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# Conservation Agriculture and Earth Observation for Durum Wheat Resilience in Mediterranean Environments: Results from a Long-Term Field Experiment

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## Introduction

Climate change is intensifying drought frequency and severity across Mediterranean agro-ecosystems, threatening the sustainability of cereal-based cropping systems. Intensive tillage further intensifies soil vulnerability by reducing water retention and accelerating organic matter loss. Conservation Agriculture (CA), through minimum tillage (MT) and no-tillage (NT), offers a mechanistically sound strategy to enhance soil health and crop resilience. Long-term experimental evidence under real field conditions remains limited.

## Objectives

This study aims to quantify the agronomic and environmental performance of MT and NT on durum wheat (*Triticum durum* Desf. cv. Sfinge) over multiple seasons, integrating Earth Observation (EO) with ground-based measurements to capture soil–plant–climate interactions at field scale.

## Materials and Methods

A long-term field trial (2014–2024) was established at the CREA-CI "Manfredini" experimental farm (Foggia, southern Italy), a representative site of the semi-arid Mediterranean environment. Treatments (MT, NT) were arranged in a randomized complete block design with four replicates on ~1 ha elementary plots (Fig. 1). Multi-temporal satellite imagery from Landsat 8 and Sentinel-2 was processed in Google Earth Engine, deriving spectral vegetation indices (NDVI, MCARI, OSAVI, NDTI, GNDVI, NDWI) across key phenological windows. EO data were correlated with field measurements including grain yield, plant biomass, canopy height, phenological staging, and grain quality traits (protein content, gluten index, test weight). Soil organic carbon and soil moisture were monitored as key edaphic drivers.

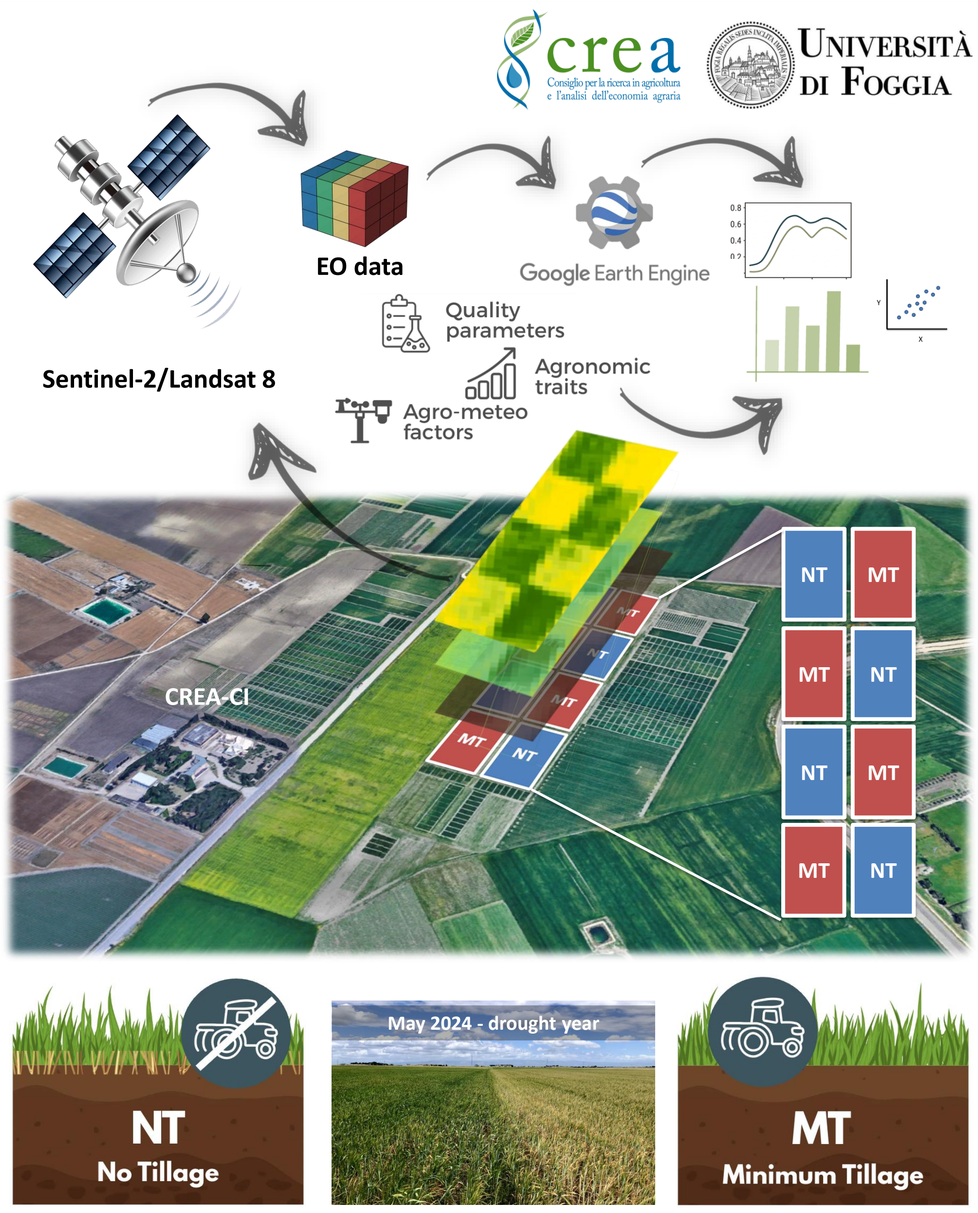



**Fig. 1.** Methodological workflow for integrating satellite data (Sentinel-2/Landsat 8), agrometeorological parameters, and field traits across NT and MT tillage treatments at the CREA-CI site.

**Tables 1-2.** Pearson correlation coefficients between grain yield and spectral indices (VIs) at key growth stages and AUC (Area Under the Curve) under MT and NT soil tillage.

| MINIMUM TILLAGE | | | | | | |
|---|---|---|---|---|---|---|
| VIs | tillering | jointing | booting | heading | grain filling | AUC |
| NDVI | 0,119 | 0,271 | 0,776 | 0,632 | 0,624 | 0,653 |
| MCARI | 0,106 | 0,479 | **0,915** | 0,797 | 0,749 | **0,860** |
| OSAVI | 0,196 | 0,350 | 0,845 | 0,791 | 0,634 | 0,778 |
| NDTI | 0,082 | 0,127 | 0,816 | 0,430 | 0,642 | 0,621 |
| GNDVI | 0,069 | 0,229 | 0,740 | 0,564 | 0,696 | 0,606 |
| NDWI | 0,043 | 0,288 | 0,856 | 0,802 | 0,504 | 0,734 |

| NO TILLAGE | | | | | | |
|---|---|---|---|---|---|---|
| VIs | tillering | jointing | booting | heading | grain filling | AUC |
| NDVI | 0,354 | 0,331 | 0,808 | 0,390 | 0,048 | 0,687 |
| MCARI | 0,442 | 0,465 | 0,757 | 0,701 | 0,168 | **0,768** |
| OSAVI | 0,391 | 0,410 | **0,822** | 0,603 | 0,043 | **0,756** |
| NDTI | 0,184 | 0,264 | 0,799 | 0,293 | 0,023 | 0,621 |
| GNDVI | 0,181 | 0,289 | 0,743 | 0,242 | 0,181 | 0,641 |
| NDWI | 0,295 | 0,349 | 0,641 | 0,550 | -0,035 | 0,627 |

**Tab. 3.** Grain yield (t ha$^{-1}$) and yield ratio for MT and NT over the years.

| | **Yield** (t ha$^{-1}$) | | |
|---|---|---|---|
| **Year** | **MT** | **NT** | **NT/MT** |
| 2013/14 | 3,43 | 3,42 | 0,99 |
| 2014/15 | 2,99 | 3,09 | 1,03 |
| 2015/16 | 3,58 | 3,48 | 0,97 |
| 2016/17 | 2,44 | 2,76 | 1,13 |
| 2017/18 | 2,34 | 2,15 | 0,92 |
| 2019/20 | 1,47 | 1,70 | 1,16 |
| 2021/22 | 4,64 | 4,12 | 0,89 |
| 2023/24 | 1,60 | 1,77 | 1,10 |
| | **2,81** | **2,81** | **1,02** |

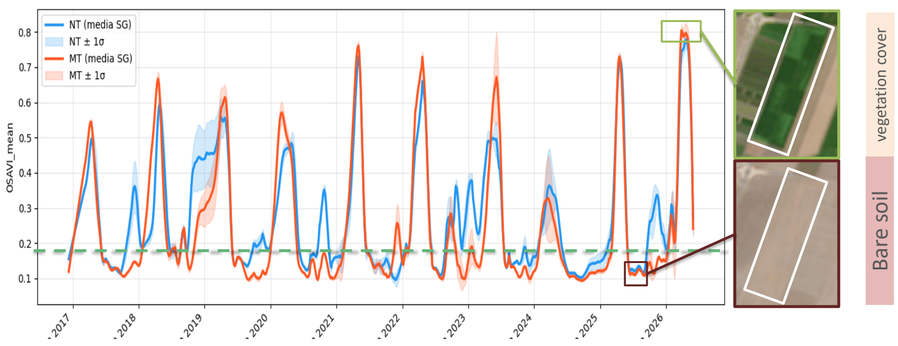



**Fig. 2.** OSAVI time series (2017–2026) for NT and MT systems, showing peak values (vegetation cover) and bare soil (threshold ≈ 0.20).

## Results

EO-derived indices demonstrated good correlations with ground-truth observations across all seasons, validating the multi-temporal satellite approach for long-term CA monitoring. Among the growth stages, booting consistently emerged as the most responsive window, exhibiting the highest correlation between vegetation indices and yield across all indices. MT achieved higher peak correlations with MCARI during booting, whereas NT demonstrated a higher correlation with OSAVI, highlighting index-specific sensitivities to different tillage practices (Tab. 1-2). NT consistently showed higher VIs values than MT during stem elongation and grain filling, particularly in drought years, reflecting superior canopy vigor and drought resilience. This response could be attributed to enhanced soil moisture conservation under residue cover, which limits evaporative losses during physiologically critical growth stages

## Conclusions

The long-term integration of multi-temporal EO data with field-scale agronomic and soil measurements provides a powerful framework for monitoring CA effects under Mediterranean drought conditions. Preliminary results confirm NT as an effective strategy to enhance crop resilience and yield stability in semi-arid environments. The dataset generated supports improved calibration of remote sensing models and contributes to the development of precision agriculture and decision-support tools for sustainable dryland management.

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