2024

SATELLITE MONITORING REPORT

LT-007-SPA-072023 CÁCERES, SPAIN

Ecological restoration in Alia, Cáceres, Spain

Life Terra

November, 2024

I. GENERAL INFORMATION

Project name	Ecological Restoration in Alia, Caceres (Spain)
aOCP Registered Project ID	LT-007-SPA-072023 CACERES, SPAIN
Name of the Project Proponent	Life Terra
Name of authorized representative of the Project Proponent	Sven Kallen
Project start date	May 2023
Project end date	May 2062
aOCP Scopes in which the project participates	☒ Greenhouse gases ☒ Biodiversity ☒ Water ☐ United Nations Sustainable Development Goals

II. MONITORING INFORMATION

Start of monitoring period	January 2024
End of monitoring period	November 2024
Duration of monitoring period (months)	11
Number of monitoring period (consecutive). Considers both onsite and remote monitoring campaigns.	2-3
Objective of this monitoring campaign	Monitoring the project
Monitoring approach	☐ On-site (yearly) ☒ Remote sensing (satellite images, acoustic sensors, etc) (quarterly)

III. METHODOLOGY

The quarterly remote sensing procedure forms a critical component of the monitoring framework for restoration and reforestation projects. This procedure aims to systematically evaluate changes in vegetation health and coverage over time, providing insights into the effectiveness of project interventions.

To establish baseline conditions, satellite imagery spanning six months prior to the project's implementation is acquired. These pre-project images are analyzed to calculate vegetation indices, which serve as reference points for assessing changes in vegetation cover and condition during subsequent monitoring phases.

After project implementation, satellite images are obtained quarterly to track and evaluate the progress of restoration or reforestation activities. This involves Randomly generated sampling points selected within the project area. The number of points is determined proportionally to the size of the project area to ensure representative coverage during assessments.

Sentinel-2 multi-spectral images, with a spatial resolution of 10 meters, are utilized due to their high-quality data, frequent revisit times, and suitability for vegetation analysis. Only images with cloud cover below 30% are selected to ensure accurate and reliable results.

The vegetation indices implemented for the purpose of this assessment are the Normalized Difference vegetation Index (NDVI) and the Green Normalized Difference Vegetation Index (GNDVI).

III.1. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI).

The Normalized Difference Vegetation Index (NDVI) is a widely used indicator for assessing vegetation health, density, and photosynthetic activity. It is calculated using the formula:

$$NDVI = \frac{(NIR-RED}{(NIR+RED)},$$

where NIR is the near-infrared reflectance (band 8 in Sentinel-2 imagery), and RED is the red-light reflectance (band 4 in Sentinel-2 imagery).

NDVI leverages the contrast between strong near-infrared reflection (high in healthy vegetation) and low red-light reflectance (absorbed by chlorophyll during photosynthesis). Higher NDVI values indicate dense, healthy vegetation, while lower values suggest sparse or stressed vegetation. This index is instrumental in monitoring vegetation phenology, tracking land use and cover changes, and detecting natural events such as droughts. By analyzing NDVI time series, we can gain insights into long-term trends and seasonal variations in vegetation, making it an essential tool for restoration monitoring.

III.2. Green Normalized Difference Vegetation Index (GNDVI)

The Green Normalized Difference Vegetation Index (GNDVI) complements NDVI by providing enhanced sensitivity to chlorophyll levels in vegetation. It is calculated using the formula:

$$GNDVI = \frac{(NIR-GREEN}{(NIR+GREEN)},$$

where NIR is the near-infrared reflectance (band 8 in Sentinel-2 imagery), and GREEN is the green-light reflectance (band 3 in Sentinel-2 imagery).

GNDVI measures "greenness" or the photosynthetic activity of vegetation. It is particularly useful for assessing nitrogen uptake and water content in the plant canopy, making it a valuable indicator for evaluating plant health and crop productivity. By combining GNDVI with NDVI, we gain a more comprehensive understanding of vegetation conditions, enabling more nuanced monitoring of restoration progress and ecosystem recovery.

Figure 1 illustrates the project area and the corresponding sampling points utilized for the current analysis. These points, along with the processed satellite imagery, facilitate an in-depth evaluation of vegetation dynamics, enabling the identification of progress and areas requiring further intervention.

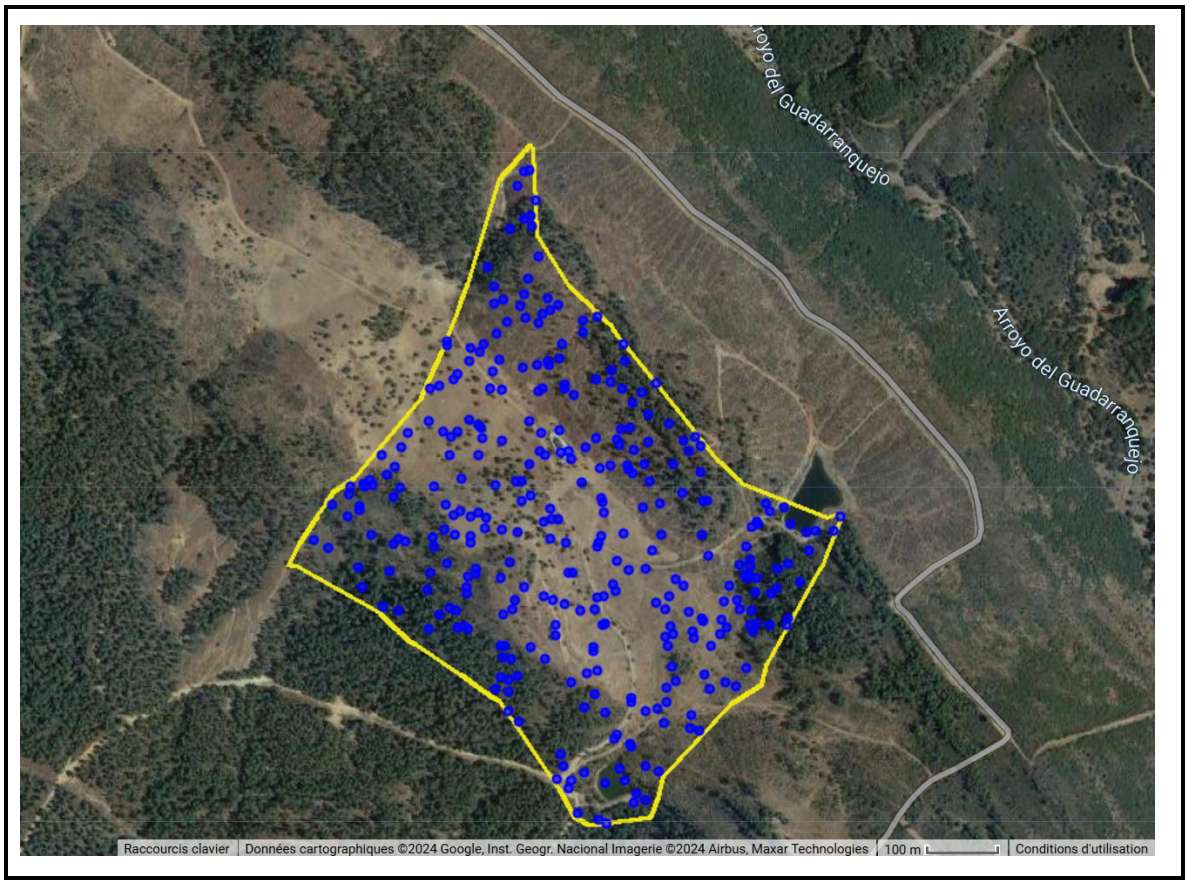

Figure 1. Project area and sampling points used for the NDVI analysis.

IV. BASELINE (2023 BEFORE PROJECT IMPLEMENTATION)

During the baseline phase of 2023, the NDVI and GNDVI values indicate a gradual decline in vegetation health and density within the project area. Starting with relatively higher values in January (NDVI: 0.53, GNDVI: 0.55), there is a consistent decrease through the months, reaching the lowest levels in May (NDVI: 0.33). The GNDVI shows a similar trend. The overall mean NDVI of 0.44 and GNDVI of 0.50 reflect moderate vegetation activity typical of the area but reveal a need for intervention to maintain or improve plant health.

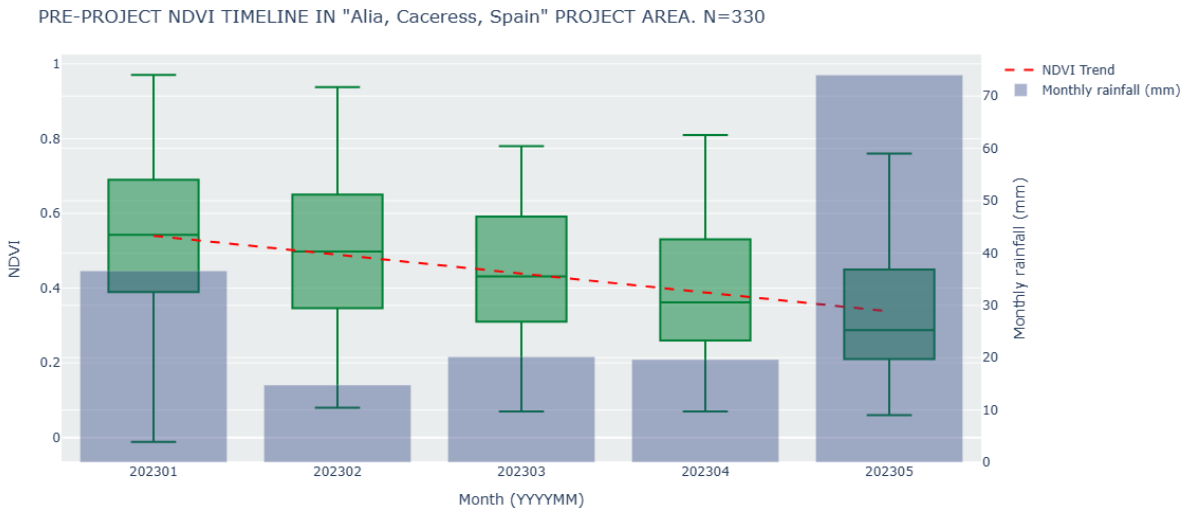

Figure 2. Pre-Project NDVI and Rainfall Trend within Project Area.

2023	January	February	March	April	May	Mean
NDVI	0.53	0.50	0.45	0.39	0.33	**0.44**
GNDVI	0.55	0.50	0.49	0.45	-	**0.50**

V. FIRST-QUARTER MONITORING (2024)

The results for the first quarter of 2024 show a marked improvement in vegetation health within the project area. NDVI values remain stable and elevated, with January through March reporting consistent levels around 0.59, indicating healthy and dense vegetation. GNDVI follows a similar trend, with values ranging from 0.58 to 0.60, reinforcing the observation of vigorous photosynthetic activity.

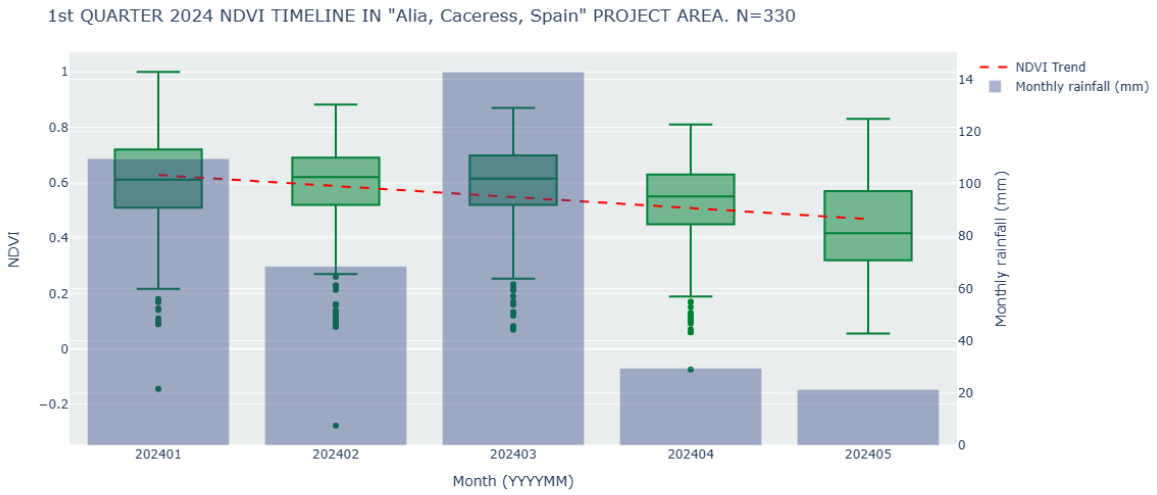

Figure 3. 2024 1st Quarter NDVI and Rainfall Trend within Project Area.

2024	January	February	March	April	May	Mean
NDVI	0.60	0.59	0.59	0.53	0.43	**0.55**
GNDVI	0.58	0.60	0.57	0.53	0.47	**0.55**

VI. SECOND-QUARTER MONITORING (2024)

The second quarter of 2024 shows a noticeable decline in NDVI and GNDVI values within the project area, signaling a reduction in vegetation health and density. NDVI decreases steadily from 0.43 in May to 0.32 in August, while GNDVI follows a similar pattern, dropping from 0.47 in May to 0.39 in August. This decline reflects seasonal challenges such as reduced rainfall, or natural vegetation dormancy during the mid-year period. The mean NDVI of 0.36 and GNDVI of 0.43 suggest moderate vegetation activity but reveal stress compared to the earlier months.

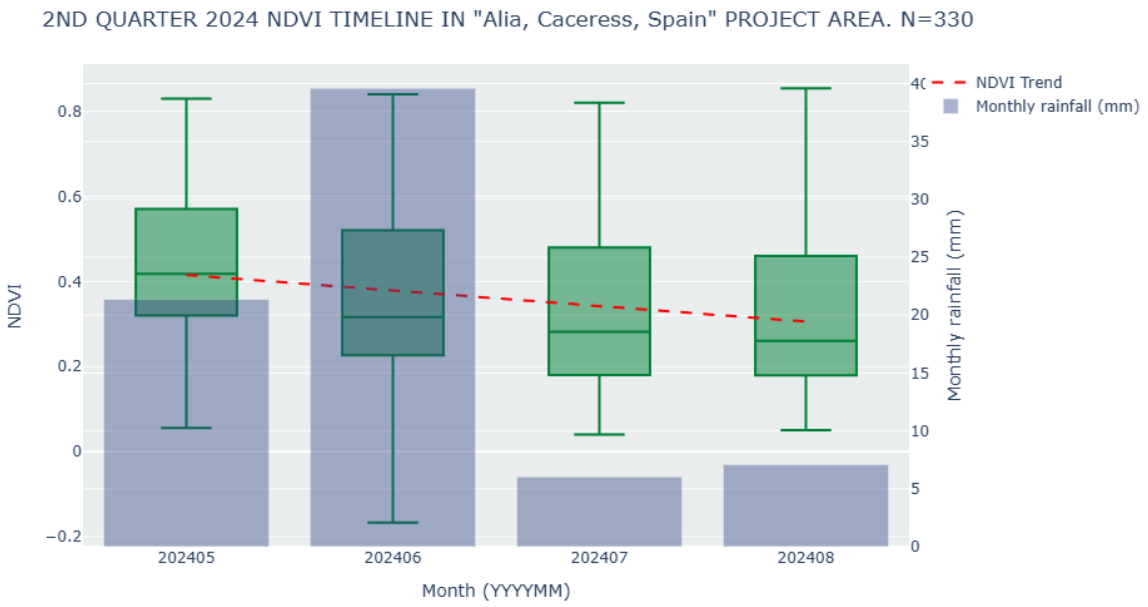

Figure 4. 2024 2nd Quarter NDVI and Rainfall Trend within Project Area.

2024	May	June	July	August	Mean
NDVI	0.43	0.36	0.33	0.32	**0.36**
GNDVI	0.47	0.45	0.40	0.39	**0.43**

VII. THIRD-QUARTER MONITORING (2024)

The third quarter shows a gradual recovery in vegetation health within the project area, as evidenced by increasing NDVI and GNDVI values. NDVI rises from 0.32 in August to 0.51 in November, indicating a revival of plant cover and density. GNDVI also exhibits an upward trend, improving from 0.39 in August to 0.49 in October. These increases coincide with potential seasonal improvements such as the onset of rains supporting vegetation growth. The absence of data for November and December limits a complete understanding of the year-end conditions, but the mean NDVI of 0.41 and GNDVI of 0.43 for the period suggest a return to healthier vegetation activity compared to the mid-year decline.

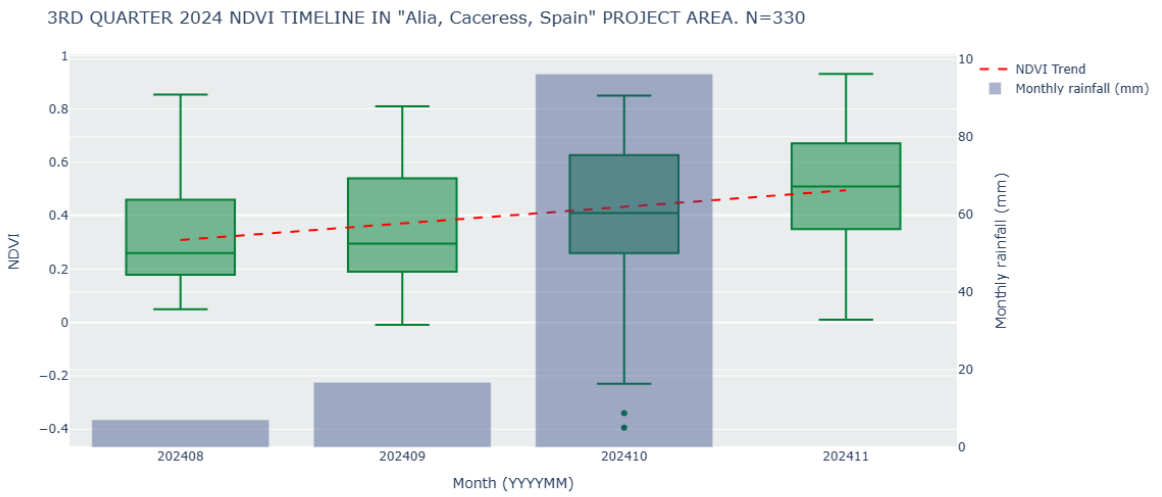

Figure 5. 2024 3rd Quarter NDVI and Rainfall Trend within Project Area.

2024	August	September	October	November	December	Mean
NDVI	0.32	0.36	0.43	0.51	-	**0.41**
GNDVI	0.39	0.42	0.49	-	-	**0.43**

VIII. GLOBAL VARIATION

To accurately evaluate the evolution of NDVI within the project area, it is crucial to establish control areas in the vicinity. These control areas are selected within a defined buffer zone surrounding the project site, ensuring their environmental and ecological conditions are comparable to those of the project area. The selection of suitable control areas allows for a robust comparative analysis, distinguishing the effects of project interventions from natural or external factors influencing vegetation trends. This method ensures that observed changes in NDVI and vegetation health can be confidently attributed to the project activities rather than broader regional variations or unrelated environmental factors.

Figure 6 illustrates the control areas and sampling points strategically identified for this assessment. These sampling points within the control areas provide a representative dataset for tracking vegetation dynamics over time.

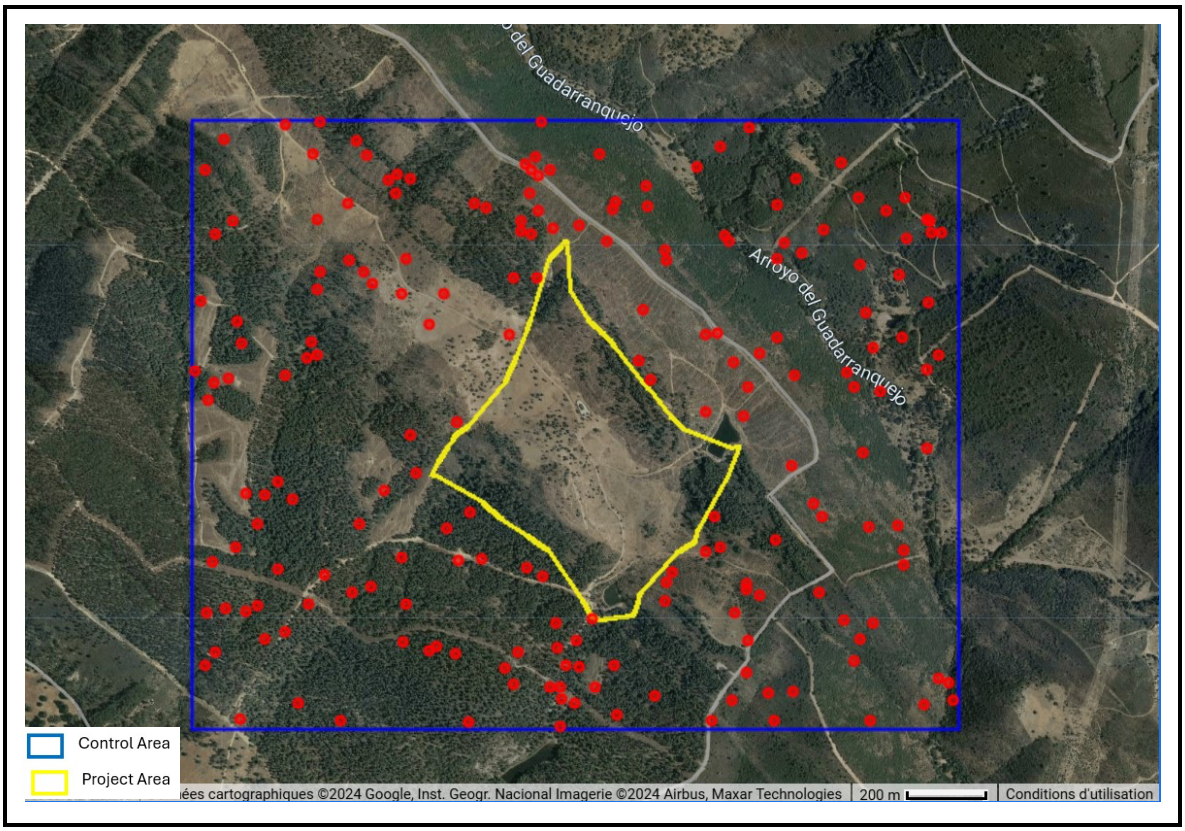

Figure 6. Selected Control Area and Sampling Points

Figure 7 illustrates the spatial distribution of NDVI for four key assessment periods: the pre-project phase, the first quarter of 2024, and the second and third quarters of 2024. During the pre-project phase, NDVI values within the project area were noticeably lower than those of the surrounding areas. This disparity reflects the sparse vegetation within the project area compared to the established vegetation in the surrounding control areas. In the first quarter of 2024, the NDVI map indicates early signs of greening within the project area, suggesting the onset of vegetation development as a result of project interventions. However, during the second and third quarters, NDVI values in the project area declined compared to the surrounding control areas. This trend is likely attributable to seasonal variations or environmental stress affecting vegetation growth.

To enable a more detailed assessment and comparison of vegetation dynamics between the project and control areas, sampling points within both areas were analyzed. These comparisons provide a quantitative basis for understanding changes in vegetation cover over time.

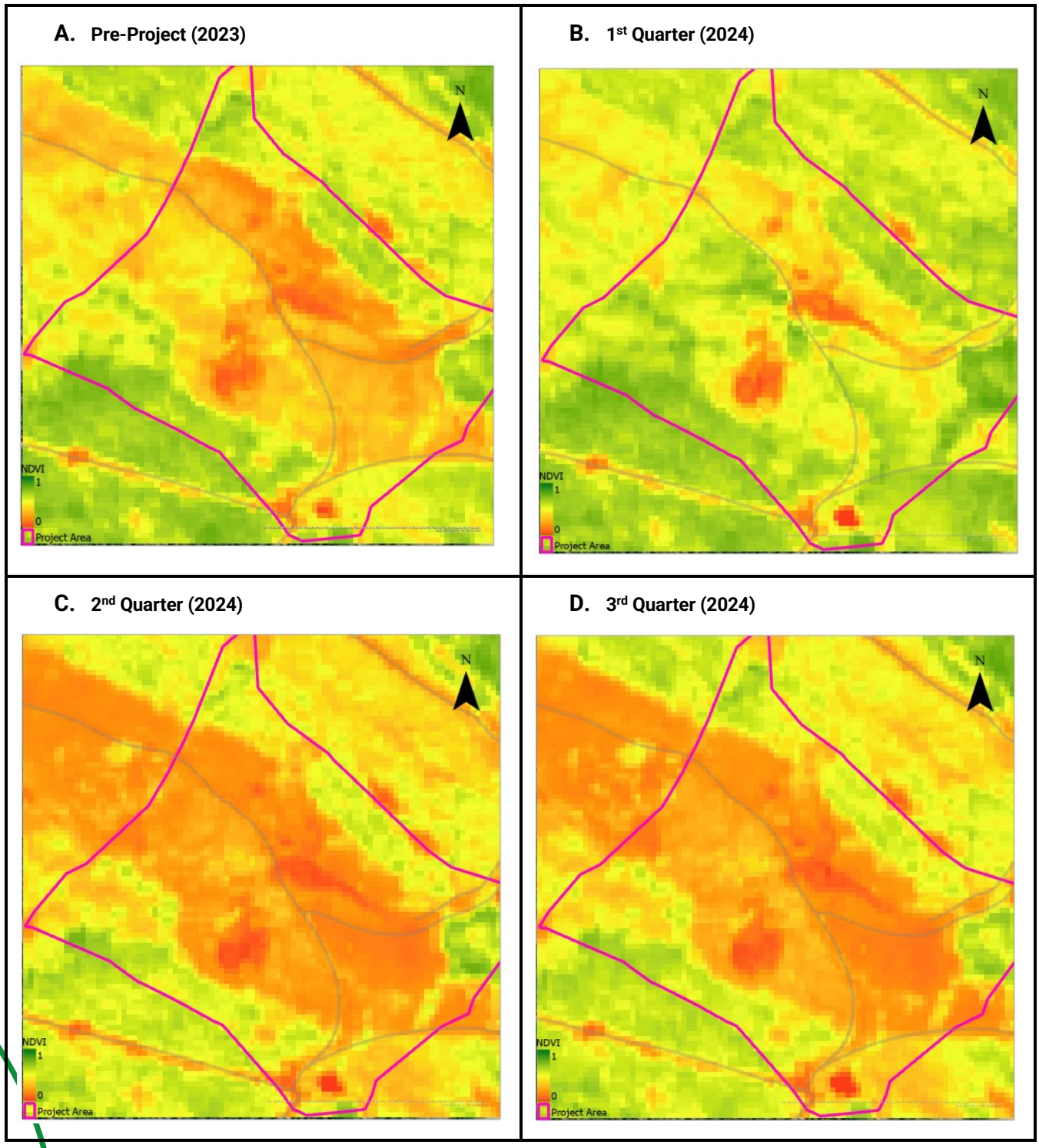

Figure 7. Spatial Evolution of NDVI Within Project area.

The comparison of NDVI and GNDVI trends between the project and control areas (Figure 8) highlights clear differences in baseline conditions and early vegetation recovery. The control area, characterized by pre-existing vegetation, maintains higher and stable indices, while the project area, starting with sparse vegetation, shows a gradual improvement, particularly in early 2024. Seasonal declines are observed in both areas mid-year, but the project area demonstrates promising signs of ecological recovery. With continued interventions, the project area is expected to achieve or surpass the vegetation health of the control area, underscoring the importance of sustained monitoring and adaptive management to ensure long-term success.

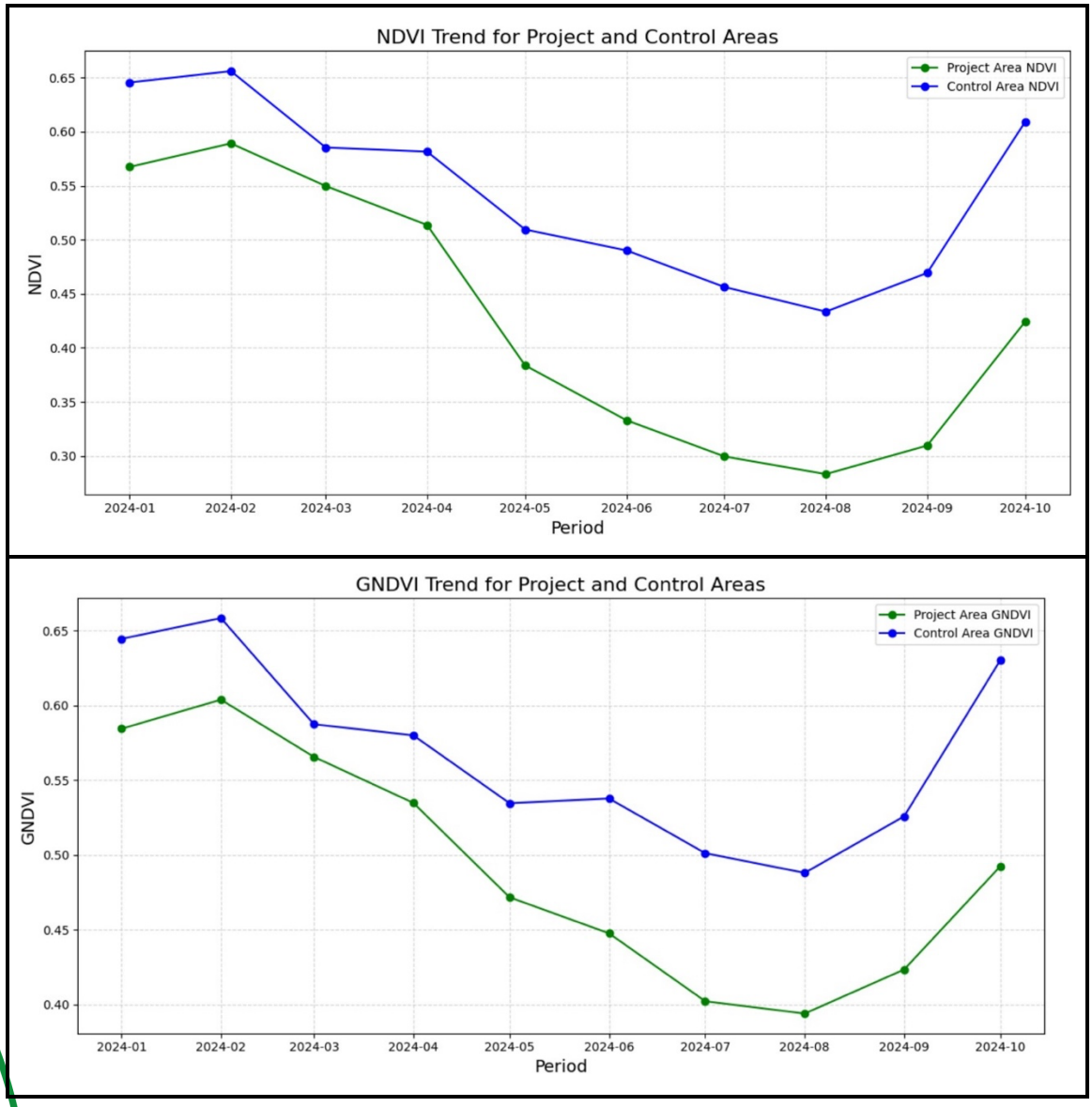

Figure 8. Comparison of NDVI and GNDVI trends between the project and control areas.

IX. OBSERVATIONS AND COMMENTS

Date	Comments and observations
Pre-project (2023)	The values of NDVI and GNDVI in the year 2023 were relatively low, reflecting the sparse vegetation in the project area. The average NDVI was 0.44, and GNDVI was 0.50, consistent with baseline conditions before project implementation. These values indicate limited vegetative cover, underscoring the need for intervention.
May 2024	By May 2024, the project area showed slight improvements in GNDVI (0.47) and NDVI (0.43). However, both indices were lower compared to the early months of 2024, reflecting seasonal declines as vegetation activity reduced due to climatic factors.
August 2024	In August 2024, GNDVI and NDVI continued to decline, reaching 0.39 and 0.32, respectively. This seasonal low aligns with reduced vegetation vigor during the dry months, though a gradual stabilization compared to previous months is observed, suggesting the establishment of some vegetation in the project area.
November 2024	By November 2024, NDVI showed a rebound, reaching 0.51. This recovery reflects increased vegetation vigor during the growing season, indicating that project interventions may be starting to show more tangible effects, with vegetation health approaching that of the control area.

X. CONCLUSIONS

The upward trajectory in both NDVI and GNDVI values demonstrates the effectiveness of the restoration interventions. Continued monitoring will be essential to ensure sustained progress and to identify any seasonal or spatial variations requiring adaptive management. This positive trend reinforces the project's contribution to ecological recovery and carbon sequestration objectives.