

NIGER: Evaluating Land Restoration Effectiveness Using Remote Sensing

Program Evaluation, but using satellite data instead of field teams

In 2024 DataPalette began a project - helping a global management consulting firm, Social Impact, to answer a simple outcome question:

Did the land restoration interventions actually work?

The activity we set out to evaluate— the Integrated Climate Resilience Investment Plans (ICRIP) — had been active across hundreds of remote village sites in Niger since 2019, deploying a range of land rehabilitation techniques: reforestation plantings, farmer managed natural regeneration (FMNR), demi-lune micro-catchments, and farmer training.

The **intervention sites were remote, scattered across multiple communes** in a country with limited accessibility. There were hundreds of them. A traditional field evaluation — sending people to look at the land, count trees, measure soil — would have been expensive, slow, and only possible for a small sample.

So, we looked to **GIS and remote sensing to evaluate the activity's effectiveness** in a innovative way.

The Data Already Exists

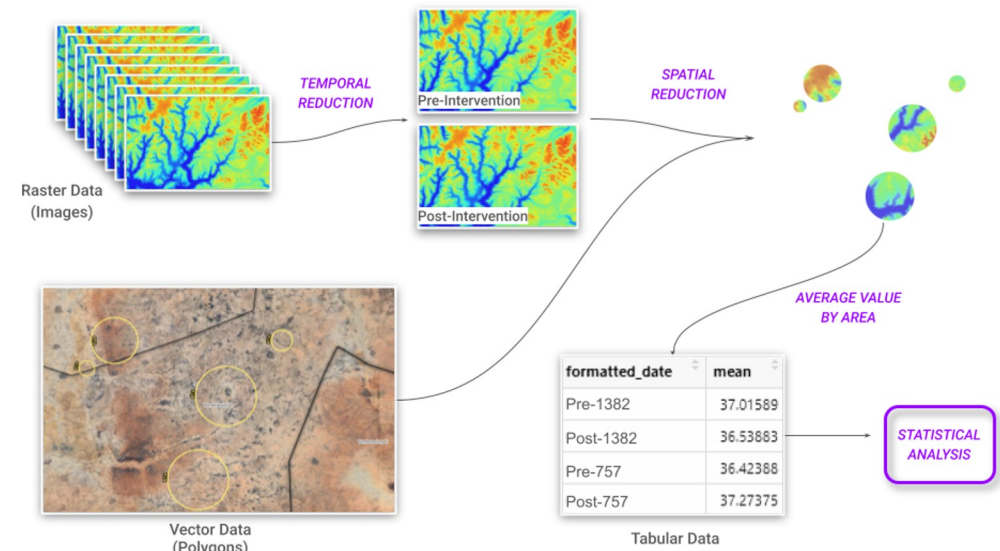
Every 5 days, the European Space Agency's Sentinel-2 satellites pass over Niger. Together, this imagery, and other free, publicly available datasets give us a continuous record of what the land surface has looked like going back years.

No travel was necessary. The data was already being collected by satellites -- expertise was all that we needed to then do the analysis.

Datapalette worked with Social Impact to complete the following workflow:

1. Pulled satellite imagery stacks from 2018 to 2024 across all project and control areas
2. Temporally reduced the data to cloud-masked seasonal averages
3. Clipped those images to hundreds of study area polygons
4. Computed five key spectral indices, then averaged per area, per time period
5. Exported everything as tabular data for statistical modelling

Remote Sensing Workflow



The Relevance of Partner-Reported Data

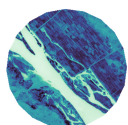
Even though the analysis relied on open source data (remotely sensed satellite data), partner-reported data was an important part of the analysis. As a part of the land restoration intervention activity, location data was reported by partners. This data documented the lat/ lng location of the intervention, estimated area and the associated village.

We used village catchment areas as our spatial unit of analysis. A 1.5km radius buffer around each intervention village (n=320) centroid, capturing the area within which interventions took place, and farmer-to-farmer knowledge spillovers would likely happen. An equal number of randomly selected **control villages were incorporated into the analysis as well.**

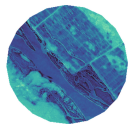
Although satellite data was the star of the show, the analysis wouldn't have been possible without the collection of partner-reported data with information on activity locations.

Satellite Imagery → Measures

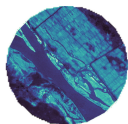
We extracted five spectral indices from the satellite imagery, **each measure capturing a different dimension of land health:**



SAVI (Soil-Adjusted Vegetation Index): vegetation density/vigor, adjusted for sparse cover conditions. Perfect for semi-arid landscapes where standard NDVI overestimates bare soil signal.



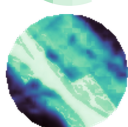
NDMI (Normalized Difference Moisture Index): soil and vegetation moisture content. Should increase as restoration improves water retention capacity of the soil.



BSI (Bare Soil Index): proportion of exposed soil. Should decrease as plant cover returns.



ET (Evapotranspiration): water movement from soil and plant surfaces. A proxy for vegetation activity and soil moisture which we would expect to increase.



LST (Land Surface Temperature): thermal emission from the land surface. Expected to decline as vegetation and shade increase, though this requires larger-scale coverage changes to manifest.

We also extracted **precipitation and temperature data** (CHIRPS and ERA5 ECMWF Climate Reanalysis) to use **as controls in the statistical model** – because rainfall in Niger is highly variable year to year, and to account for vegetation increase attributed to climate rather than program interventions.

Statistics: Ruling out Coincidence, Seasonality, etc.

We used a Difference-in-Differences (DiD) design – a common approach in causal program evaluation – estimating annual treatment effects from 2020 to 2024 using 2019 as the baseline year. The model included:

Village fixed effects – each village is only compared to its own baseline, removing time-invariant differences in elevation, soil type, proximity to water, etc.

Quarter-year fixed effects – to absorb seasonal variation across the 6-year panel

Precipitation and pre-intervention temperature controls – to isolate the restoration signal from climate noise

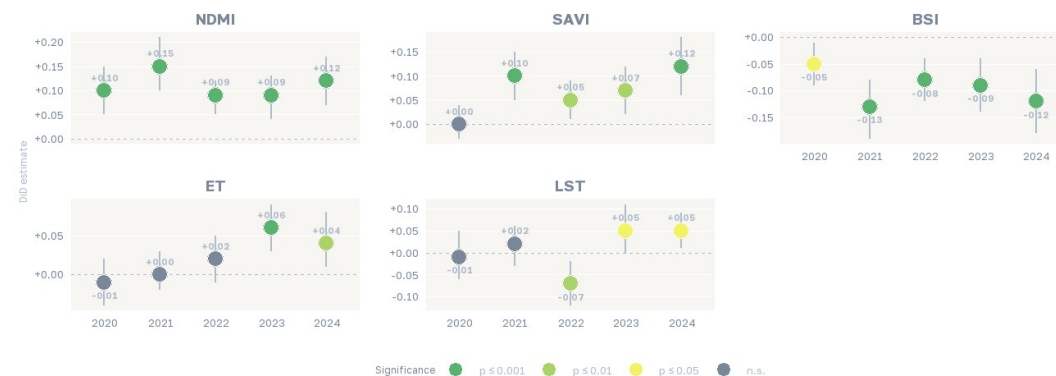
Standard errors clustered at the village level – correct inference under within-village temporal correlation so effects don't look more “statistically significant” than they should be

As a robustness check, we also ran a Linear Mixed Effects (LME) model with random village effects and an interaction between treatment group and pre/post period. Results were consistent across both, which served to strengthen our confidence in the findings.

Results Show Evidence of Activity Success

Niger Land Restoration – DiD Treatment Effects by Year

Annual DiD coefficient vs 2019 baseline · whiskers = 95% CI · dot colour = significance level



The DiD results, confirmed by linear regression and a landcover change analysis show that indeed, **restoration areas are showing signs of an impactful activity**.

SAVI: +0.12 ($p < 0.001$) – vegetation density is measurably higher in ICRIP areas. Statistically significant each year since 2021.

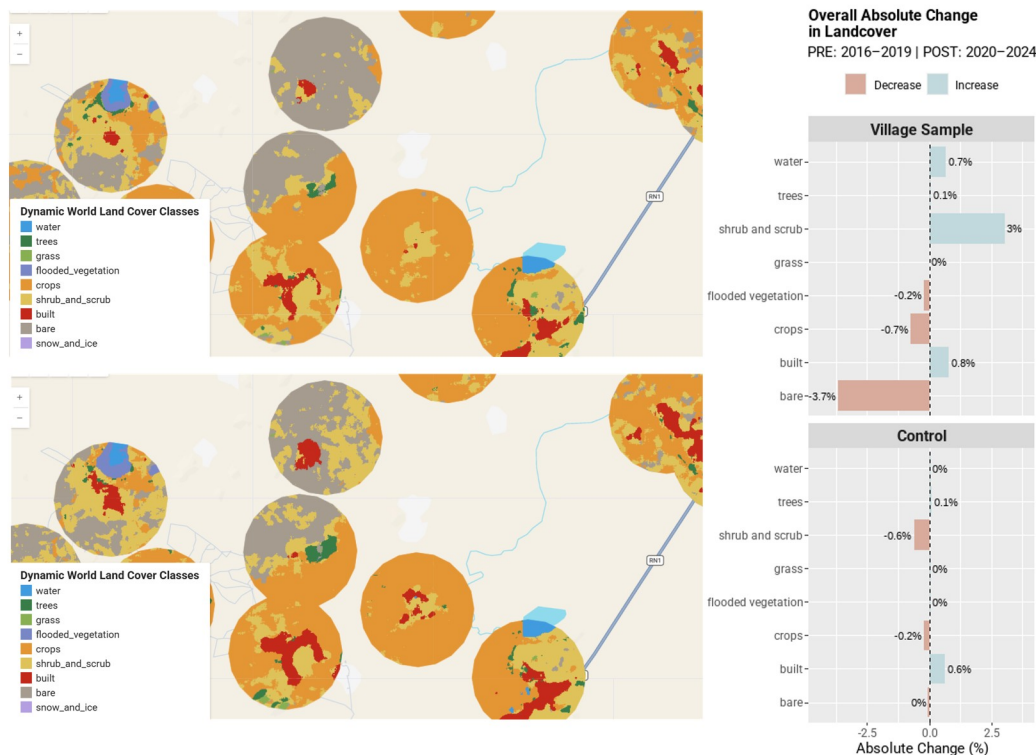
NDMI: +0.12 ($p < 0.001$) – restoration areas show significantly higher soil and vegetation moisture than controls. Significant every year from 2020.

BSI: -0.12 ($p < 0.001$) – bare soil exposure is significantly lower in restoration areas. Significant from the very first post-intervention year.

ET: +0.04 mm/day ($p = 0.01$) – increased water flux through vegetation and soil. Significant by 2023.

LST: inconclusive – no consistent directional pattern. Some years show marginal cooling, others marginal warming. Land surface temperature change is a response to landscape-scale vegetation change, and perhaps localised restoration at the village level has not yet crossed that threshold.

An additional exploratory analysis of Land use / land cover using the Dynamic World dataset corroborated the index findings: a clear shift from bare land to shrub and scrub cover in restoration areas post-2020.



The Power of Remote Sensing

This analysis used a remote sensing-based approach to look for early signals of land restoration outcomes across a large and spatially dispersed set of activity sites.

Four of the five measures evaluated showed statistically significant differences between intervention and control areas. NDMI and BSI detected effects beginning in the first post-intervention year, while SAVI and evapotranspiration strengthened progressively through 2023 and 2024. Seeing these patterns emerge across multiple independent indicators—each measuring a different physical property of the land surface—strengthens confidence that observed changes are associated with restoration activities rather than noise in any single metric.

What stands out about this work is that the analysis was done using a low-cost, scalable approach. By pairing open-source satellite imagery with partner-provided activity location data, the analysis was able to assess change across every activity site, including pre-intervention conditions. A field-based evaluation at this scale would have required large teams, travel, and extensive data collection, while likely covering only a fraction of the sites. The satellite archive made it possible to look not just at whether conditions changed, but when they changed, and how that change compares to control villages.

This work reflects a partnership that combined sectoral knowledge, M&E expertise, and GIS/remote sensing skills to explore practical, cost-effective ways of measuring environmental change at scale. The findings are encouraging and point to the value of geospatial analysis as a complement to existing M&E approaches.



DataPalette specializes in filling these sorts of insight gaps -- data (especially spatial data) driven independent analysis for land, environmental, humanitarian, outdoor recreation and agricultural programs worldwide.

