Changes of Increased Land Restoration in The Republic of Djibouti using Landsat

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Objective

The Great Green Wall, an initiative launched by the African Union in 2007, aims to restore the continent's degraded landscapes that borders the Sahara Desert. The project is being implemented across 22 countries aiming to restore 100 million hectares of degraded land with one of the nations being the Republic of Djibouti. Djibouti, located on the Horn of Africa, by the Gulf of Aden and Bab al-Mandab Strait, has a highly arid climate full of barren highlands and deserts. The objective of this project is to collect imagery that focuses on the areas between Ethiopia before the Great Green Wall initiative during the wet season to see clearer results. We then collected imagery of Djibouti 17 years after the start of the Great Green Wall initiative to compare the data to. The project aims to visualize and measure the amount of degraded land that has been restored in the nation and pinpoint where in the nation this new land restoration is most present, or not present in. We wish to see if the Great Green Wall is working in Djibouti or if it is having little impact on the local ecosystem.

Data

For our project we plan on using a combination of Landsat data and Google Earth Engine. Our primary source of data is Landsat information that has high visibility, Landsat 7(ETM+) and Landsat 8. The spatial and temporal resolutions are as follows: 30 meter resolution across 4 years. We will obtain this data using the Google Earth Engine Tier 1 Level 2 image collections from both satellites. We will focus on the data from 2007, 2012, 2017 and 2022 to look at the vegetation health in our focus area. Most importantly we are looking at the wet season from July 1st to September 15th in order to observe our area at the time plants are getting the most water. We will be looking at Google Earth Engine to find the best locations within Djibouti to study and measure our results. We will also use ArcGIS to help with proper formatting. In addition, there were some implementation areas of the Great Green Wall that should be noted both above and below Djibouti. These are areas within Ethiopia that show significant greeness. These areas were included in the overall analysis of land degradation due to the spreading desertification.

Methodology

To assess the effectiveness of the Great Green Wall initiative in Djibouti, we employed a combination of Google Earth Engine (GEE) and ArcGIS for data processing, visualization, and analysis. Our study area encompassed two regions within Djibouti: the northern region around Lalibela and the eastern region near Dire Dawa. These areas were chosen due to their proximity to significant restoration efforts. The regions were defined as rectangular geometries, which were combined to form a single study area for streamlined analysis.

We utilized data from two satellite platforms: Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for the year 2007 and Sentinel-2 Multispectral Instrument (MSI) for 2022. Both datasets were filtered to isolate imagery captured during the wet season, spanning July 1 to September 30. This seasonal focus ensured that vegetation health was evaluated during its peak period, thereby maximizing the visibility of restoration effects. To reduce atmospheric distortions and noise, we applied a cloud cover threshold of 30% for Landsat 7 and 20% for Sentinel-2 imagery.

Data preprocessing involved multiple steps. For Landsat 7, the “QA_PIXEL” band was used to mask clouds and saturated pixels, while Sentinel-2 relied on the “QA60” band to remove cloud and cirrus contamination. To generate composites for the wet season, we adopted a multi-step approach. Landsat 7 data from the primary wet season window (July 1 to September 30) was compiled into a median composite. A secondary composite, spanning June 15 to October 15, was created to fill gaps caused by missing data or excessive cloud cover. These two composites were merged into a single mosaic to ensure complete spatial coverage. Similarly, Sentinel-2 imagery from 2022 was processed to create a median composite for the wet season.

The processed imagery was then used to calculate vegetation indices that quantified vegetation health and extent. Two key indices were employed: the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI). NDVI was computed using the formula (NIR- RED) / (NIR + Red), where NIR and Red represent the near-infrared and red bands of the imagery, respectively. For SAVI, the formula (NIR- Red) / (NIR + Red + L) x (1-L) was used, with L= 0.5 to adjust for soil reflectance. In Landsat 7, NIR and Red corresponded to Bands 4 and 3, while in Sentinel-2, these were Bands 8 and 4.

The outputs from GEE were exported to Google Drive for further refinement and analysis in ArcGIS. Within ArcGIS, the NDVI and SAVI composites were used to create visually interpretable maps, including false-color composites to highlight vegetation. These maps enabled a clear comparison of vegetation changes between 2007 and 2022. Additionally, statistical summaries were generated to quantify the changes in mean NDVI and SAVI values over the 15-year span, providing insights into the effectiveness of the restoration efforts.

While our approach incorporated robust methods to process and analyze the data, several limitations were noted. The spatial resolution of Landsat and Sentinel-2 imagery, while sufficient for regional-scale studies, may not capture finer details of vegetation changes. Additionally, cloud cover and atmospheric conditions, though mitigated through masking and compositing, posed challenges in ensuring consistent data quality. Future studies could benefit from incorporating higher-resolution datasets, analyzing additional time points, and conducting field validation to corroborate remote sensing findings.

In conclusion, this methodology allowed us to systematically evaluate vegetation trends in Djibouti over 15 years, providing valuable insights into the progress of the Great Green Wall initiative. By leveraging advanced remote sensing tools and techniques, we laid the groundwork for continued monitoring and assessment of restoration efforts in the region.

Associated Code:

Year 2007 - using Landsat 7 imagery

https://code.earthengine.google.com/e2beb221e117aff212fe85eeaf862ed7?noload=true

Year 2012 - Using Landsat 7 imagery

https://code.earthengine.google.com/68fe0375c4991e22c77c9692ff79b999?noload=true

Year 2017 - Using Landsat 8 imagery

https://code.earthengine.google.com/59236b2476c8764b0f8d28b606dfea46?noload=true

Year 2022 - Using Landsat 8 imagery

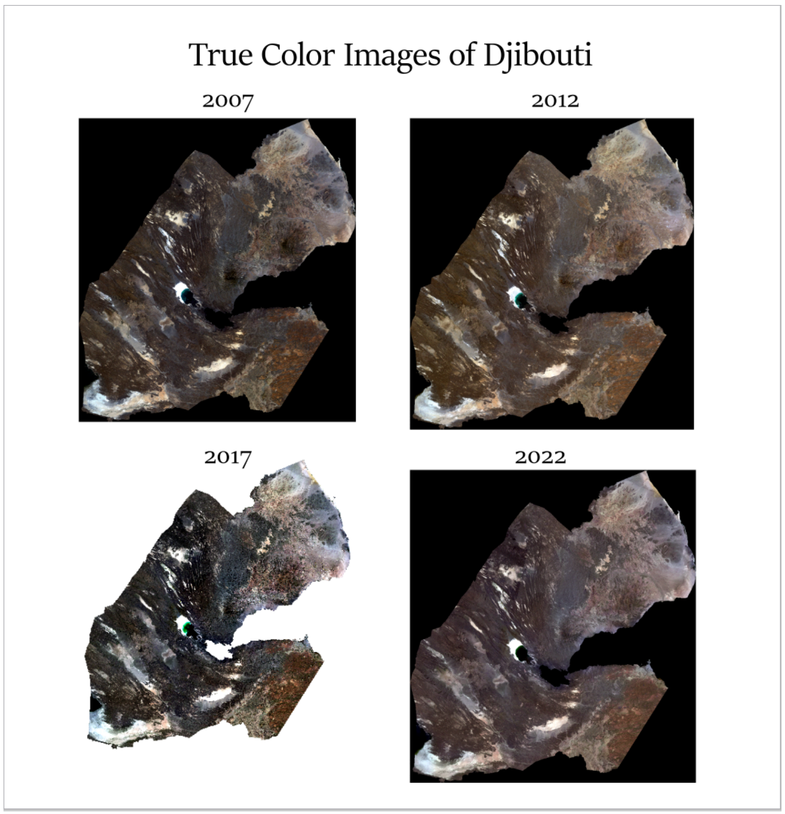
https://code.earthengine.google.com/6f738f0b2a3d6b48ab36a7c623daebef?noload=true

True Color ROI using Landsat 7 & 8 imagery

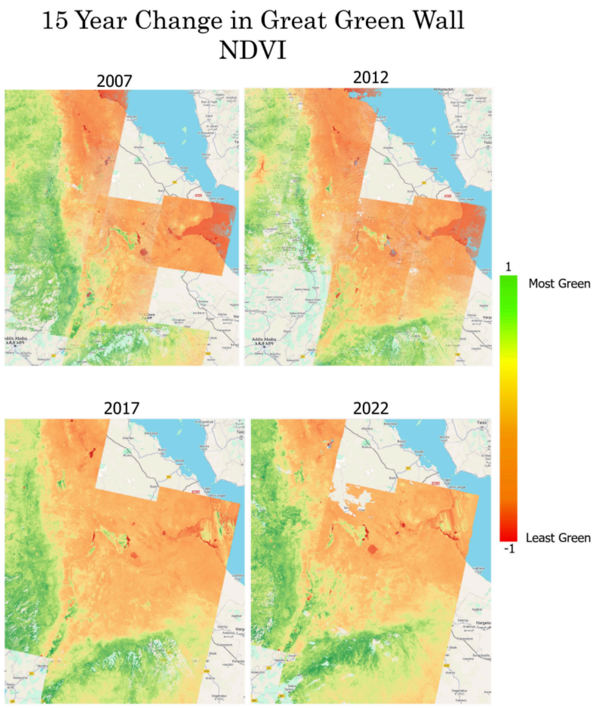
https://code.earthengine.google.com/888478b0b9fa55aed4018c76317f53ea

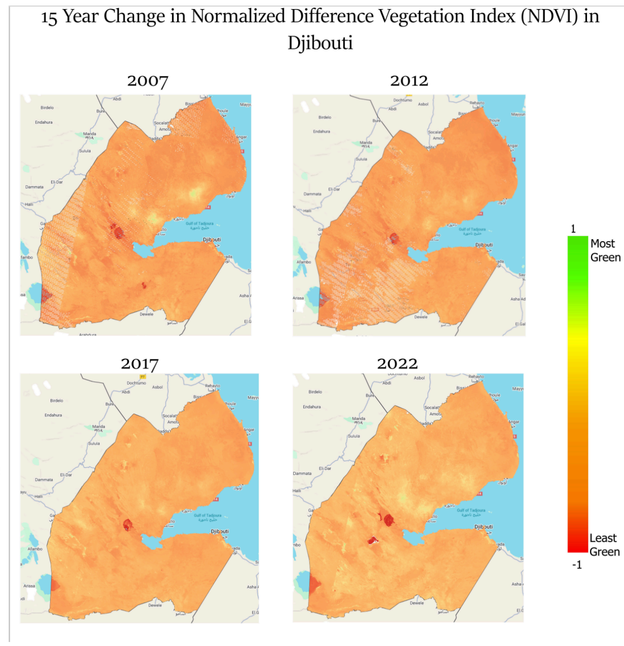
Results

Our initial approach was first to isolate true color images for the country of Djibouti both for our own purposes of visual comparison and also to provide context for the general public or average viewer. The true color images were made in Google Earth Engine specifying: the year of collection, the region of interest, >10% cloud cover, and the true color bands used. For years 2007 and 2012, the Landsat 7 satellite was used with bands 3, 2, and 1 compiled in that order to form our RGB true color composite. For years 2017 and 2022, Landsat 8 was used for more accurate data purposes, in this instance there is an aerosol band in the band 1 slot so bands 4, 3, and 2 were used in that order to create the RGB true color composite for those specific years.



The NDVI and SAVI composites generated for the wet seasons of 2007 and 2022 reveal subtle but consistent improvements in vegetation health across the Republic of Djibouti. False-color imagery highlights regions of increased vegetation density, particularly in areas targeted by the Great Green Wall initiative. Notable changes are evident near key restoration zones along the border with Ethiopia, where vegetation coverage appears more robust in 2022 compared to 2007 as you can see in the maps below. While some areas remain arid, these visual comparisons indicate that pockets of restoration are taking root gradually.





Quantitative analysis of NDVI and SAVI indices supports the visual findings, showing measurable increases in vegetation health over the 15-year period. The mean NDVI value rose from 0.06 in 2007 to 0.14 in 2022, while the mean SAVI value increased from 0.04 to 0.07. Although these changes are modest, they align with the expectations for a long-term ecological restoration project in an arid climate. The observed trends suggest that vegetation in Djibouti is becoming both more extensive and healthier, reflecting the early successes of the Great Green Wall initiative.

Year	**Mean NDVI**	**Mean SAVI**
2007	0.06	0.04
2022	0.14	0.07

The spatial and temporal patterns observed suggest that while progress has been made, restoration efforts are unevenly distributed. Areas with higher baseline vegetation in 2007 generally show more significant improvement, likely due to better initial conditions for restoration. Conversely, the most arid and degraded regions demonstrate slower recovery, underscoring the challenges of ecological restoration in harsher environments. The findings highlight the importance of continued support and targeted interventions in areas where progress is lagging.

Conclusion

Our study examined the impact of the Great Green Wall initiative on vegetation restoration in the Republic of Djibouti using Landsat-derived NDVI and SAVI indices over a 15-year period. The results indicate a modest yet measurable improvement in vegetation health and extent, with mean NDVI values increasing by 0.08 and SAVI values rising by 0.03 between 2007 and 2022. These findings suggest that efforts to combat desertification and restore degraded land in Djibouti are beginning to yield positive results, albeit gradually.

The observed changes underscore the challenges of achieving rapid ecological restoration in arid climates like Djibouti's, where environmental and climatic constraints may slow progress. However, even subtle increases in vegetation can have significant implications for local ecosystems, potentially improving soil quality, reducing erosion, and supporting biodiversity. These outcomes highlight the importance of sustained investment and monitoring to ensure the long-term success of initiatives like the Great Green Wall.

Future research could benefit from incorporating higher-resolution datasets and field validation to more accurately capture localized changes and assess the initiative's broader ecological and social impacts. While the current study provides a valuable snapshot of progress, long-term studies will be critical to fully understand the Great Green Wall's effectiveness and inform adaptive strategies for its continued implementation.

References

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