

Monitoring Tanzania's Forests with Satellite Imagery

July 27, 2020

By: Theron Morgan-Brown

Email: theronmb@gmail.com

Introduction

This manual describes a simple process for monitoring changes in forest cover using freely available satellite imagery. Rather than classifying satellite imagery, which usually involves downloading large files and complicated imagery processing steps, this approach relies on hand-digitizing changes in forest cover from direct observation by comparing satellite imagery from different dates. This approach relies on the human eye to quickly distinguish between real land-cover change and other differences like clouds, shadows, haze, and seasonal changes in vegetation appearance. All that is required is the freely available QGIS program, basic GIS skills, and a working knowledge of satellite image interpretation.

Accessing imagery

1. If you do not already have one, create a gmail account at <https://accounts.google.com/Signup>.
2. Fill out a request for satellite image coverage specifying the area of interest and the time frame and submit to MJUMITA/TFCG at https://docs.google.com/forms/d/e/1FAIpQLSei_fl_N9XUaGEX7oGFrtZMvy8AGVzQNGmk6WfqwsvnKkB3Ww/viewform?vc=0&c=0&w=1&usp=mail_form_link. Remember that a kml file of the forest(s) of interest can be created from a shapefile using the export option from QGIS.
3. Receive the XYZ connections xml file by email.
4. Load the XYZ connections in QGIS by opening the browser panel (found under the panel options in the View drop down menu) and right clicking on the XYZ Tiles Icon. Select "Load Connections" and then select the XYZ connections xml file sent by email. This only needs to be done once. After that, the image connections will always be available under the XYZ tiles list in the QGIS Browser.
5. If not already loaded, also load the XYZ connections xml file for Google Earth and Bing Satellite imagery which will also be provided by email.

Digitizing non-forest and deforestation

1. Load the shapefile for the area of interest (e.g. Forest Reserve Boundary). Set the style to line only and set the line color to something like a bright green color.
2. Zoom to the area of interest in QGIS by right clicking on the shapefile in the layers panel and selecting Zoom to Layer.

3. Load the XYZ tiles into the layers panel by shift selecting all the desired connections and then right click and selecting Add selected Layers to Canvas.
4. Create a new polygon shapefile to store the non-forest area polygons. Include an whole number field called year with a length of 4, also optionally include a text field for notes and for land-cover class.
5. Turn on snapping to Vertex and Segment for All Layers. Set the snapping tolerance to 12 px.
6. Turn on editing of the new Shapefile Layer and start digitizing the non-forest areas in the oldest imagery provided. Make sure to include the correct year of the image in the year field for non-forest polygons.
7. Once finished digitizing all non-forest areas in the oldest image, move on to the next and again remember to record the year for each new non-forest polygon. After digitizing all of the non-forest areas in the first year of the analysis, only digitize new non-forest areas for subsequent years.

Digitizing Advice:

- **Know the Tanzania definition of forest** - Read the next section on this manual on defining forest and non-forest carefully.
- **Make use of layer styles to aid interpretation** - When digitizing, have a copy of the non-forest area polygons open with a filled style with no pen and another copy open with a line only style. Have the line only version open for editing to add new non-forest areas and make non-forest areas from past years opaque to make it easier to pick out new areas of non-forest. Optionally use a categorized style to give each years non-forest areas a different fill and line color.
- **Always use snapping** – It is very important that the non-forest polygons from one year do not overlap with the new non-forest polygons in a subsequent year.
- **Use tracing carefully** - Use the tracing feature in the QGIS snapping toolbar to automatically snap non-forest areas to each other and to the boundaries of the forest, but pay close attention to make sure it is working as expected. If the tool does not behave as expected, delete the mis-snapped points and then add them using snapping with tracing turned off.
- **Save frequently** - Save changes the non-forest polygon shapefile frequently to guard against data loss in the event QGIS freezes or computer shuts down
- **Use high resolution imagery to aid interpretation** - Have XYZ connections open to Google Earth and Bing satellite imagery to aid in interpreting lower resolution satellite imagery. However, be aware that the dates of the Google Earth and Bing XYZ connections may be significantly different from the period being digitized.
- **Learn to understand false color imagery** - Compared to natural color imagery, false color Sentinel-2 imagery (Figure 1 and Figure 2) makes it easier to distinguish differences in vegetation. Take time to familiarize yourself with the appearance of different forest and non-forest land-covers in false color imagery by comparing with Google Earth and Bing imagery or areas that you have been to on the ground.
- **Pay attention to texture** - In addition to changes in color, changes in texture can also indicate land-cover change. Generally, non-forest areas will have a smoother appearance than forested areas.
- **Patches of trees less 0.5 ha are not forest.**
- **Use the ring tool for patches greater than 0.5** - For isolated forest patches 0.5 ha or greater, the Add Ring tool in QGIS can be used to create a gap within a non-forest polygon to exclude the forest patch from the polygon.

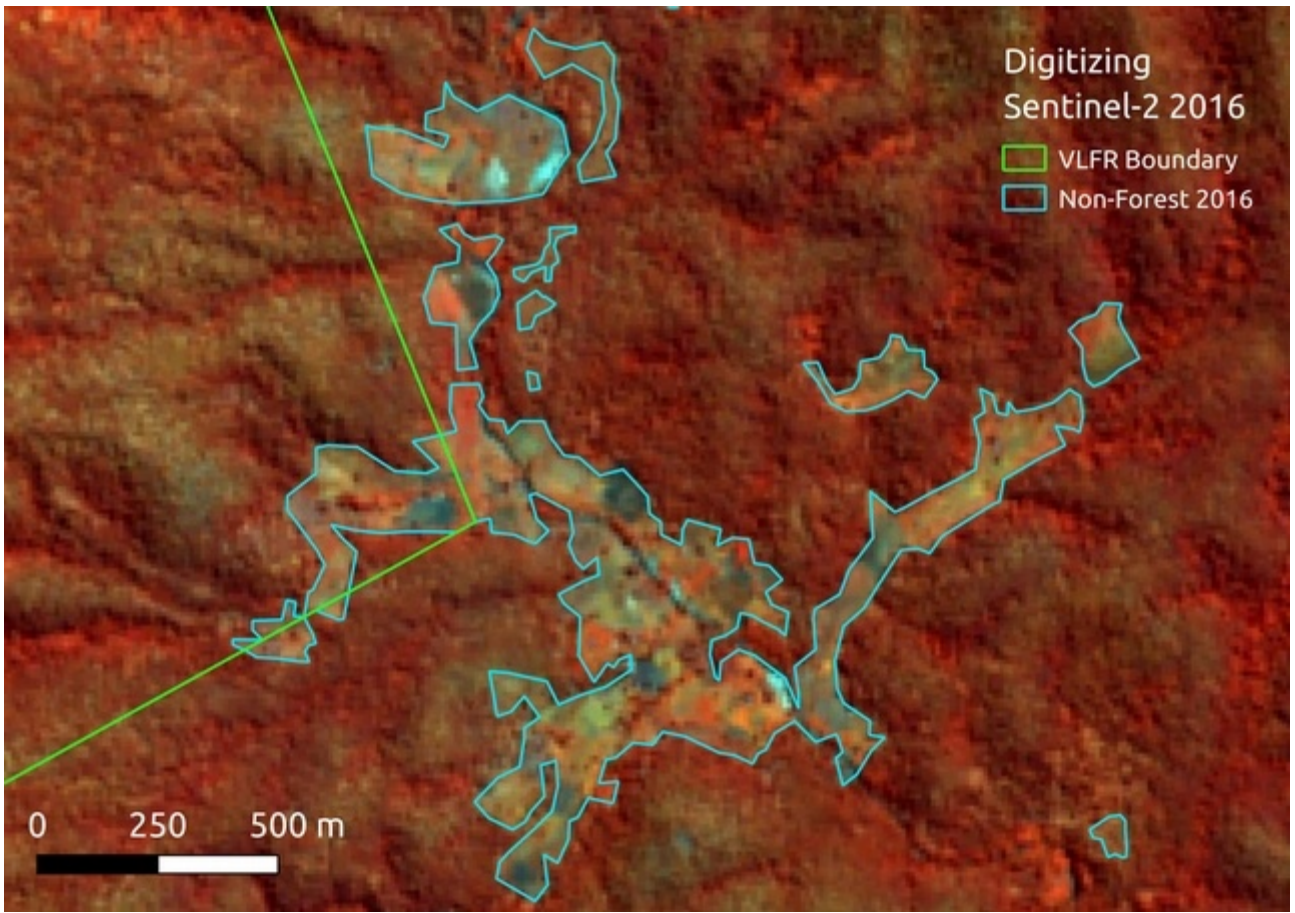


Figure 1: Digitized non-forest areas from May 2016 Sentinel-2 imagery in two village forest reserves in Kilosa District

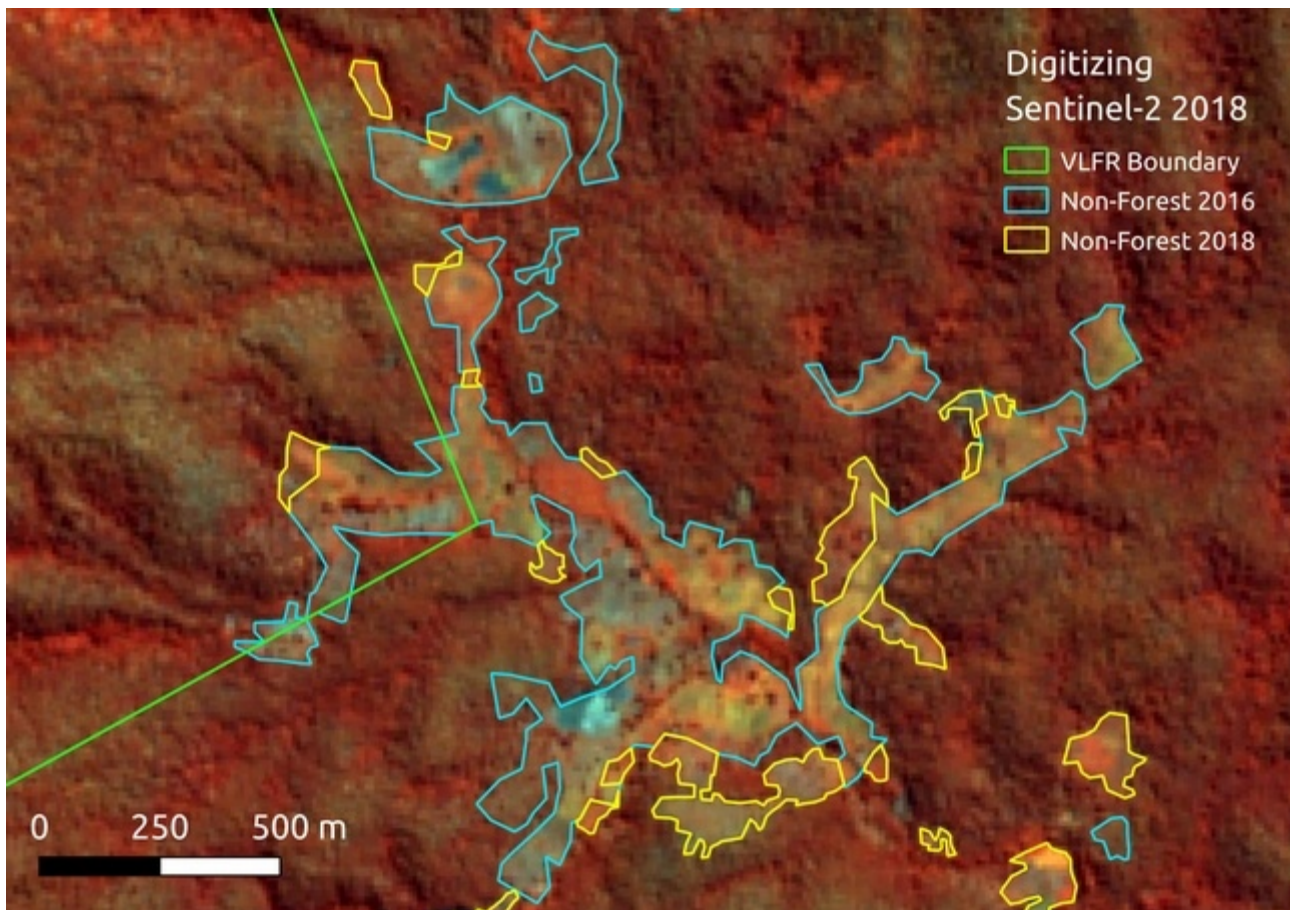


Figure 2: Digitized non-forest areas from May 2016 and May 2018 Sentinel-2 imagery in two villages forest reserves in Kilosa district.

Defining forest

Non-Forest and Deforestation can be tricky to define. Tanzania has provided a definition to the UNFCCC for forests as areas at least 0.5 hectares with trees greater than 3 meters in height with 10% tree canopy cover or more. NAFORMA defines other land as simply all land that is not defined as Forest. Since other lands do not have a strict minimum area for their definition, it is not clear what the minimum size is for areas to be defined as non-forest. In practice, many researchers use a kind of reverse definition to define non-forest areas as areas with less than 10% tree canopy cover and a minimum size of 0.5 ha, which is also about the minimum size of an object that can be mapped reliably with Landsat data, equivalent to about 5 Landsat pixels.


Sentinel-2 resolution is fine enough to pick up on the loss of individual large trees, but mapping all such losses would be extremely time consuming and most forests scientists would define such losses as degradation rather than deforestation. However, it is also difficult to know that an area is greater than 0.5 ha before digitizing it and once digitized, it doesn't make sense to discard a digitized non-forest polygon. It should be noted that mapping smaller clearings should not greatly affect the total detected deforestation compared to methods with larger minimum mapping units. This is because small clearings grow into larger clearings over time and then become detectable

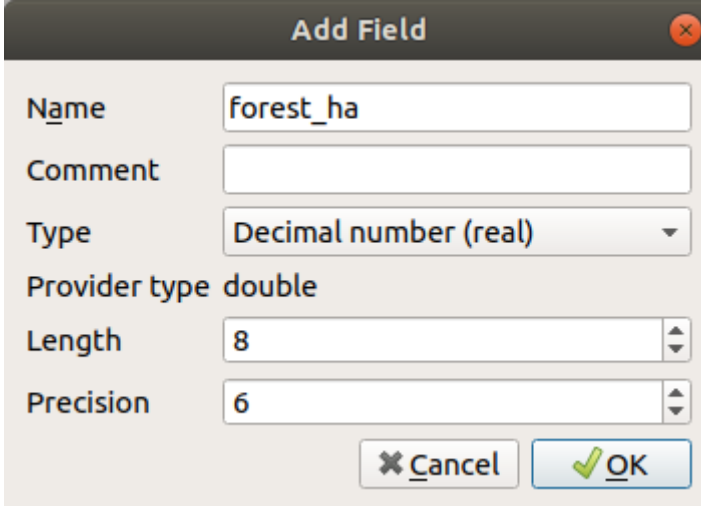
with other approaches. However, mapping small clearings and directing forest patrol teams to those small clearings could help prevent them from growing larger.


Therefore, it is recommended to digitize all clearings of at least 0.25 hectares and above, giving a minimum size of at least 25 Sentinel-2 pixels per polygon. Smaller polygons can still be included, but all clearings 0.25 hectares or greater must be digitized. Some experimentation in Kilosa suggests that clearings 0.25 hectares and above account for 95% of the area cleared in a given year.

Calculating Deforestation Statistics

Starting forest areas

1. The forest area(s) shapefile should have unique names for each unique forest area. However, if the forest area(s) shapefile has multiple polygons for the same forest name, e.g. a village has more than one village forest reserve, then use “Dissolve...” from “Geoprocessing Tools” from the “Vector” menu to create a new dissolved version of the forest areas where the forest name is selected as the dissolve field.
2. Open the dissolved shapefile data table for the forest(s) of interest, turn on editing and click on the “New Field” button . Create a decimal field called ‘forest_ha’ as shown below:



3. Select the new field from the field selector at the top left of the table and enter the formula as shown: 
4. Click on “Update All”. The area in hectares for each forest polygon should appear in the table under the ‘forest_ha’ field.
5. Right click on the dissolved forest area(s) layer and select “Export” and then “Save Feature as...”. Select CSV for the Format and save file with an appropriate name.

Intersect non-forest polygons with forest area polygon(s)

1. From the “Vector” menu, select “Geoprocessing” and then “Intersection...”

2. For the Input Layer, select the digitized non-forest area polygon file. For the Overlay layer, select the forest area(s) polygon file. Choose an appropriate name for the output file and Click Run. If an error occurs, run the fix geometry tool first on one or both layers.
3. Open the new intersection file data table. For each non-forest polygon within a forest area of interest, the name of the forest should now be associated with that polygon. Any non-forest areas outside of forests or interests perhaps drawn by mistake, are no longer in the table.

Add a an area field for the intersected non-forest areas

1. Follow the process described in the start of this section to create a new field called 'clear_ha' in the intersected non-forest area shapefile created in the last step and calculate the hectares for all the polygons in the file.

Create a pivot table with Group Stats

1. Select "Manage and Install Plugins..." from the "Plugins" menu. Search for 'Group Stats'. Select the plugin and click Install Plugin. This only needs to be done once.
2. From the "Vector" menu, select "Group Stats".
3. Select the intersected shapefile from the Layers dropdown list. Then drag the 'year' field to the Columns section and drag the 'name' field to the Rows section. Drag the "clear_ha" field to the Value section and then the sum calculation to the Value section. Click Calculate.
4. A new table should appear to the left with rows for each village and columns for each year. The values for the first year are the total non-forest at the beginning of the analysis and the values for each year after represent the total forest loss from the previous year to that year.
5. From the "Data" menu, select "Save All to CSV File" and give the file an appropriate name.

Calculate Annual Deforestation Rates

1. Open the two CSV files in Excel or similar and sort both by forest name. Copy the "forest_ha" column from the forest areas spreadsheet to the non-forest areas spreadsheet and insert it just after village name.
2. For each year in the analysis, create a column calculating the number of hectares of forest remaining in that year by subtracting that year's and all previous years' non-forest areas from the total forest area.
3. Calculate the deforestation rate for each time period as follows:

Deforestation rates should be calculated as per Puyravaud, 2003:

$$r = \frac{1}{t_2 - t_1} \ln \left(\frac{A_2}{A_1} \right)$$

Where:

- r Annual deforestation rate; %
 t 1, 2, 3 ... T , an analysis year;

A Forest area at time t ; ha
 \ln Natural Log