Deforestation in Northern Mato Grosso, Brazil

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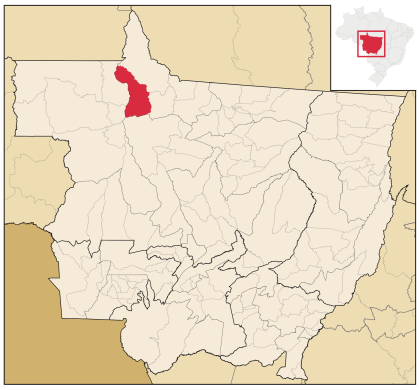
1 Abstract

Northern Mato Grosso, Brazil is in uniquely situated to experience drastic deforestation as a result of the region's rapid expansion of agriculture and livestock cultivation. The southern reaches of the Amazon extend down with flat, densely forested land with ample local irrigation, but new economic expansion and infrastructure have made it possible to profitably deforest the area in favor of large farms and rangeland. Spectral Mixture Analysis on Landsat satellite images, combined with NDFI index analysis has shown that the area has undergone substantial deforestation from 2000 to 2023, resulting in a recent loss of nearly 40% of the dense forest to logging or clear-cutting. This has a substantial impact on the local ecology, and also contributes further to climate change and the erosion of the Amazon's boundaries.

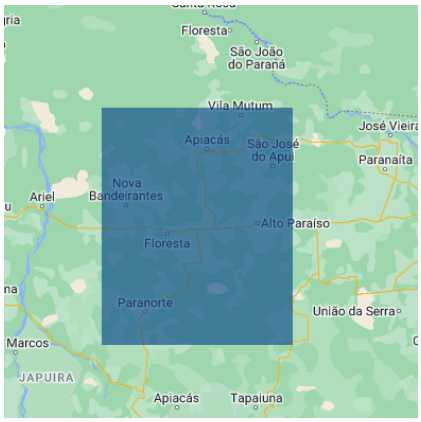
2 Introduction

2.1 Topic Area

The region of interest is defined in Figure 1. The state of Mato Grosso has undergone significant development since 2000. The state is situated at the convergence of the southern reaches of the Amazon Rainforest and the western and northern extent of the Cerrado. Multiple river systems run southward out



(a) Extent of Nova Bandeirantes. Courtesy Wikpedia



(b) Area of Study

Figure 1: Region of Interest

of the Amazon into the flatter and less densely forested edges in the north of the states. This combines with a flatter topography, geographic proximity to the population sprawl in the center of the country, and the Brazilian Federal government's fair weather support for the expansion of irrigated agriculture and rangeland in the region. All these factors come together to create an area that is extremely susceptible to rapid economic expansion and severe deforestation as a result.

2.2 Motivating Research Question

To what extent to the economic expansion starting in 2000 deforest the area between the Juruena and Teles Pires rivers in the north part of the state of Mato Grosso.

2.3 Significance

The expansion of agriculture in the periphery of the Amazon continues to be of great concern to climate scientists and conservationists. The deforestation of the Amazon has far reaching impacts that should be considered as Brazil

continues to expand its agriculture and bovine rangelands in the center of the country. The erosion of the soil in recently deforested areas, the destruction of one of the largest carbon sinks on the planet, the reduction in habitat for the most biodiverse forest on the planet, and the disruption to the river water supply for irrigation can all be counted as adverse effects of this deforestation project.

3 Methodology

3.1 Sources

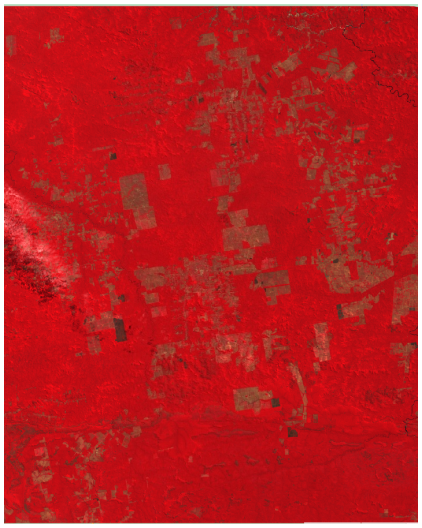
The data used in the analysis was sourced from Google Earth Engine's Landsat 7 ETM+ Tier 1 Level 2 collection for the 2000 image and Google Earth Engine's Landsat 8 OLI Tier 1 Level 2 collection for the 2023 image. Both Image collections feature a DN representation and include 6 Bands (Blue, Red, Green, NIR, SWIR1, SWIR2) that are of interest.

3.2 Composite Images

Rainforest images between 0-15 degrees latitude are heavily subject to cloud cover due to the high precipitation that the area receives. Though the area of study is slightly south of the Amazon proper and is influenced by the comparatively drier winter months of the Cerrado, the image still must undergo Median Reducer Algorithm. Both images are sampled from the collection between the drier winter months June until September. The oldest image is from the year 2000. The newest is from 2023.

3.3 Spectral Mixture Analysis

Densely forested areas actively undergoing deforestation can be subject to a wide variety of changes over a wide area, but also causes significant changes with the sub-pixel fractions themselves. Currently alive and active vegetation, recently logged or incompletely felled/burned vegetation, barren soil/rangeland,



(a) Composite 543 Image from 06/01/2000 to 09/01/2000

(b) Composite 543 Image from 06/01/2023 to 09/01/2023

Figure 2: Two Composite Cloud Free Images of the Region of Interest

tree canopy dependent shade, and water/clouds are all useful metrics to analyze when looking at sub-pixels to determine if there is significant loss of forest areas. Using the Median Image bands, a spectral unmixing algorithm can be applied for precalculated end members of Landsat 7 and 8 images. Green Vegetation (GV), non-photosynthetic vegetation (NPV), Soil, cloud/water, and Shade caused by canopy cover.

```
[0.0119,0.0475,0.0169,0.625,0.2399,0.0675], // GV
[0.1514,0.1597,0.1421,0.3053,0.7707,0.1975], // NPV
[0.1799,0.2479,0.3158,0.5437,0.7707,0.6646], // Soil
[0.4031,0.8714,0.79,0.8989,0.7002,0.6607] // Cloud
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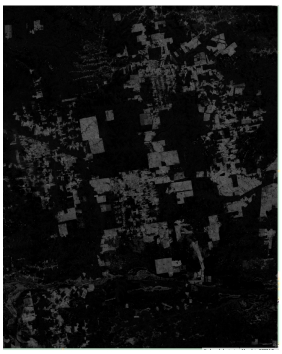
Figure 3: Pre-calculated Landsat End Members from Souza et Al. Ch A3.4. pg 63

(a) GV End Members, lighter is higher



(b) NPV End Members, lighter is higher

(c) Soil End Members, lighter is higher

Figure 4: Spectral Mixture Results from Composite 2000 Image

(a) GV End Members, lighter is higher

(b) NPV End Members, lighter is higher

(c) Soil End Members, lighter is higher

Figure 5: Spectral Mixture Results from Composite 2023 Image

(a) Composite NDFI from 2000

(b) Composite NDFI from 2023

Figure 6: NDFI Calculation from SMA, Pink Shows higher Green Vegetation disturbance

3.4 NDFI

Normalized Difference Fraction Index (NDFI): These end members calculated for Landsat 7 and Landsat 8 respectively can be used in the calculation of NDFI. NDFI has been shown to better detect areas of deforestation compared to traditional spectral indices like Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). NDFI can be found using the following equations calculated from the end members.

$$NDFI = \frac{GV_{shade} - (NPV + Soil)}{GV_{shade} + NPV + soil}$$

where

$$GV_{shade} = \frac{GV}{100 - Shade}$$

Then a water mask is applied to prevent water end members from influencing the ending calculation. After, a Δ NDFI is calculated between the two images.

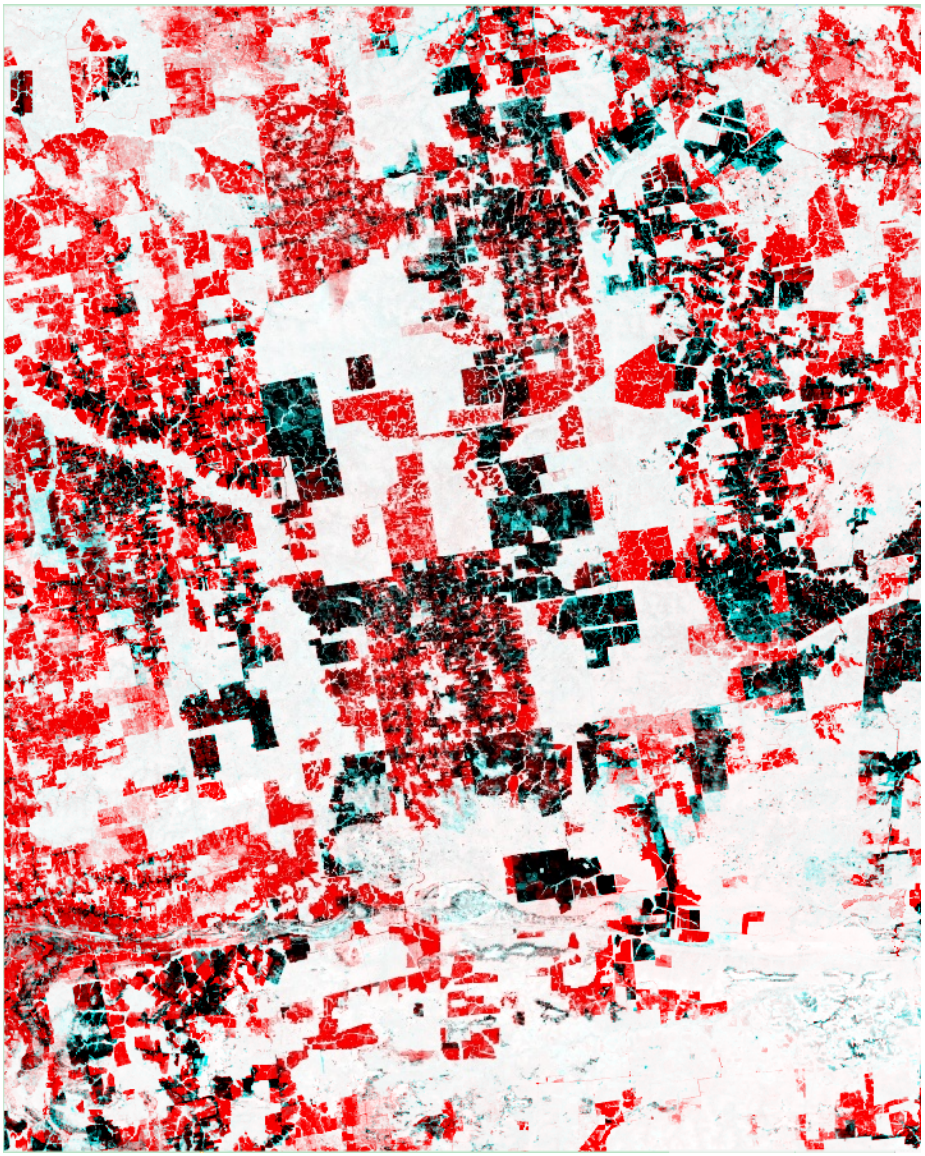


Figure 7: NDFI Changes from 2000 to 2023, Red Indicates Losses, Cyan Indicates Gains

3.5 Classification

Using the Δ NDFI, a simple classification mask can be applied. The NDFI values in the first image that are classified as deforested and that had no regrowth are excluded, along with water and cloud values. The remaining NDFI is classified using a cutoff that will allow for a tight window around no forest change, and classifies negative NDFI changes into separate classes depending on the severity of the destruction. Blue is no change ($<$ -.0095 && $>$.0095). Orange is moderate decrease (-.0095 to -.25). Red is significant decrease ($<$ -.25). Cyan is any increase ($>$ .0095). Black is areas that were deforested prior to 2000 and did not have any regrowth.

3.6 Preliminary Interpretation

The outcomes observed here by the classification match the earlier visual observation can be seen when looking at the individual NDFI calculations. The area suffered from extensive deforestation as marked by both the large amounts of red in the classification and the large increase in soil cover in the second NDFI figure.

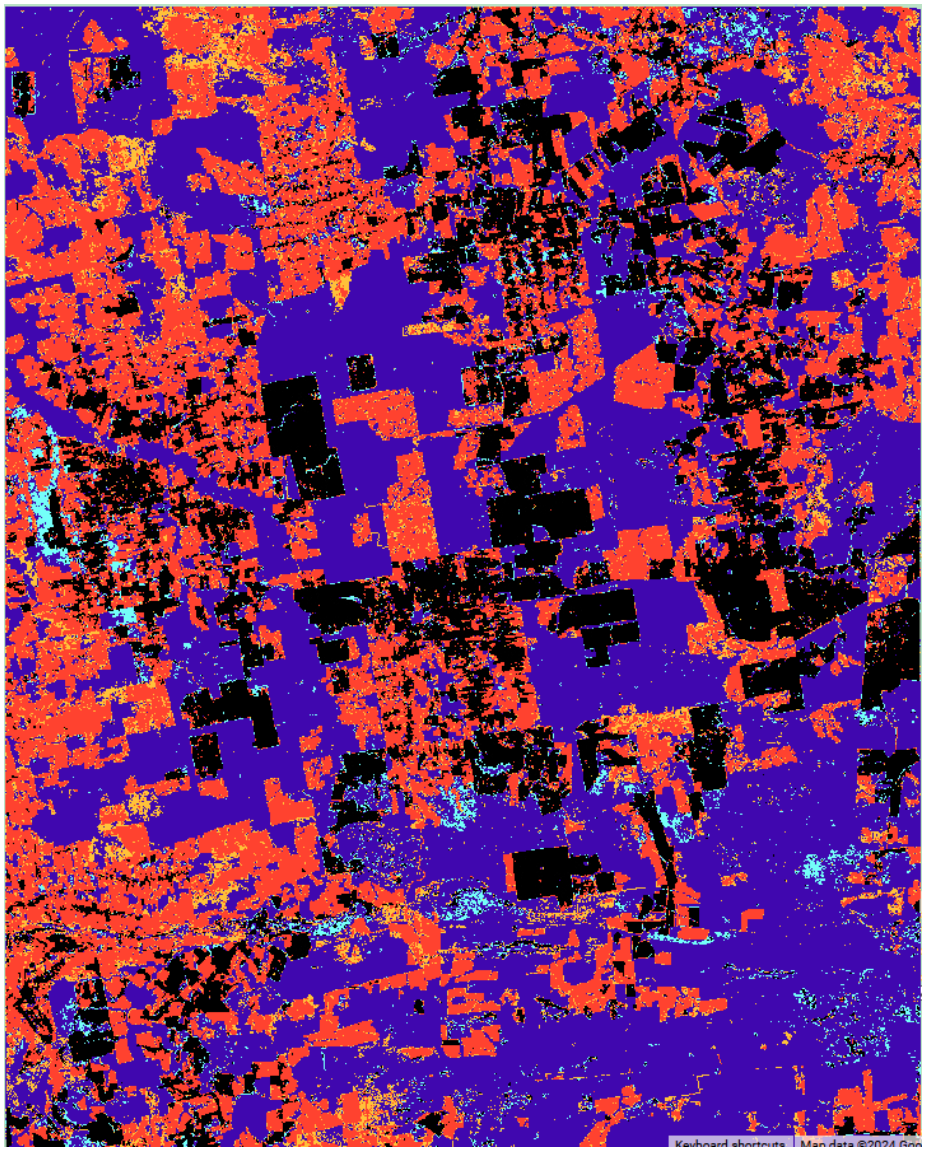


Figure 8: NDFI Classification

NDFI Positive	756,469
NDFI No Change	3,418,713
NDFI Minor Decrease	721,020
NDFI Major Decrease	1,985,907

Table 1: NDFI Changes

4 Results

Analysis on the image shows the area experienced significant deforestation in the 23 year period. The area of analysis was reduced to the center third of the image to account for cloud computations restrictions placed by G.E.E. The center was chosen because it represents a good mixture of old deforestation, a significant area of regrowth, and a lot of grid agriculture expansion. A total of 6,882,110 pixels are taken into account, and 2,706,927 pixels were classified as recent reductions in NDFI. This means that 39.33 % of the pixels were subject to some manner of recent deforestation.

Figure 9 shows a right skewed histogram of the changes of NDFI. The most notable feature is the values lower than 0 but higher than -0.0095. This classification scheme still groups these as no change pixels, but there exists a very slight NDFI decrease in a majority of pixels. The NDFI is a difference based classification, and therefore is subject to an arbitrary cut off that may slightly over represent the no-change "blue" pixels that exist.

Table 1 shows the total values for each class.

5 Discussion

5.1 Evidence of Deforestation

The analysis has presented enough evidence to conclude that this area has undergone significant deforestation in the previous 23 years. The reduction of densely forested green vegetation that cast shade into bare soil and non-photosynthetic

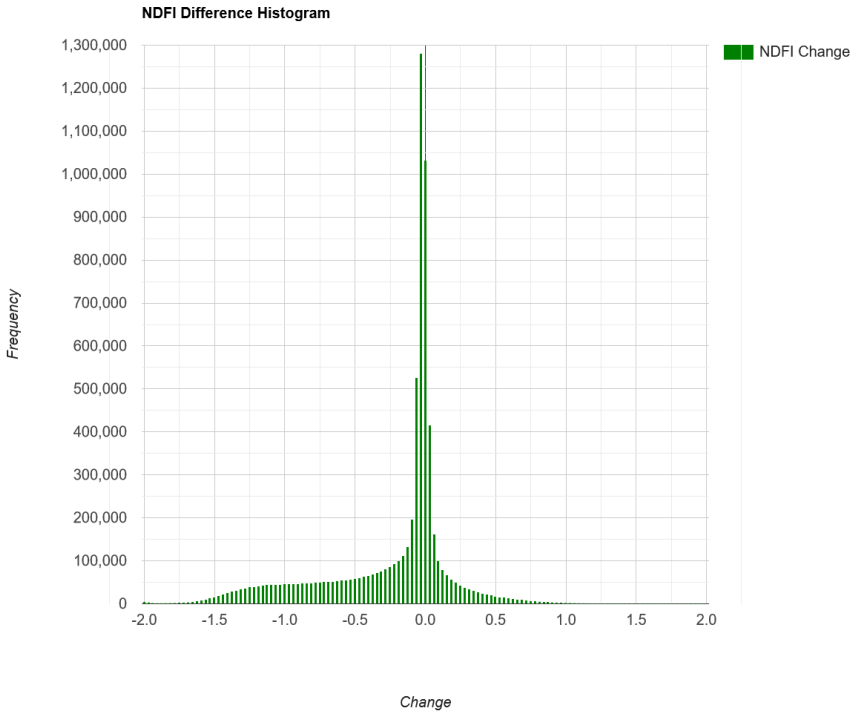


Figure 9: Histogram of NDFI changes

felled/burned vegetation is very apparent from both the spectral mixture analysis and the subsequent NDFI analysis.

5.2 Previous Research

Souza et Al created the NDFI deforestation end members in the southern Amazon, so the end members should be fairly accurate and wont need significant verification. This paper also shows that the NDFI can show modest improvements over NDVI to showcase deforestation without contamination of other non-forest related vegetation like crops that may moderately influence vegeta-

tion readings(this is not a broad problem in the composite as the dry winter months are not prime cultivation times). Other papers like VanWey et Al show that Mato Grosso has undergone rapid population and agriculture in the southern reaches nearer to the Cerrado, and this would supplement analysis around the expansion of infrastructure and rangeland in the region. This paper also suggests that nearby infrastructure can further spur encroachment into the Amazon, and highlights the growth of infrastructure in the center of the state.

5.3 Implications

The expansion of agriculture and livestock into the Amazon has multiple implications. The expansion has brought unprecedented economic opportunity to the area. This also comes at cost of many external factors. The reduction in soil quality, strain on local watersheds, reduced biodiveristy in favor of monocropping, and contribution to the reduction of the worlds largest carbon sink are all negetive external costs.

6 Bibliography

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