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THE **CGS, CZECH REPUBLIC**

WITH THE **NEA, GEORGIA**

Installation and processing manual of Landslider24 application

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1. Background theory

1.1 Optical data principles

Landslider24 tool is based on the utilization of optical remote sensing (RS) data. Optical RS data are data acquired within the visible to short-wave infrared part of the electromagnetic (EM) spectrum (Figure 1).

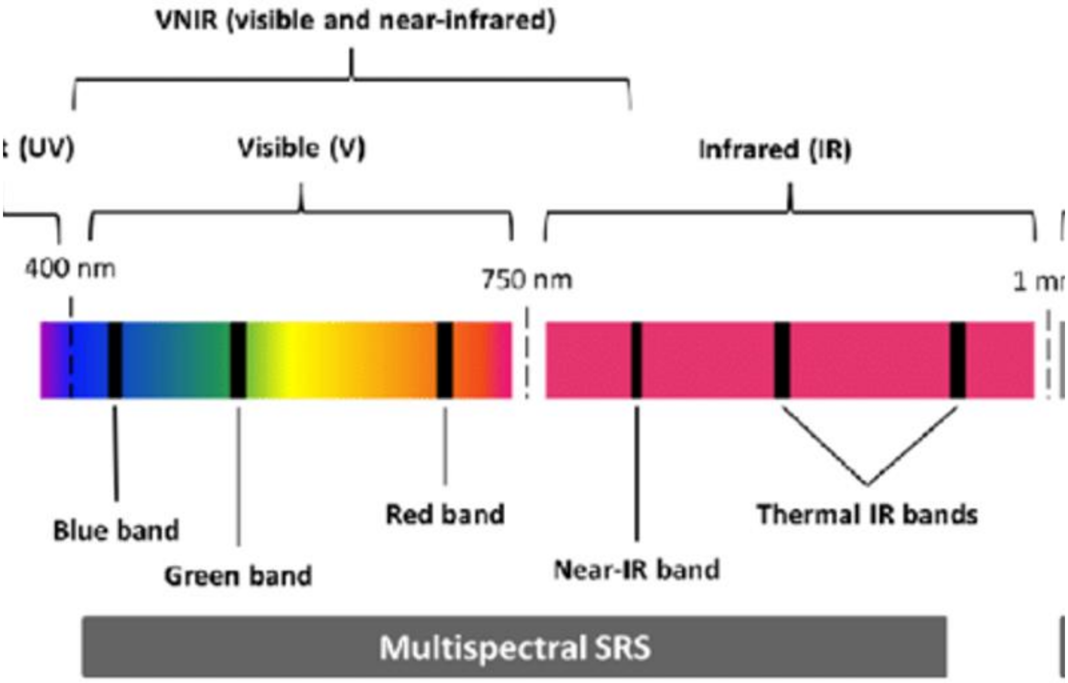


Figure 1 Optical data are using the Visible to infrared part of the EM spectrum (Pettorelli et al., 2018)

Optical data represent the reflected part of the Sun radiation which is sensed by the sensor carried by a platform (UAV, plane or satellite). By studying the parameters of the reflected light sensed by the sensor, it is possible to observe and map different types of the objects at the Earth surface, or even evaluate changes within the same type of the object. Optical data are passively sensed data and thus able to observe only the top visible surface (i.e. not able to penetrate vegetation or top soil layer). Having this in mind, it is necessary to plan the utilization of optical data with respect to the working targets.

Optical data have three key features which are defining the quality of the data. These are: spatial resolution, spectral resolution and temporal resolution. Spatial resolution defines how large area on the sensed surface is represented by a single pixel of the acquired data. Spectral resolution defines how many spectral bands are sensed by the sensor. Temporal resolution defines how often the platform with the sensor visits the studied area within the observed period.

Optical data are prone to several obstacles, the cloud cover being the most prominent one. Clouds are impenetrable with the optical data and thus when using this type of RS data it is necessary to choose scenes with low cloud cover or use cloud mask to remove clouds from the scene before any further analysis.

1.2 Multispectral data

The Landslider24 tool uses the multispectral optical data. This is the type of optical data where several, up to approximately 20, spectral bands are acquired within the single sensing (Figure 2). These bands are usually placed conveniently at the specific wavelengths of the EM spectrum. The more bands the data contain, the better spectral resolution, and the better capabilities during the post-processing and further analysis.

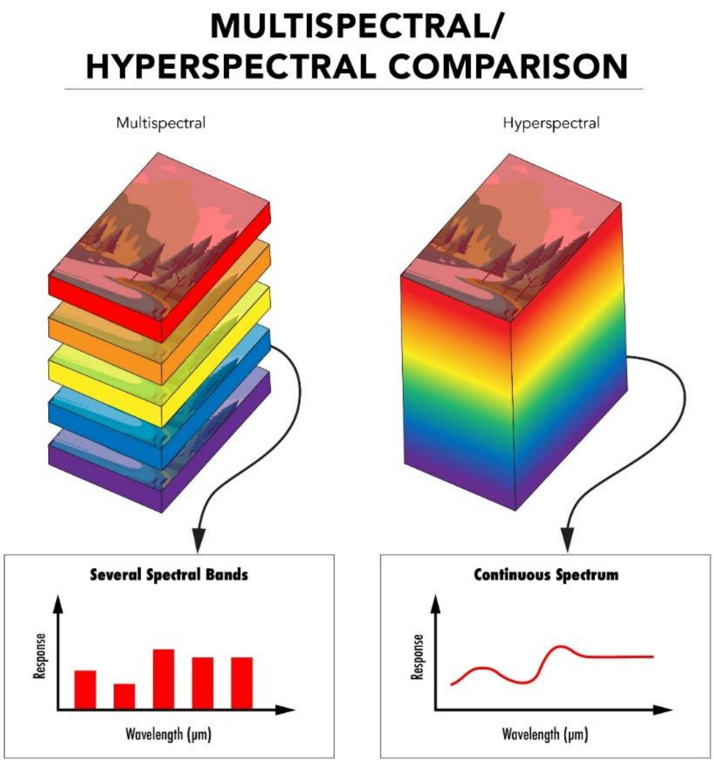


Figure 2 Differences between multispectral and hyperspectral optical data

Usually, multispectral optical data contain several band within the visible part of the EM spectrum (enabling RGB true color representation) and then several band within the near-infrared (NIR) and short-wave infrared (SWIR) part of the EM spectrum.

1.3 Available satellites

Currently, there are growing opportunities for the optical satellite data. Among others, the data provided for free are especially useful for building tools with wide utilization. Two satellite programmes are providing long times series of optical data, Sentinel-2 of the Copernicus programme (ESA) and Landsat 8/9 of the Landsat programme (USGS/NASA). Both satellites cover approximately the same spectral range, with Sentinel-2 being slightly superior in the spatial resolution (having 10-m pixel size for four of its spectral bands). The rest of the spectral bands feature 20-m pixel size. Landsat 8 and 9 offer 15-m pixel size for all of its spectral bands except of the thermal bands. Besides the freely available data, very-high-resolution (VHR) optical data can be also considered valuable for the various remote sensing tasks. Such data offer sub-meter pixel sizes, on the other hand usually do not offer high spectral resolution and are often very costly with limited spatial coverage.

1.4 Spectral indices

Spectral indices are a way how to process multiple-band spectral optical data. In principle, spectral index is a mathematical operation suing spectral bands. The key operation is dividing which creates a ratio of two spectral bands:

$$\frac{Band\ A}{Band\ B}$$

Next option is to normalize such ratio using formula of:

$$\frac{Band\ A - Band\ B}{Band\ A + Band\ B}$$

The main purpose of indexing is to make us of large differences in reflectance values among the compared spectral bands. Bz doing this, it is possible to highlight certain types of surfaces which might help to either highlight them or to omit them from the optical data. One of the first indexes were focused on geology and vegetation, with Normalized difference vegetation index (NDVI) being probably the best example. NDVI is using the large difference between red and NIR reflectance in the optical data which is characteristic only for vegetation (leaves, needles) (Figure 3). The key driver in NDVI intensity is the pigment content in the vegetation, mainly chlorophyll A and B. NDVI values range between +1 and -1, where the higher value, the denser or the healthier the vegetation is. Obviously such index can be also used to distinguish vegetation and non-vegetation covered surface (Figure 4).

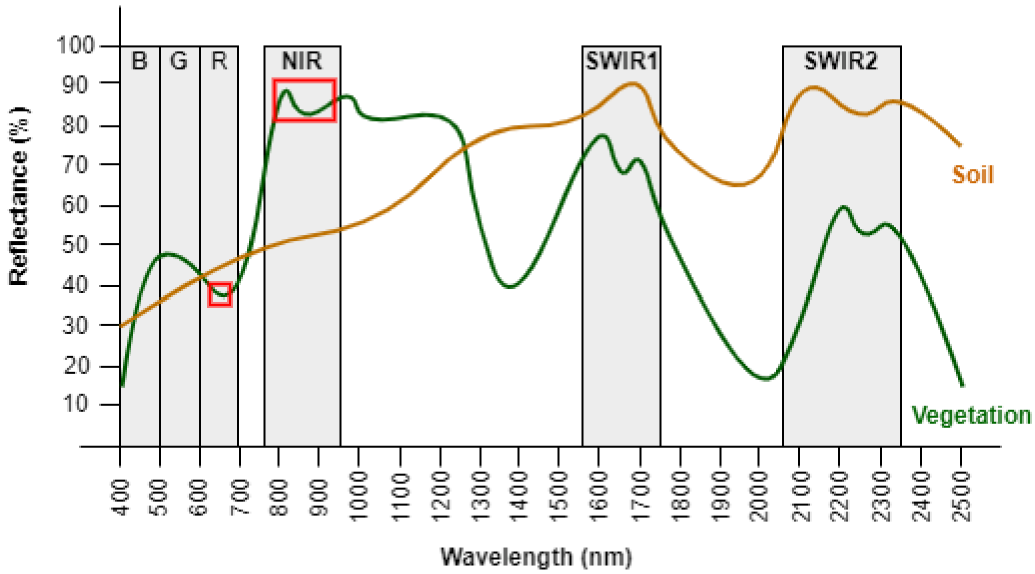


Figure 3 Band position of red and NIR reflectance of typical vegetation

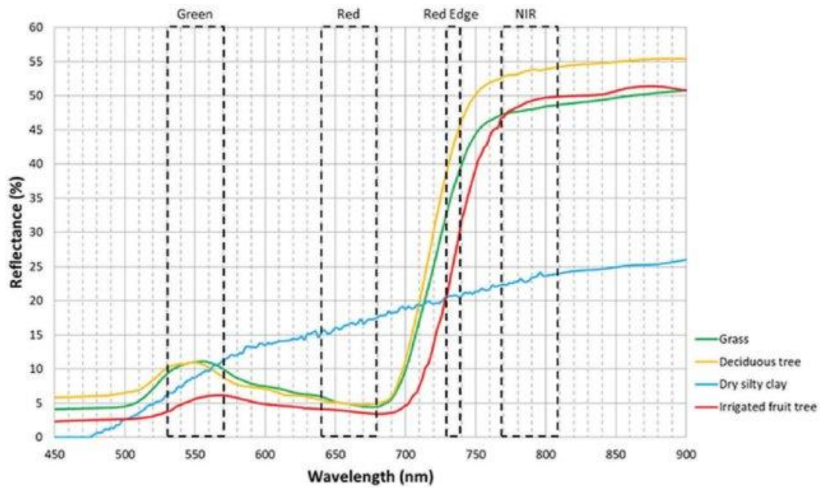


Figure 4 Difference of vegetation and clay spectral curves (Source: Jorge et al., 2019)

1.5 Change detection

Change detection is a type of remote sensing data analysis when a change in the observed data over a defined period of time is being observed. In case of optical data, a type of surface is selected (i.e. vegetated surfaces) and the change between two selected days or more complex time series is observed. Changes in vegetation cover are among the easiest ones due to the simplicity of NDVI index. Crucial step is to set the proper threshold which defines the proper classification of each pixel (Figure 5).

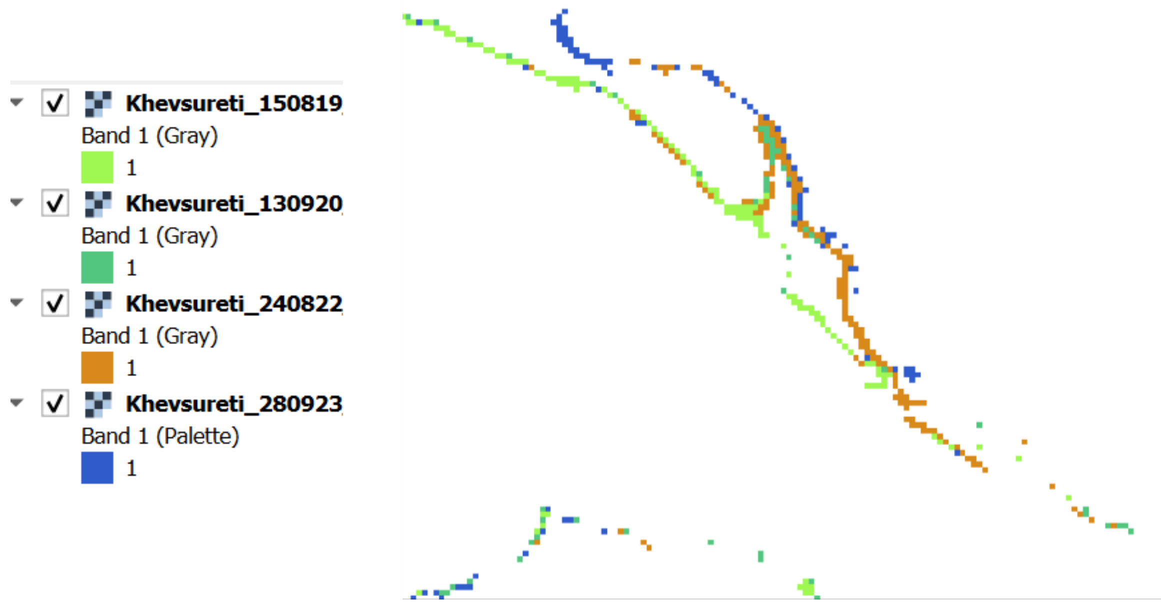


Figure 5 Example of the time series of the non-vegetated surfaces in the Khevsureti area (years 2019-2023)

2. Landslider24 – theory

Landslider24 is a landslide detection tool powered by Google Earth Engine. The application is available online on: https://ee-georgia24.projects.earthengine.app/view/landslider24,

2.1 Google Earth Engine (GEE)

Google Earth Engine offers a web-based Integrated Development Environment (IDE) where users can write and execute code using the Earth Engine JavaScript API (Figure 6). This eliminates the need for complex software installations, requiring only an account creation.

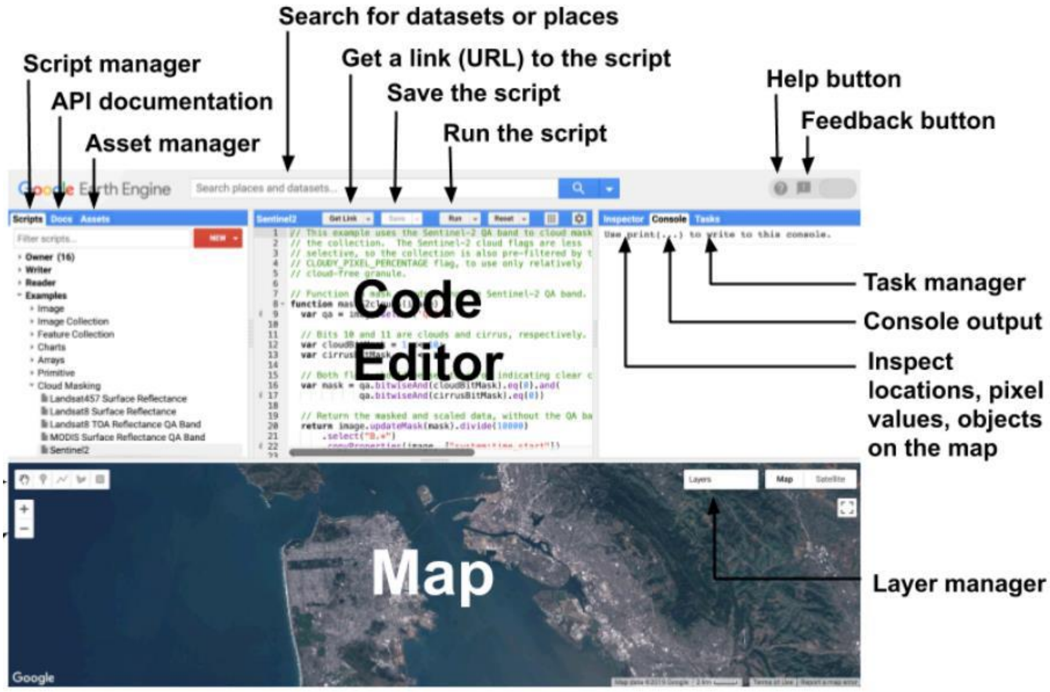


Figure 6 Google Earth Engine code editor layout

GEE provides access to a comprehensive public data archive known as the Earth Engine Data Catalog (https://developers.google.com/earth-engine/datasets). This catalogue encompasses over four decades of historical imagery from various satellites like Sentinel, Landsat, MODIS, and Digital Elevation Models (DEMs) (Figure 7).

2.2 General description

Landslider24 is an online tool designed to identify and map changes in landscapes that might be indicative of potential geohazards, specifically landslides. It uses the capabilities of Google

Earth Engine (GEE), a web-based platform that provides access to a large collection of historical satellite imagery and offers a JavaScript application programming interface (API) for analysis.

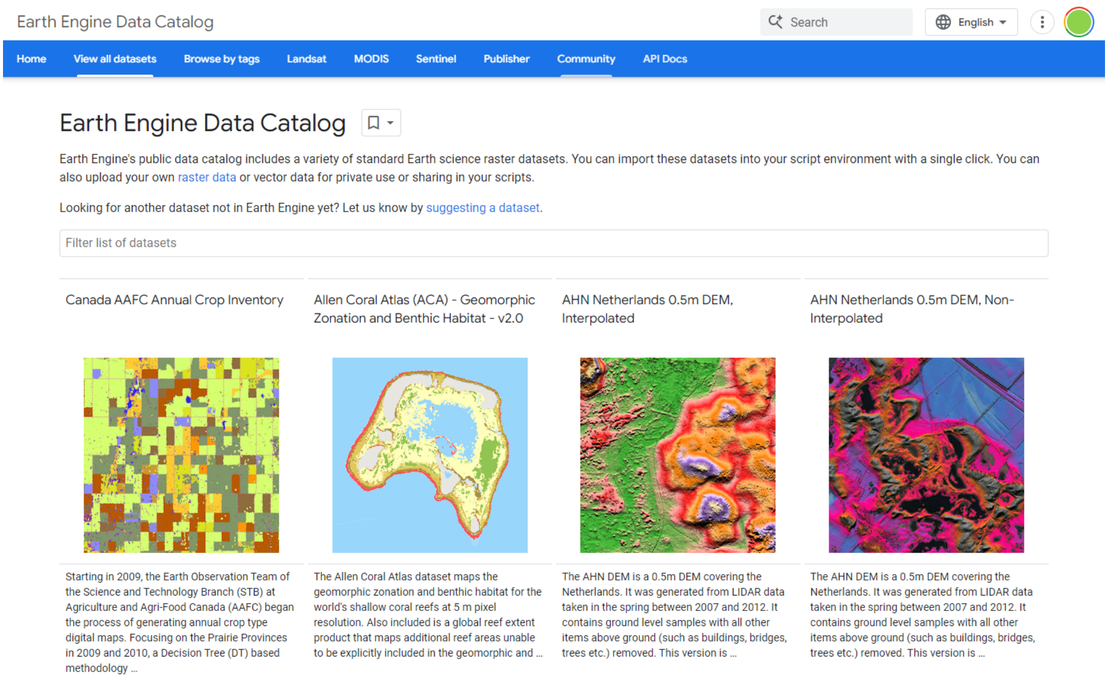


Figure 7 Earth Engine Data Catalog

Key functionalities of Landslider24:

- Landslide Detection: Landslider24 analyses changes in landscapes between user-specified years, primarily focusing on identifying potential landslides.
- Sentinel-2 Data: The tool utilizes data from Sentinel-2 satellites, which provide high-resolution imagery (10 m) suitable for detailed land cover analysis.

In principle, Landslider24 is a specialized tool built within the Google Earth Engine environment (Figure 8). It capitalizes on GEE's extensive data resources and user-friendly coding platform to automate landslide detection through analysis of satellite imagery.

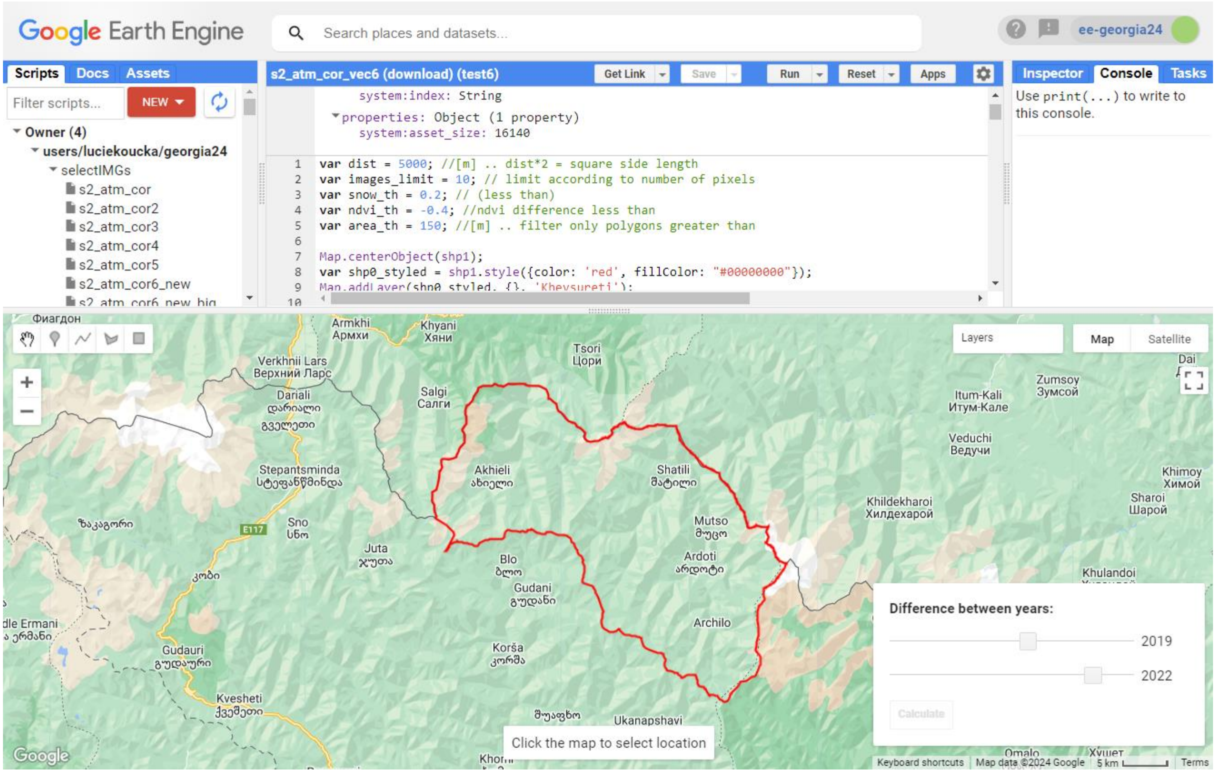


Figure 8 Landslider24 tool shown in GEE environment

2.3 Application workflow

The Landslider24 tool is designed to identify differences between two Sentinel-2 images taken at different times (years). A crucial step is selecting the most suitable satellite image for each year to analyse. The image selection process is executed through the following steps (Figure 9):

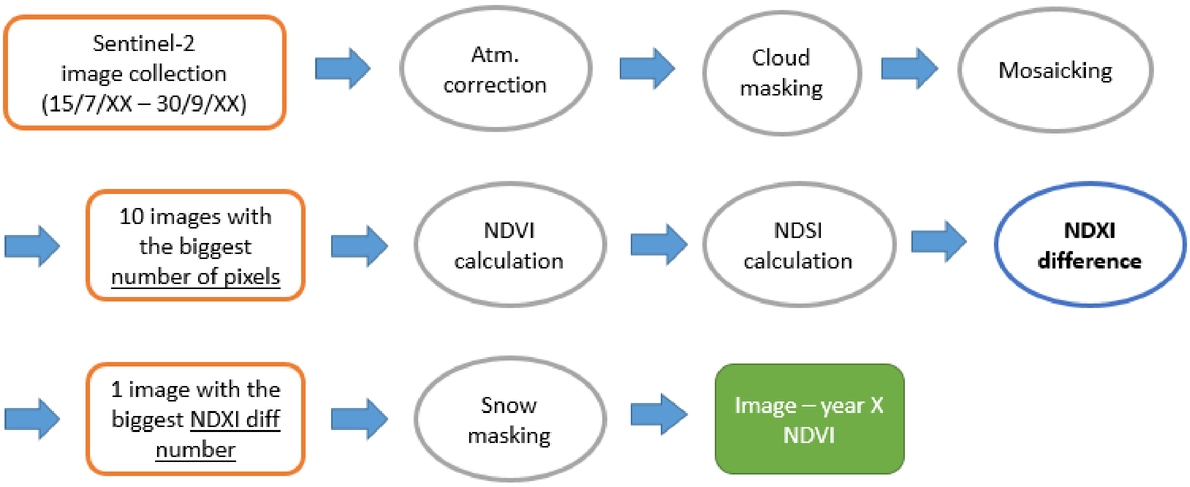
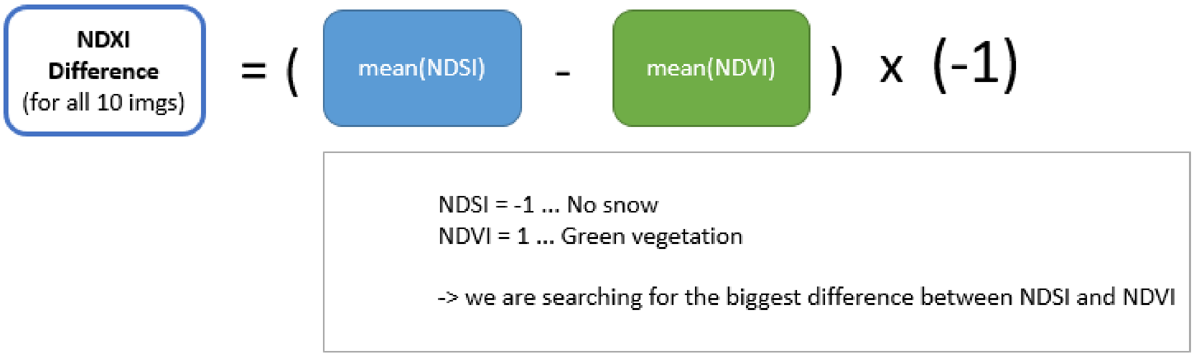


Figure 9 Application workflow

where the NDXI difference is calculated using the following equation:



After selecting two Sentinel-2 satellite images from user-specified years, vegetation analysis using the Normalized Difference Vegetation Index (NDVI) is conducted for both images. This difference raster is then thresholded at a value of -0.4 to identify potential landslide areas, which are characterized by significant changes in vegetation (Figure 10). To enhance data clarity, detected polygons smaller than 100 m^2 (equivalent to one Sentinel-2 pixel) are removed.

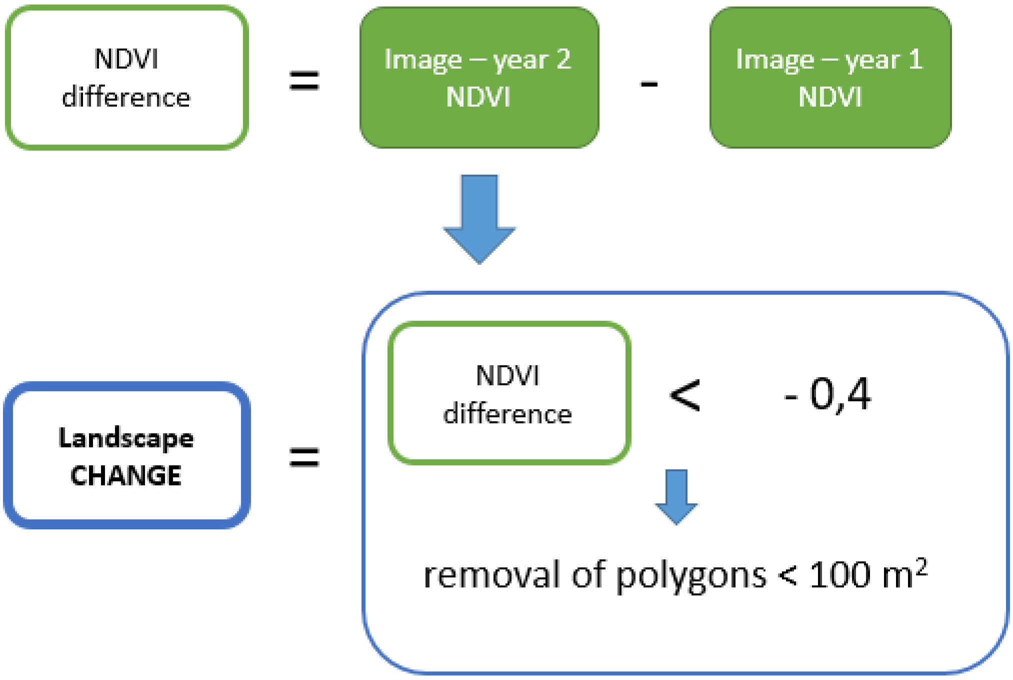


Figure 10 Change detection workflow

3. Landslider24 – use in practice

3.1 Application layout

Open the web application using this link (recommended for use with Google Chrome):

https://ee-georgia24.projects.earthengine.app/view/landslider24.

Once opened, you will see the main interface with tools to begin your analysis (Figure 11).

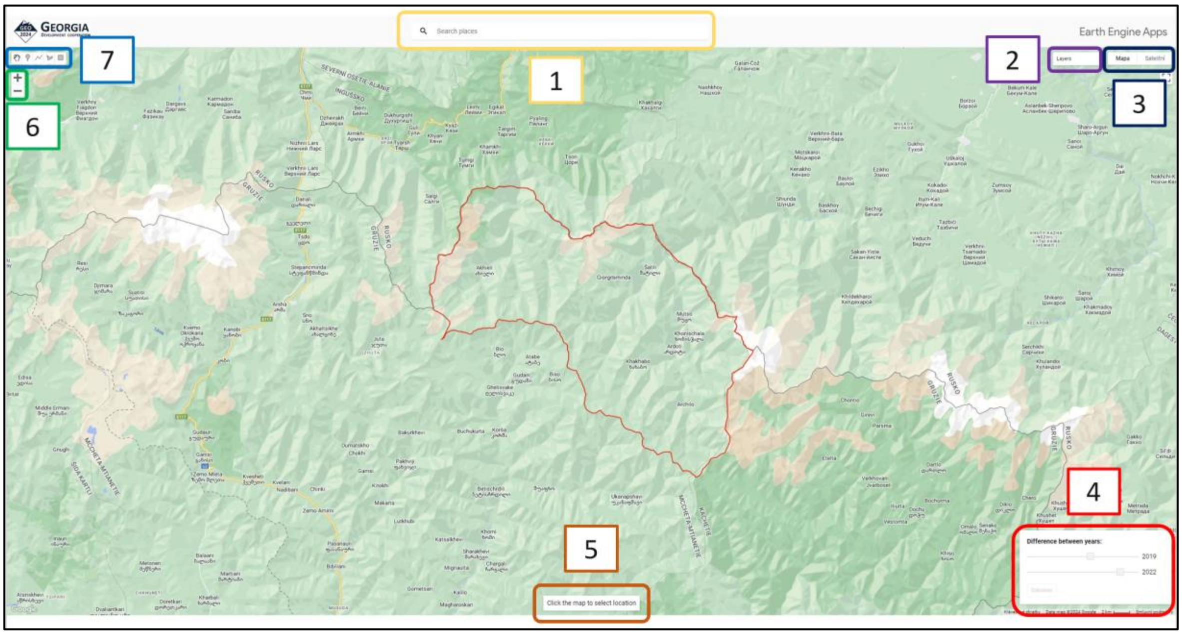


Figure 11 - Landslider24 interface

1. Using search engine to find areas
2. Layers manager
3. Types of maps
4. Landslides period
5. Selecting the location for the landslide
6. Zoom in and zoom out
7. Crate your own shapes on the map

3.2 User guide

3.2.1 Setup for landslides calculation

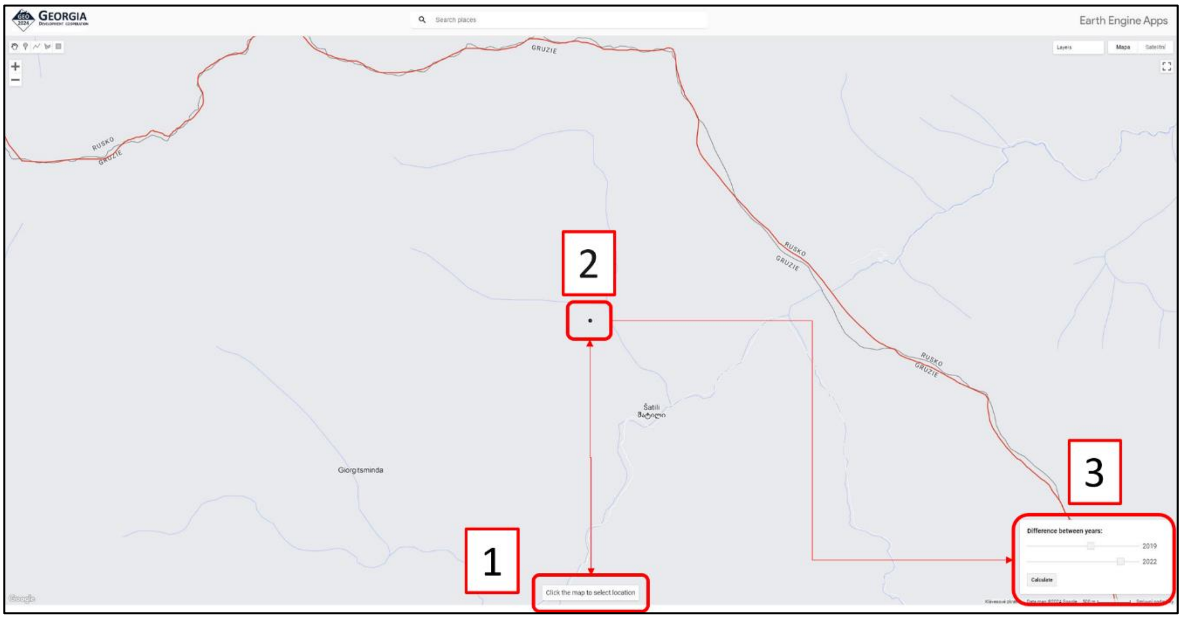


Figure 12 - Choosing the area of interest

Zoom in wherever you want calculate landslides and click the map to select the location (Figure 12). After initiating a landslide calculation, a box will appear on the map to highlight the area you've selected. The area is default set on 10 × 10 km (Figure 13). Set the difference between years for the calculation of the landslides. Once the parameters are set, click "Calculate" to start the landslide calculation.

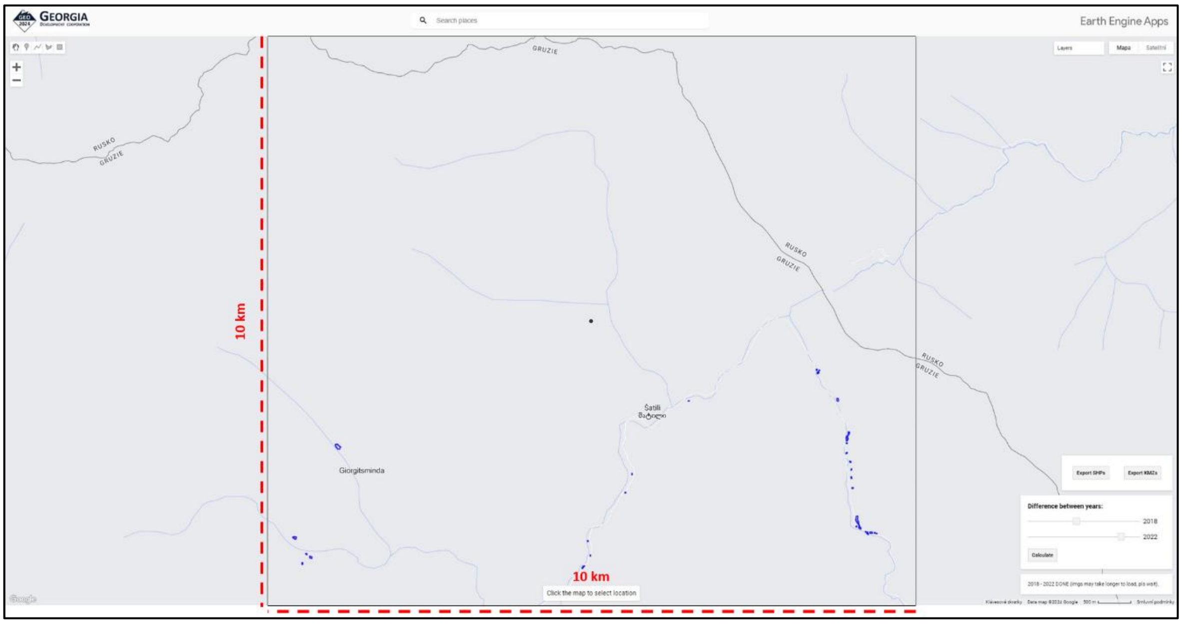


Figure 13 - Area of interest

There is also a layers manager that allows you to show and hide layers in the project for easier control of the Landslider24 tool (Figure 14).

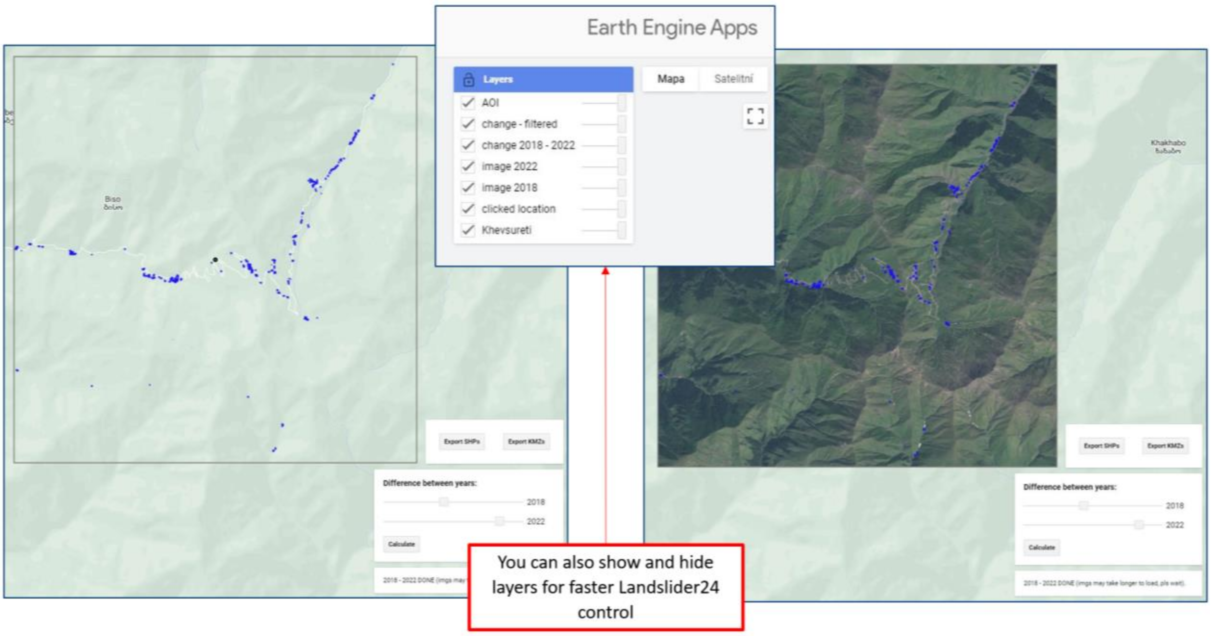


Figure 14 - Layers Manager

3.2.2 Result exporting

Landslider24 allows to export resulting layers in either SHP or KMZ file format (Figure 15).

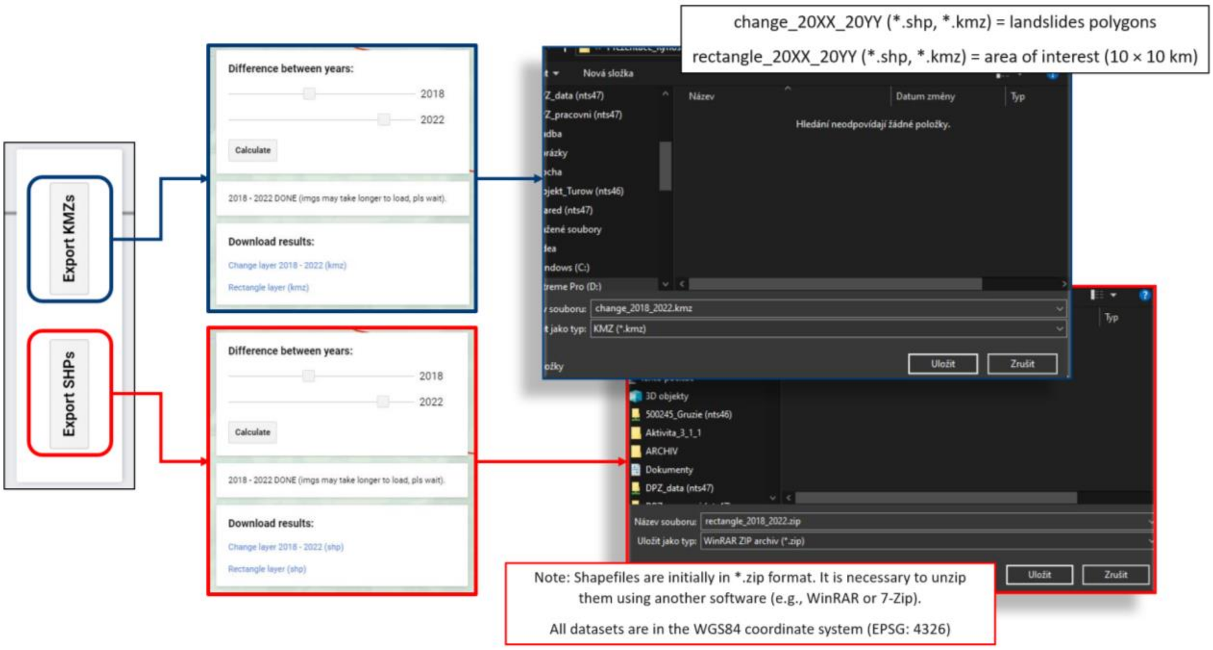


Figure 15 - Export Settings for Landslide Files

3.2.3 Additional functions of Landslider24

Landslider24 also provides a basemap manager (Figure 16) that allows users to switch between terrain, satellite, and Google street map.

Figure 16 - Basemaps manager

To simplify location search, Landslider24 includes a search engine (Figure 17) that allows users to find locations using geonames or addresses.

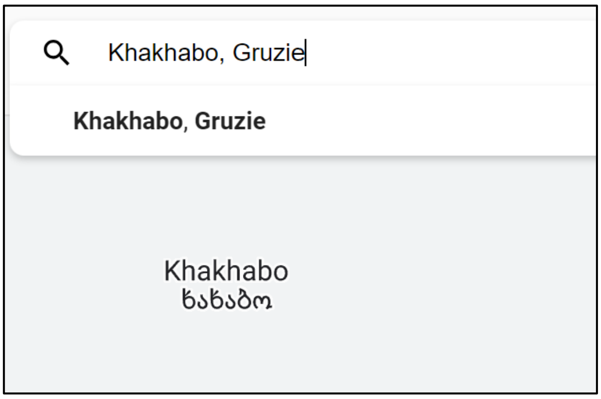


Figure 17 - Searching locations in Landslider24

You can add or highlight specific points, lines, or polygons by creating geometries in the tool (Figure 18). In the menu, select the Create point (or line, polygon, rectangle) feature to add points, lines, or polygons. Use the drawing tools on the map to highlight specific areas of interest or to segment regions for analysis.

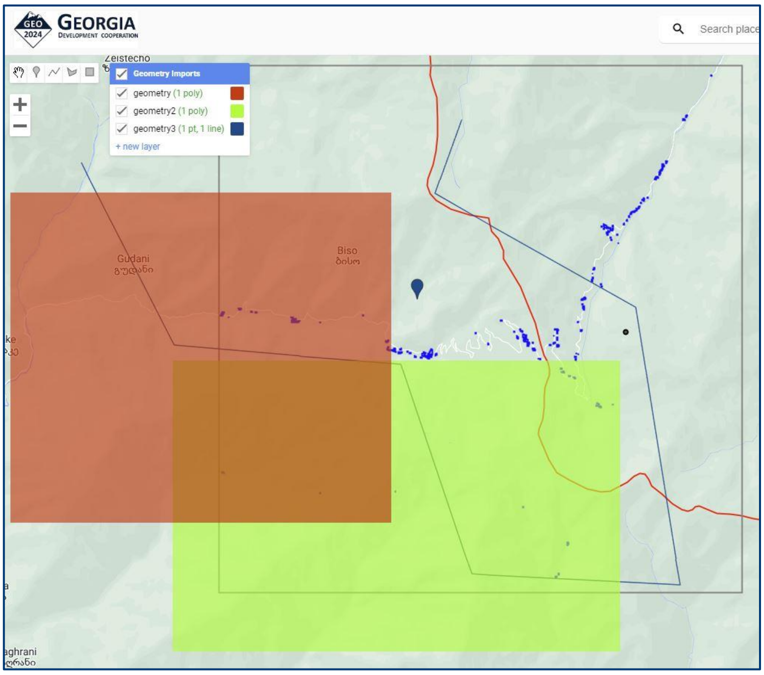


Figure 18 - Creating our own geometry

3.3 Visualizing in supporting GIS software (QGIS)

The results exported from Landslider24 in SHP format, allowing visualization and analysis in compatible GIS software (Figure 19). One of the most popular open-source GIS tools for this purpose is QGIS (https://www.qgis.org/).

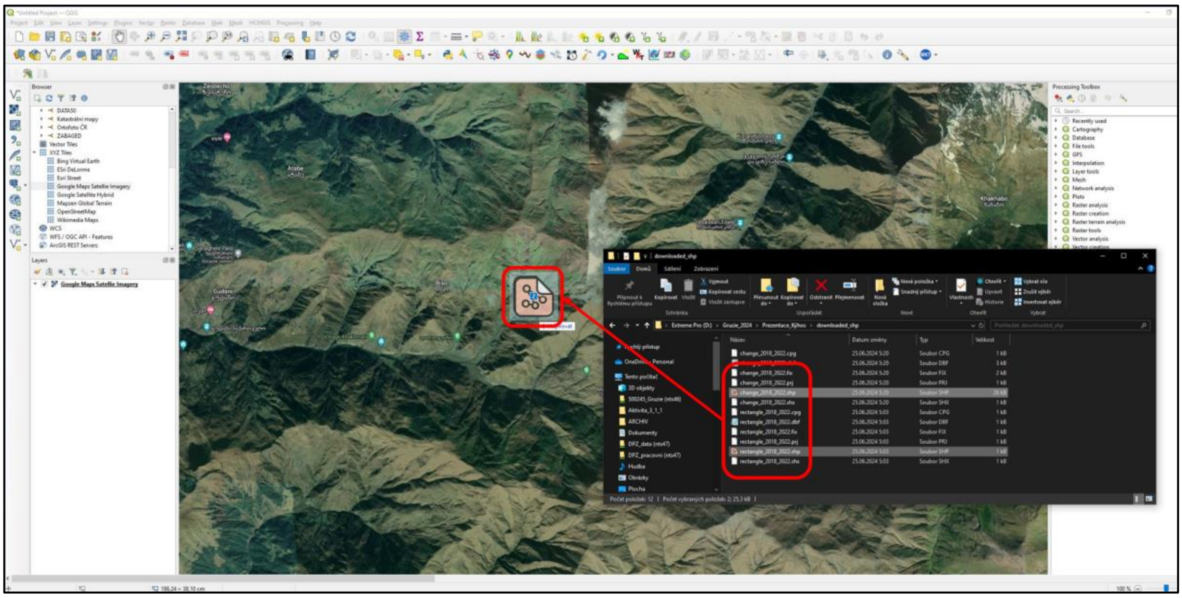


Figure 19 - Drag and drop SHP files in the supporting GIS software (in this case QGIS)

GIS software allows users to create custom symbology for layers, enabling SHP files to be visualized according to user preferences and prepared for the further analysis (Figure 20).

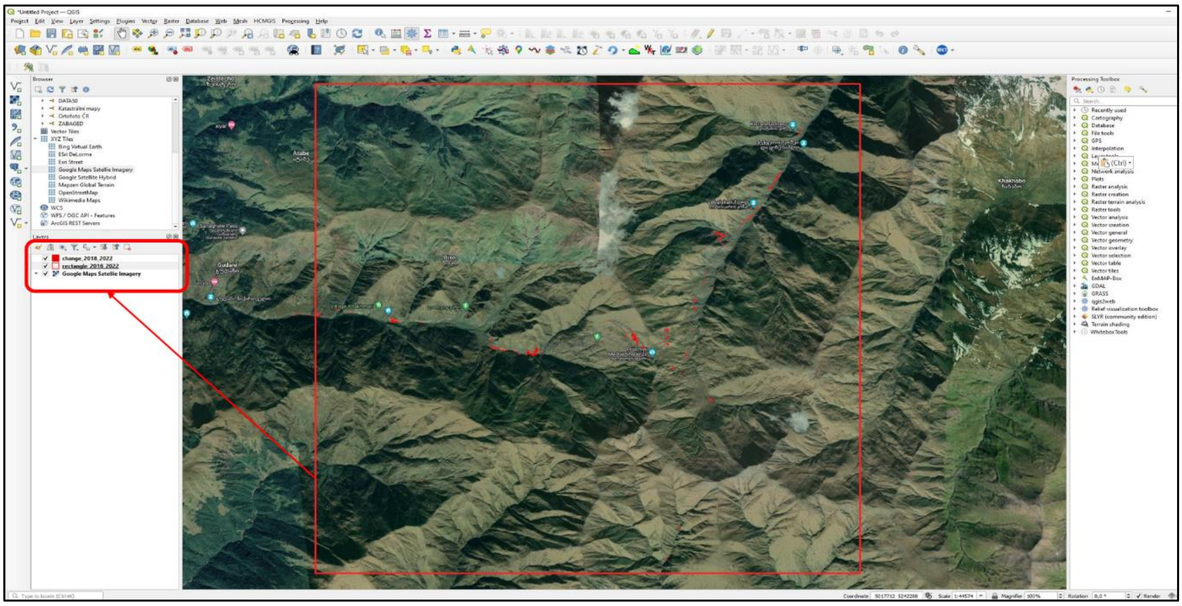


Figure 20 - Visualizing Landslider24 Results in QGIS

The KML files are created predominantly for the Google Earth Pro software (Figure 21) by Google, Inc. This software is also free available to download and use (https://www.google.com/intl/en/earth/index.html), even as an online platform (https://earth.google.com/web), so there is no need to download the desktop application.

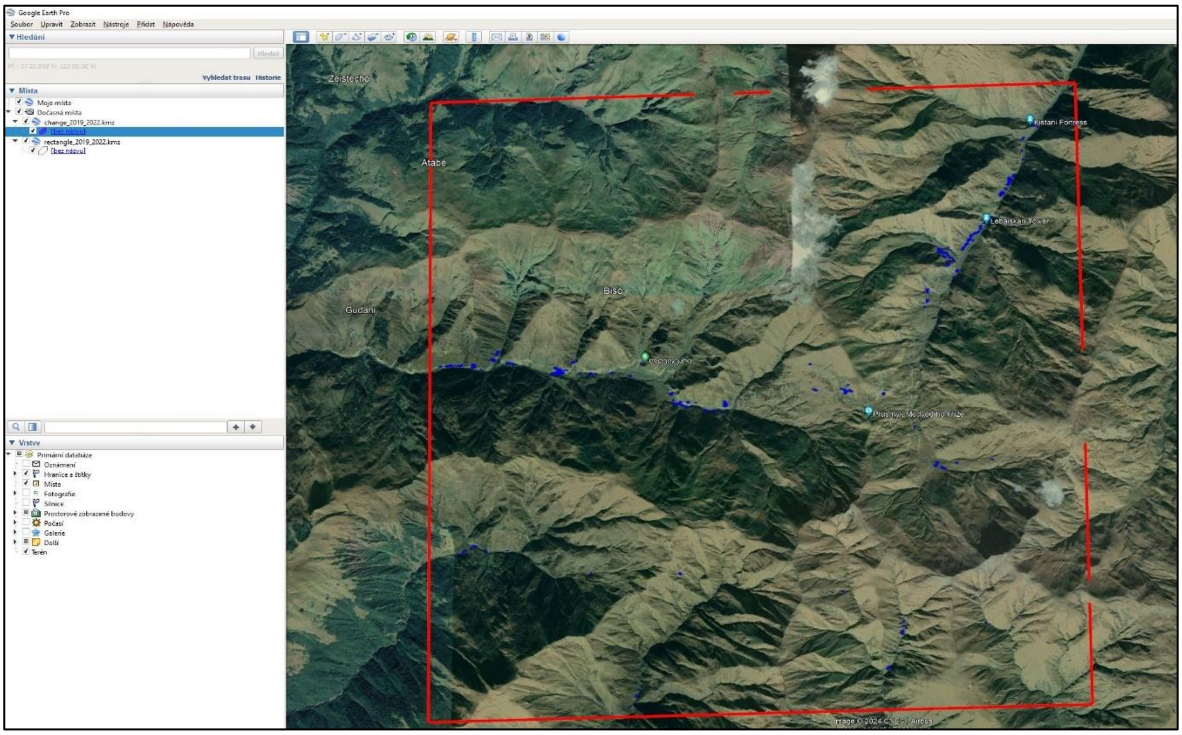


Figure 21 - KML Files Opened in Desktop Application Google Earth Pro

3.4 Case studies

To demonstrate phenomena which might be observed within the results of the Landslider24 tool, four different cases were selected.

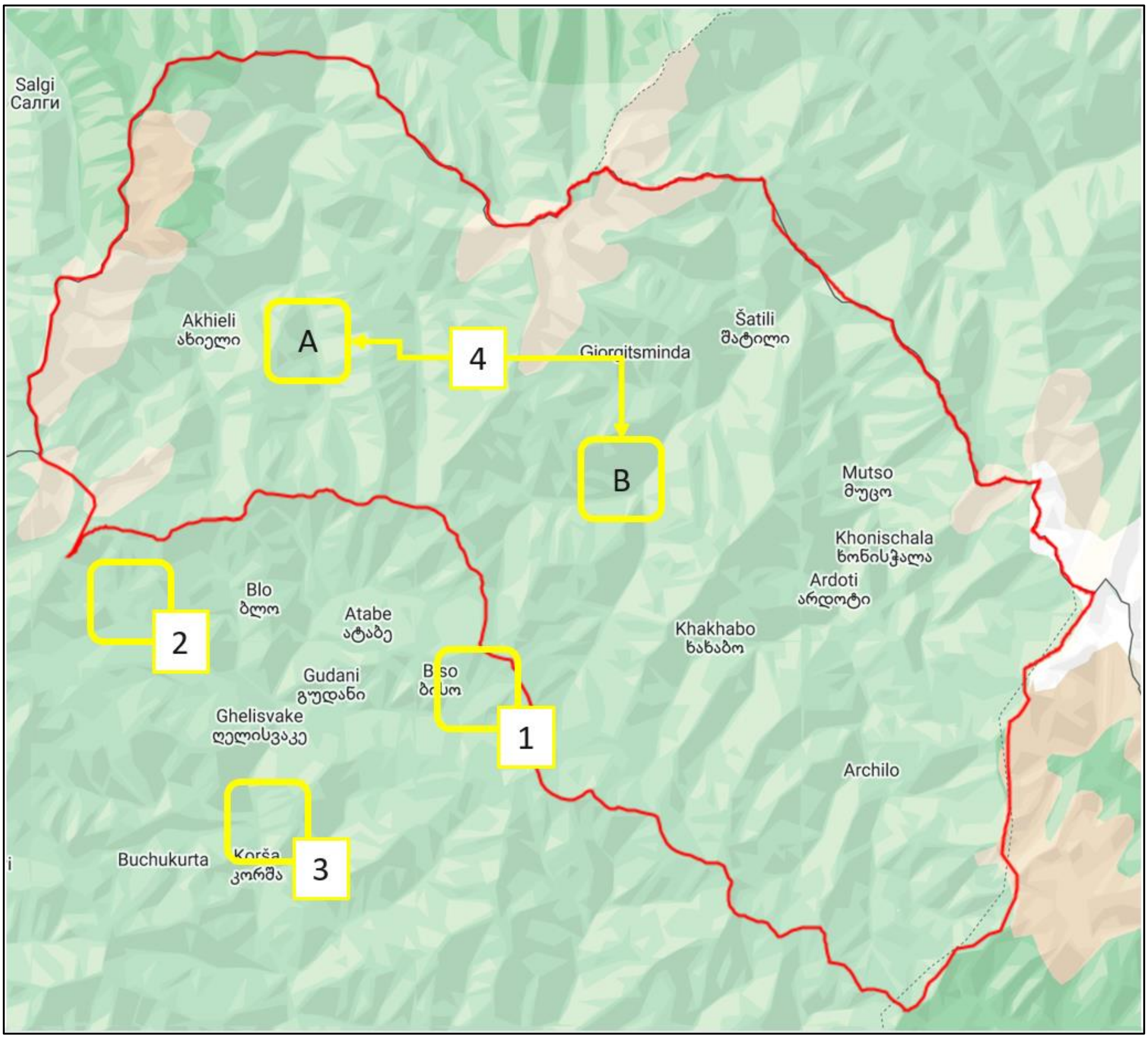


Figure 22 Location of four examples of case studies

The first example (Figure 23) of changes tracked within the timeseries of optical data are the landslides along the road, some of which being induced by the road construction itself and some being just construction remnants.

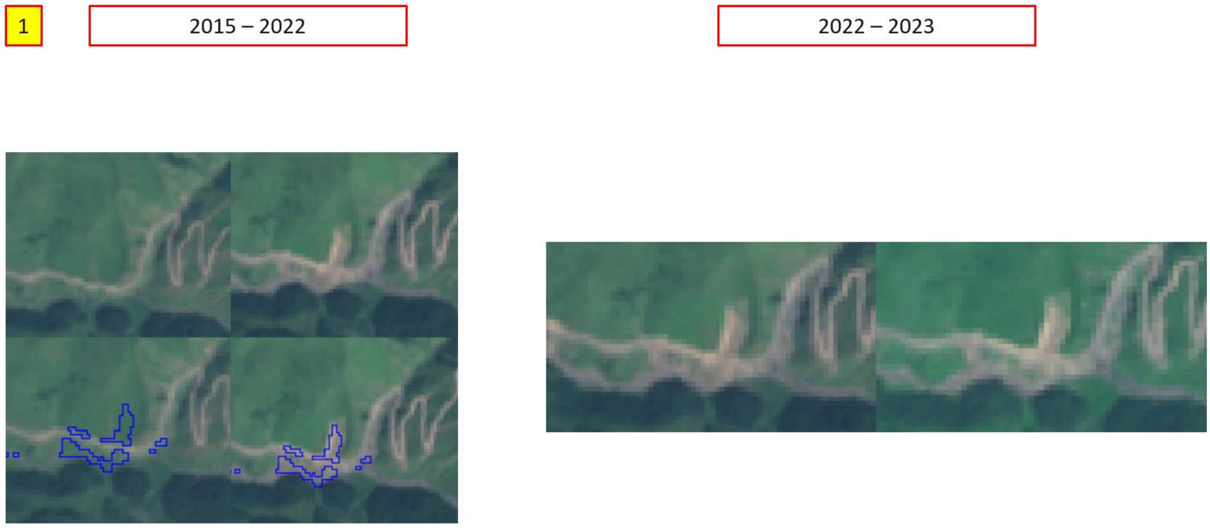


Figure 23 First case study

The second case study (Figure 24) represents the case of a wholly new road construction which then appears as a continuous linear change within the results.

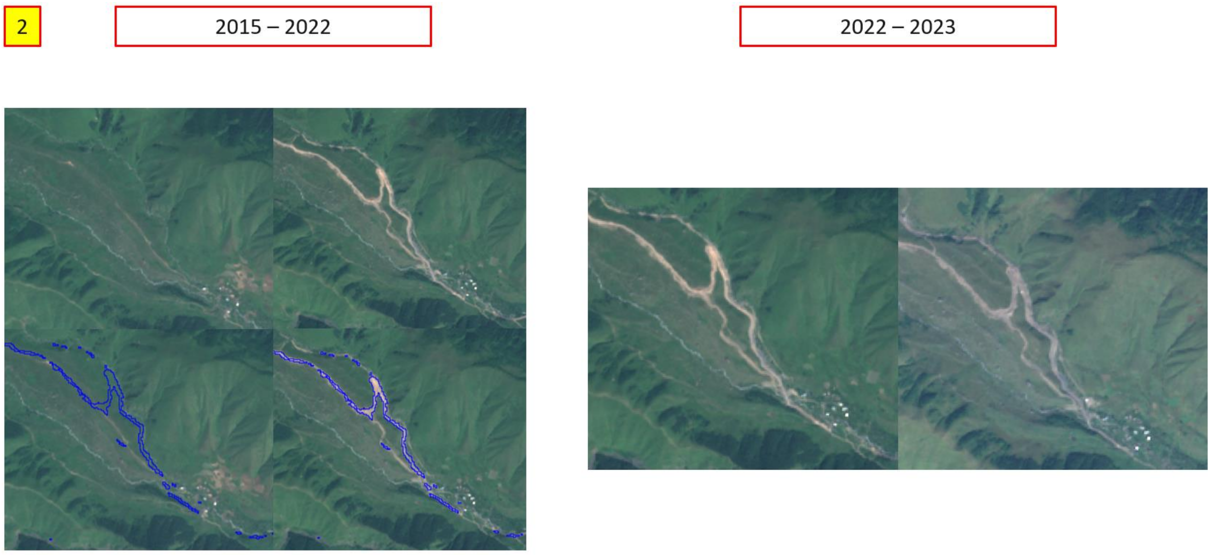


Figure 24 Second case study

The third case study (Figure 25) represents the large group of changes caused by the fluvial processes, either slow, regular ones or those being caused by floods. Usually within the mountainous areas, river streams tend to relocate the actual position of the water flow. Floods on the other hand can cause wider changes among the nearby vegetation cover. Both changes can be present within the results from the Landslider24.

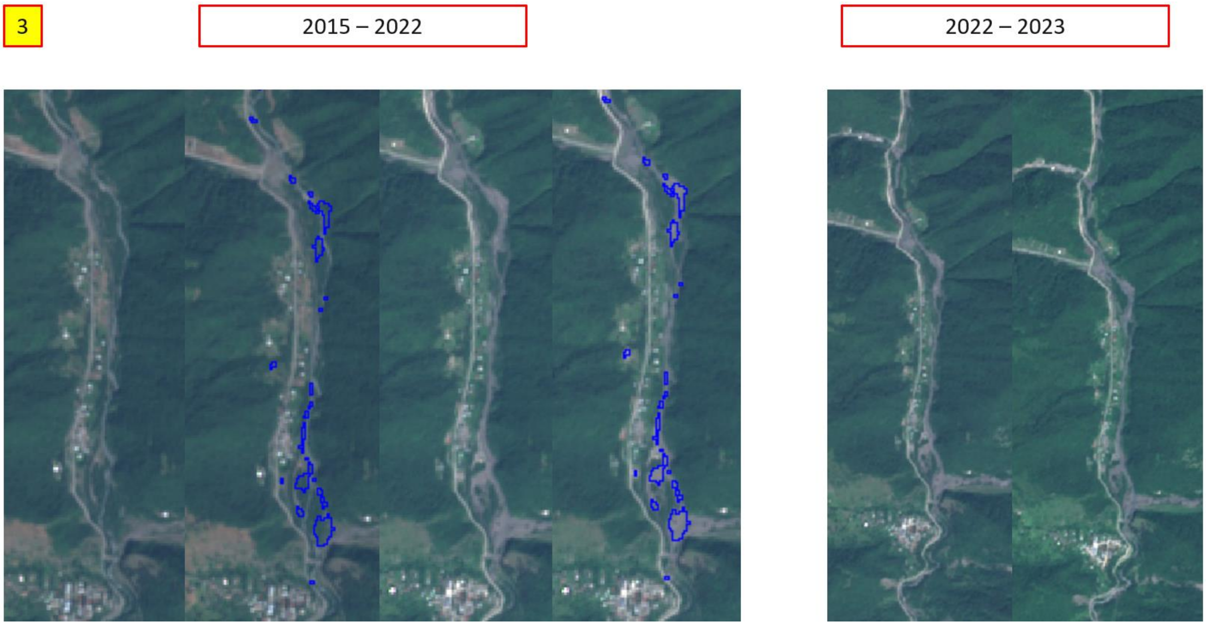


Figure 25 Third case study

The fourth case study represents natural slope movements which were not directly induced by human activity. Case study 4A (Figure 26) represents rather rock avalanche, while the 4B (Figure 27) case study represents more typical landslide.

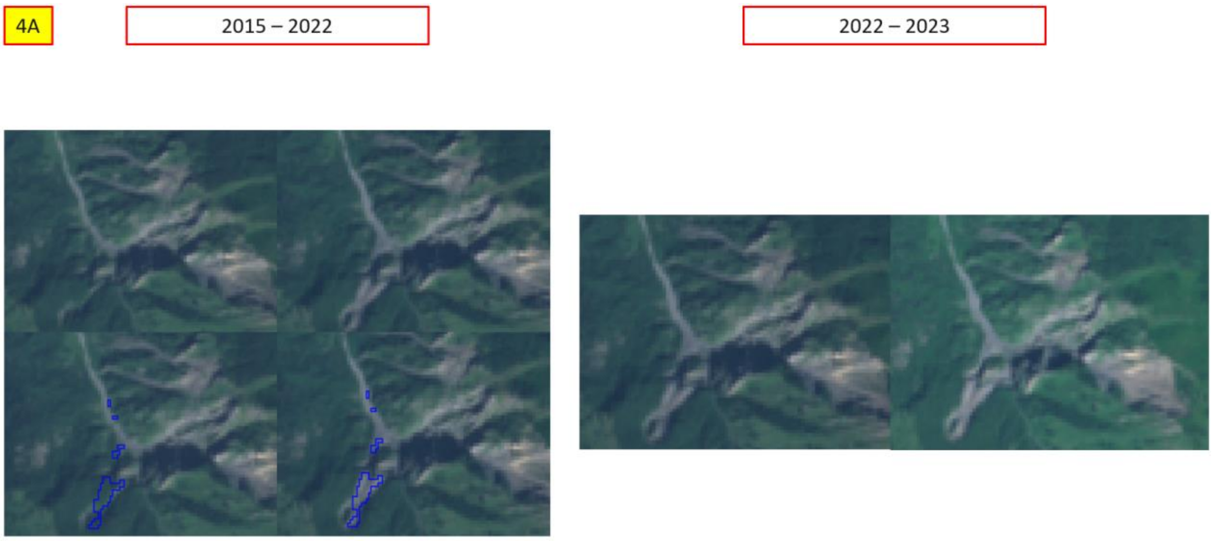


Figure 26 Fourth case study first scenario

Figure 27 Fourth case study second scenario