Quarry Evolution in the Nova Olinda Region, Ceará, Brazil

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ABSTRACT

Quarry growth in the Nova Olinda region is rapid and poorly understood. This study aims to quantify changes in quarry areas due to active quarrying and quarry abandonment/revegetation using Google Earth satellite imagery from 2008 to 2016. Quarries in the region have almost tripled in area over the past eight years, with nearly one square kilometer of new quarry growth.

INTRODUCTION

The Araripe Basin (AB) is located in the northeast of Brazil between the states of Ceará and Pernambuco (Fig. 1). This study focuses on an area of 39 km² in the Araripe Geopark near Nova Olinda (Fig. 2). The Crato and Ipubi Formations of the Araripe Basin are heavily quarried in the Nova Olinda region. The Crato Formation is a laminated limestone deposit that is used for construction and decorative purposes and the Ipubi Formation is a massive gypsum deposit used primarily for the production of concrete. This study aims to estimate the change in area of quarries in the Nova Olinda region from 2008 to 2016. Changes include growth due to active quarrying and creation of rubbish piles and shrinkage from reclamation by vegetation after quarry abandonment, both of which are active processes in the region. This question will be addressed using ArcMap to map quarries visible in current and historical satellite imagery from Google Earth.
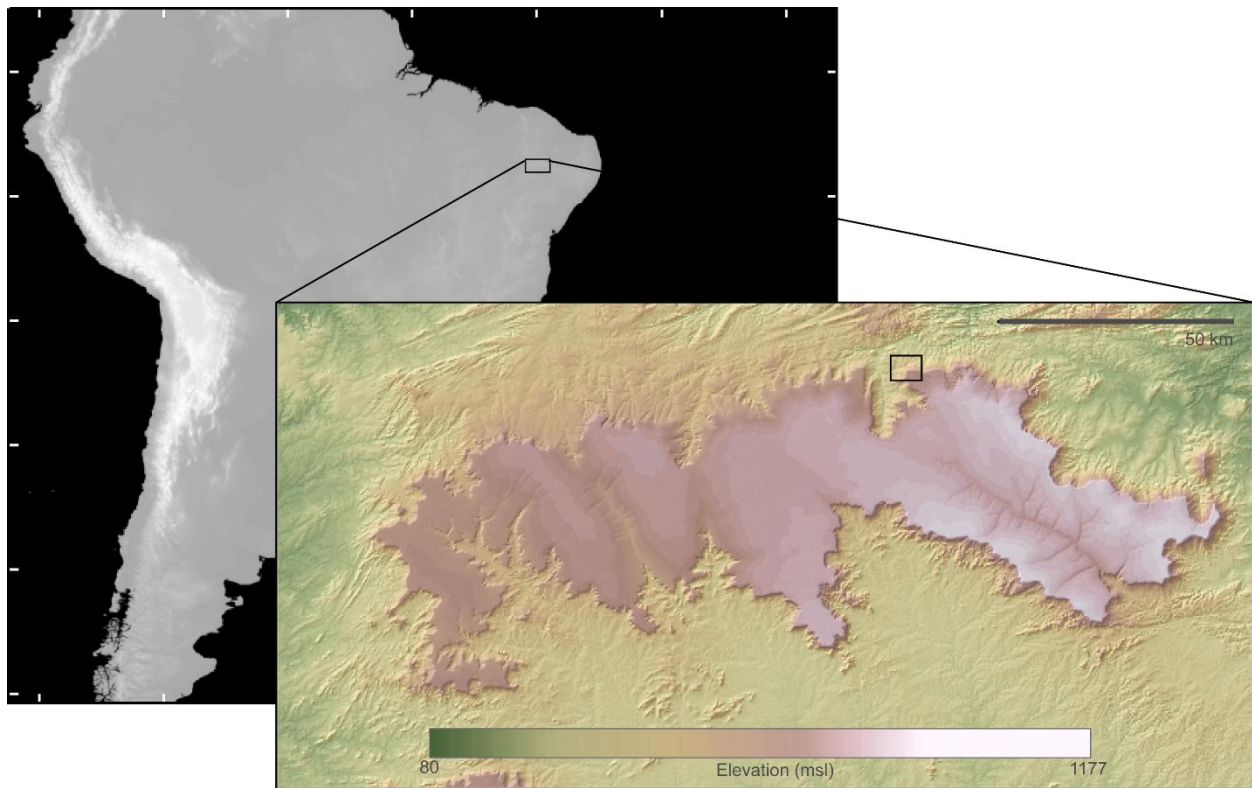

Figure 1. Location of Araripe Basin on the South American continent. Topographic map of AB created using 1-arc second SRTM data. Study area is indicated by the black box on the northern margin of the plateau.

Figure 2. 2016 Google Earth satellite imagery of study region. Yellow box indicates the location of the quarry shown in Figures 5 & 6.

DATA COLLECTION AND PREPROCESSING

All data was stored in a personal geodatabase file that was created before data collection. Georeferenced high resolution images for regions of the study area that had visible quarries during the year of interest were generated using the Image Overlay tool in Google Earth (Fig. 3).
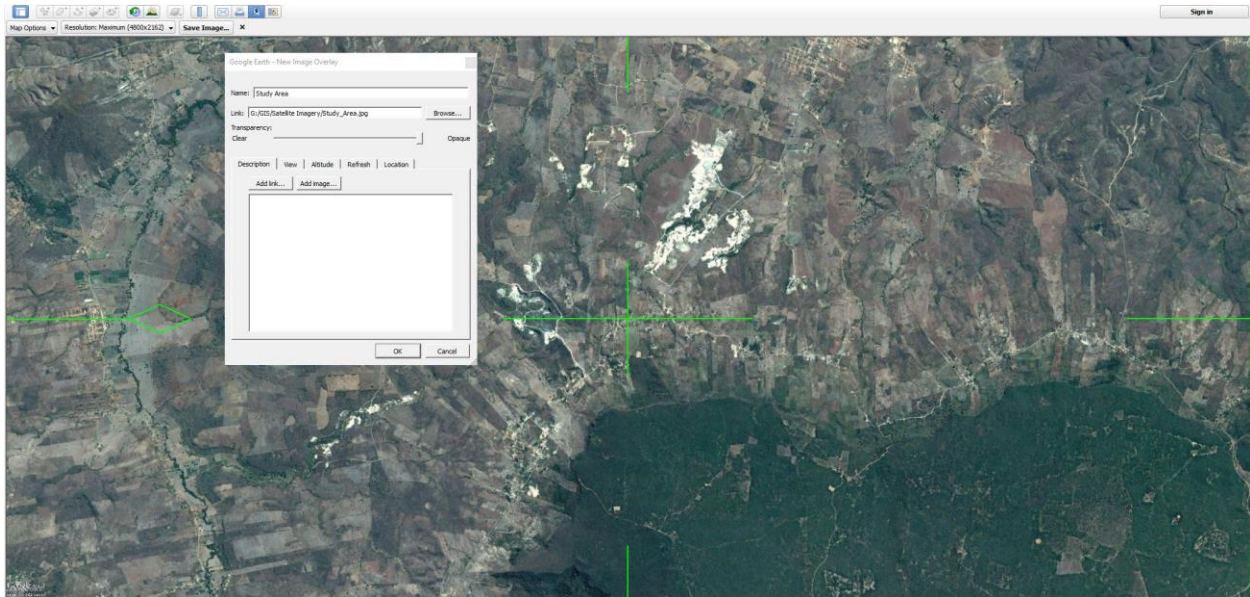
Figure 3. Image overlay tool in Google Earth.

The years 2008 and 2016 were chosen for study because they both had reliable, high resolution satellite imagery available in the study area. These Image Overlays were saved as KML files and converted using the KML to Layer file in ArcCatalog with the "include Ground Overlay" box checked (Fig. 4). Two raster catalogs were created within the database to hold the satellite images. After conversion, the Ground Overlay rasters were added to their respective raster catalogs by dragging and dropping them in ArcCatalog. Twelve images were processed for quarried areas in 2016 and eleven were processed for quarried areas in 2008.
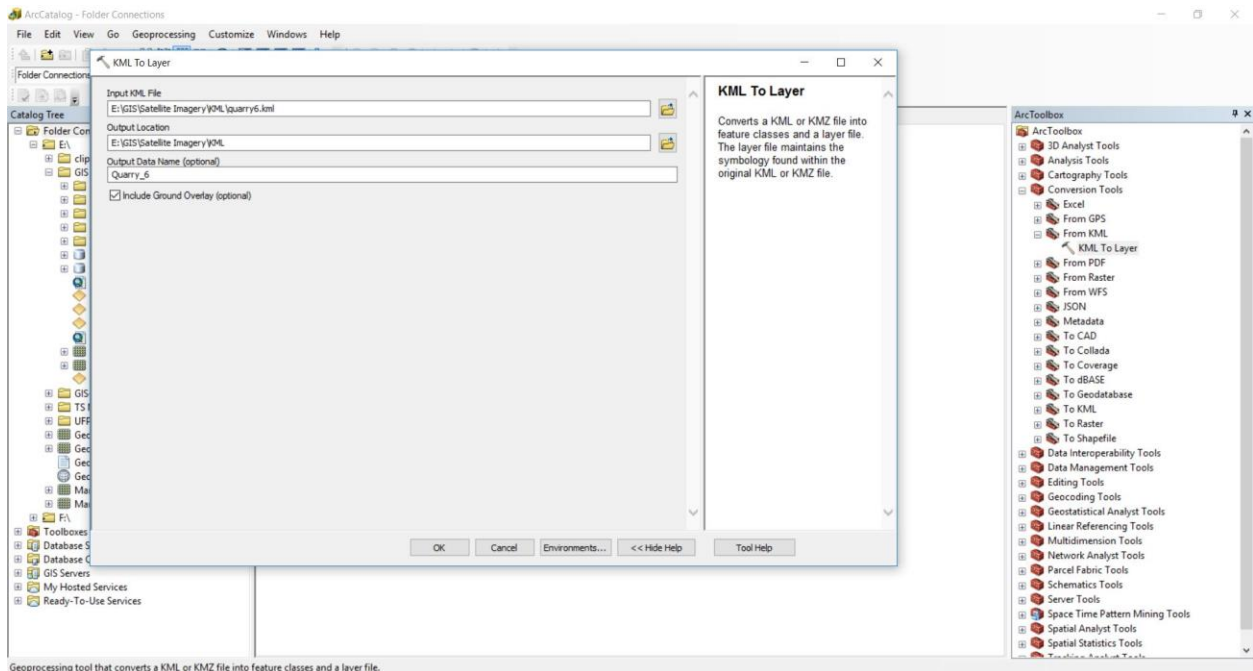

Figure 4. KML to Layer tool in ArcCatalog. Ground Overlay box must be checked as it contains the georeferenced raster.

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A new feature dataset was created in the database to house any feature classes used for the project. A new polygon feature class was created to hold the quarry boundary data. Two fields were added to this feature class, one for the year of image the data was collected from and one for the type of quarry. The Type field will be used to distinguish between stable quarry areas, new quarry growth and quarry abandonment/revegetation.

After the rasters had been converted and the polygon feature class created, the two raster catalogs and the feature class were added to a new ArcMap document. Quarry boundaries were digitized in an editing session using the polygon tool and assigned the proper year to the "Year" field of their attribute table. Although the growth of rubbish piles is an interesting process due to their massive size and tendency to attract vermin, it was impossible to resolve the difference between rubbish and quarried areas on the 2008 satellite imagery, so quarries were mapped in their entirety without accounting for what was rubbish, active quarrying or operations areas (Figs. 5 & 6).

Figure 5. Historical (2008) Google Earth satellite imagery. Quarry area can be resolved but rubbish piles, operations and areas of active quarrying are not obvious. GCS: WGS84.
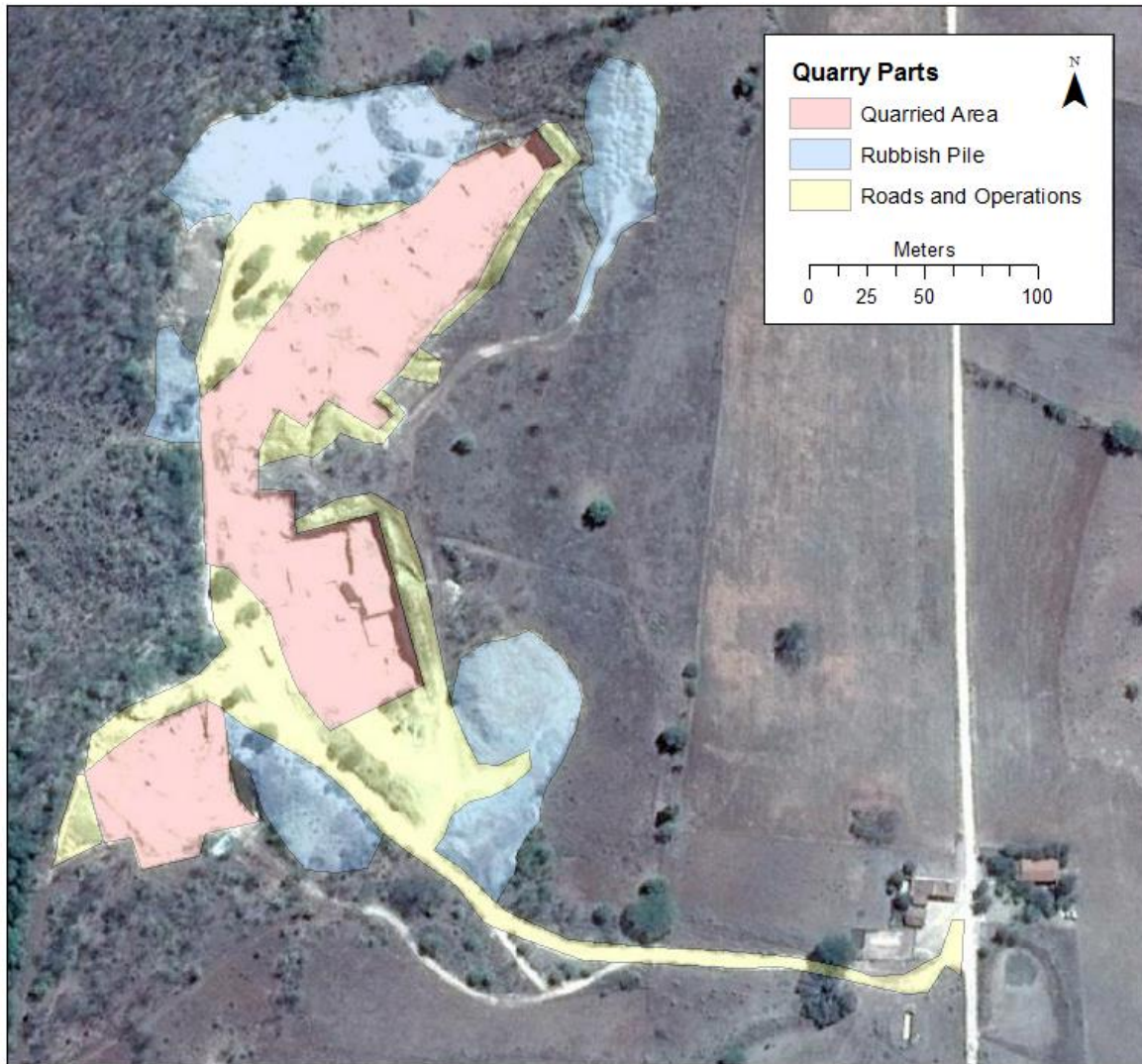
Figure 6. Google Earth 2016 satellite imagery of the same area as Figure 5. Areas of active quarrying, operations and rubbish piles are easily resolved. For simplicity, all of these units were mapped together as a 2016 quarry footprint. GCS: WGS84.

ARCGIS PROCESSING

After data collection and processing, the polygon data needed to be converted to raster data to calculate the overlap between polygons. The data was selected by year and exported as two new feature classes, one for 2008 and one for 2016. These new feature classes were converted to rasters using the Feature to Raster tool with an output cell size of 1.65365131999806E-06 to ensure smoothness along quarry edges (Figs. 7, 8 & 9).
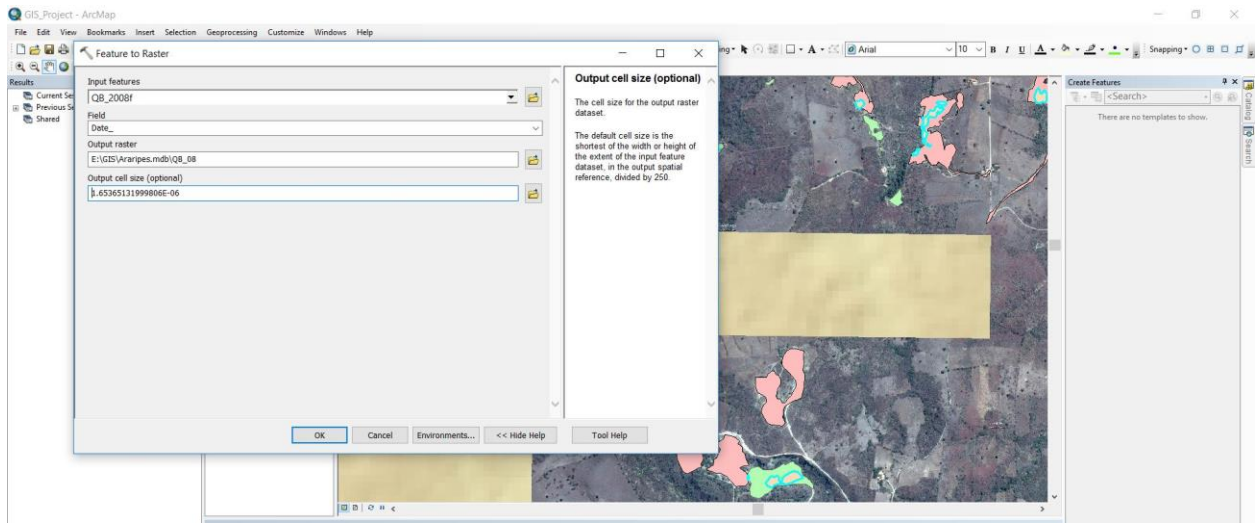
Figure 7. Feature to Raster tool in ArcMap. The small cell size is crucial to ensure smoothness along quarry boundaries.
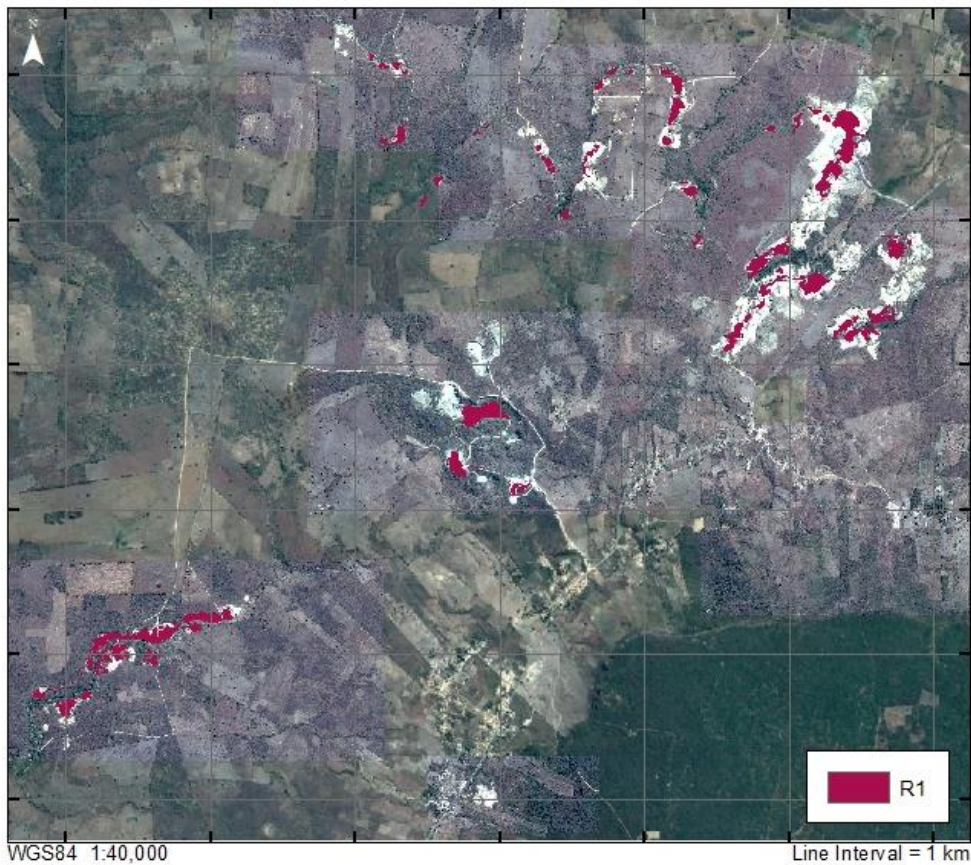

Figure 8. Raster of 2008 quarry footprints (R1) over 2016 Google Earth satellite imagery.

WGS84 1:40,000   Line Interval = 1 km
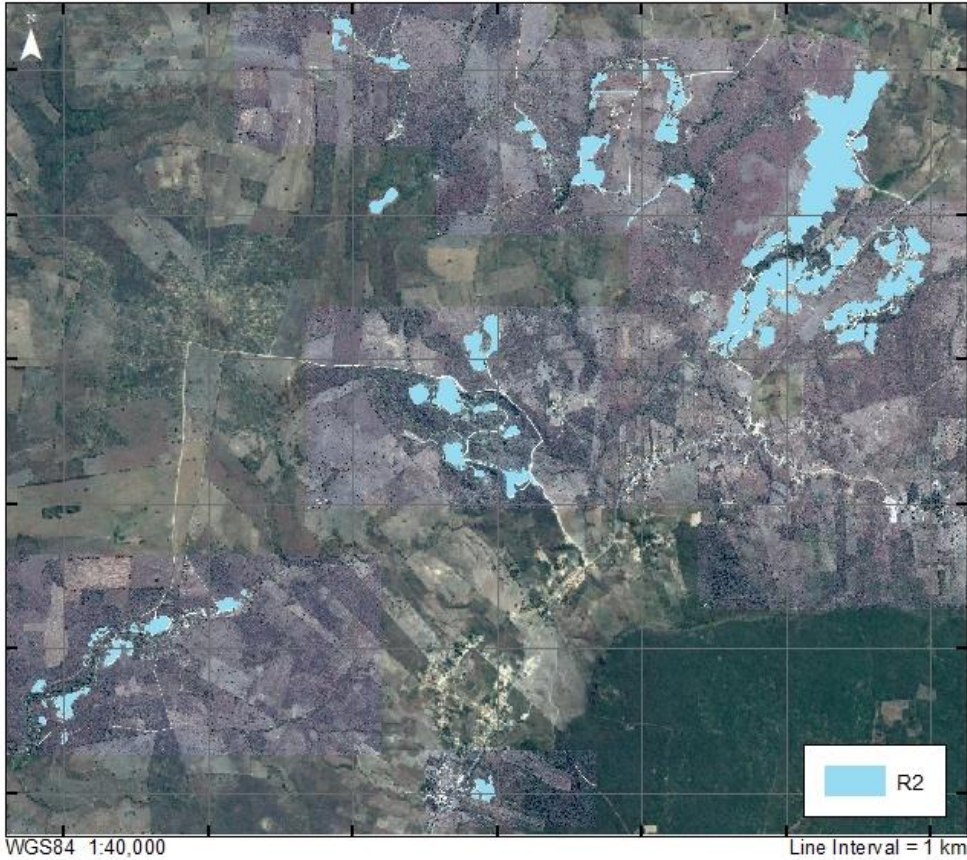
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Figure 9. Raster of 2016 quarry footprints (R2) over 2016 Google Earth satellite imagery.

The Raster Calculator tool was used to create a new raster that showed the intersection between these two rasters (Fig. 10). This intersection area represents quarry areas that have been stable over the past eight years (Fig. 11).
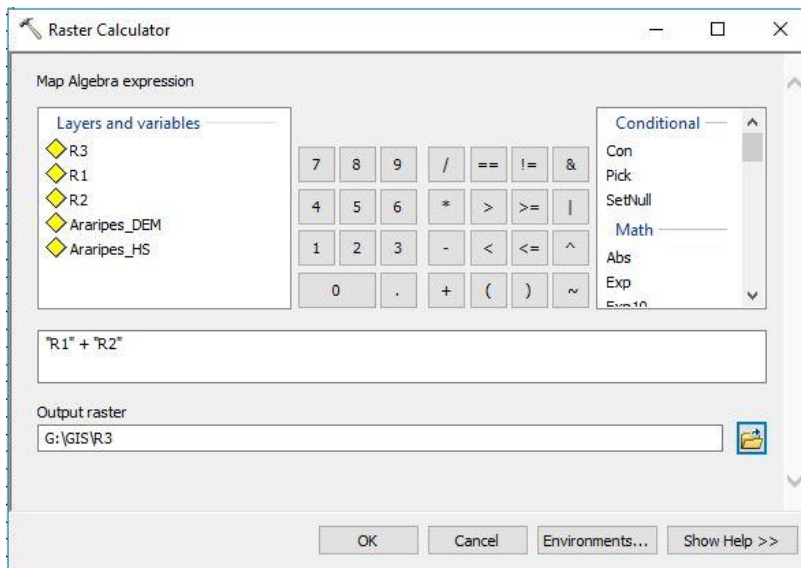

Figure 10. Raster calculator tool in ArcMap with expression used to generate the intersection raster. This raster contains values where the 2008 (R1) and 2016 (R2) satellite imagery overlap.

Figure 11. Raster of the intersection between R1 and R2. These are the areas of quarries that have remained stable over the past eight years.

Anything outside of this area on the 2016 raster represents new quarry growth. Anything outside of this area on the 2008 raster represents reclamation of quarries by vegetation/quarry abandonment. In order to properly calculate these areas, it was necessary to return to working with feature classes, so the intersection raster was converted to a polygon feature class using the Raster to Polygon tool.

There were now three independent polygons to work with, one from each raster. These three features were combined using the Merge tool (Fig. 12). This resulted in a polygon with eight fields. A ninth field was added for the calculation of area of the feature. All areas of intersection were recorded as <null> for the "Year" field. These values were selected from the attribute table and the Clip function was used from the editing toolbar to remove this area from the 2008 and 2016 polygons to prevent errors in area calculations. In the attribute table, the Calculate Geometry function was used to fill in the new Area field for each object. The area calculation was completed in square meters. This calculation was also performed on an Area field created for the individual 2008 and 2016 feature classes as well to understand the total area of these quarries during each year. Three attribute tables were exported in dBase format: one for the 2008 feature class, one for the 2016 feature class and one for the feature class that contained the data for 2008, 2016 and their intersection.
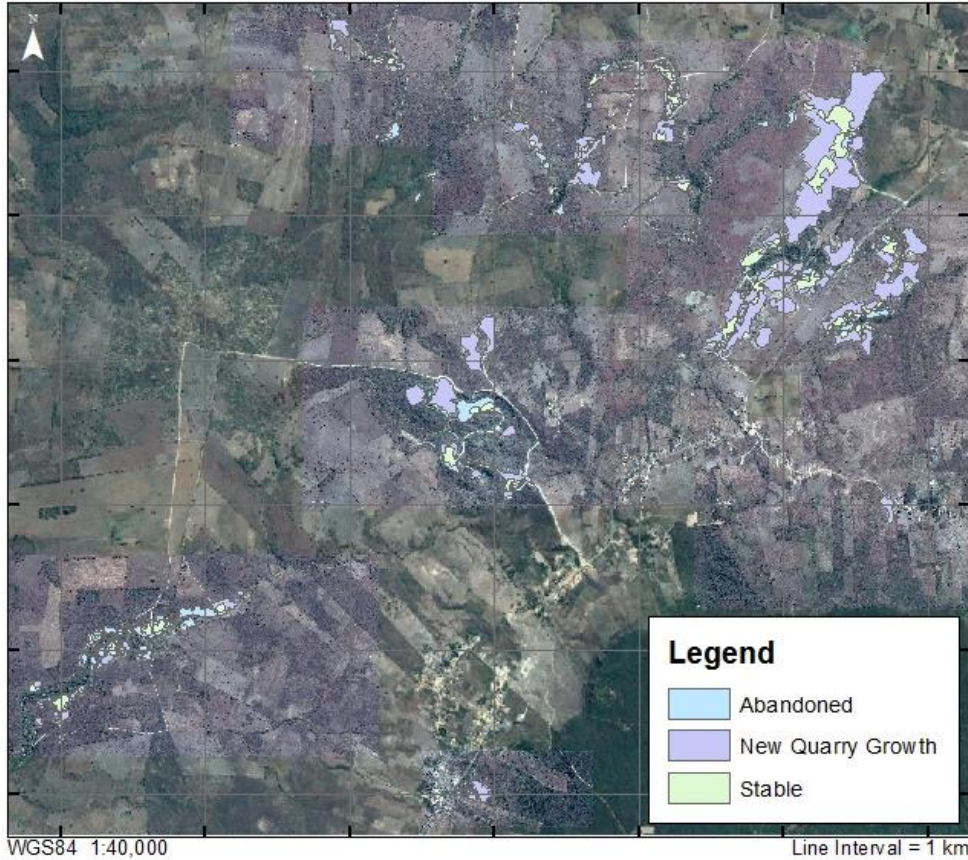
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Figure 12. Final map of quarry footprint polygons showing stable, abandoned and newly quarried areas.

WGS84 1:40,000   Line Interval = 1 km

RESULTS

In 2008, quarries in the study region comprised an area of 411,211 m^2. In 2016, quarries in the study region comprised an area of 1,207,526 m^2, meaning that quarried areas in the region nearly tripled in size over this eight-year period. Not all of this was new quarry growth. From 2008 to 2016, 227,752 m^2 of quarry remained stable. 183,459 m^2 of quarries were abandoned and reclaimed by vegetation. Quarry growth over this period was impressive, with 979,774 m^2 of new quarries added over eight years. Values for quarry growth are summarized in the following table:

Year	Total Area (m^2)
2008	411,211
2016	1,207,526
Category	
Stable	227,752
New	979,774
Abandoned	183,459

Future work is necessary to understand how much of this growth was the result of quarrying and how much was the result of rubbish pile accumulations. In many quarries, rubbish piles cover large areas, especially when they accumulate on hillslopes like in the Três Irmãoes quarry, the largest quarry in the region. Hopefully this will lend insight into vegetation loss due to rubbish pile accumulation and prompt better management of rejected material from these quarry sites.

DATA SOURCES

Source: "Nova Olinda Region, 2016." 7° 7'52.85"S and 39°42'56.80"W. **Google Earth.** November 28, 2016. July 20, 2016.

Source: "Nova Olinda Region, 2008." 7° 7'52.85"S and 39°42'56.80"W. **Google Earth.** November 28, 2016. December 24, 2008.