



Integrating Remote Sensing and Soil Analysis for Long-Term Land Restoration Assessment in Mediterranean Ecosystems

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The soil is key!

Soil health is foundational in all restoration areas – agriculture, food forests, and natural forests – because it supports plant growth, stores carbon and maintains water cycles essential for ecosystem resilience. By improving soil structure and biodiversity, restoration efforts enhance nutrient availability and boost the ecosystem's ability to recover and sustain itself over time.

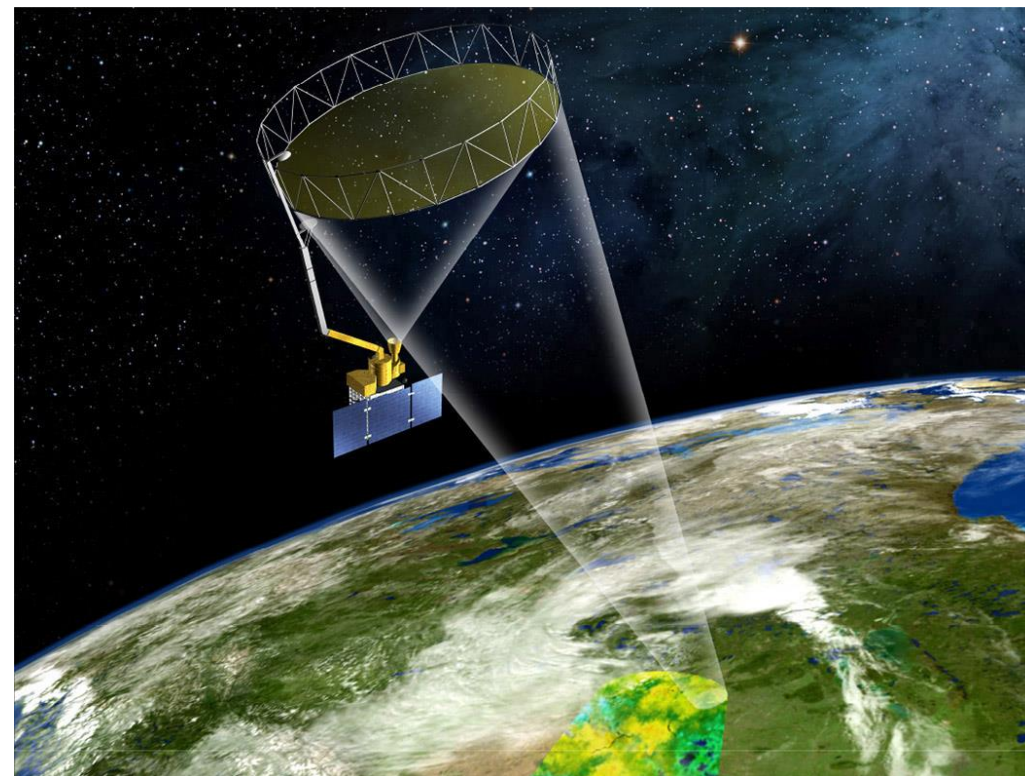


Restoration is crucial!

Restoration in agriculture, food forests, and natural forests is crucial for rebuilding biodiversity, enhancing ecosystem resilience, and combating climate change. By restoring degraded areas, we improve soil health, water retention, and carbon storage, creating healthier environments that support both human and ecological well-being.

Satellite Remote Sensing - Soil

Satellite remote sensing enables efficient, large-scale monitoring of soil properties, such as moisture, organic content, and degradation, by capturing spectral data across vast areas. Its effectiveness lies in its ability to provide consistent, long-term data, allowing for accurate tracking of soil health and changes over time, which is crucial for sustainable land management.



Bottom-Up Analysis

Soil samples from Food Forest (ROI), and 2 comparison sites (natural forest and agricultural field)

Chemical Analysis

Physical Analysis

Spectroscopic Analysis

Remote Sensing Score

Top-Down Analysis

Sentinel 2 data collection on Food Forest (ROI) and a comparison site (agricultural field)

Indicators Analysis

Temporal Trends

Soil Health Score

Linking Scores

Score Alignment

Unified Integration Model

Applications of the Integrated Model

Soil Health Monitoring

Decision Support for Land Managers

Framework for Adaptive Management



Pilot Areas



Bethlehem of Galilee Food Forest

A food forest is a sustainable agricultural system designed to mimic a natural forest ecosystem, where diverse layers of plants, including trees, shrubs, herbs, and ground cover, work together to produce food. By promoting biodiversity and natural soil health, food forests create resilient environments that support a variety of crops and require minimal human intervention.



Heraklion Forest

The Heraklion forest restoration project demonstrates the power of long-term ecological recovery, where reforestation efforts have successfully revived native species and improved biodiversity. Through sustainable management and conservation practices, the forest now serves as a model for resilience and habitat restoration in Mediterranean ecosystems.

Major Differences in Pilot Areas

Purpose

Food forest; Natural forest

Size

~3 acres; Hundreds of acres

Time of Restoration

Less than 10 years; Several decades

Plant Composition

Diversity of mostly edible plants; Native Mediterranean flora, with a focus on trees

Management Approach

Active - with a focus on polyculture and permaculture techniques; Focus on conservation and minimal human intervention to allow natural regeneration

Biodiversity Goals

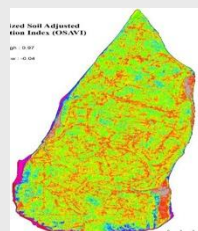
Aims to increase biodiversity while producing food sustainably; Aims to restore and maintain native biodiversity specific to Mediterranean forest ecosystems

Top-Down Indicators



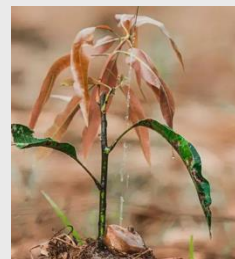
SIPI

Structure
Insensitive
Pigment Index
(assess the
amount of
chlorophyll in
vegetation)



SAVI

Soil Adjusted
Vegetation
Index
(how healthy
and dense the
vegetation is,
considering soil
brightness)



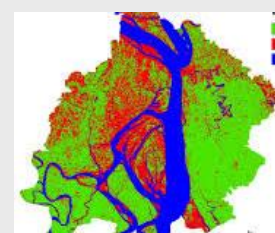
PSRI

Plant Senescing
Reflectance
Index
(Identifying
plants getting
older or
entering a
senescent stage)



NSDI

Normalized
Shortwave
Infrared
Difference
index
(identifies soil
salinity)



NDWI

Normalized
Difference Water
Index
(useful for
mapping
moisture)



NDII

Normalized
Difference
Infrared Index
(water stress /
stiffness
moisture in
plants)

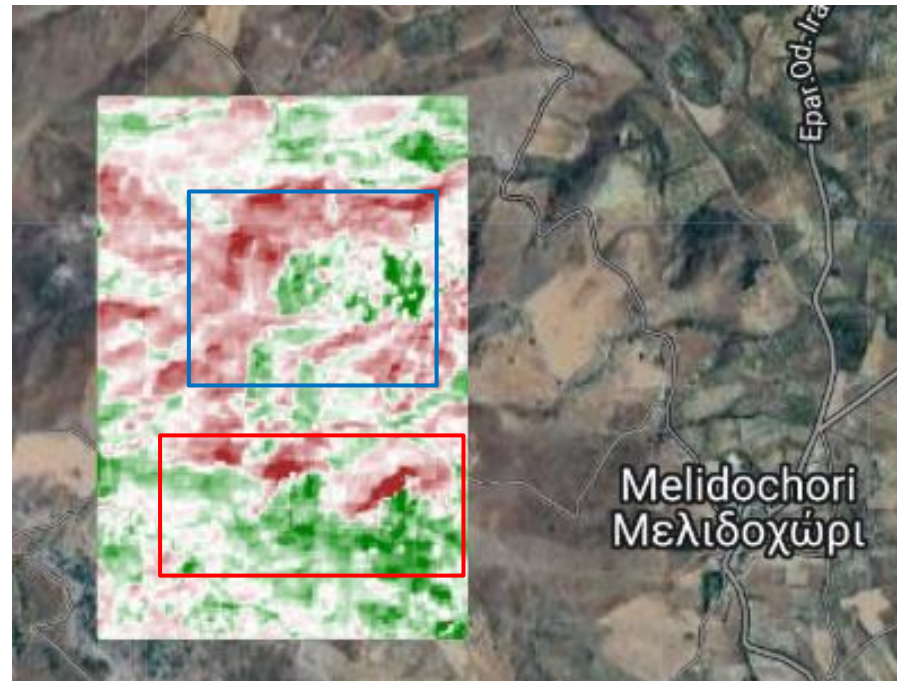
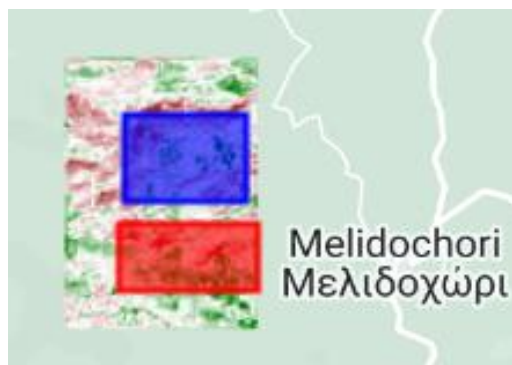
Results

SIPI

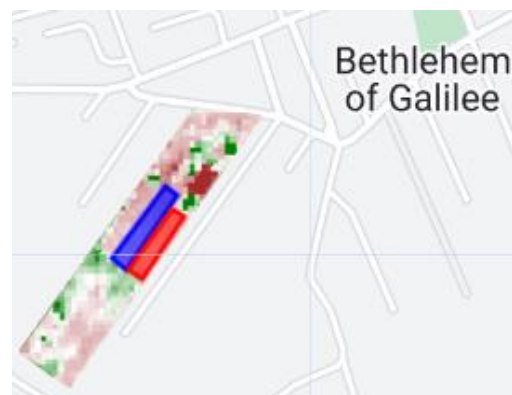
Assess the amount of chlorophyll in vegetation

 Restored Area

 Control Area



Heraklion Forest



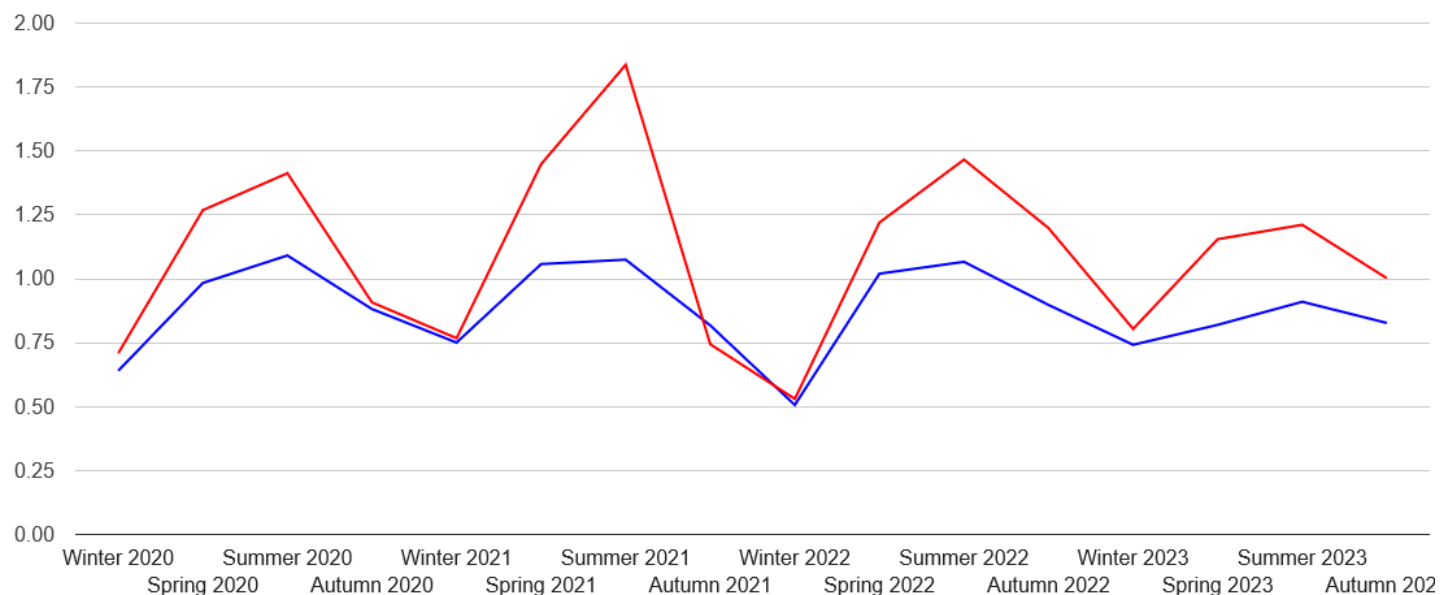
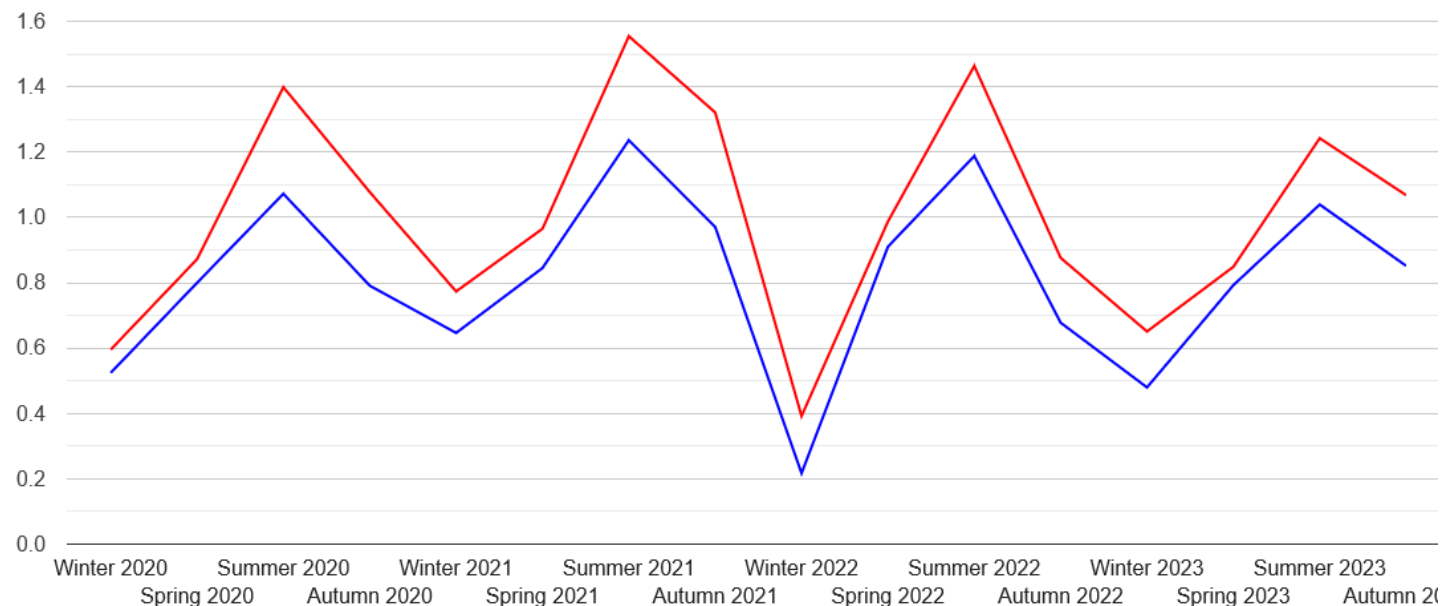
Food Forest

Results

SIPI

Assess the amount of chlorophyll in vegetation

 Restored Area
 Control Area

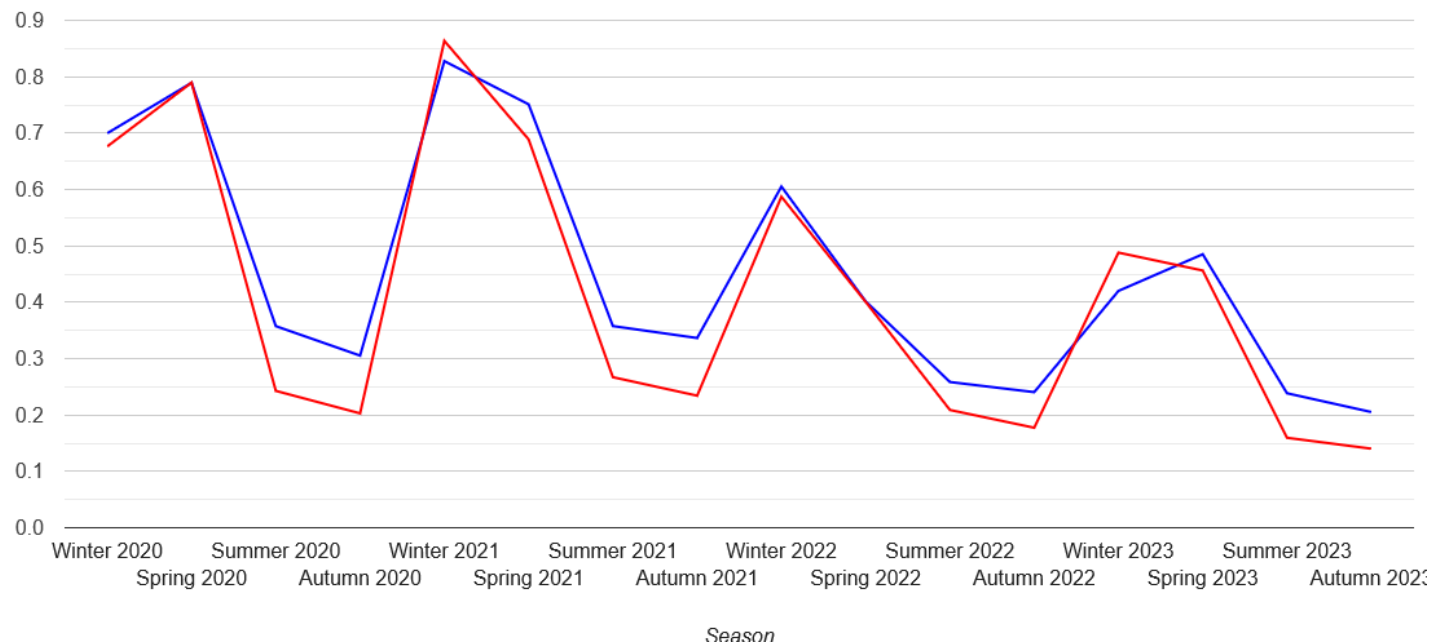


Results

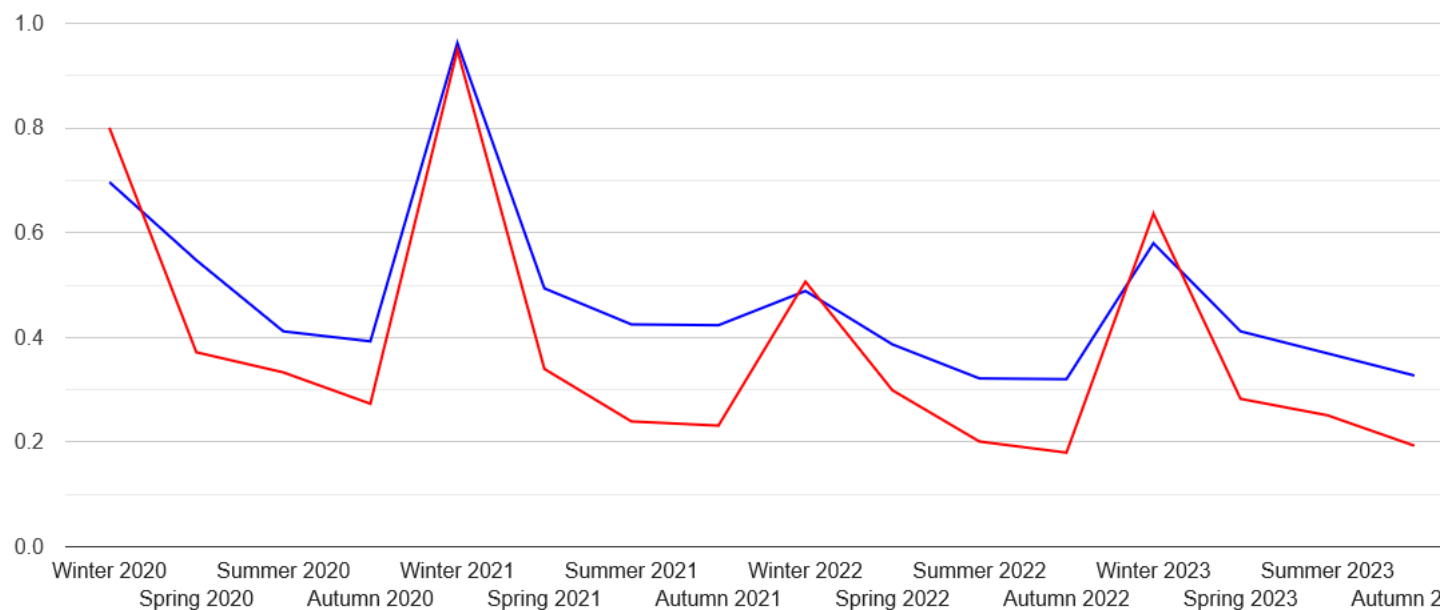
SAVI

How healthy and dense the vegetation is, considering soil brightness

 Restored Area
 Control Area



Heraklion Forest



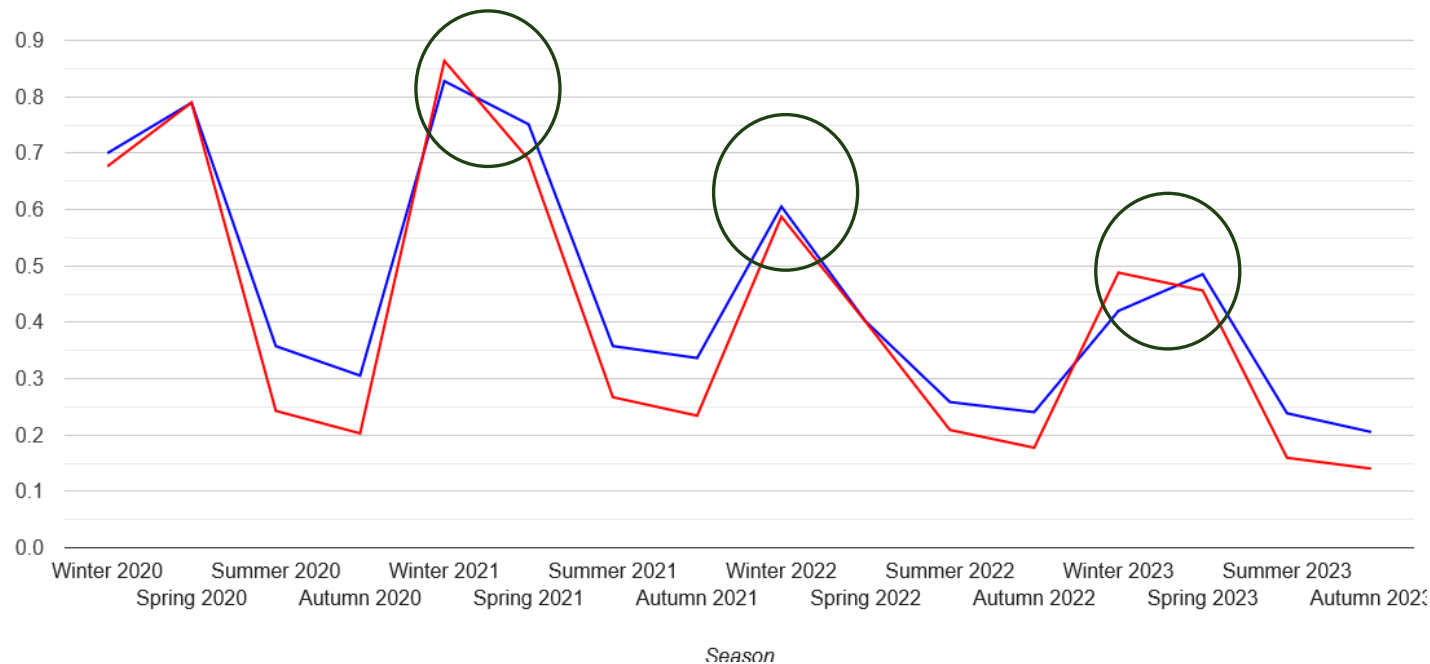
Food Forest

Results

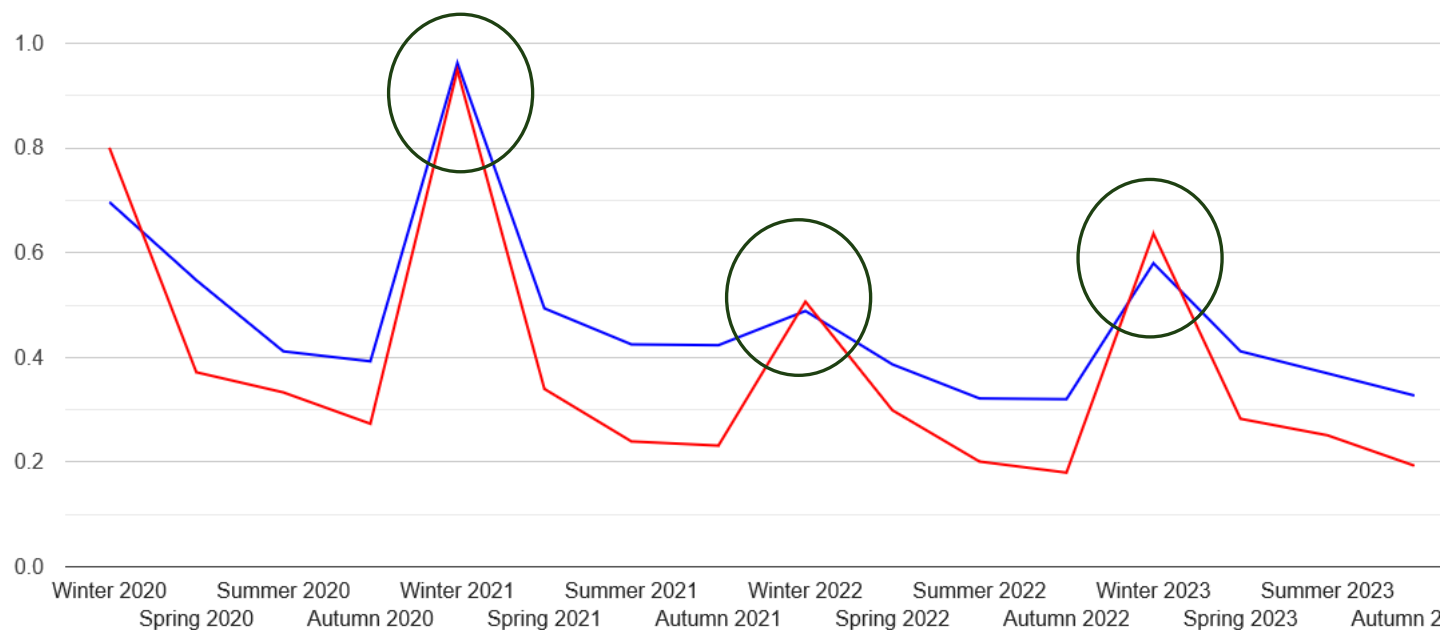
SAVI

Winters –
Almost no difference

 Restored Area
 Control Area



Heraklion Forest



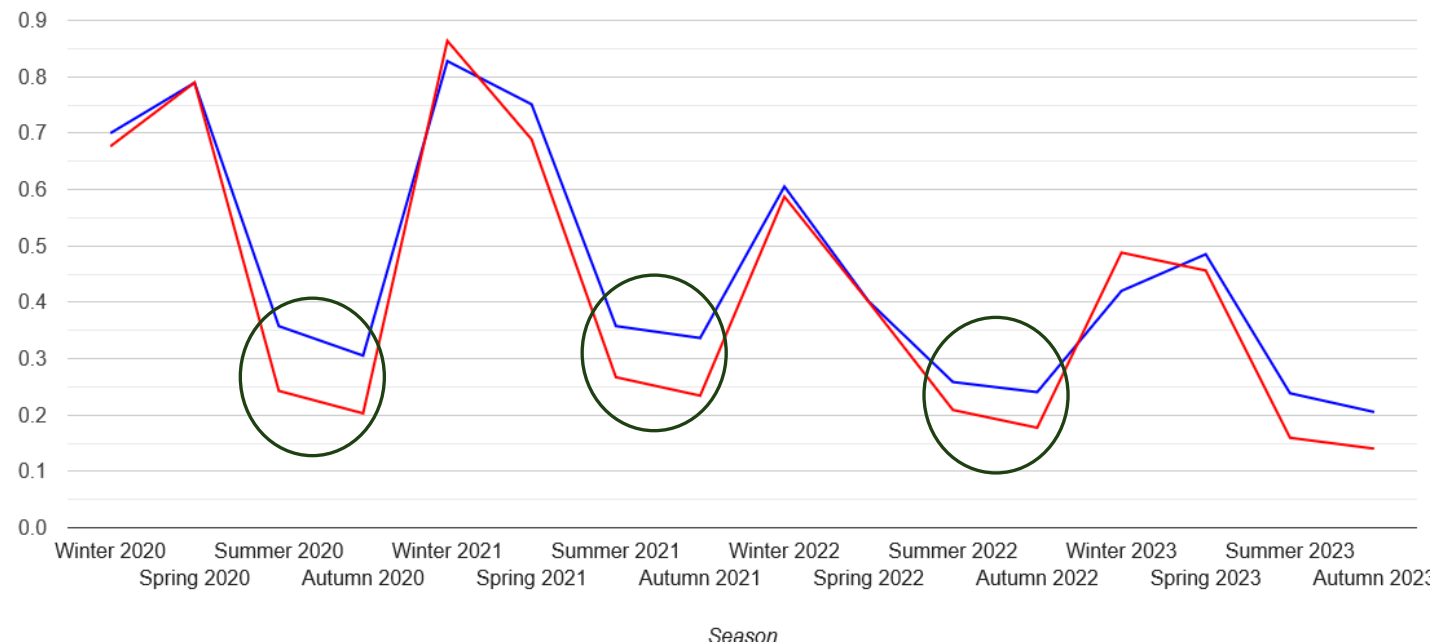
Food Forest

Results

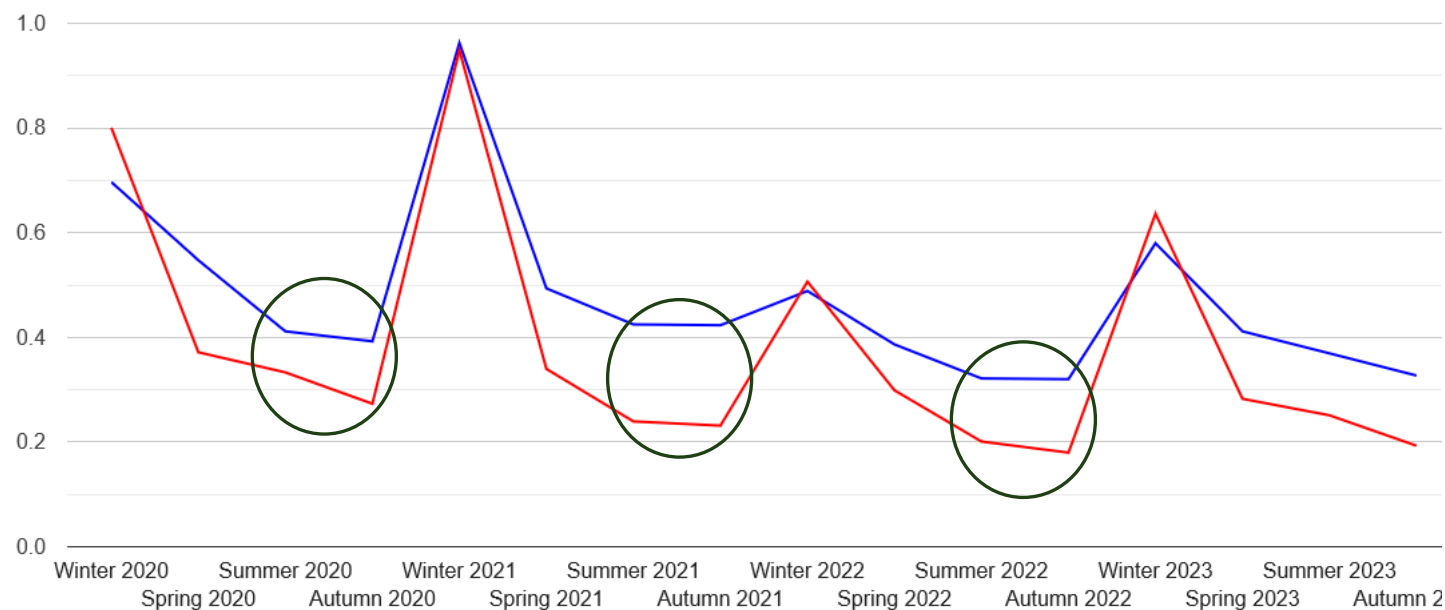
SAVI

Summers –
Noticed difference

 Restored Area
 Control Area

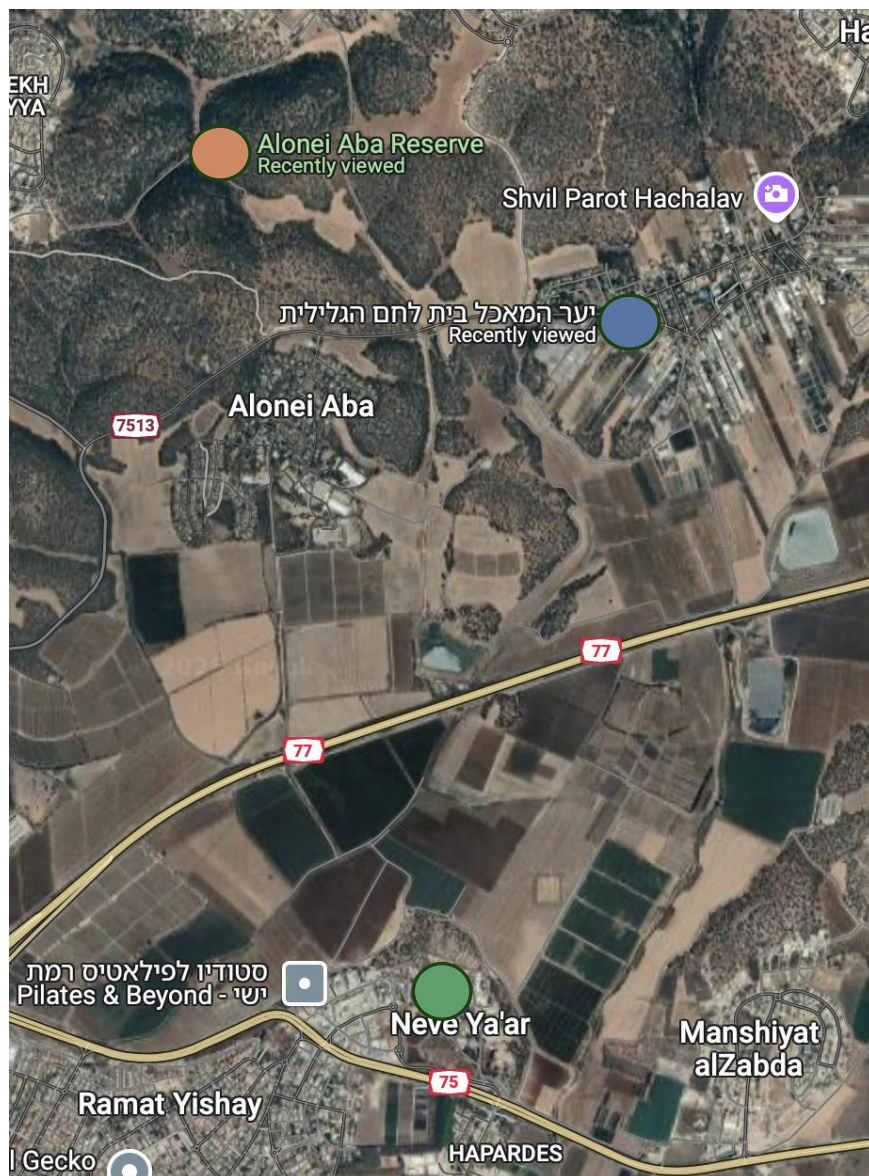


Heraklion Forest



Food Forest

Comparison sites



 Bethlehem of Galilee Food Forest

 Alonei Aba Natural Forest

 Neve Ya'ar - Agricultural



PRIMA
IN THE MEDITERRANEAN AREA



Soil Sampling and Laboratory Analysis

Sampling Sites:

- **FF – Food Forest:** 40 samples at various depths (restoration site)
- **AA – Natural Oak Forest:** 20 samples (reference for healthy ecosystem)
- **Conventional Field:** 20 samples from a nearby, non-restored agricultural site

Soil Parameters Tested:

- Total Organic Carbon (TOC%), Total Nitrogen (NO₂-N, NO₃-N, NH₄-N), C/N ratio
- pH, Electrical Conductivity, Active Carbon
- Bulk and Particle Density, Porosity

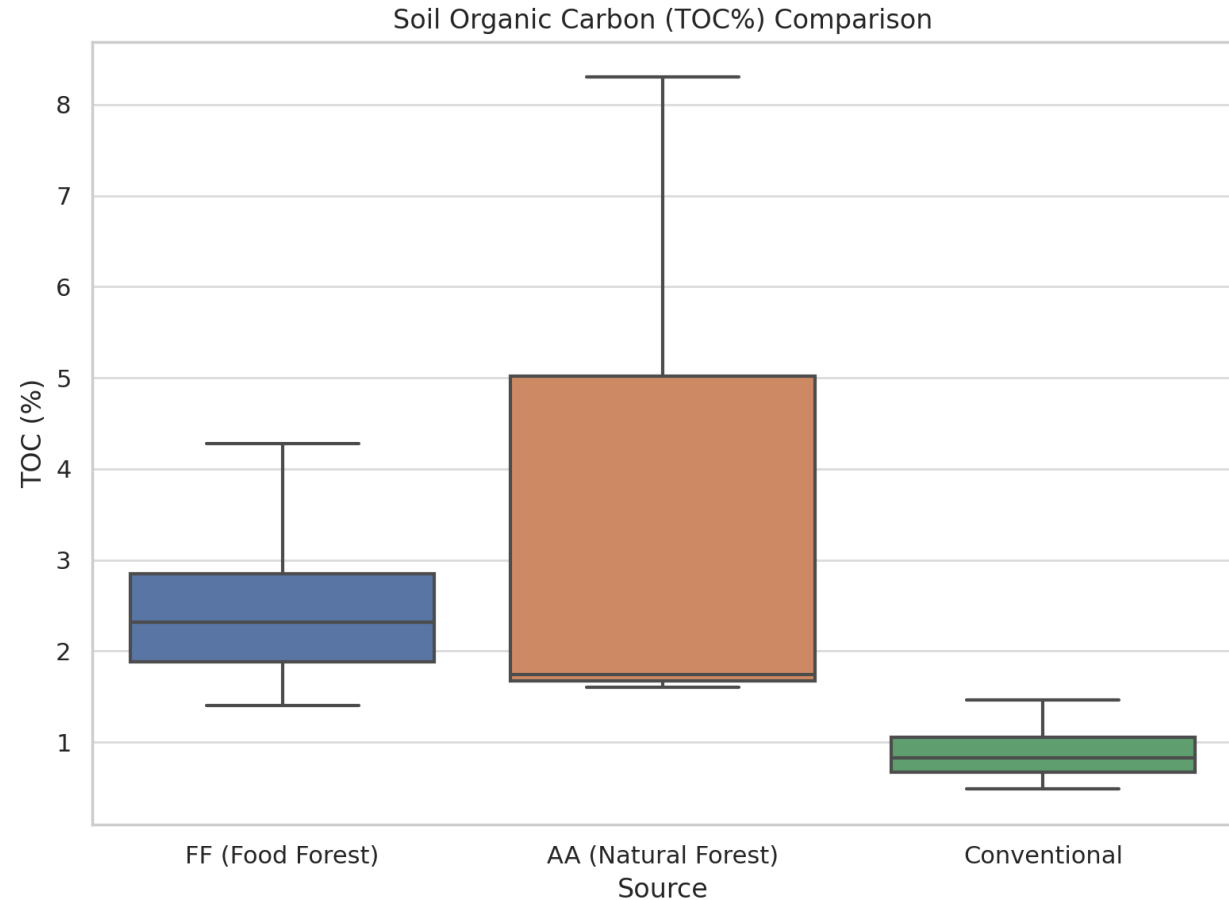


PRIMA
IN THE MEDITERRANEAN AREA



Organic Carbon Levels Reflect Restoration Progress

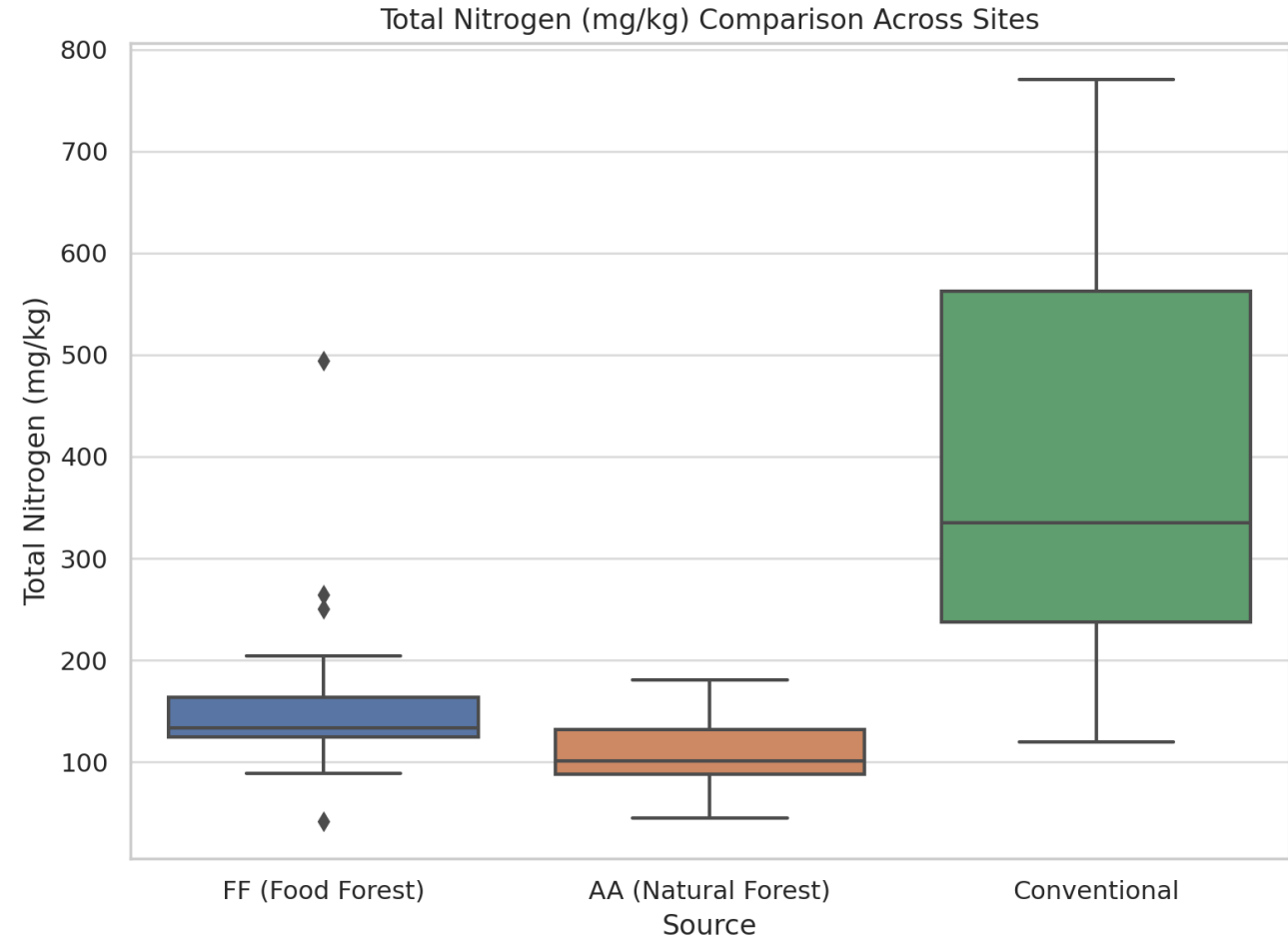
- **FF** samples exhibit TOC% levels that **fall between** the degraded (conventional) and natural (AA) conditions.
- Several FF samples reach or even **surpass the TOC%** values observed in the natural forest.
- Indicates an **improvement in organic matter** accumulation—a key indicator of soil restoration.



Nitrogen Dynamics and Ecosystem Function

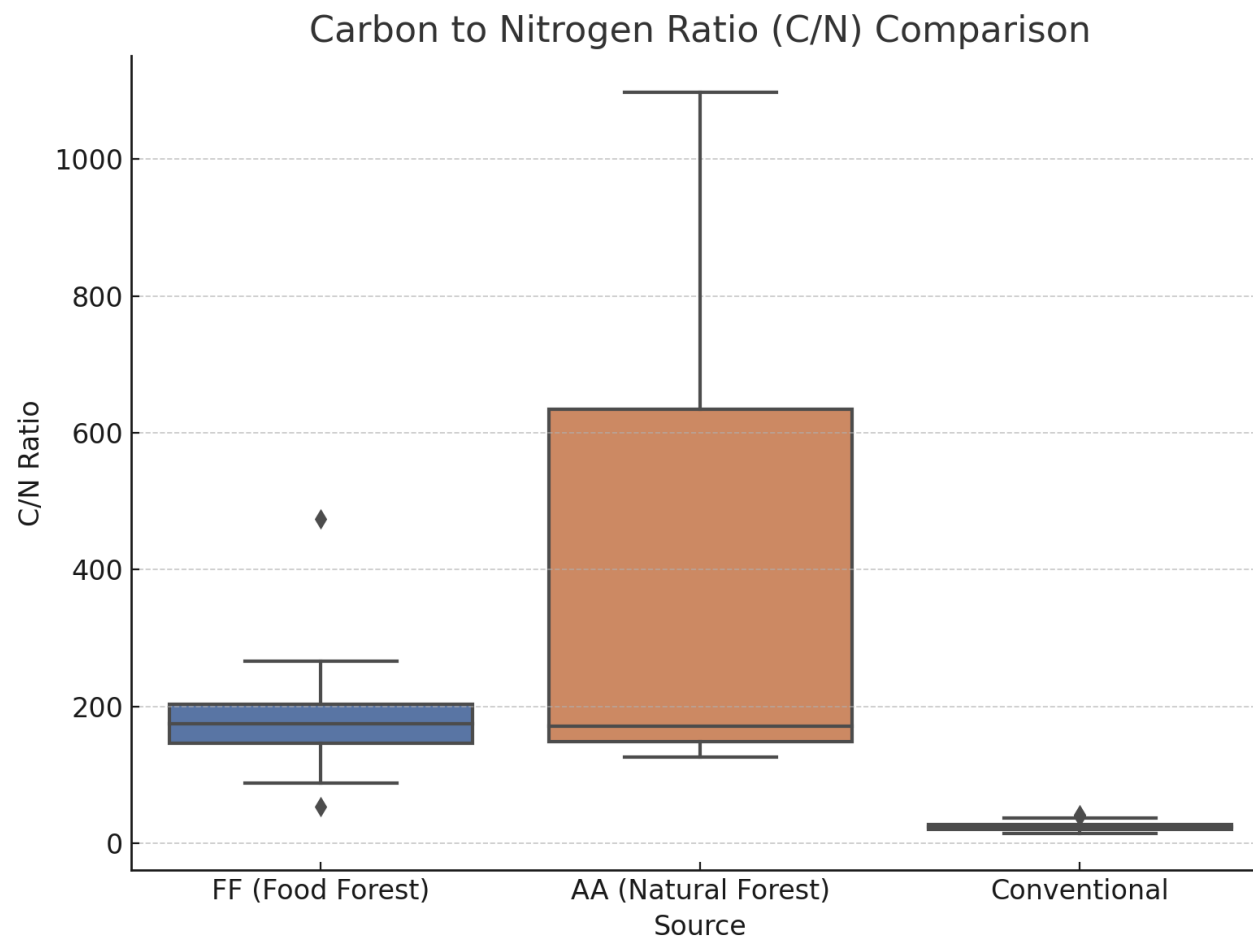
Total Nitrogen:

- FF and AA soils show significantly **higher nitrogen availability** than the conventional field.
- Indicates **nutrient retention and cycling** are improving in the FF.



C/N Ratio:

- The **carbon to nitrogen ratio** in FF and AA falls within biologically expected ranges (typically ~10–20).
- FF's values **trend toward** those of the natural forest (AA).
- This reflects a **restored balance between organic matter input and microbial decomposition**, supporting **soil health recovery**.

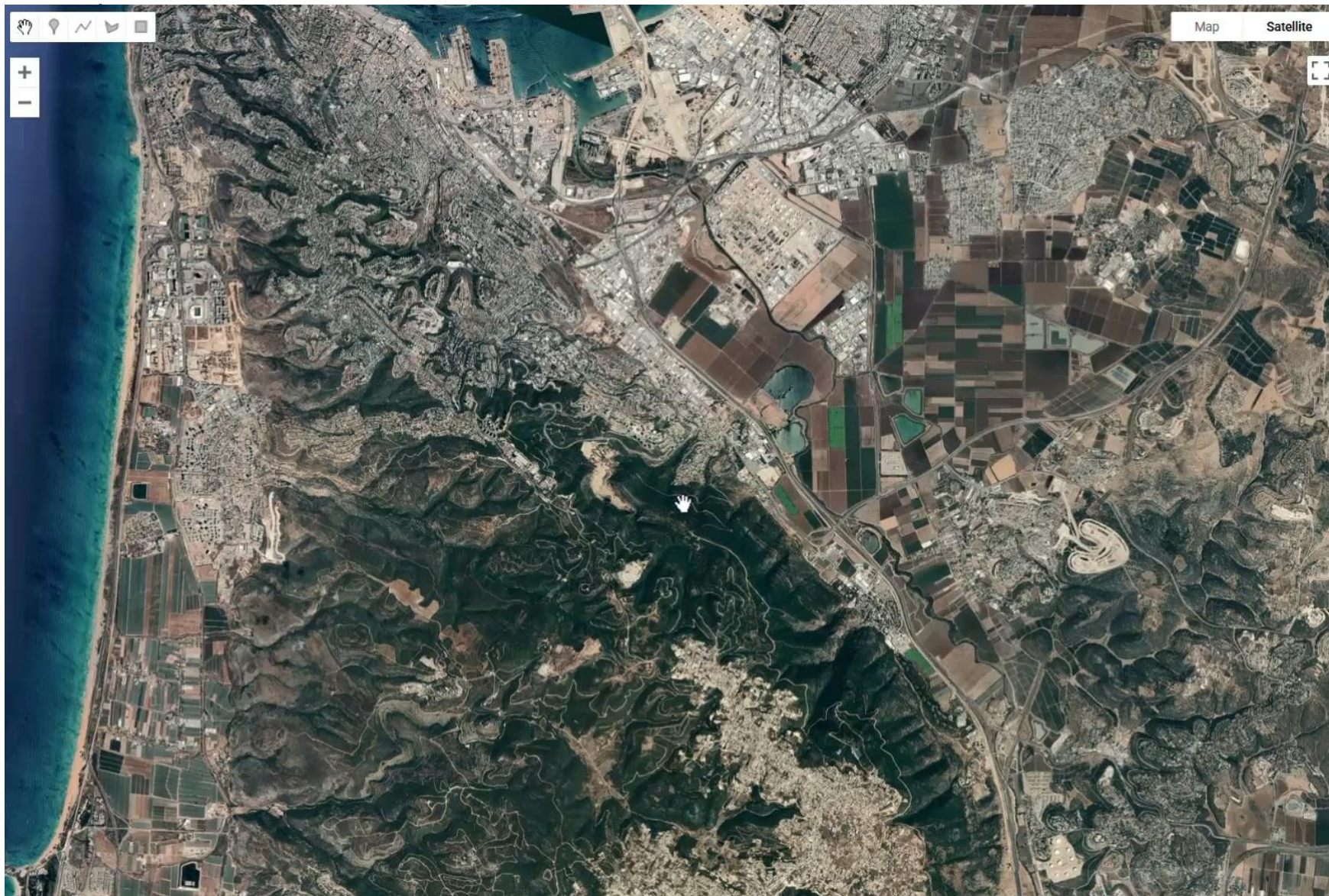


Results and Conclusions

- Notable Differences in the restored areas, compared to the control areas in both pilots
- Ability to detect changes and restoration impact in different scales and in small areas
- Ability to overcome the lack of data over time, using the compared area
- Forecasting seasonal changes over time
- Covering large areas over long timeseries to understand patterns



What`s Next?



CarbonFIX

Carbon Sequestration Potential

1. Draw a polygon to define the area of interest. 2. Select a date range. 3. Click "Calculate Potential" to analyze.

Start Date:

2024-10-01

End Date:

2024-11-30

Calculate Weighted Score and Map

Results:

Temperature (°C):

N/A

Soil Moisture:

N/A

Erosion Risk:

N/A

DBSI:

N/A

SAVI:

N/A

Recalculate Weighted Score

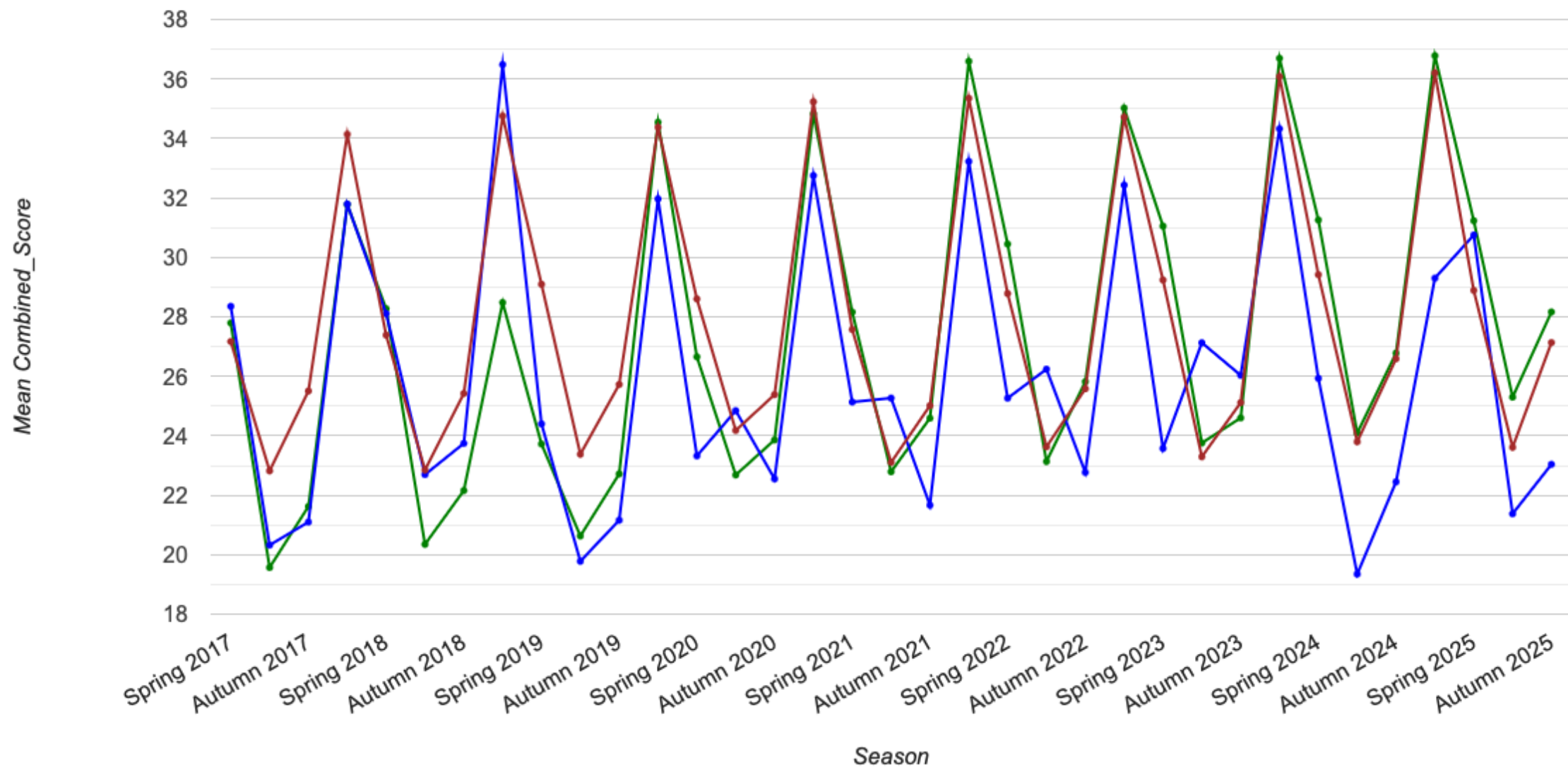
Overall Weighted Score:

N/A



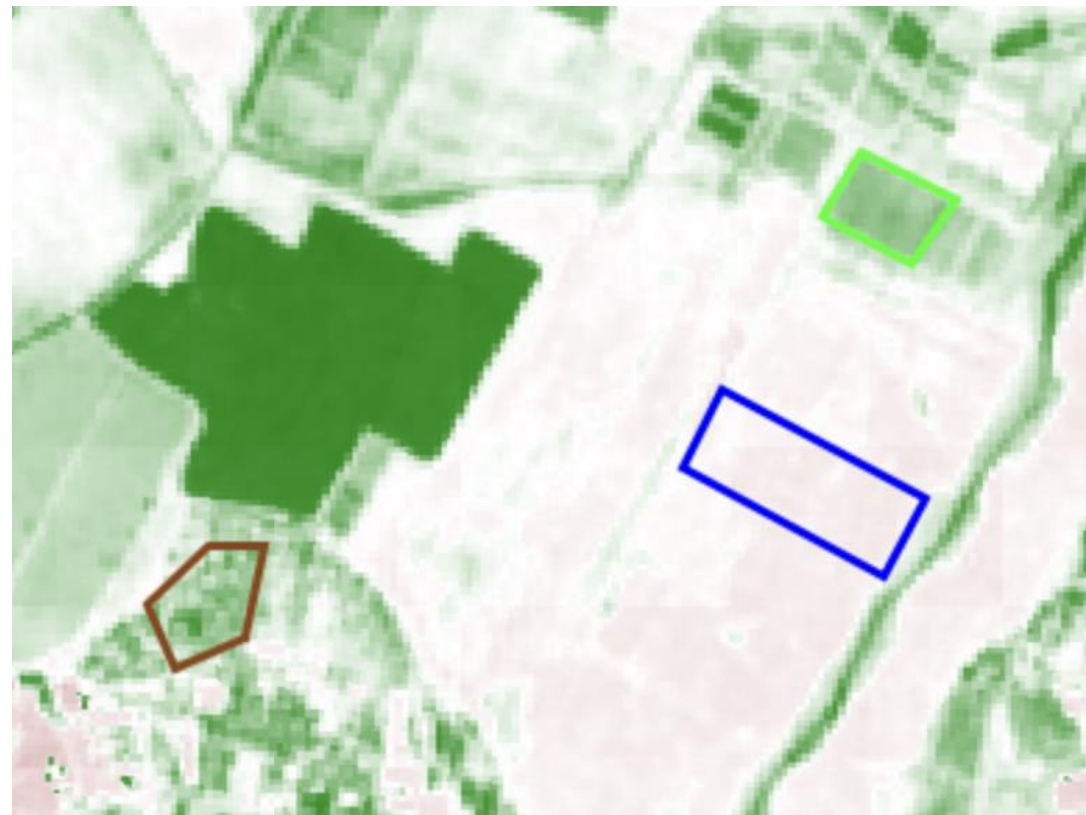
Seasonal Mean Combined_Score (2017 → Autumn 2025)

—●— Polygon_1
 —●— Polygon_2
 —●— Polygon_3





Summer 2017



Summer 2024



ANY
QUESTIONS?

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