AGENG2024

The use of Sentinel-2 satellite data for spatially variable rate fertilisation of durum wheat crop in the centre of Sicily

Vincenzo Cascio[1], Antonio Comparetti[1], Jose Rafael Marques da Silva[2,3], Santo Orlando[1]

[1] Department of Agricultural, Food and Forest Sciences, University of Palermo, Viale delle Scienze, Building 4, 90128 Palermo, Italy

[2] Mediterranean Institute for Agriculture, Environment and Development (MED), Department of Rural Engineering, School of Science and Technology, University of Évora, 7000-671 Évora, Portugal

[3] Agroinsider Lda., PITE, R. Circular Norte, NERE, Sala 18, 7005-841 Évora, Portugal

Remote Sensing of plant vegetative vigour from UAVs or satellites for spatially variable rate fertiliser management ?

Remote Sensing (RS) using Unmanned Aerial Vehicles (UAVs) and satellites, specifically the Copernicus Sentinel-2B satellite, is a valuable technique in Precision Agriculture.

It employs the Normalised Difference Vegetation Index (NDVI) as an indicator of vegetation vigour to generate maps for spatially variable rate fertilisation.

Differently from RS using UAVs, that using the Copernicus Sentinel-2B satellite, via the online platform AgroInsider, allows the application of 2 or 3 fertiliser rates in 2 or 3 Management Zones (MZs), each having a different level of vegetation vigour.

Moreover, Sentinel-2B satellite provides not only NDVI but also NDWI (Normalised Difference Water Index), as index of plant leaf water content, in order that both indexes can be used for establishing the optimal fertilisation time.

Furthermore, the Sentinel-2B satellite provides data and images of both the above indexes for any date, every 5 days, independently from weather conditions (e.g. wind speed), and an archive of data and images from 2017 (launch of Sentinel-2B satellite on 7 March 2017), at an affordable cost also for areas larger than 5 ha.

RS using the Sentinel-2B satellite provides a spatial resolution of 10 m, that is enough to overlap a grid having cells of 10 x 10 m on a field base map.

In order to eventually sense the spatial variability of vegetation vigour and plant leaf water content inside a field, a minimum area of 3 ha is needed.

The aim of this study

This study aims at assessing the potential of RS from the Copernicus Sentinel-2B satellite in sensing the spatial variability of vegetation vigour and plant leaf water content in durum wheat (*Triticum durum*) fields of inland Sicily.

The objective is to integrate this information into a Decision Support System (DSS) for generating fertilisation maps divided into MZs.

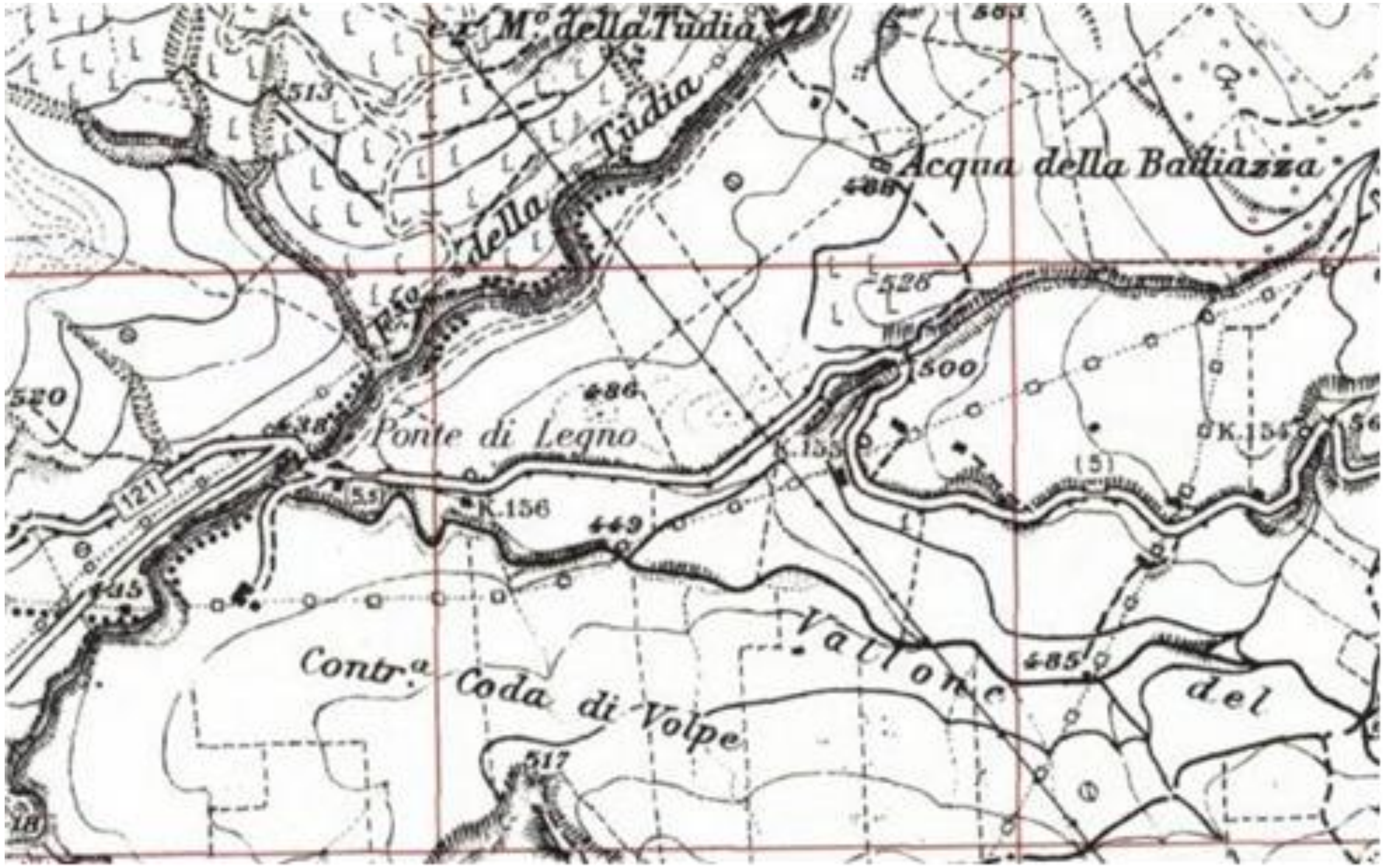
Location of the study area in inland Sicily

For this case study, a continuous durum wheat field of 4.23 hectares ca., located in the centre of Sicily, was chosen.

This field is located in Vallone del Landro district, Petralia Sottana, 12 km ca. far from Resuttano town (Caltanissetta, Sicily, Italy) by road.

The above field is called as Acqua della Badiazza (Water of Badiazza) by the inhabitants of the area, because it includes water troughs for livestock on grazing.

Study area shown in the Regional Technical Map - CTR (scale 1:25,000; altitude 435-470 m a.s.l.)



Methods

Google Earth Pro was used to identify and delineate the study area, and the resulting polygon was saved as a .kml file. This vector map was incorporated into the AgroInsider online platform.
The investigation spanned the growing seasons 2021-2022 and 2022-2023.

During the growing season 2021-2022, the key crop operations/phenological growth stages of durum wheat, cv. Arcangelo, were the following :

- seeding on 4 January 2022;
- sprouting in March 2022;
- raising in April 2022;
- harvest on 25 June 2022.

During this season, the crop yield resulted 2.60 t ha^{-1}.

During the growing season 2022-2023, the key crop operations/phenological growth stages of durum wheat, mix of cv. Arcangelo, Simeto and Garigliano, were the following :

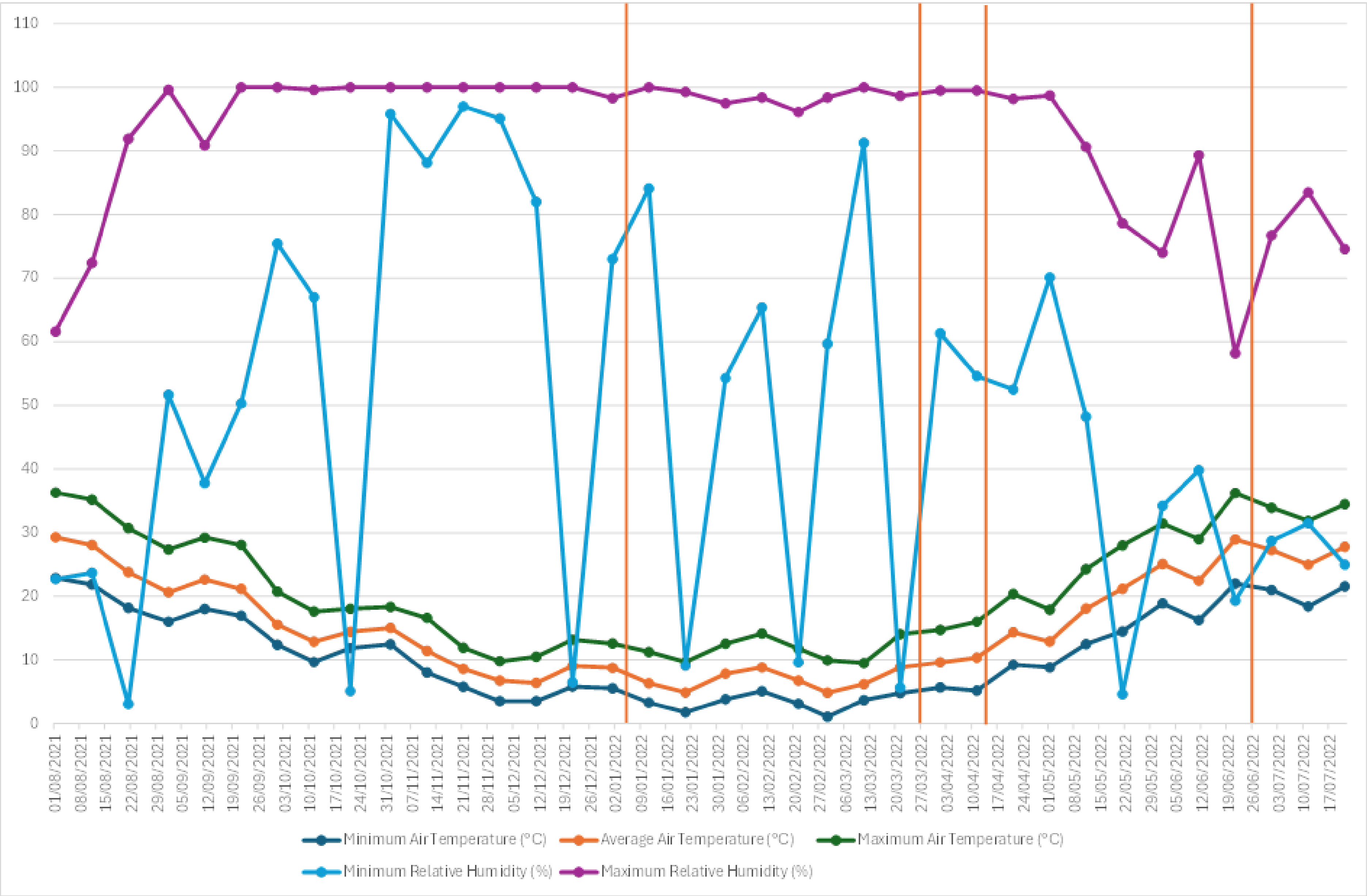
- seeding on 21 November 2022;
- sprouting in March 2023;
- raising in April 2023;
- harvest on 1 July 2023.

During this season, fertilisation was carried out on 21 November 2022 with a nitrogen rate of 34.04 kg ha^{-1} (urea) and on 10 February 2023 with a nitrogen rate of 87 kg ha^{-1} (urea), so that the crop yield resulted 2.84 t ha^{-1}.

Key crop operations and growth phenological stages in Badiazza field during the growing seasons 2021-2022 and 2022-2023

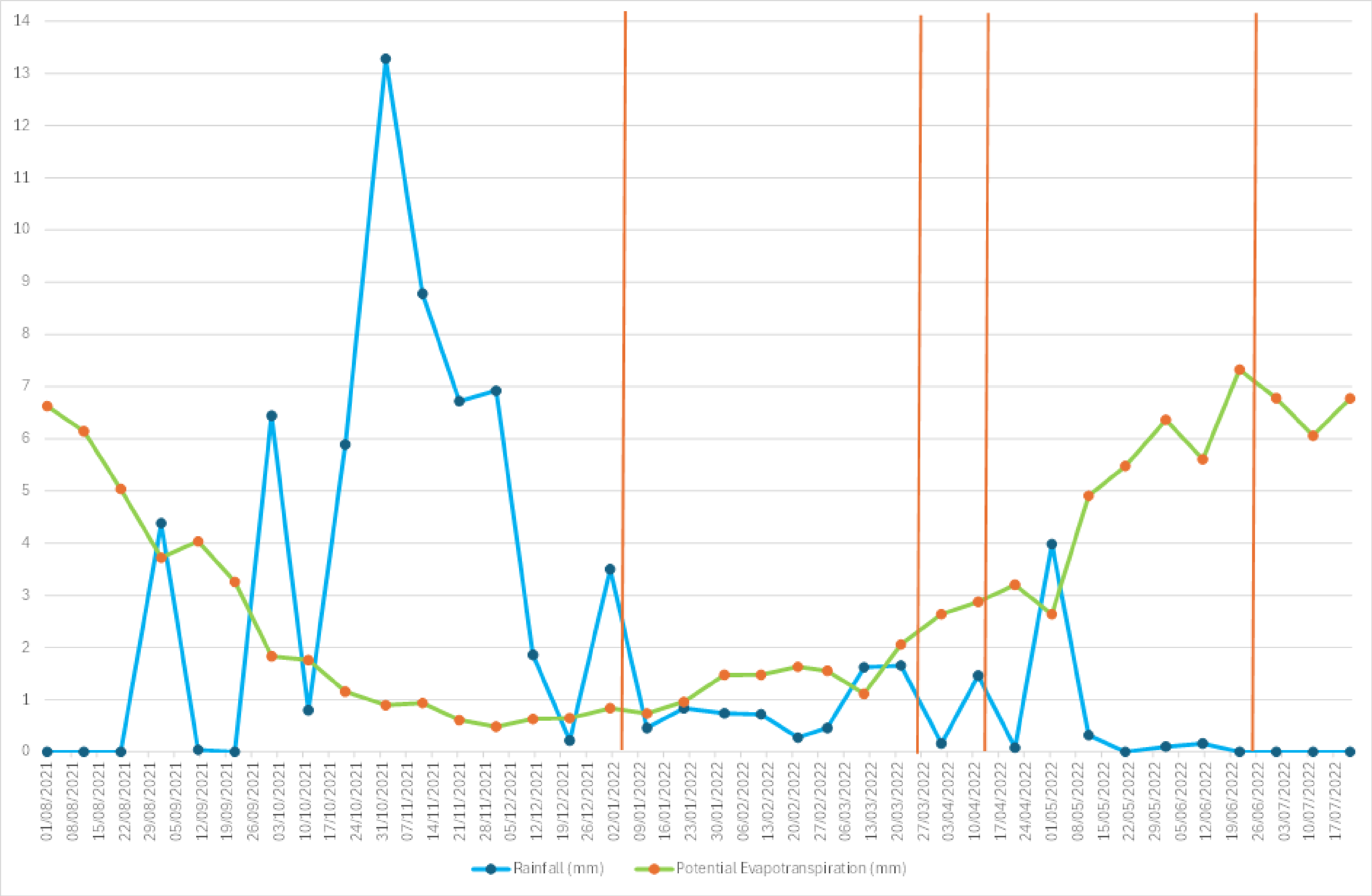
Growing season	Time	Time from RS	Crop operation / growth phenological stage	Agricultural machines / implements	Crop Input	Input rate	N rate	Yield	Notes
						kg ha^{-1}	kg ha^{-1}	t ha^{-1}	
2021/2022									
	10/09/2021		Ripping	Ripper					depth 35 cm
	03/01/2022		Herbicide spraying	Sprayer		4,73			against all weeds
	04/01/2022		Seeding	Centrifugal spreader		236,41			
	March	23/03/2022 (from NDVI)	Sprouting						
	April	12 o 27/04/2022 (12 from NDWI)	Raising						
	25/06/2022	after 06/06/2022 (from NDWI)	Harvest	Combine harvester				2,60	
2022/2023									
	10/11/2022		Ripping	Ripper					depth 30 cm
	21/11/2022		Fertilisation	Centrifugal spreader	18-46 (N 18%, P 46%)	189,13	34,04		
	21/11/2022		Seeding	Centrifugal spreader		59,10			
	09/02/2023		Herbicide spraying	Sprayer		4,00			against dicotyledon weeds
	"		"	"		1,00			against monocotyledon weeds
	10/02/2023	06/02/2023 (map of 01/02/2023) (from NDVI)	Fertilisation		urea (N 46%)	189,13	87,00		
	March	13/03/2023 (from NDVI)	Sprouting						
	April	07 o 22/04/2023 (07 from NDWI)	Raising						
	01/07/2023	after 11/06/2023 (from NDWI)	Harvest	Combine harvester				2,84	

Temperature and Relative Humidity data (average values of 10 days) logged by the station of Petralia Sottana, from the beginning of August 2021 to the end of July 2022



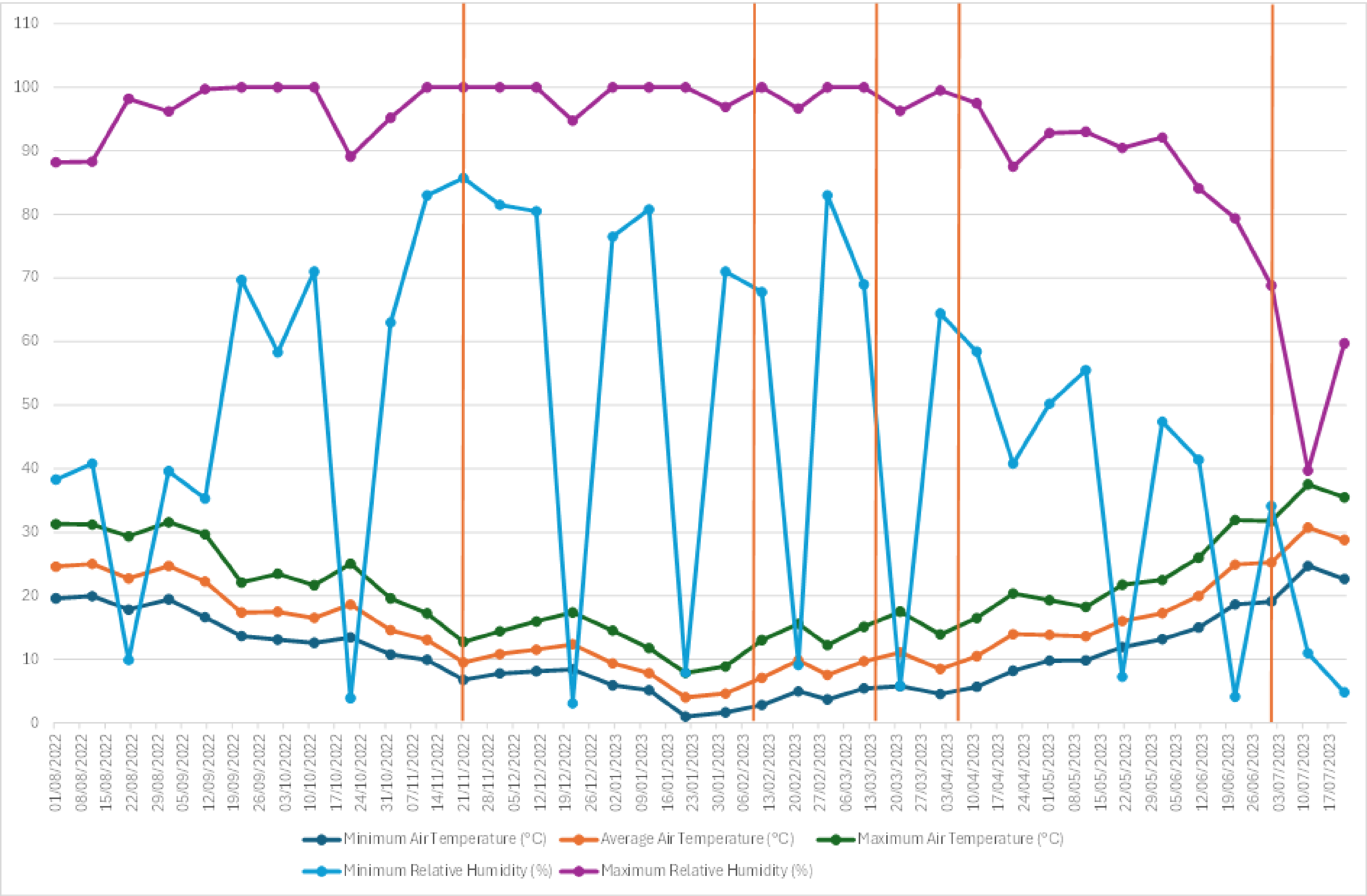
The red vertical lines indicate, from left to right : 04/01/2022 (seeding); 23/03/2022 (sprouting onset); 12/04/2022 (raising onset); 25/06/2022 (harvest).

Rainfall and Potential Evapotranspiration data (average values of 10 days) logged by the station of Petralia Sottana from the beginning of August 2021 to the end of July 2022



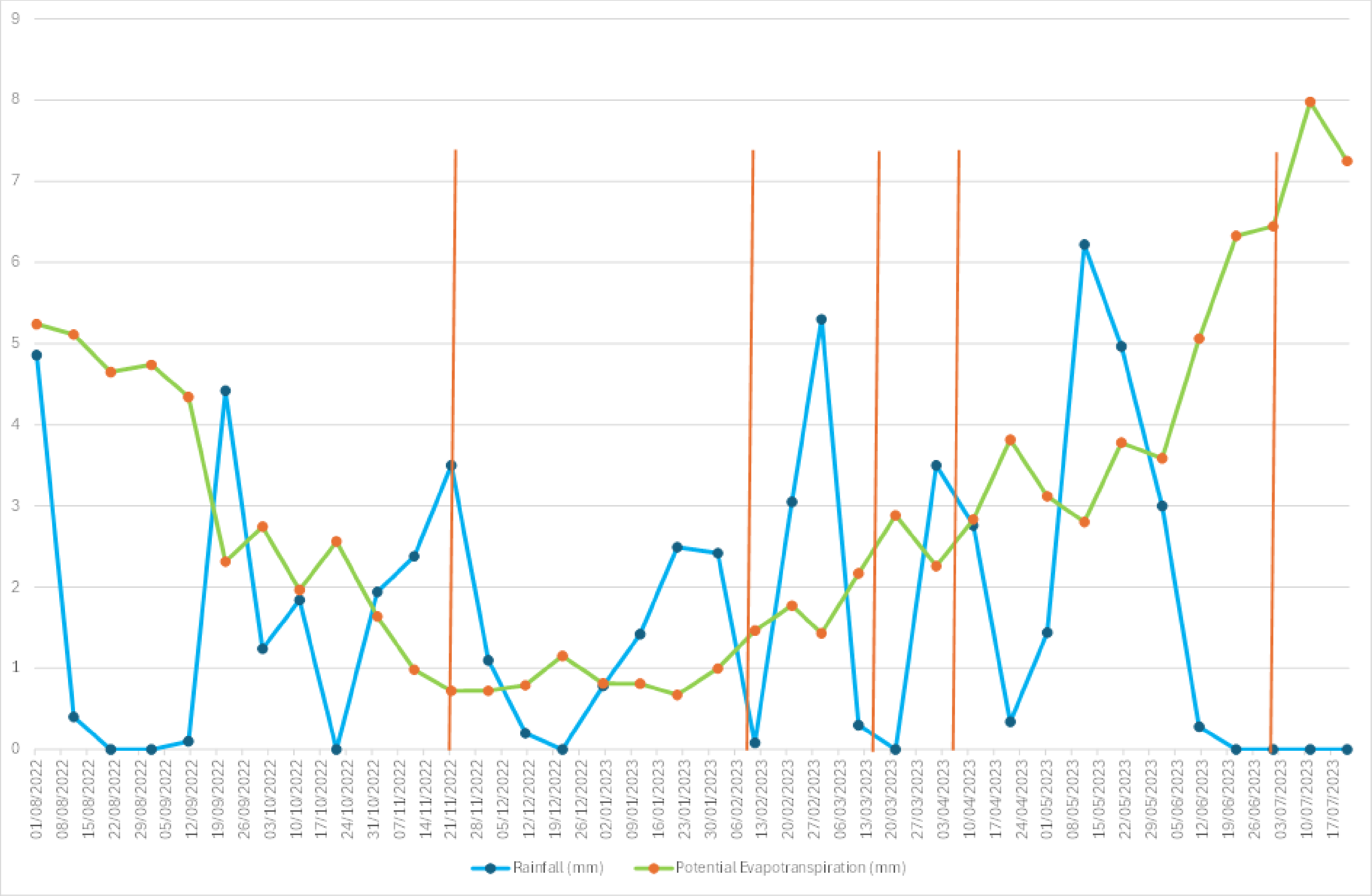
The red vertical lines indicate, from left to right : 04/01/2022 (seeding); 23/03/2022 (sprouting onset); 12/04/2022 (raising onset); 25/06/2022 (harvest).

Temperature and Relative Humidity data (average values of 10 days) logged by the station of Petralia Sottana, from the beginning of August 2022 to the end of July 2023



The red vertical lines indicate, from left to right :
21/11/2022 (1st fertilisation and seeding);
10/02/2023 (2nd fertilisation);
13/03/2023 (sprouting onset);
07/04/2023 (raising onset);
01/07/2023 (harvest).

Rainfall and Potential Evapotranspiration data (average values of 10 days) logged by the station of Petralia Sottana from the beginning of August 2022 to the end of July 2023



The red vertical lines indicate, from left to right :
21/11/2022 (1st fertilisation and seeding);
10/02/2023 (2nd fertilisation);
13/03/2023 (sprouting onset);
07/04/2023 (raising onset);
01/07/2023 (harvest).

Applied methods

The total rainfall was 727 mm from 1 August 2021 to 31 July 2022 and 605 mm from 1 August 2022 to 31 July 2023.

NDVI and NDWI values were collected, and NDVI images were extracted from the AgroInsider platform at the time of the key crop operations/phenological growth stages when the vegetation vigour was expected to temporally vary :

- after seeding;
- before and after sprouting;
- before and after raising;
- before and after harvest

The optimal fertilisation time was selected by relying on the NDVI graph.
Moreover, the onset of sprouting stage was identified by relying on the graph of NDVI, while the onset of raising stage was identified by comparing the graphs of NDVI and NDWI.

Then, the fertilisation map divided in 2 MZs was extracted from AgroInsider platform for the date immediately before that of optimal fertilisation.

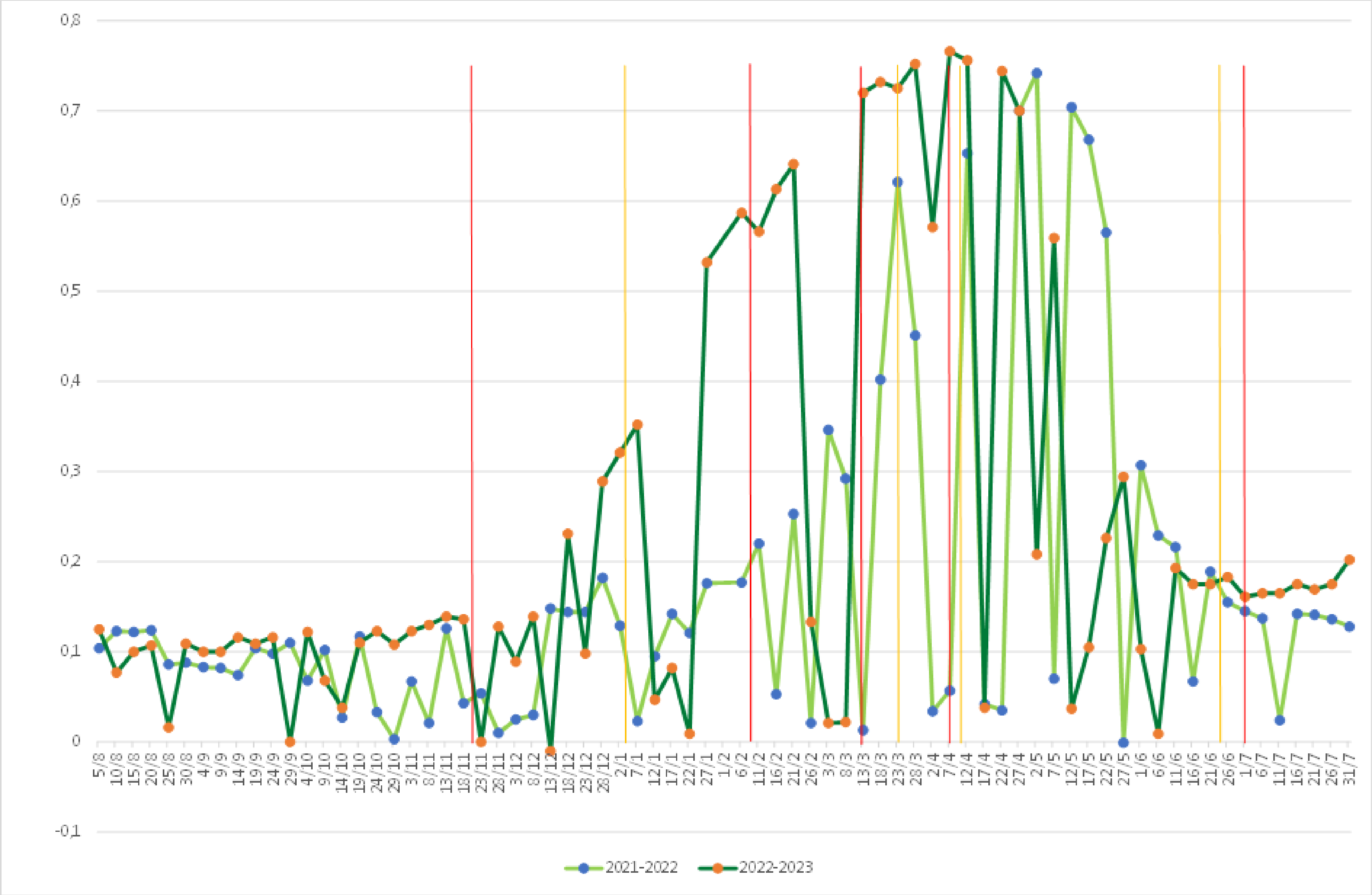
Results

By analysing the NDVI graph, the optimal fertilisation time (06/02/2023) and the sprouting onset (23/03/2022 and 13/03/2023 for the two growing seasons 2021-2022 and 2022-2023, respectively), were identified.

The raising onset (12/04/2022 and 07/04/2023 for the two growing seasons 2021-2022 and 2022-2023, respectively) was determined by comparing NDVI and NDWI graphs.

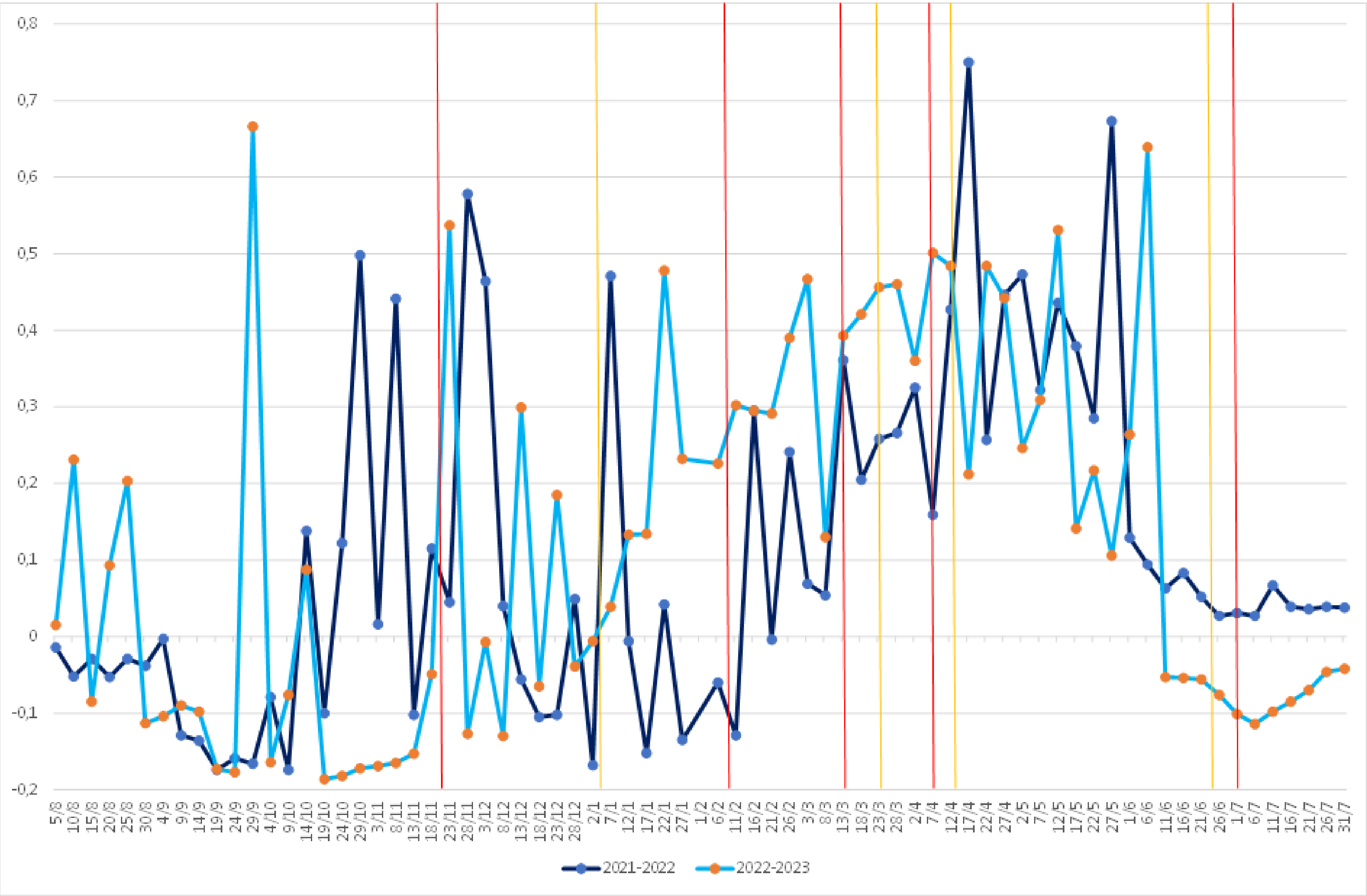
During the growing season 2023-2024, the key crop operations of fava bean (*Vicia faba*) and vetch (*Vicia sativa*) were seeding, on 1 December 2023, and herbicide spraying, on 28 March 2024 (photo of 02/04/2024).

Graph of average NDVI from the beginning of August 2021 to the end of July 2022 (light green line) and from the beginning of August 2022 to the end of July 2023 (dark green line)



The orange vertical lines indicate, from left to right :
04/01/2022 (seeding);
23/03/2022 (sprouting onset);
12/04/2022 (raising onset);
25/06/2022 (harvest).
The red vertical lines indicate, from left to right :
21/11/2022 (1^{st} fertilisation and seeding);
10/02/2023 (2^{nd} fertilisation);
13/03/2023 (sprouting onset);
07/04/2023 (raising onset);
01/07/2023 (harvest).

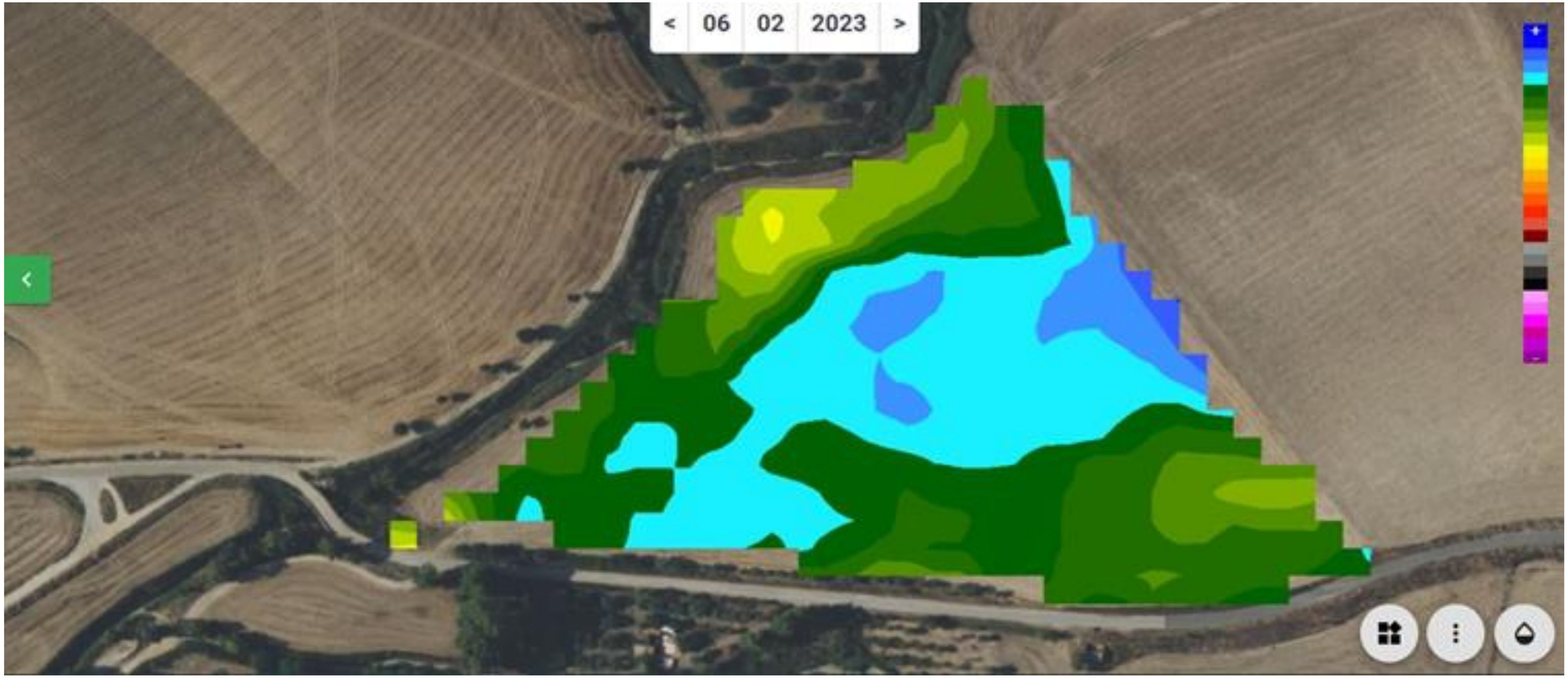
Graph of average NDWI from the beginning of August 2021 to the end of July 2022 (dark blue line) and from the beginning of August 2022 to the end of July 2023 (light blue line)



The orange vertical lines indicate, from left to right :
04/01/2022 (seeding);
23/03/2022 (sprouting onset);
12/04/2022 (raising onset);
25/06/2022 (harvest).

The red vertical lines indicate, from left to right :
21/11/2022 (1st fertilisation and seeding);
10/02/2023 (2nd fertilisation);
13/03/2023 (sprouting onset);
07/04/2023 (raising onset);
01/07/2023 (harvest).

NDVI map of the study area for 01/02/2023, immediately before the optimal fertilisation date (06/02/2023)



Mean NDVI for Badiazza field = 0.58

This map shows a high spatial variability, that can be quantified by computing the median Coefficient of Variation, that resulted 16.6% for the growing season 2022-2023 (compared to 14.5% for the growing season 2021-2022).

This value moves away from the threshold (25.6%) calculated by Pringle et al. (2003) for different crops, by using yield maps in a similar study (Arnò et al., 2017).

Spatially variable rate fertilisation map of the study area, divided in 2 MZs, for 01/02/2023, immediately before the optimal fertilisation date (06/02/2023)

The cells having higher NDVI and NDWI values are in black, while the cells having lower values of these indexes are in white.

Conclusions

The RS data from the Sentinel-2B satellite proved highly effective in discerning the spatial variability of vegetation vigour and plant leaf water content in the marginal areas of inland Sicily.

This underscores the utility of RS as an integral component of a DSS, capable of efficiently generating fertilisation maps divided into MZs.

This map can be logged in the portable computer equipping the cab of a tractor connected to a fertiliser spreader, according to PA principles.

In fact, from AgroInsider platform, it is possible to download the fertilisation map (VRT), divided into 2 or 3 MZs, for Trimble or John Deere or other manufacturers of the portable computer (display of the tractor assisted steering system).

Thank you for your attention !

EFRARIXTO

OBRIGADO

GRAZIE