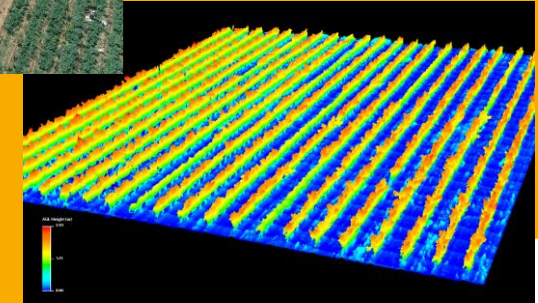


# A multispectral UAV imaging for optimizing cover crop management in viticulture : application of a multivariate multi-block modelling approach

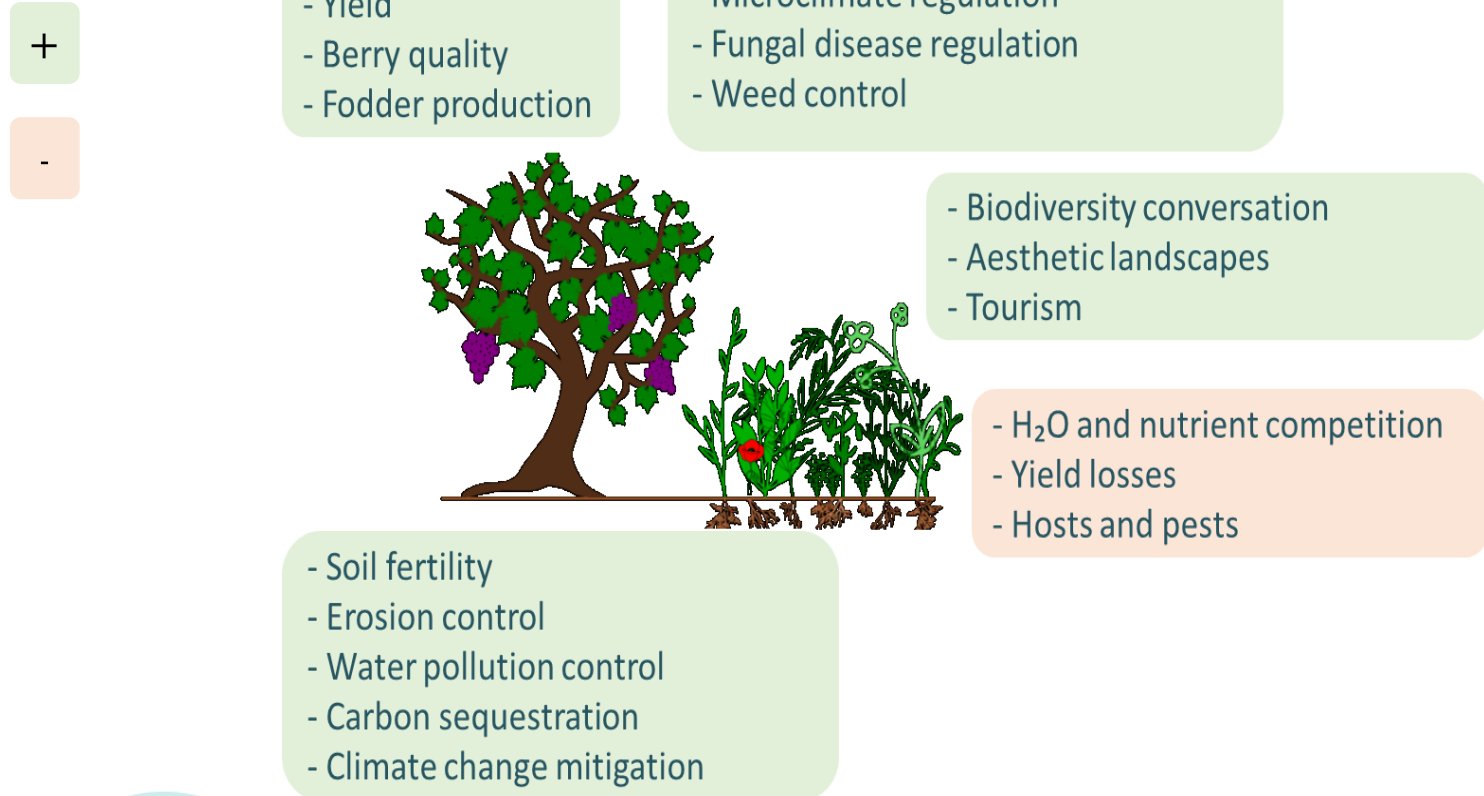


A. Cheraiet; A. Metay; G. Brunel; L. Garcia



# Context - Managing service crops to avoid dysservices

- The management of service crops in viticulture appears to be a key lever to reach trade-offs between ecosystem services and disservices (Garcia et al. 2018, Winter et al. 2018, Giffard et al. 2022)



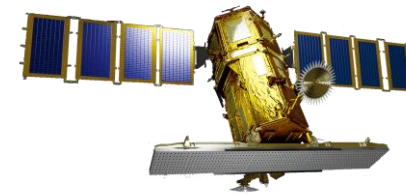
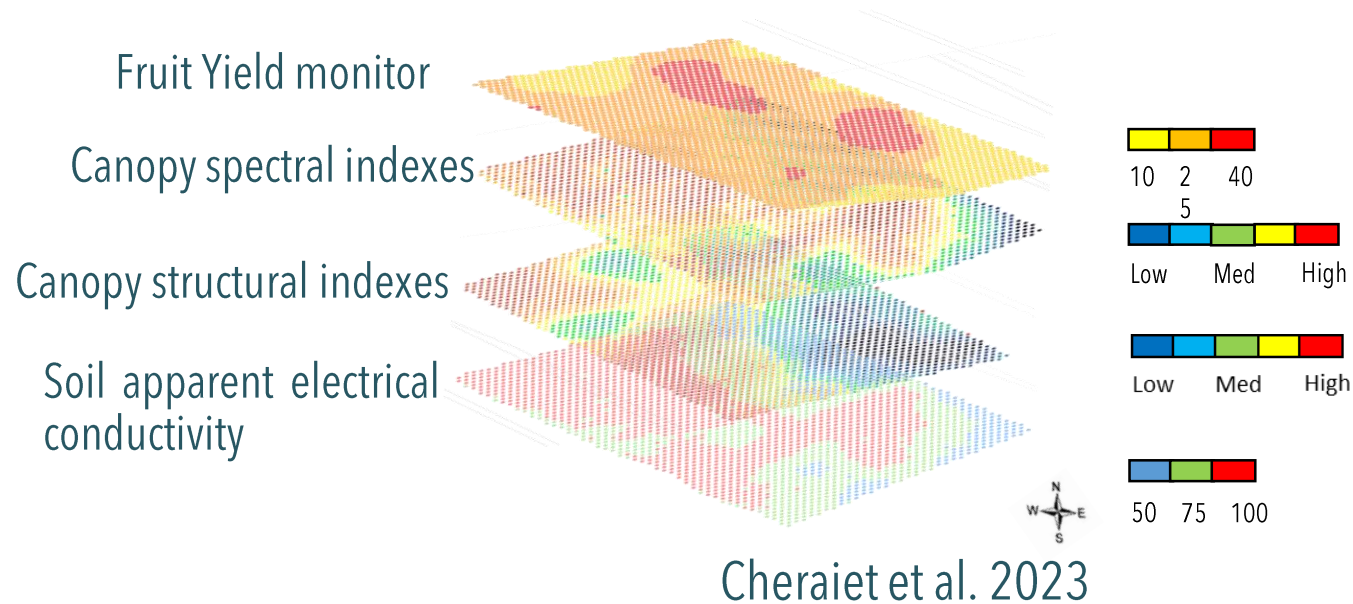
To minimize disservices and achieve the targeted services :

- Choice of species
- Seeding density, period
- Service crop duration
- Destruction tool
- Residue management

A greater adaptability in decision-making is required to manage services crops

# Context – Contribution of sensing technologies

- High-resolution spatio-temporal data are increasingly available in viticulture
- These data enable the study of agroecosystems at scales difficult to achieve through conventional experimentation, and facilitate on-farm experimentation



**When and what types of agricultural data are needed to optimize service crops management in viticulture ?**



# Strategy & Objectives

**Strategy: data fusion analysis using multi-block methods** to extract more relevant information from UAV data sources (Surowiec et al. 2019)

## Objectives:

- **Explore the applicability of a multi-block modelling approach (SO-PLS)** to a multivariate data structure (spatio-temporal) to predict two variables of interest: Yield and Pruning weight
- **Identify relevant, data types and timings** for predicting these two variables














# Experimental set up

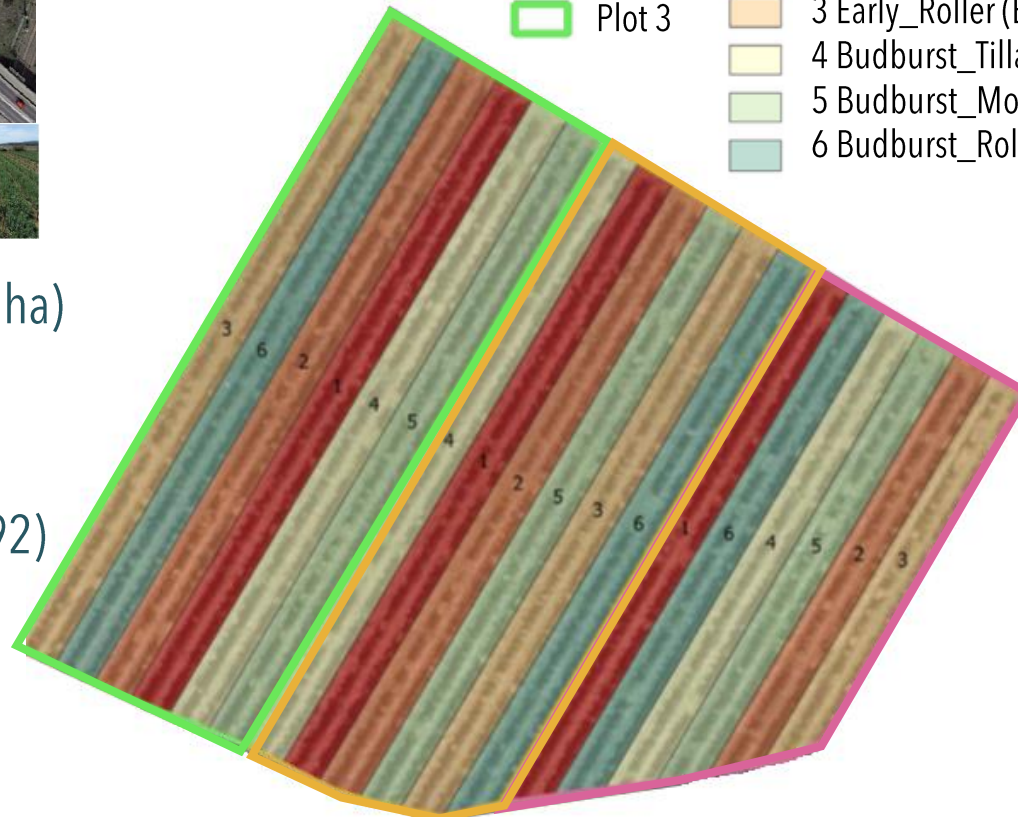
- One year: **2022**
- Site: **Domaine du Chapitre (Villeneuve-lès-Maguelone)**



Aerial photos of Syrah block (1 ha)

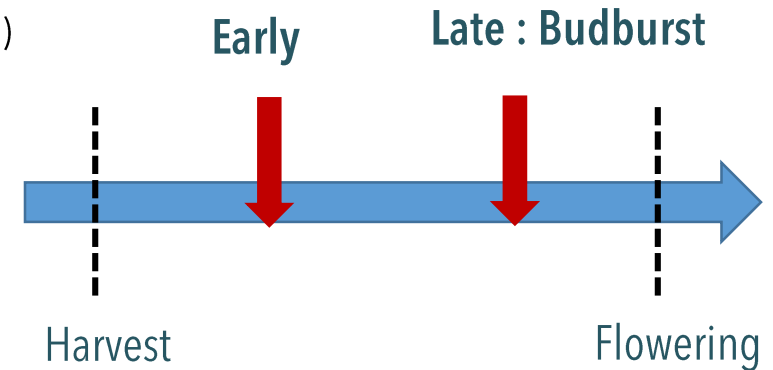
(Garcia et al. 2024, poster 192)

Plot	Treatment
 Plot 1	 1 Early_Tillage (E_T)
 Plot 2	 2 Early_Mowing (E_M)
 Plot 3	 3 Early_Roller (E_R)
	 4 Budburst_Tillage (B_T)
	 5 Budburst_Mowing (B_M)
	 6 Budburst_Roller (B_R)



## 3 plots – 6 treatments

### Two termination periods :



### Three termination methods :



# Data collection

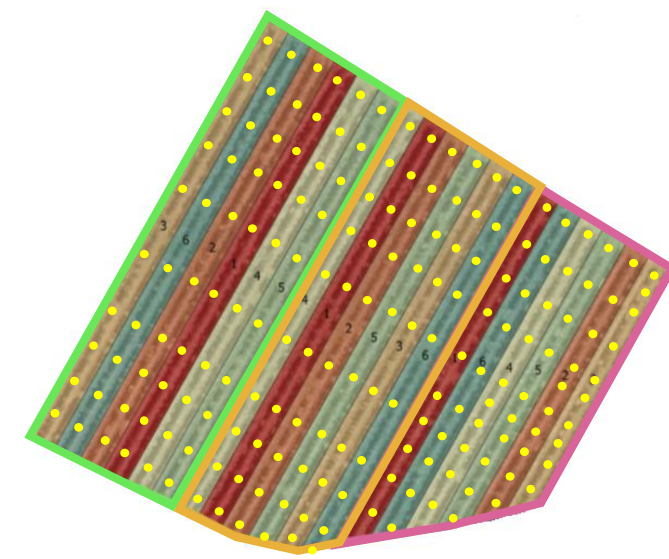
## Crop data

For each treatment, two types of data were collected on 10 individual vines per treatment and block (total 180):

- **Yield** (kg/vine stock)



- **Pruning weight** (kg/vine stock)



# Data collection

## Spectral & geometric data of vines canopy and service crops

**Phantom 4**  
- Multispectral + ProV2  
- 5 narrow bands (475, 560, 668, 717 & 840 nm)  
+ RGB images  
- Spatial resolution: ~2 cm  
- Flight height: 35-40 m

2022 = 10 dates

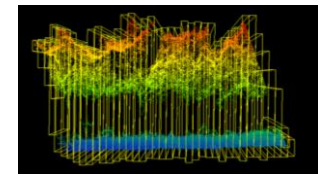
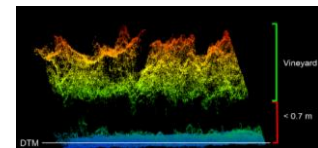
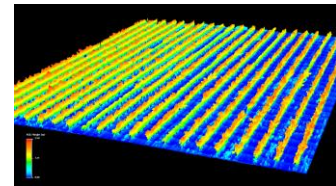
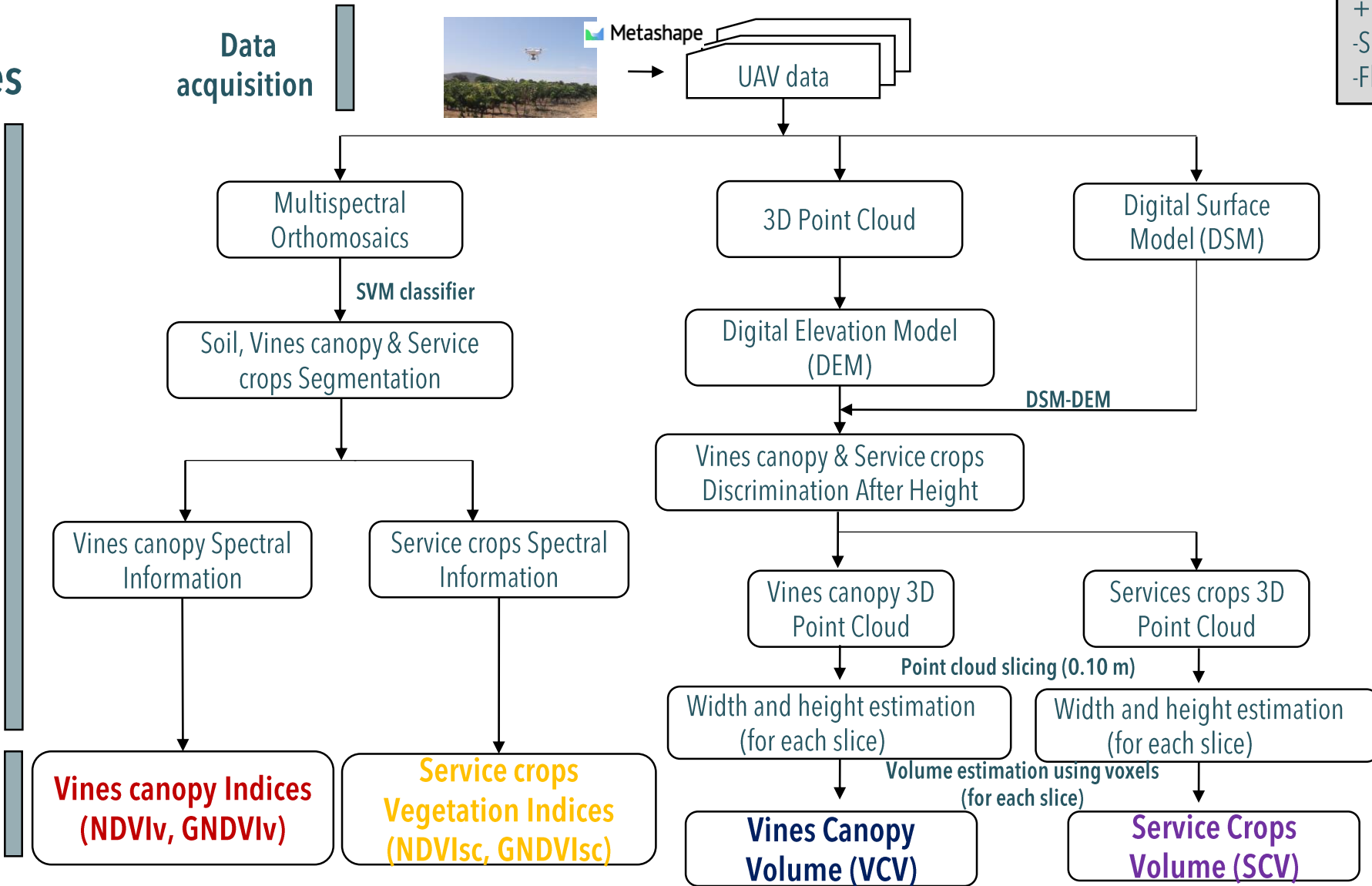
07/12/2021



03/06/2022



Data Processing

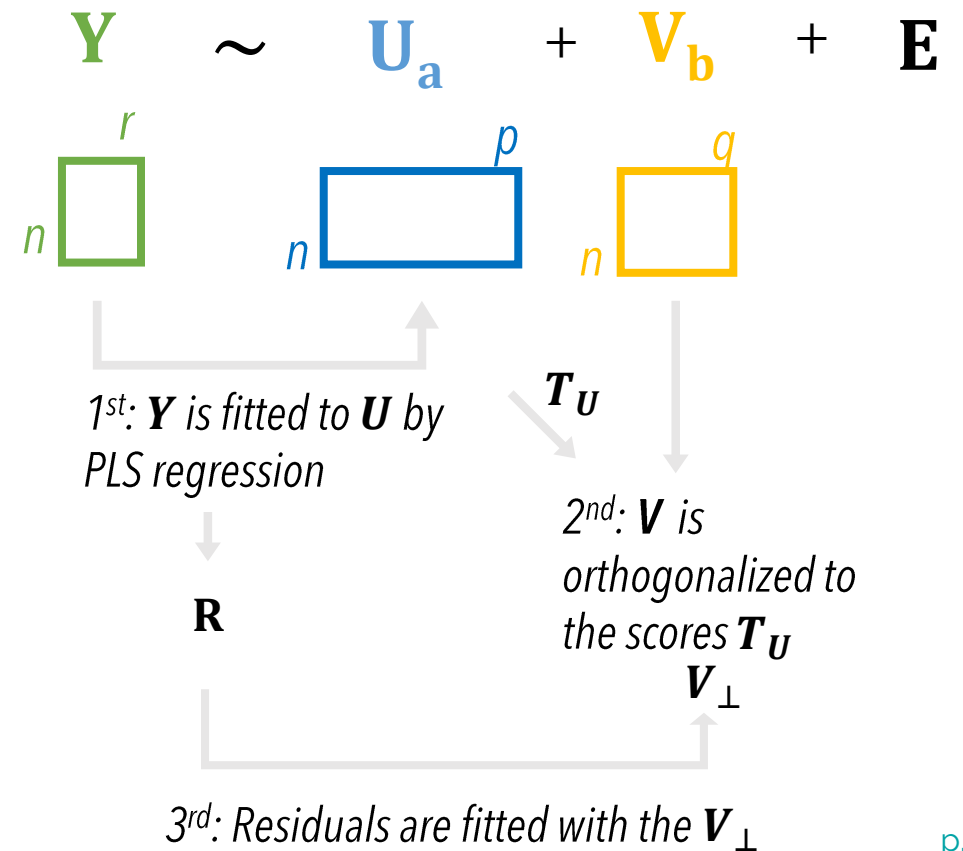


# Theory - Multi-bloc method

## Sequential and Orthogonalized Partial Least Squares: SO-PLS (Naes et al. 2013)

How it works: example with 2 predictor blocks

- \*  $\mathbf{Y}$  is the response variable
- \*  $\mathbf{U}$  and  $\mathbf{V}$  are the predictor blocks
- \*  $\mathbf{a}$  and  $\mathbf{b}$  are the regression coefficients
- \*  $\mathbf{E}$  is the residual matrix.



Advantage: **blocks of different sizes to be combined**



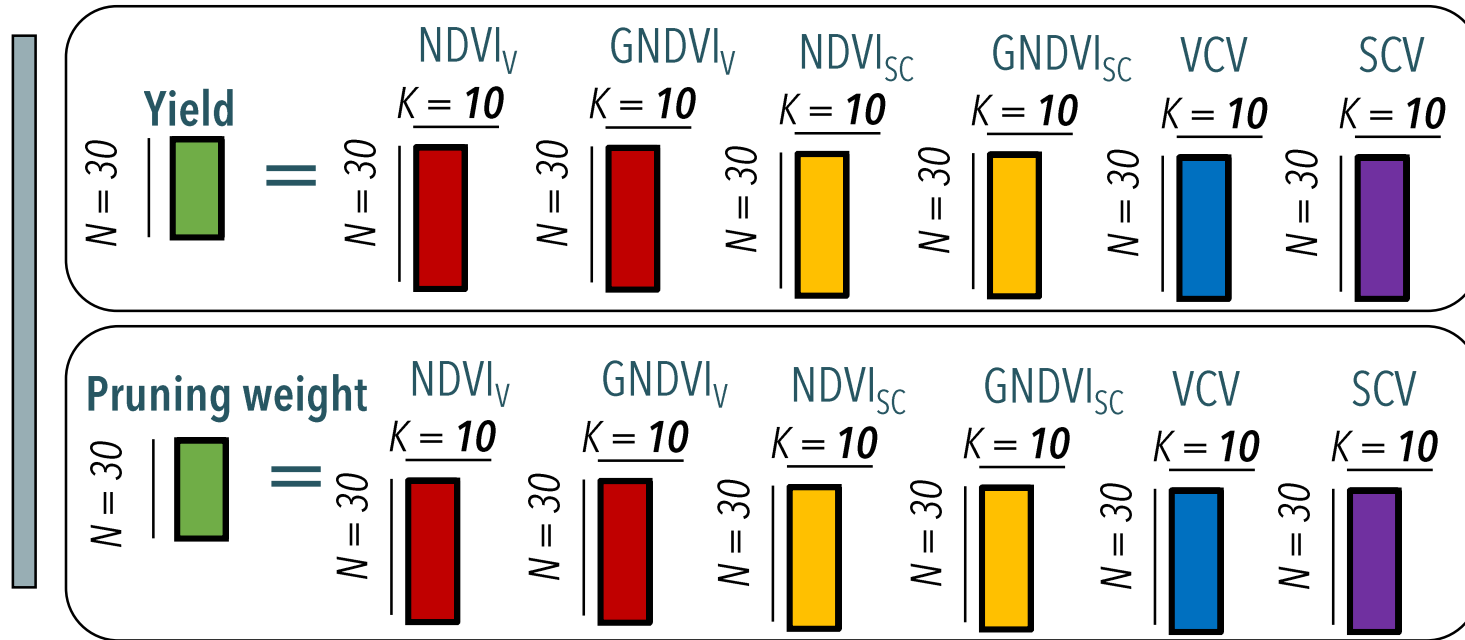


# Application - Multi-bloc analysis

2022 - 1 model per treatment (aggregation of data from 3 blocks) - combination of 8 predictor blocks  
 (2 Vines Canopy indices + 2 Services Crops vegetation indices + 1 Vine Canopy volume + 1 Service Crops volume)

$N$  = individual vines &  $K$  = Dates

Model :  
Early\_Tillage (E\_T)



calibration data set ( $N = 20$ ) - validation data set ( $N = 10$ )

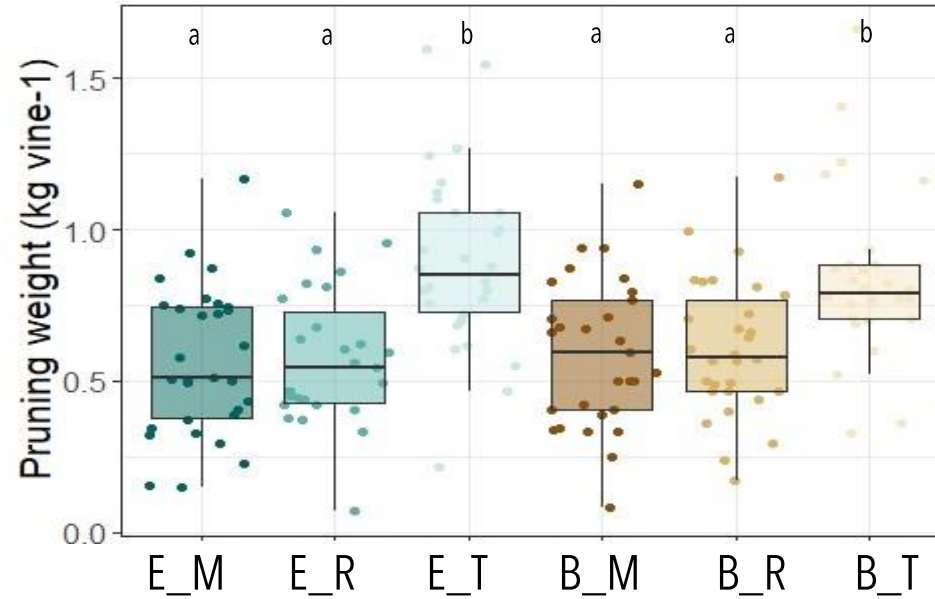
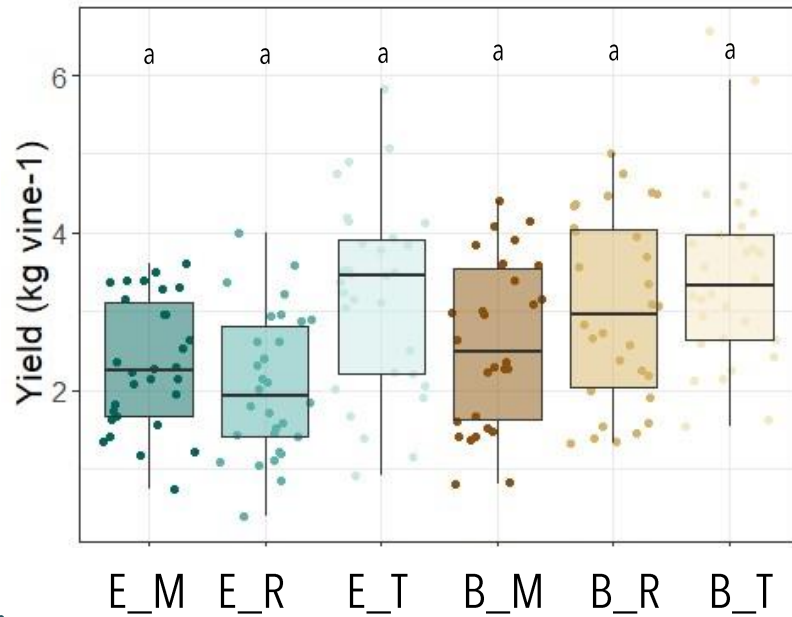
Model :  
Late\_Roller (B\_R)



12 models constructed

# Results - Data visualisation: Variables of interest

Distributions of response variables in 2022



Early\_Tillage (E\_T)  
Early\_Mowing (E\_M)  
Early\_Roller (E\_R)  
Budburst\_Tillage (B\_T)  
Budburst\_Mowing (B\_M)  
Budburst\_Roller (B\_R)

Letters represent significantly different classes obtained by ANOVA and a Bonferroni test with a risk of  $\alpha = 0.05$ .

- **Yield :**

- The destruction tool and the presence of cover crops do not seem to be prejudicial to yields
- Yields can be ordered by destruction tool: Tilled > Rolled > Mowed
- Great variability in measurements according to vine stock (0.68 kg/vine stock to 5.9 kg/vine stock)

- **Pruning weight :**

- The destruction tool has a significant effect on pruning weights, with Tilled modalities > Mowed and Rolled modalities

# Results - Cross-validation results

N = 20

Independently select the number of latent variables for each block

Treatment	Variable	nRMSE <sub>cv</sub>	R <sup>2</sup> <sub>cv</sub>	Latent variables per block					
				NDVI <sub>v</sub>	GNDVI <sub>v</sub>	NDVI <sub>sc</sub>	GNDVI <sub>sc</sub>	VCV	SCV
E_T	Yield	6.9	0.77	2	1	1	1	1	0
	Pruning weight	8.7	0.69	1	1	0	1	2	1
E_M	Yield	9.6	0.74	2	1	0	1	1	1
	Pruning weight	11.1	0.67	1	2	0	1	1	1
E_R	Yield	7.1	0.71	2	0	1	1	1	1
	Pruning weight	9.4	0.68	1	2	1	0	1	0
B_T	Yield	5.8	0.73	2	1	0	2	1	0
	Pruning weight	12.2	0.64	1	2	0	1	2	0
B_M	Yield	7.8	0.75	2	1	1	0	1	1
	Pruning weight	9.1	0.61	1	2	0	1	1	1
B_R	Yield	5.9	0.72	2	1	0	1	1	1
	Pruning weight	10.1	0.65	1	2	0	1	1	1

- Regardless of the treatment, **the quality and robustness** of the models **remain satisfactory**
- Depending on the response variable considered, the **contribution of the 6 predictor blocks is not the same**
- **Geometry indices (VCV & SCV)** appears to **provide additional information** to spectral data



# Results - Validation results

Performance evaluation of multivariate prediction models for each response variables

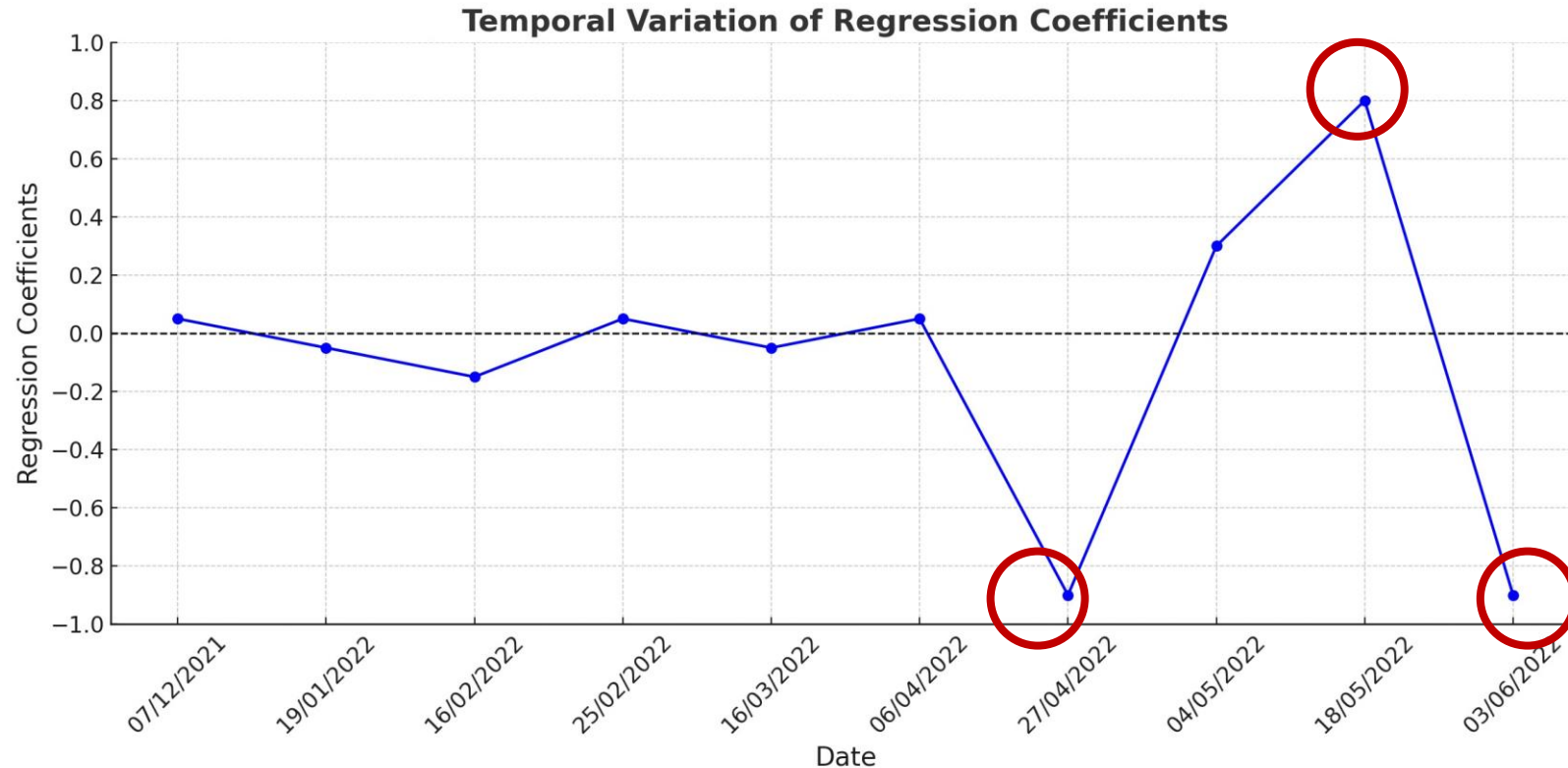
Treatment	Variable	nRMSEp	R <sup>2</sup> <sub>1:1</sub>
E_T	Yield	10.9	0.78
	Pruning weight	13.0	0.69
E_M	Yield	9.1	0.75
	Pruning weight	13.5	0.67
E_R	Yield	9.8	0.76
	Pruning weight	12.3	0.69
B_T	Yield	10.1	0.74
	Pruning weight	14.2	0.65
B_M	Yield	11.1	0.76
	Pruning weight	13.4	0.66
B_R	Yield	10.2	0.77
	Pruning weight	13.1	0.69

N = 10

- The performance of the prediction models was satisfactory for each treatments tested, **despite the significant variability seen in productivity and vigor**

# Results - Interpretation tool: Regression coefficient of models indicating optimal detection dates

Example: Regression coefficients derived from the E\_T yield prediction model with the NDVIv predictor block



- Identify the **canopy detection dates that are relevant for predicting harvest & vigor variables**, in order to provide clear information to winegrowers





# Take Home Message

- **Experimental validation:**

Field experiments showed that destruction tools and residue management appear to influence vine yield and pruning weight (see Garcia et al. 2024, poster 192)

- **Application of SO-PLS modeling:**

SO-PLS approach, which combines spectral & geometric blocks of data obtained on vine canopy and service crops :

- Can create synergies to improve the prediction performance of these 2 key variables
- Can improve information on the optimal timing of detection, and supports more informed and adaptive strategic decision-making for vineyard management

- **Next steps**

- Assess robustness in other years and vineyards
- Refine predictive models by including additional variables (from other data sources) to improve the accuracy and robustness of predictions

 **UAV imagery could be used as a decision-support tool for the management of service crops**

# References

Cheraïet, A., Gobrech, A., Naud, O., & Taylor, J.A., 2023. Digital Tools Revolutionizing On-Farm Experimentation: Empowering Agro-Ecological Transitions, OFE2023 – 5th – 7th December - Second International Conference on Farmer-centric On-Farm Experimentation.

Garcia, L., Celette, F., Gary, C., Ripoche, A., Valdés-Gómez, H., Metay, A., 2018. Management of service crops for the provision of ecosystem services in vineyards: A review. *Agric. Ecosyst. Environ.* 251, 158–170. <https://doi.org/10.1016/j.agee.2017.09.030>

Garcia, L., Krafft, G., Enard, C., Bouisson, Y., Metay, A., 2024. Adapting service crop termination strategy in viticulture to increase soil ecosystem functions and limit competition with grapevine. *Eur. J. Agron.* 156, 127161. <https://doi.org/10.1016/j.eja.2024.127161>

Giffard, B., Winter, S., Guidoni, S., Nicolai, A., Castaldini, M., Cluzeau, D., Coll, P., Cortet, J., Le Cadre, E., d'Errico, G., et al., 2022. Vineyard Management and Its Impacts on Soil Biodiversity, Functions, and Ecosystem Services. *Front. Ecol. Evol.* 10, 850272.

Naes, T., Tomic, O., Afseth, N.K., Segtnan, V., & Måge, I., 2013. Multi-block regression based on combinations of orthogonalisation, PLS-regression and canonical correlation analysis. *Chemometrics and Intelligent Laboratory Systems*, 124, 32-42.

Surowiec, I., Skotare, T., Sjögren, R., Gouveia-Figueira, S., Orikiiriza, J., Bergström, S., et al. 2019. Joint and unique multiblock analysis of biological data–multiomics malaria study. *Faraday Discussions*, 218, 268-283.

Winter, S., Bauer, T., Strauss, P., Kratschmer, S., Paredes, D., Popescu, D., Landa, B., Guzmán, G., Gómez, J.A., Guernion, M., Zaller, J.G., Batáry, P., 2018. Effects of vegetation management intensity on biodiversity and ecosystem services in vineyards: A meta-analysis. *J. Appl. Ecol.* <https://doi.org/10.1111/1365-2664.13124>

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