[1] with a tool to scrutinize the extensive USGS historical datasets from the Landsat Satellite missions for an area of interest (AOI) in cloud-prone areas of the world, where only a handful of good imagery is obtained through decades of passive remote sensing.

The project focused on the highest available data quality datasets for each Landsat Mission and instrument [1], retrieving the imagery intersecting the AOI and then performing different algorithms to filter, process and sort the data. The outputs consist of a description of the series of initial AOI matching datasets, and their corresponding sorted image collections by the percentage of valid (non-cloud) pixels, displaying the best one of each dataset on the Map of the code editor and providing an animated Graphics Interchange Format (GIF) visualization.

The idea for the project was crafted after the extensive work conducted curating a data pool for the temporal trajectory analysis of some Paramo protected areas in the Colombian Andes, a high-altitude ecosystem prone to the constant presence of clouds. This manual and labour-intense procedure was envisaged to be partially automated, using an objective criterion like the percentage of valid pixels within the AOI. This approach was proven to be better than relying solely on the imagery metadata on cloud cover, in which often low cloud cover percentages on the whole scene correspond to clouds that are located above the target AOI.

[1] Openly accessible through a Gmail account at: code.earthengine.google.com

1.2. ABBREVIATIONS

Table 1. Abbreviations used in both the script and technical report.

Abbreviation	Definition
AOI	Area of Interest
BOA	Bottom of the Atmosphere
CT	Cloud Threshold
DN	Digital Number
ETM	Enhanced Thematic Mapper (L7)
GEE	Google Earth Engine
L2/L4/L5/L7/L8/L9	Short for Landsat Mission Number
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LaSRC	Land Surface Reflectance Code
MSS	Multispectral Scanner (L2/L4/L5)
NIR	Near Infrared
OLI	Operational Land Imager (L8/L9)
QA	Quality Attributes (of a pixel)
RF	Random Forest
RMSE	Root Mean Square Error
SR	Surface Reflectance
SWIR	Shortwave Infrared
T1/T2	Tier 1 (RMSE≤12m) or Tier 2 level data (RMSE>12m)[2]
TIFF	Tag Image File Format
TIRS	Thermal Infrared Sensor (L8/L9)
TM	Thematic Mapper (L4/L5)
TOA	Top of the Atmosphere
URL	Uniform Resource Locator
USGS	United States Geological Survey

[2] Refer to https://www.usgs.gov/landsat-missions/landsat-collections

2. SCRIPT DESCRIPTION

2.1. FUNCTIONAL OVERVIEW

The JavaScript code has been crafted with the premise that most of the imagery on the Landsat Datasets are covered in clouds, thus only a small percentage of the vast historical dataset is useful. However, both the input parameters and the outputs were designed as to give the user an overview of the amount of useful data and tailor the results according to different needs.

From a functional point of view, the script performs 4 general operations on each dataset:

1. Initial filtering and sorting: To save computational costs, an initial filter on the bounds of the AOI and the input parameters is performed, and the resulting image collection is sorted by the 'CLOUD_COVER_LAND' property (ascending order). The resulting dataset is added to the map for inspection and printed to the console along with three descriptive lists, corresponding to the Paths, Rows and Dates of the images.

2. Processing: Depending on the dataset, some of the following processing steps are performed through specific functions: DN to TOA Reflectance Transformation, Custom Cloud Masking, Cloud Masking with QA_Pixel Band, Cropping to AOI, Valid Pixel Area Calculation and Valid Pixel Area Percentage Calculation. For the oldest missions, Landsat 2, 4 and 5, the MSS datasets are made available as a raw image, and the DN must be transformed to TOA reflectance, with parameters provided in the metadata. For all the other datasets, atmospherically corrected images are available as BOA Surface Reflectance (SR). A comprehensive table of the processing steps applied to each dataset is found on the section 2.2.2, and a description of all the datasets used is found on section 2.2.3. All datasets are added to the Map after the cloud masking step for inspection.

3. Final filtering and sorting: The steps for the Valid Pixel Area Calculation and Valid Pixel Area Percentage Calculation add their corresponding results as a new property of the image. On this basis, the resulting collection can be filtered by a minimum 'VALID_AREA_PERCENTAGE' property, and it is sorted in descending order.

4. Best Image Visualization: the best images for each dataset i.e. the image with the most valid area percentage in the collection is added to the Map for visual inspection. A subset of the best images available corresponding to the comparable T1 SR imagery from Landsat 4 and 5 TM, Landsat 7 ETM, and Landsat 8 and 9 OLI-TIRS are shown in a GIF animation on the console as a URL and as a Thumbnail.

2.2. STRUCTURE

The code is structured in 4 sequential parts: The user input, the functions, the dataset processing, and the final visualization. The code is provided with extensive comments on each section to provide clarity on the workings of each section, so it can be interpreted without the need of the present technical report.

2.2.1. USER INPUT

The following table summarizes the user input and possible range of parameters:

Table 2. User input parameters required in the script.

Variable	Description	Type	Range	Default Value (Use Case)
AOI	Area of Interest	Table/Polygon	[3]<8930 Km^2	2795
max_CloudCover	Starting maximum cloud cover for first filter of scenes	Percentage	0-100	40
Date_from	Starting date for first filter of scenes ['yyyy-mm-dd']	Date String	1975-01-31 to 5/ 6 days before current date	'1972-07-01'
Date_to	Final date for first filter of scenes ['yyyy-mm-dd']	Date String	1975-01-31 to 5 to 6 days before current date	'2024-02-01'
L2_CT	Reflectance threshold under which a pixel is valid (non-cloud) for Landsat 2 MSS Collection. [B4,B5,B6,B7] for [green,red,NIR1,NIR2]	Float List	0.01-0.99	[0.20,0.20,0.20,0.20]
L2_Px_buffer	Number of pixels to buffer in circle around cloud pixels for haze/cloud edge removal	Integer	0-[2]<1000	4
L2_Shadow_dist	Average distance in meters in which to cast shadows from the clouds	Integer	0-[2]<9450	360
min_validA_L2	Minimum valid (No Cloud) pixel Area percentage on AOI for final filtering	Percentage	0-100	40[4]
L4_CT	Reflectance threshold under which a pixel is valid (non-cloud) for Landsat 4 MSS Collection. [B1,B2,B3,B4] for [green,red,NIR1,NIR2]	Float List	0.01-0.99	[0.18,0.18,0.18,0.18]
L4_Px_buffer	Number of pixels to buffer in circle around cloud pixels for haze/cloud edge removal	Integer	0-*<1000	3
L4_Shadow_dist	Average distance in meters in which to cast shadows from the clouds	Integer	0-*<9450	360
min_validA_L4	Minimum valid (No Cloud) pixel Area percentage on AOI for final filtering	Percentage	0-100	40**
L5_CT	Reflectance threshold under which a pixel is valid (non-cloud) for Landsat 4 MSS Collection. [B1,B2,B3,B4] for [green,red,NIR1,NIR2]	Float List	0.01-0.99	[0.18,0.18,0.18,0.18]
L5_Px_buffer	Number of pixels to buffer in circle around cloud pixels for haze/cloud edge removal	Integer	0-*<1000	3
L5_Shadow_dist	Average distance in meters in which to cast shadows from the clouds	Integer	0-*<9450	300
min_validA_L5	Minimum valid (No Cloud) pixel Area percentage on AOI for final filtering	Percentage	0-100	40**

3 AOI Size must have less than 10 million pixels due to GEE processing constraints, at a 30 m resolution that is roughly an area of 94.5 Km by 94.5 Km, equivalent to 8930 Km^2.

4 This filter is discouraged when the AOI sits on different Landsat scenes overlapping, particularly regarding consecutive Rows, as partially matching scenes could be out ruled.

2.2.2. FUNCTIONS

All the functions used throughout the code and their description are compiled in the following table:

Table 3. Functions used in the script.

Name	Parameters	Mission L[#]	Description
applyScaleFactors	image	4/5/7	Applies scaling factors for optical and thermal bands
applyScaleFactors_new	image	8/9	Applies scaling factors for optical and thermal bands
TOA_from_Metada_L[#]	image	2/4/5	Custom function to obtain TOA Reflectance with Metadata for Landsat MSS
Cloud_Mask_MSS_L[#]	image, L[#]_CT[0]*, L[#]_CT[1]*, L[#]_CT[2]*, L[#]_CT[3]*, L[#]_Px_buffer*, L[#]_Shadow_dist*	2/4/5	Custom Cloud Masking function by thresholding, buffering mask pixels and translating the buffer to mask shadows for Landsat MSS
Get_Cloud_Mask_QA	image	4/5/7/ 8/9	Cloud Masking Function based on the PIXEL_QA bitmask for Landsat TM, ETM, and OLI-TIRS. As defined, Bit 1: Dilated Cloud, Bit 3: Cloud, Bit 4: Cloud Shadow
Get_Valid_px_Area_MSS	image, mask	2/4/5	Valid pixel area calculation for MSS Landsat Missions (60 m resolution)
Get_Valid_px_Area	image, mask	4/5/7/ 8/9	Valid pixel area calculation for Landsat TM, ETM, and OLI-TIRS (30 m resolution)
Get_Valid_px_Area_Perc	image	2/4/5/ 7/8/9	Valid pixel area percentage calculation for all Landsat Missions

*Refer to Table 2 for user input parameters. Array notation is used for the CT[ ], 0 corresponding to the first element of the array and so on.

2.2.3. Datasets Processed

The datasets processed correspond to the USGS Landsat Collection 2 products, as the highest data quality available for the scope of the project. Landsat scenes placed into T1 are considered suitable for time-series processing analysis and include Level-1 Precision Terrain processed data that have well-characterized radiometry and are inter-calibrated across the different Landsat sensors. Scenes not meeting T1 criteria during processing are assigned to Tier 2 due to significant cloud cover, insufficient ground control, and other factors [1].

The GEE script retrieves following datasets as image collections for processing:

Table 4. Datasets accessed for processing in the script.

Directory[5] LANDSAT/	Description	Relevant Bands			
		Name	**Description**	**Resolution**	**Wavelength**
LM02/C02/T1	Landsat 2 MSS Collection 2 Tier 1/2 DN values, representing scaled, calibrated at-sensor radiance.	B4	Green	60 meters	0.5 - 0.6 µm
		B5	Red	60 meters	0.6 - 0.7 µm
LM02/C02/T2	Available 1975-01-31T10:19:55 to 1982-02-03T00:49:25	B6	NIR 1	60 meters	0.7 - 0.8 µm
		B7	NIR 2	30 meters	0.8 - 1.1 µm
		QA_PIXEL	Collection 2 QA Bitmask	30 meters	-
		Name	**Description**	**Resolution**	**Wavelength**
LM04/C02/T1	Landsat 4 MSS Collection 2 Tier 1/2 DN values, representing scaled, calibrated at-sensor radiance.	B1	Green	60 meters	0.5 - 0.6 µm
		B2	Red	60 meters	0.6 - 0.7 µm
LM04/C02/T2	Available 1982-08-14T18:22:17 to 1992-08-28T07:14:35	B3	NIR 1	60 meters	0.7 - 0.8 µm
		B4	NIR 2	30 meters	0.8 - 1.1 µm
		QA_PIXEL	Collection 2 QA Bitmask	30 meters	-
		Name	**Description**	**Resolution**	**Wavelength**
LM05/C02/T1	Landsat 5 MSS Collection 2 Tier 1/2 DN values, representing scaled, calibrated at-sensor radiance.	B1	Green	60 meters	0.5 - 0.6 µm
		B2	Red	60 meters	0.6 - 0.7 µm
LM05/C02/T2	Available 1984-04-07T10:04:11 to 2013-01-01T16:51:58	B3	NIR 1	60 meters	0.7 - 0.8 µm
		B4	NIR 2	30 meters	0.8 - 1.1 µm
		QA_PIXEL	Collection 2 QA Bitmask	30 meters	-
		Name	**Description**	**Resolution**	**Wavelength**
LT04/C02/T1_L2	Landsat 4 TM Collection 2 Level 2 Tier 1/2 SR values, atmospherically corrected surface reflectance and land surface temperature derived from the data produced by the sensor, created with the LEDAPS algorithm (version 3.4.0).	SR_B1	Blue SR	30 meters	0.45-0.52 µm
		SR_B2	Green SR	30 meters	0.52-0.60 µm
LT04/C02/T2_L2	Available 1984-04-07T10:04:11 to 2013-01-01T16:51:58	SR_B3	Red SR	30 meters	0.63-0.69 µm
		SR_B4	NIR SR	30 meters	0.77-0.90 µm
		QA_PIXEL	QA from CFMASK algorithm [2]	30 meters	-

[5] Refer to https://developers.google.com/earth-engine/datasets/catalog/landsat

<table>
<tr><th>Directory[5] LANDSAT/</th><th>Description</th><th>Relevant Bands</th></tr>
<tr><td>LT05/C02/T1_L2</td><td rowspan="2">Landsat 5 TM Collection 2 Level 2 Tier 1/2 SR values, atmospherically corrected surface reflectance and land surface temperature derived from the data produced by the sensor, created with the LEDAPS algorithm (version 3.4.0).

Available
1984-03-16T16:18:01 to
2012-05-05T17:54:06</td><td rowspan="2"><table>
<tr><th>Name</th><th>Description</th><th>Resolution</th><th>Wavelength</th></tr>
<tr><td>SR_B1</td><td>Blue SR</td><td>30 meters</td><td>0.45-0.52 µm</td></tr>
<tr><td>SR_B2</td><td>Green SR</td><td>30 meters</td><td>0.52-0.60 µm</td></tr>
<tr><td>SR_B3</td><td>Red SR</td><td>30 meters</td><td>0.63-0.69 µm</td></tr>
<tr><td>SR_B4</td><td>NIR SR</td><td>30 meters</td><td>0.77-0.90 µm</td></tr>
<tr><td>QA_PIXEL</td><td>QA from CFMASK algorithm [2]</td><td>30 meters</td><td>-</td></tr>
</table></td></tr>
<tr><td>LT05/C02/T2_L2</td></tr>
<tr><td>LE07/C02/T1_L2</td><td rowspan="2">Landsat 7 ETM Collection 2 Level 2 Tier 1/2 SR values, atmospherically corrected surface reflectance and land surface temperature derived from the data produced by the sensor, created with the LEDAPS algorithm (version 3.4.0).

Available
1999-05-28T01:02:17 to
Present (2024-01-11T01:18:36)</td><td rowspan="2"><table>
<tr><th>Name</th><th>Description</th><th>Resolution</th><th>Wavelength</th></tr>
<tr><td>SR_B1</td><td>Blue SR</td><td>30 meters</td><td>0.45-0.52 µm</td></tr>
<tr><td>SR_B2</td><td>Green SR</td><td>30 meters</td><td>0.52-0.60 µm</td></tr>
<tr><td>SR_B3</td><td>Red SR</td><td>30 meters</td><td>0.63-0.69 µm</td></tr>
<tr><td>SR_B4</td><td>NIR SR</td><td>30 meters</td><td>0.77-0.90 µm</td></tr>
<tr><td>QA_PIXEL</td><td>QA from CFMASK algorithm [2]</td><td>30 meters</td><td>-</td></tr>
</table></td></tr>
<tr><td>LE07/C02/T2_L2</td></tr>
<tr><td>LC08/C02/T1_L2</td><td rowspan="2">Landsat 8 OLI/TIRS Collection 2 Level 2 Tier 1/2 SR values, atmospherically corrected surface reflectance and land surface temperature derived from the data produced by the sensor, created with the LaSRC.

Available
2013-03-18T15:58:14 to
Present (2024-01-26T09:46:47)</td><td rowspan="2"><table>
<tr><th>Name</th><th>Description</th><th>Resolution</th><th>Wavelength</th></tr>
<tr><td>SR_B2</td><td>Blue SR</td><td>30 meters</td><td>0.452-0.512 µm</td></tr>
<tr><td>SR_B3</td><td>Green SR</td><td>30 meters</td><td>0.533-0.590 µm</td></tr>
<tr><td>SR_B4</td><td>Red SR</td><td>30 meters</td><td>0.636-0.673 µm</td></tr>
<tr><td>SR_B5</td><td>NIR SR</td><td>30 meters</td><td>0.851-0.879 µm</td></tr>
<tr><td>QA_PIXEL</td><td>QA from CFMASK algorithm [2]</td><td>30 meters</td><td>-</td></tr>
</table></td></tr>
<tr><td>LC08/C02/T2_L2</td></tr>
<tr><td>LC09/C02/T1_L2</td><td rowspan="2">Landsat 9 OLI/TIRS Collection 2 Level 2 Tier 1/2 SR values, atmospherically corrected surface reflectance and land surface temperature derived from the data produced by the sensor, created with the LaSRC.

Available
2021-10-31T00:00:00 to
Present (2024-02-02T23:56:34)</td><td rowspan="2"><table>
<tr><th>Name</th><th>Description</th><th>Resolution</th><th>Wavelength</th></tr>
<tr><td>SR_B2</td><td>Blue SR</td><td>30 meters</td><td>0.452-0.512 µm</td></tr>
<tr><td>SR_B3</td><td>Green SR</td><td>30 meters</td><td>0.533-0.590 µm</td></tr>
<tr><td>SR_B4</td><td>Red SR</td><td>30 meters</td><td>0.636-0.673 µm</td></tr>
<tr><td>SR_B5</td><td>NIR SR</td><td>30 meters</td><td>0.851-0.879 µm</td></tr>
<tr><td>QA_PIXEL</td><td>QA from CFMASK algorithm [2]</td><td>30 meters</td><td>-</td></tr>
</table></td></tr>
<tr><td>LC09/C02/T2_L2</td></tr>
</table>

2.2.4. OUTPUTS

The script produces 2 kinds of outputs: console prints and map layer additions. For the case of the console, the following data is printed for verification:

- AOI element, with the calculated size in Km^2.
- Initial statement with parameters related to the initial filtering.
- For all datasets referred in section 2.2.3 Table 4:
    - Initial filtered and sorted by cloud cover land property dataset, along with three descriptive lists corresponding to the Paths, Rows and Dates of the images.
    - Processed datasets intermediate cloud masked collection.
    - Processed datasets final collection sorted by valid pixels on AOI (descending). Filtered if a minimum valid percentage of pixels is defined.
- Best image collection from all T1 datasets (suitable for time-series analysis).
- URL for the GIF animation of the best images collection.
- Thumbnail of the GIF animation.

2.3. AVAILABILITY

The script is made publicly available by both a shareable URL and a GitHub repository with the code and the technical report. GEE users must register/sign in through a Gmail account.

All relevant documentation can be found at:
https://github.com/Daenel35/Geoinformatics_GEE.git

Script can be directly accessed through:
https://code.earthengine.google.com/9ac95ec192181a73b46185866cd69449

Use case asset (AOI) can be found at:
https://code.earthengine.google.com/?asset=users/daenel35/EO/Guerrero_bbox

Script customization and expansion is possible and actively encouraged. Script can also be optimized in length by the means of recursive functions and server-side conditionals. For further information do not hesitate to contact the author at: daenel35@gmail.com.

3. USE CASE: CENTRAL COLOMBIA

Using the default values specified in Table 2, section 2.2.1, the bounding box of the protected area of the Paramo de Guerrero is processed. This protected area is in central Colombia, along the Eastern Andes Mountain range, around 70 Km North of Bogotá.

This AOI and other Paramo areas were previously examined manually for a set of images containing under 40% cloud cover through the Sentinel Hub EO Browser [3], one image at a time, to find the best imagery available and curate a data pool. This process was documented in a Table, modified for the purpose of the present use case, included in Appendix A of this report.

3.1. RESULTS

The console output of the script regarding the best ranked images for the use case can be compared to the table in Appendix A. In order to corroborate the findings, the user can compare the directory lines in bold to the console script outputs, to verify the results. As the script is limited to only pick the top-1 of each collection, not all images listed on the appendix table are returned.

For the AOI analyzed, no T1 imagery was found for the MSS datasets. Snippets of the output Map layout for the oldest datasets are shown on Figures 1 to 3, to demonstrate the effect of the custom cloud masking functions implemented and the comparison between the properties related to cloud coverage.

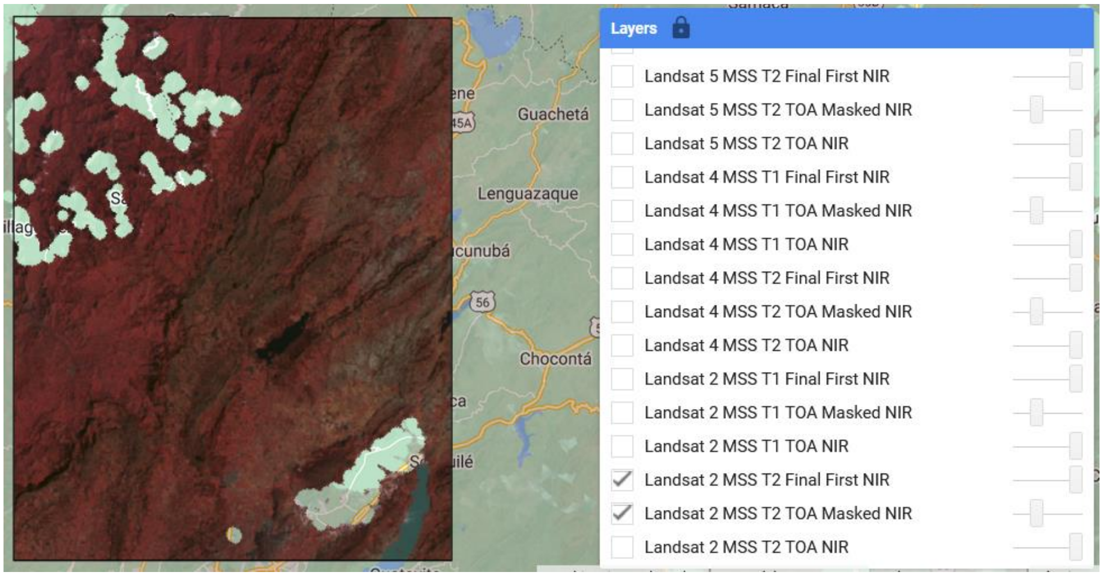

Figure 1. Snippet of best available image for L2 MSS T2 (1977-01-07) after cloud masking. Whole scene CLOUD_COVER_LAND = 12 and AOI related VALID_AREA_PERCENTAGE = 96.05.

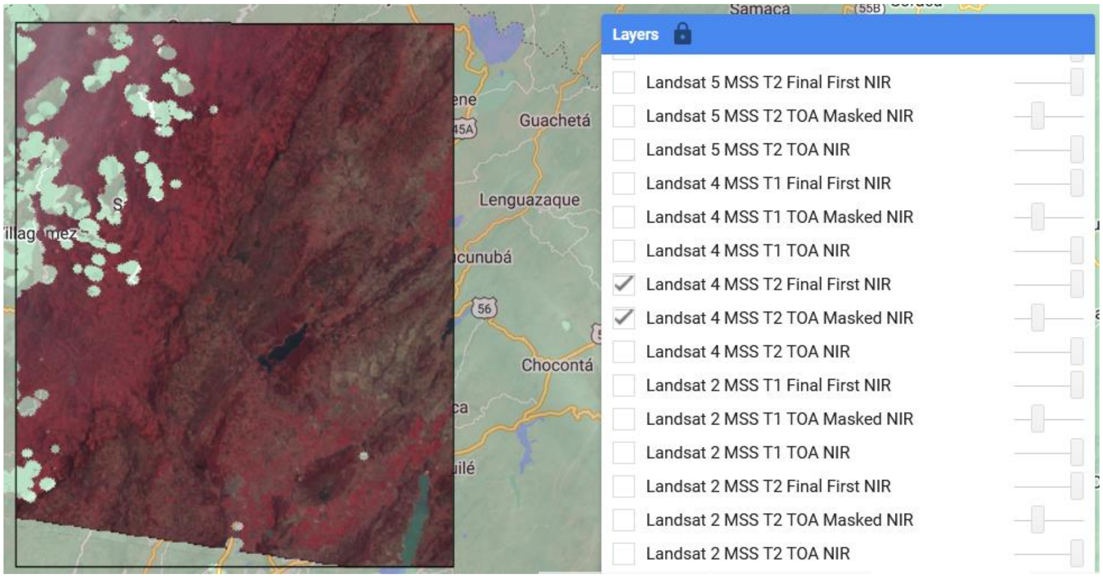

Figure 2. Snippet of best available image for L4 MSS T2 (1988-03-22) after cloud masking. Whole scene CLOUD_COVER_LAND =4 and AOI related VALID_AREA_PERCENTAGE = 92.35.

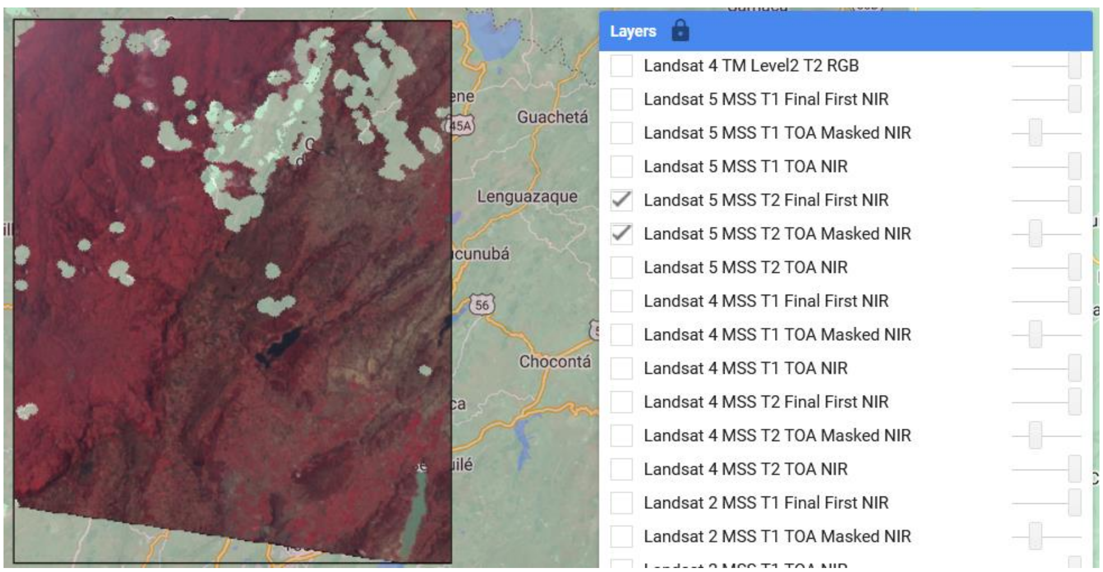

Figure 3. Snippet of best available image for L5 MSS T2 (1985-03-22) after cloud masking. Whole scene CLOUD_COVER_LAND =13 and AOI related VALID_AREA_PERCENTAGE = 89.69.

With respect to the Tier 1 data obtained, all processed datasets yielded a different best ranked image with respect to the initial sorting, with the only exception of the Landsat 8. These results confirm that the script provides a shorter route to reach the best available image by incorporating an objective criterion based on the AOI, rather than relying on the metadata properties related to the whole Landsat scene.

For instance, the best ranked image for the initial sorting of Landsat 7 fell to 135th place (out of 221 images), while the best image available from the final sorting was initially ranked at 47th place. This means that exploring the top 20 or 30 images of the initially sorted collection will not lead to the finding of the best image available for the AOI. This difference in ranking is of course smaller when the size of the dataset decreases and is highly dependent on the initial filtering parameters. Table 5 summarizes the comparison between the first ranked image from the initial filtering to the final one, obtained through the console print outputs of the script.

Table 5. T1 processed datasets best final sorting results compared to initial sorting rank based on metadata.

T1 Dataset	Size	Image Directory	Initial Rank	Scene Cloud Cover %*	AOI Valid %**	Final Rank
L4 TM	21	LT04_008056_19871217	**3**	13	93,94	**1**
		LT04_008057_19880322	**1**	5	25,53	**7**
L5 TM	71	LT05_008056_19950214	**2**	4	97,53	**1**
		LT05_008057_19950214	**1**	3	28,44	**32**
L7 ETM	221	LE07_008056_20030111	**47**	18	89,2	**1**
		LE07_007056_20230826	**1**	1	17,97	**135**
L8 OLI/TIRS	108	LC08_008056_20150104	**1**	2,05	91,89	**1**
L9 OLI/TIRS	16	LC09_008056_20230203	**14**	39,28	75,7	**1**
		LC09_008057_20220131	**1**	19,54	33,31	**7**

* CLOUD_COVER_LAND property from metadata (Whole Scene).
** VALID_AREA_PERCENTAGE property calculated (With respect to AOI).

Finally, the most visually appealing output GIF animation is obtained with the best elements of each collection (Final Rank=1 on Table 5), which are assembled in consecutive 1 second frames. These elements are shown in the following figure:

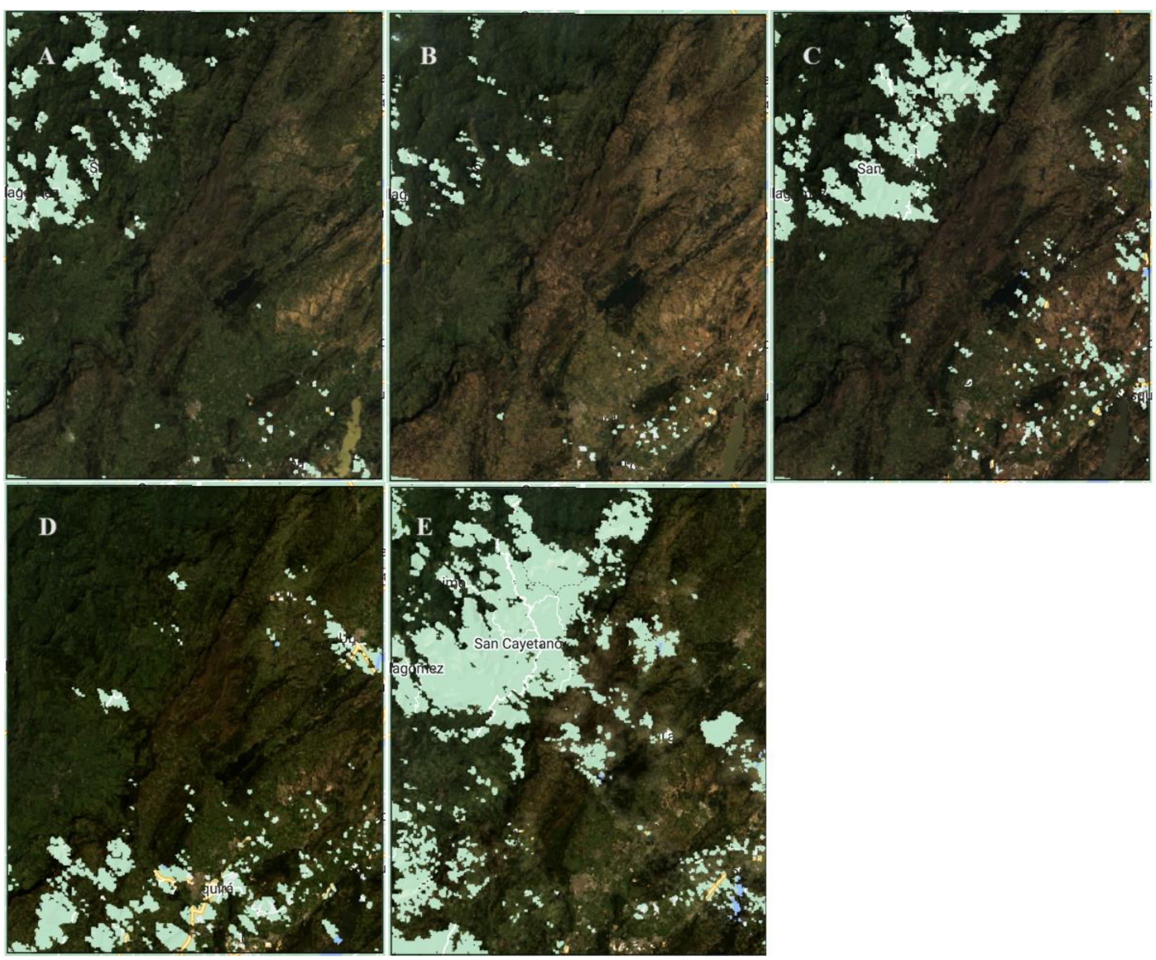

Figure 4.Map Snippets for the best images final collection. A) L4 and B) L5 TM, C)L7 ETM, D)L8 and E) L9 OLI/TIRS

3.2. CONCLUSIONS

This project has developed a script that provides a versatile tool and a more efficient way to scrutinize the highest available data quality datasets of the vast USGS Landsat Collection 2, to obtain the best available images when scouting for an AOI in a cloud-prone area. The developed script retrieves the best imagery available (clearest images) through an objective criterion, namely the percentage of valid pixel (non-cloud) area within the AOI and display a comparable subset as GIF. The script was applied to the Eastern Andes mountainous area of central Colombia, where throughout five decades of satellite passive remote sensing and continuous evolution of the sensors and processing methods [4], no cloud-free image on the AOI (~2795 Km^2) could be obtained. This is because the likelihood of the observation is controlled by constant unfavorable atmospheric conditions.

This script has been developed with the scope of the project in mind, however, with an intention for it be further customized and expanded to meet different needs. Some advisory notes to consider:

- Due to GEE processing constraints, AOI Size must have less than 10 million pixels. At a 30 m resolution that is roughly an area of 94.5 Km by 94.5 Km, equivalent to 8930 Km^2.
- Both the cloud masking functions proved to be working properly to remove the clouds from the scene, however, the custom functions rely on the input parameters given by the user, and therefore must be examined closely for each individual case.
- Script customization and expansion is possible and actively encouraged. Script can also be optimized in length by the means of recursive functions and server-side conditionals.

For further information do not hesitate to contact the author at: daenel35@gmail.com.

4. REFERENCES

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APPENDIX A

Supplementary table for curated Landsat Data Pool (For Guerrero Paramo Area). Best imagery available in bold.

Paramo Area Cloud Cover Qualitative Rating

Very Little to None — Mostly Covered

Proportion of Paramo Area Covered in Scene

100%	75-99%	50-75%	25-50%	1-25%	0%

Directory	Proc. Level	Res. [m]	Guerrero
LANDSAT/LM02/C02/T2/LM02_008056_19770107	**Tier 2 Raw**	60	
LANDSAT/LM02/C02/T2/LM02_008057_19770107	**Tier 2 Raw**	60	
LANDSAT/LM04/C02/T2/LM04_008056_19840123	Tier 2 Raw	60	
LANDSAT/LT05/C02/T1_L2/LT05_008056_19850322	Tier 1 Level 2 SR	30	
LANDSAT/LT05/C02/T1_L2/LT05_008057_19850322	Tier 1 Level 2 SR	30	
LANDSAT/LT04/C02/T1_L2/LT04_008056_19871217	**Tier 1 Level 2 SR**	30	
LANDSAT/LM04/C02/T2/LM04_008056_19880322	**Tier 2 Raw**	60	
LANDSAT/LM04/C02/T2/LM04_008057_19880322	**Tier 2 Raw**	60	
LANDSAT/LT04/C02/T1_L2/LT04_008056_19880322	**Tier 1 Level 2 SR**	30	
LANDSAT/LT04/C02/T1_L2/LT04_008057_19880322	**Tier 1 Level 2 SR**	30	
LANDSAT/LT04/C02/T1_L2/LT04_008057_19891222	Tier 1 Level 2 SR	30	
LANDSAT/LT05/C02/T1_L2/LT05_008056_19891230	Tier 1 Level 2 SR	30	
LANDSAT/LT05/C02/T1_L2/LT05_008056_19910323	**Tier 1 Level 2 SR**	30	
LANDSAT/LT05/C02/T1_L2/LT05_008057_19910323	**Tier 1 Level 2 SR**	30	
LANDSAT/LT05/C02/T1_L2/LT05_008056_19980105	Tier 1 Level 2 SR	30	
LANDSAT/LT05/C02/T1_L2/LT05_008056_20010129	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LT05/C02/T1_L2/LT05_008057_20010129	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20030111	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20030111	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20070207	**Tier 1 Level 2 SR**	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20070207	**Tier 1 Level 2 SR**	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20070223	**Tier 1 Level 2 SR**	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20070223	**Tier 1 Level 2 SR**	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20091213	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20091213	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20091229	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20091229	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20100114	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20100114	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20110101	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20110117	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20110117	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20110202	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20120221	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20120221	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20130106	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20130327	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20130327	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008056_20140101	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008057_20140101	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008056_20150104	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LC08/C02/T1_L2/LC08_008057_20150104	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LC08/C02/T1_L2/LC08_008056_20150221	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LC08/C02/T1_L2/LC08_008057_20150221	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LE07/C02/T1_L2/LE07_008056_20160115	Tier 1 Level 2 SR	30	
LANDSAT/LE07/C02/T1_L2/LE07_008057_20160115	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008056_20160123	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008057_20160123	Tier 1 Level 2 SR	30	
LANDSAT/LC08/C02/T1_L2/LC08_008056_20181230	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LC08/C02/T1_L2/LC08_008057_20181230	**Tier 1 Level 2 SR**	**30**	
LANDSAT/LC09/C02/T1_L2/LC09_008056_20211113	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008057_20211113	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008057_20211214	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008056_20220131	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008057_20220131	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008056_20230203	Tier 1 Level 2 SR	30	
LANDSAT/LC09/C02/T1_L2/LC09_008057_20230203	Tier 1 Level 2 SR	30	