UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Protección de cultivos en citricultura: nuevas tecnologías y formación para un uso sostenible de productos fitosanitarios

Prof. Emilio Gil
Universitat Politècnica de Catalunya
Barcelona (Spain)

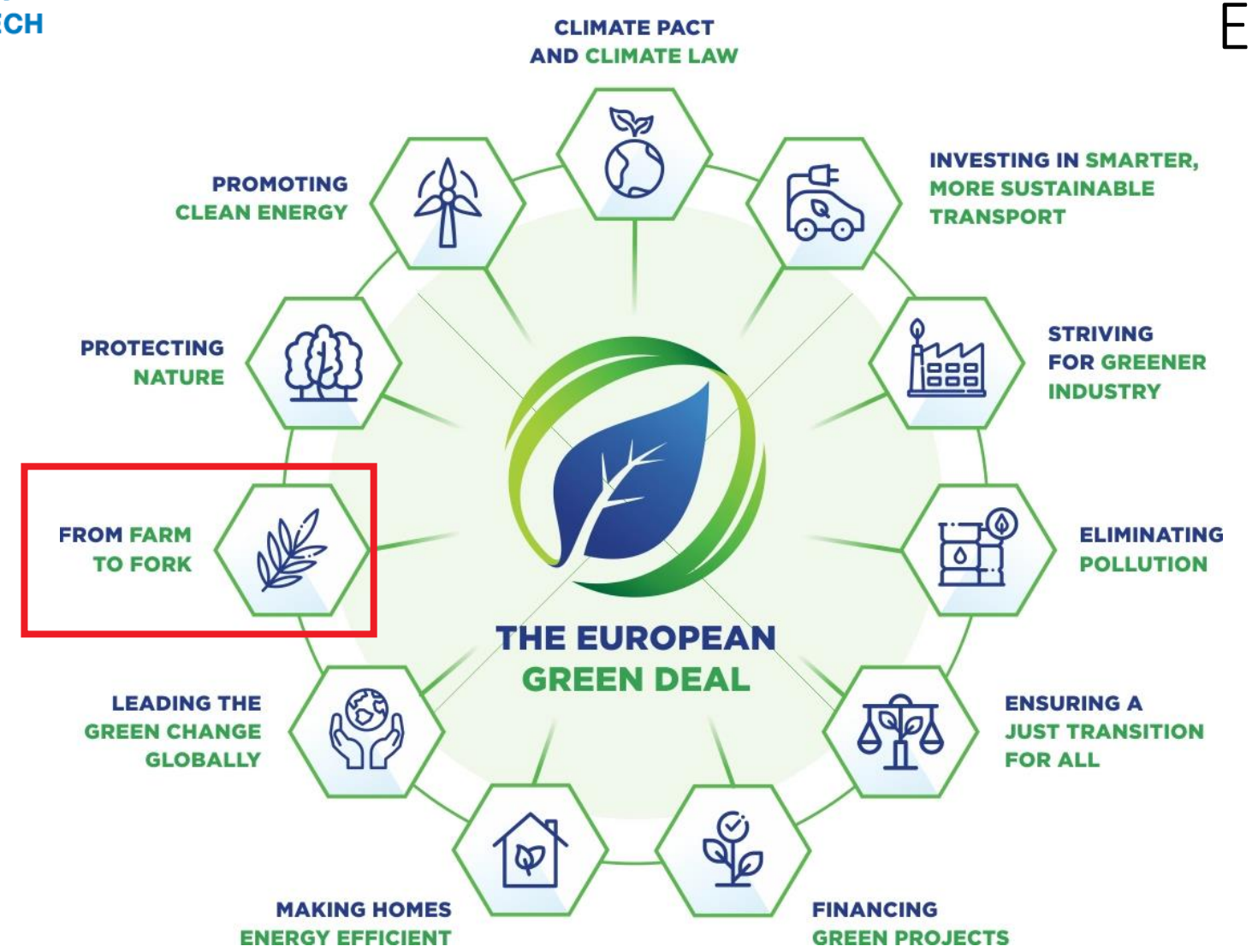
Jornada de Citricultura 2024
Santiago de Chile - Diciembre 2024

Frutas de Chile Comité de Cítricos

INIA Instituto de Investigaciones Agropecuarias

5.000 L/ha

El "*Pacto Verde*" Europeo



Introducción

¿Por qué cultivos frutales?

- Cantidad y calidad-

- Los productos fitosanitarios son especialmente relevantes en cultivos especializados como la vid, los frutales y los cítricos.
- Según EUROSTAT, España, Francia e Italia consumen alrededor del **50% de la cantidad total** de fungicidas en Europa.
- Según FAOSTAT (2019), China es el líder, con casi 44 millones de toneladas de producción representando 22% del total, seguido del Brasil (10%), la India (7%), México y Estados Unidos (4,4%) y España (3%).

(source: FAO, 2020)

¿Por qué cultivos frutales?

- Cantidad y calidad-

Gil, E. 2022 – European Scientific Conference – Towards Pesticide Free Agriculture

¿Por qué cultivos frutales?

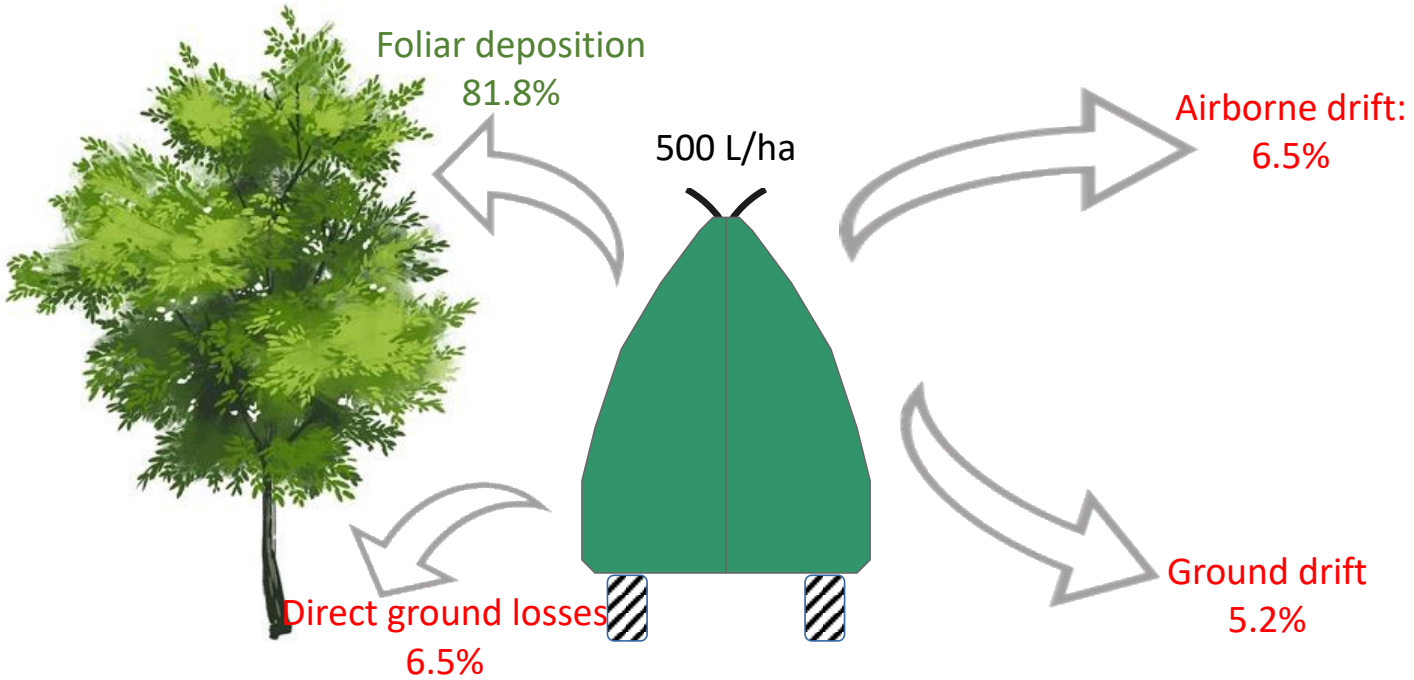
- Cantidad y calidad-

Gil et al., 2023 - Evaluation of foliar deposition, off-target losses and biological efficacy following ISO protocols (confidential report)

¿Por qué cultivos frutales?

- Cantidad y calidad-

BMP-sprayer



Gil et al., 2023 - Evaluation of foliar deposition, off-target losses and biological efficacy following ISO protocols (confidential report)

¿Por qué cultivos frutales?

- Influencia del objetivo-

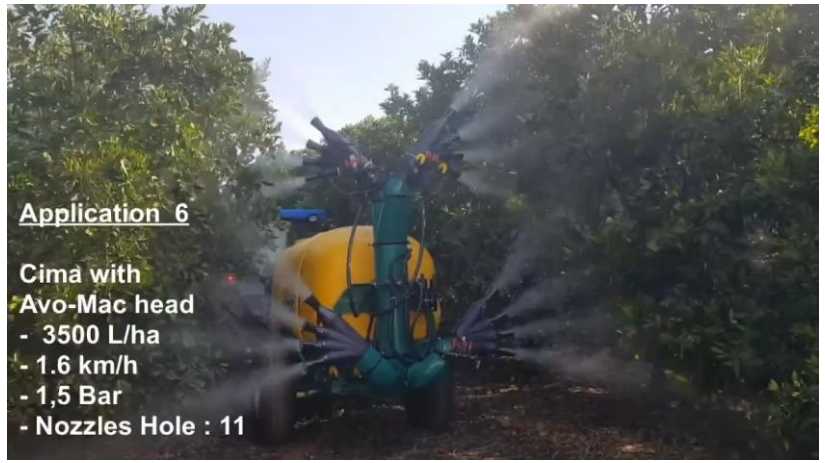
En cítricos, viñedo y en general en todos los cultivos arbóreos, un adecuado ajuste del aire mejora la distribución y reduce las pérdidas por deriva

Una gestion adeciada del aire es imprescindible para garantizar el éxito

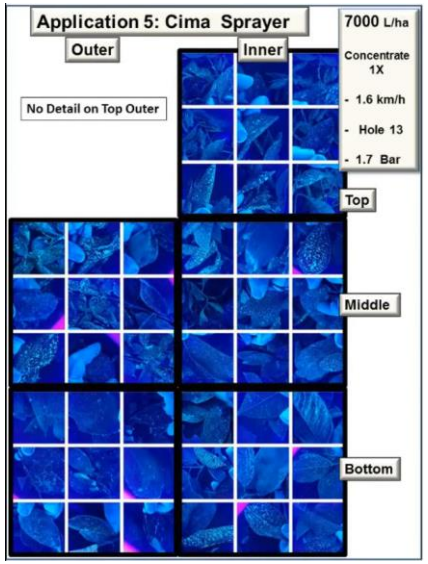
¿Por qué cultivos frutales?

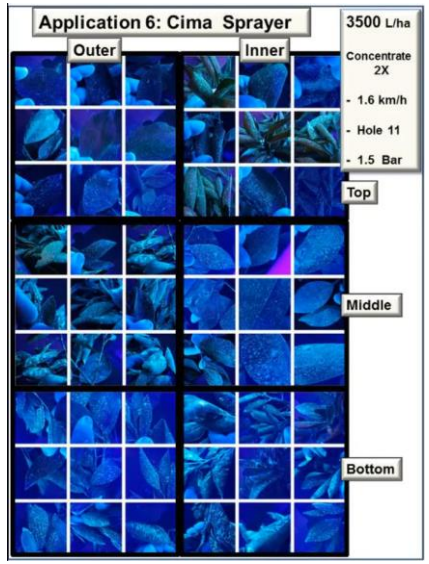
- Efecto de la tecnología-

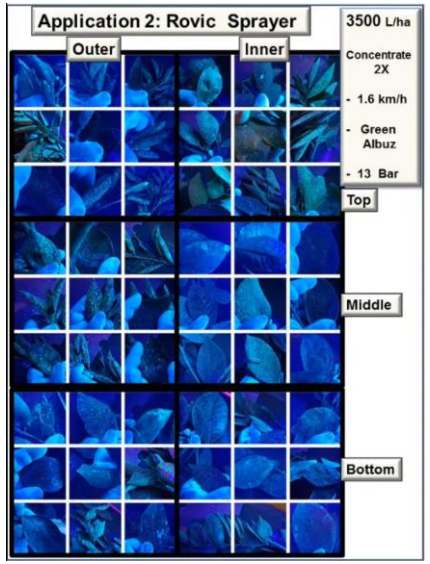
Application 5
Cima with
Avo-Mac head
- 7000 L/ha
- 1.6 km/h
- 1,7 Bar
- Nozzles Hole : 13


Application 6
Cima with
Avo-Mac head
- 3500 L/ha
- 1.6 km/h
- 1,5 Bar
- Nozzles Hole : 11

Application 2
Rovic Evenflow
- 3500 L/ha
- 1,6 km/h
- 13 Bar
- Nozzles
Albuz Hollow Cone Green
Rovic


Application 5: Cima Sprayer
7000 L/ha
Concentrate 1X
- 1.6 km/h
- Hole 13
- 1.7 Bar
Outer
Inner
No Detail on Top Outer
Top
Middle
Bottom


Application 6: Cima Sprayer
3500 L/ha
Concentrate 2X
- 1.6 km/h
- Hole 11
- 1.5 Bar
Outer
Inner
Top
Middle
Bottom


Application 2: Rovic Sprayer
3500 L/ha
Concentrate 2X
- 1.6 km/h
- Green Albuz
- 13 Bar
Outer
Inner
Top
Middle
Bottom

¿Por qué cultivos frutales?

- Influencia del objetivo-

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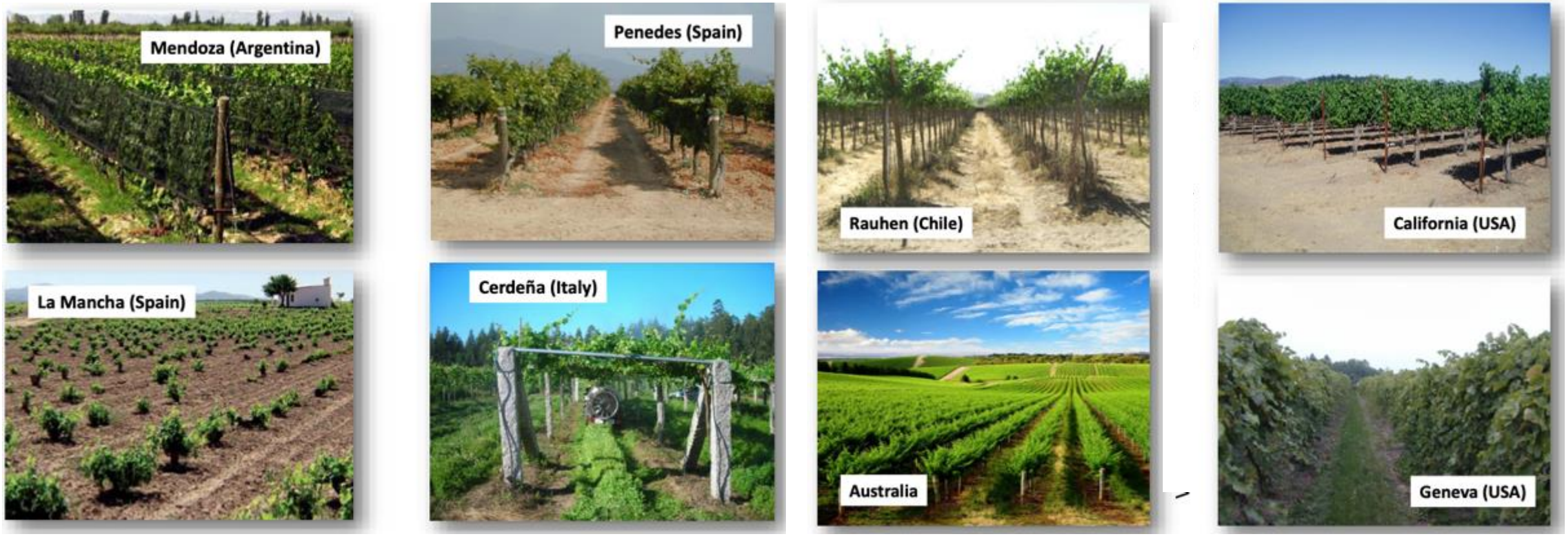
¿Por qué cultivos frutales?

- Influencia del objetivo-



Variation factor in LAI from **1 to 15**

Codis, S., Douzals, J.P., 2012. Comparaison des systèmes d'expression des doses de produits de protection de la vigne dans 5 pays européens et les besoins d'une harmonisation. In: AFPP – CIETAP – Conférence sur les techniques d'application de produits de protection des plantes, Lyon, 15-16 mars 2012, pp. 10.

Expresion de dosis – el dilema

Expresión de dosis compleja

CROP	DISEASE	APPLICATION	RECOMENDED DOSE
Cebolla	Mildiu	Normal foliar spray, with uniform coverage in the whole canopy	200-300 g per 100 L water. Max. 2.5 kg/ha
Lechuga	Mildiu		
Pepino	Mildiu		
Patata	Alternariosis y Mildiu		
Tabaco	Moho azul		
Tomate	Alternariosis, Mildiu y Septoriosis		
Viña	Mildiu		

Cultivo	Agente	Dosis	Condicionantes específicos
Uva para Vinificación	Mildiu	0.3 - 0.35	Normal spray. Use tractor with cab and low drift nozzles. Max 3 kg/ha

Vid	*Botrytis cinerea*	4 L/ha	Apply between BBCH 60-89 Interval 5 days Máx 6 applications (**Vol. 1000-1500 L/ha**)

Información poco clara

Application							PHI (days)	Remarks:
method kind (f-h)	growth stage & season (j)	number min max (k)	interval between applications (min)	kg as/hL min max	water L/ha min max	kg as/ha min max	(l)	(m)
Foliar spraying	BBCH15-73	1	n.a.	0.01	1000	0.1	14	For lower spray volumes, ensure a dose of 0.07 kg a.s./ha

[10 g/hL] —— x 7 !!!! ——→ [70 g/hL]

100 L/ha

Expresión de dosis: el dilema

ɔn

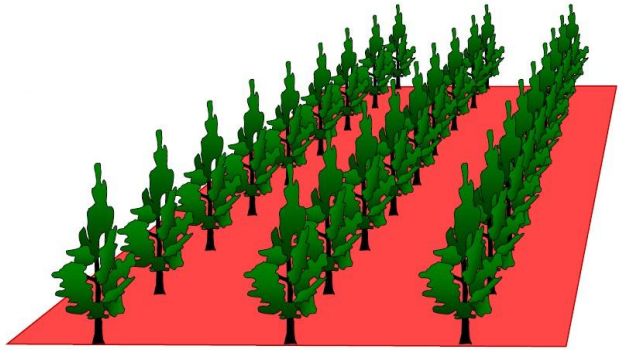
ne unit (kg or L) linked to a certain reference unit

ı the EU:

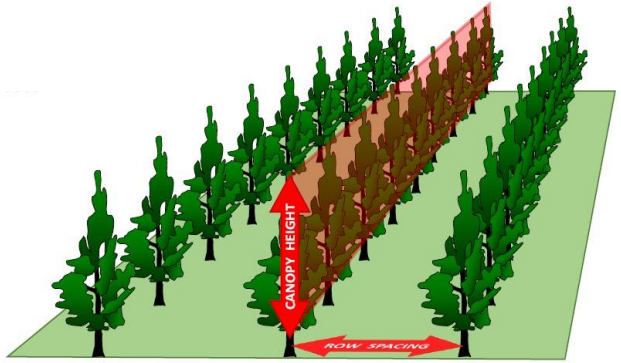
REFERENCE UNITS IN THE EU

- Ground area
- Spray volume (concentration %)
- Canopy height – CH
- Leaf wall area – LWA
- Tree row volume – TFV
- Plant row

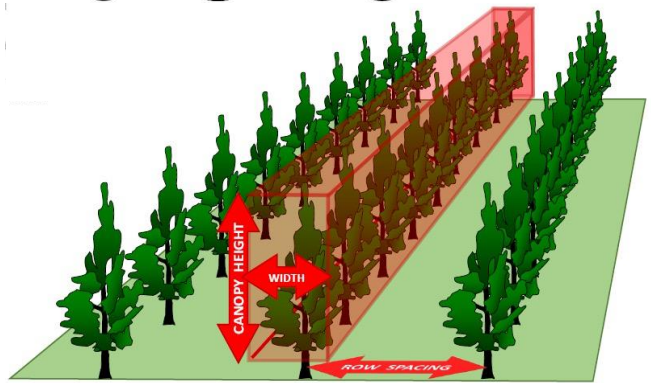
Ground area
(kg or L/ha ground)



Spray volume [conc]
(kg or L/100 L spray volume)



Leaf Wall Area – LWA
(Kg or L/10 000 m^2 LWA)



Tree Row Volume – TRV
(Kg or L/10 000 m^3 TRV)

(Doruchowski, G. 2018)

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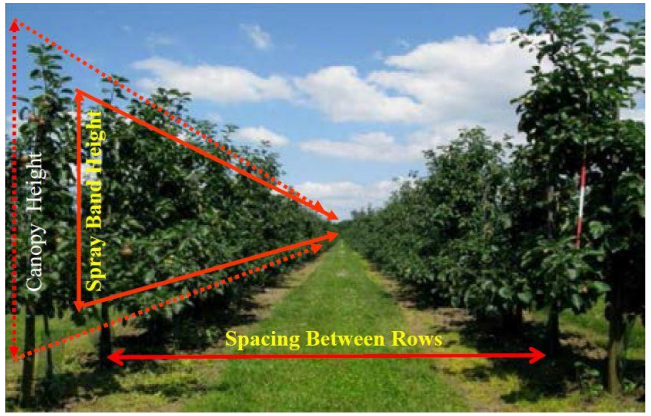
Plant Protection: 3-Dimentional Crops and Leaf Wall Area (LWA) and Tree Row Volume (TRV)



The terms “3-Dimensional crops”, “high growing crops” or “vertical crops” are used for crops such as grapes, pome fruit or tomato for which aerial spraying (upward or sideward directed spray application) has to be used. Due to the height and the special growing conditions of these crops, the area to be treated with a plant protection product per hectare can be much higher (or for special situations even lower, e.g. bunch zone application) and much more variable compared to low growing crops.

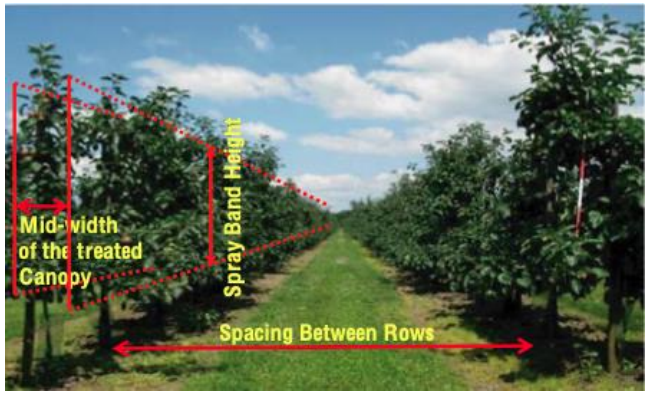
Starting January 1st, 2020 application dossiers for new products intended to be used for the vertical crops grapevine, pome fruits and high growing vegetables in the EU Central Zone are only accepted when the efficacy trials are conducted based on the so-called Leaf Wall Area (LWA) concept. Consequently, efficacy trials for these crops carried out after 1 January 2018 are only accepted if they have been conducted on basis of the LWA dose expression. Furthermore, the dose rate per hectare of LWA has to be included in the GAP table, restricted by the maximum rate per hectare ground surface and the range of possible concentrations.

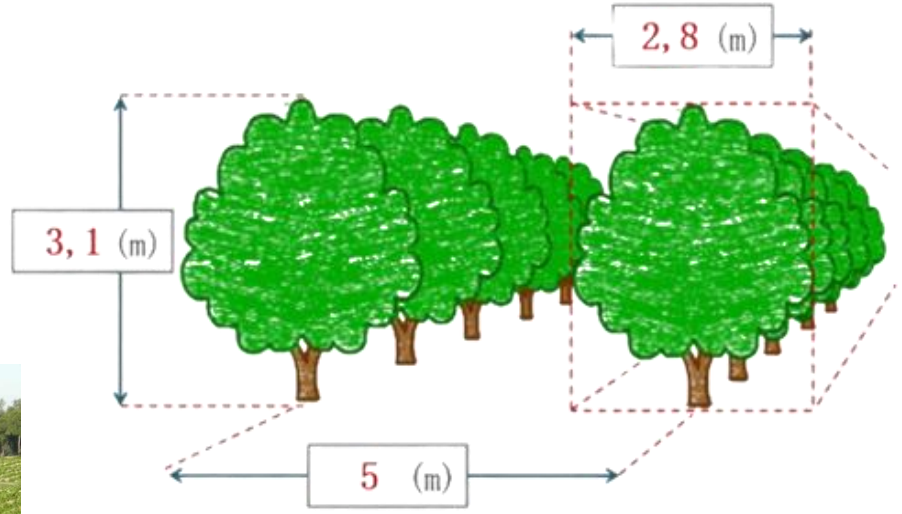
The requirement for the use of the LWA dose expression is currently only mandatory in the Central Zone. In the Southern Zone using a concentration for dose expression is quite common, which is why a transition to the LWA concept is not yet agreed.

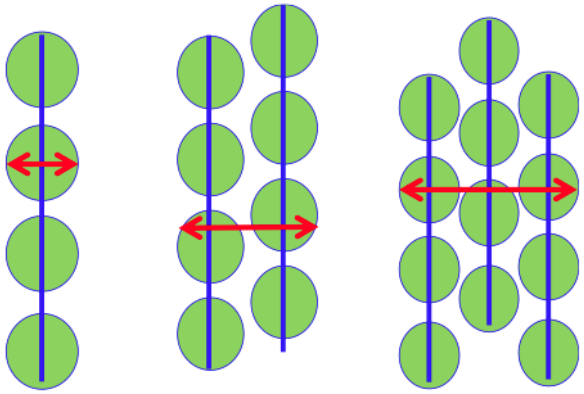
EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Dose expression for plant protection products. European and Mediterranean Plant Protection Organization – https://doi.org/10.1111/epp.12704

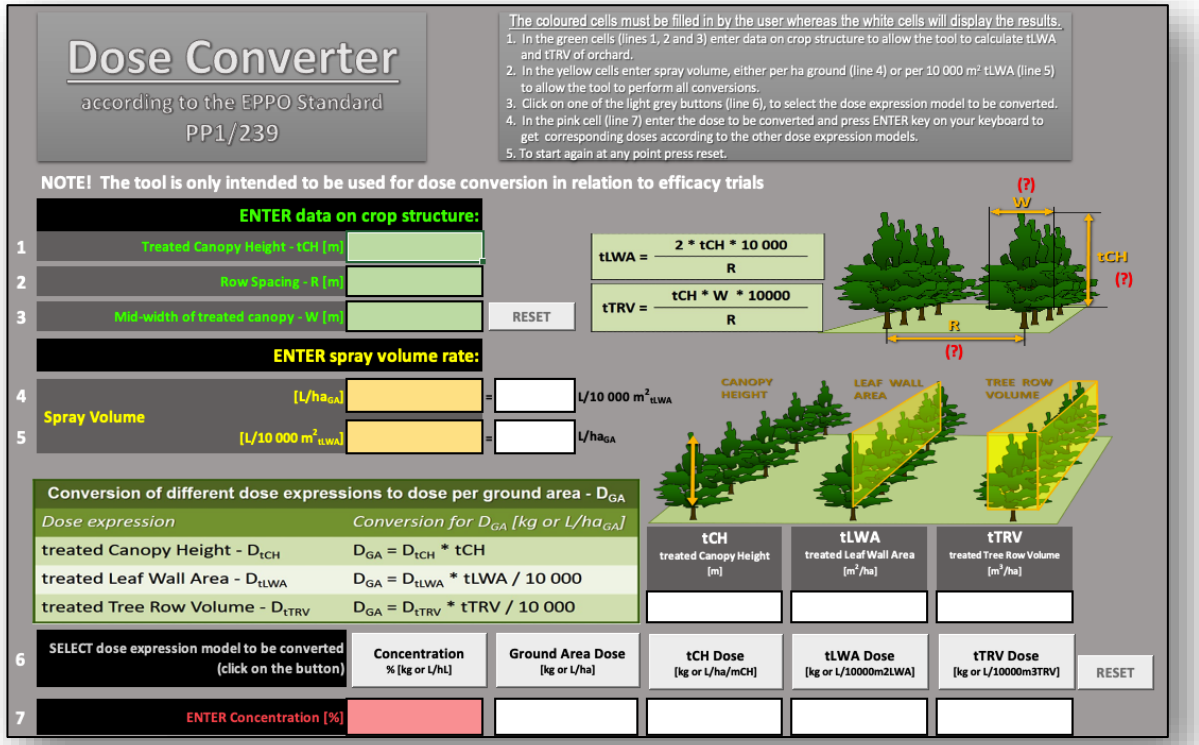
Plant Protection: 3-Dimentional Crops and Tree Row Volume (TRV)



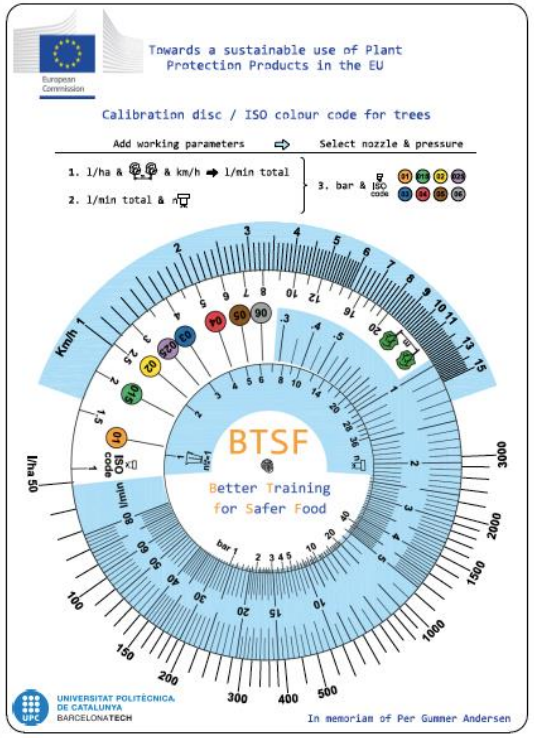


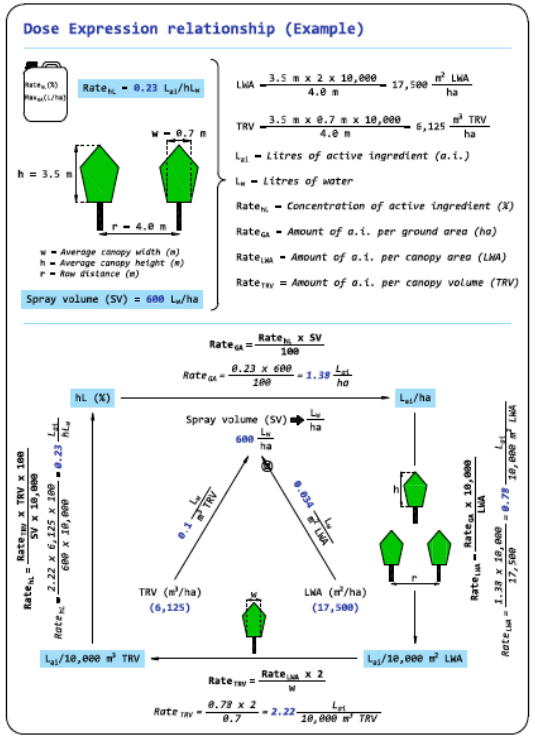


Expresion de dosis – Conversión de unidades



https://www.eppo.int/ACTIVITIES/plant_protection_products/harmonized_dose_expression





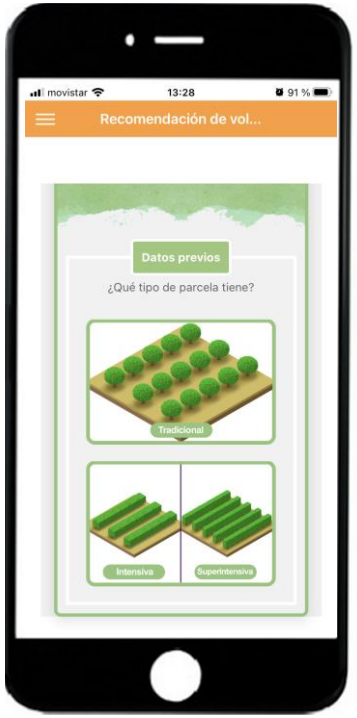
https://uma.deab.upc.edu

Determinación del volumen óptimo

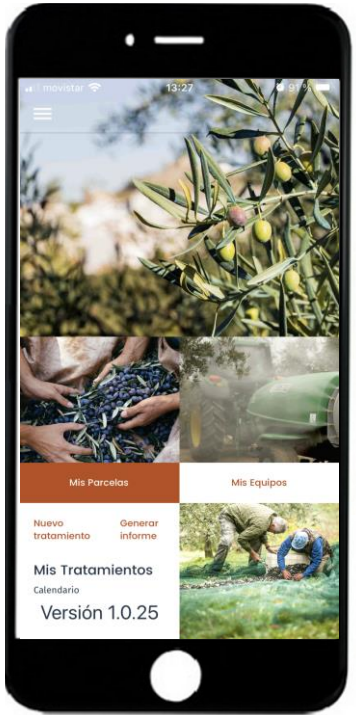
Estrucutura del cultivo, área foliar, técnica de aplicación, plaga o enfermedad …

(Gil et al., 2020)

https://sprayers101.com



(Garcerá et al., 2017)



(Miranda-Fuentes et al., 2019)

https://citrusvol.com/recomendacion-de-volumen/

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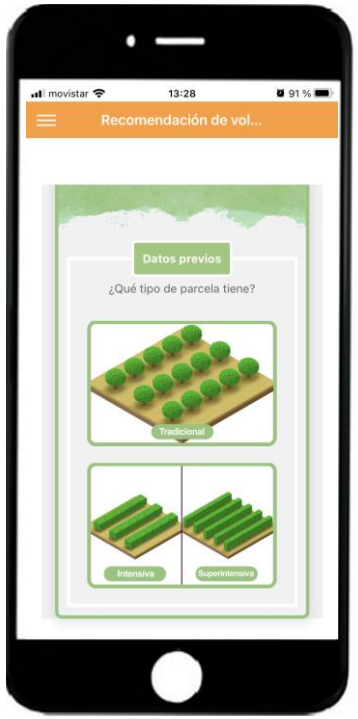
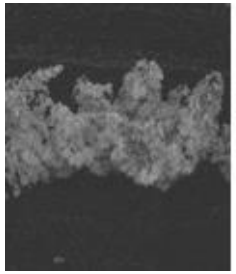


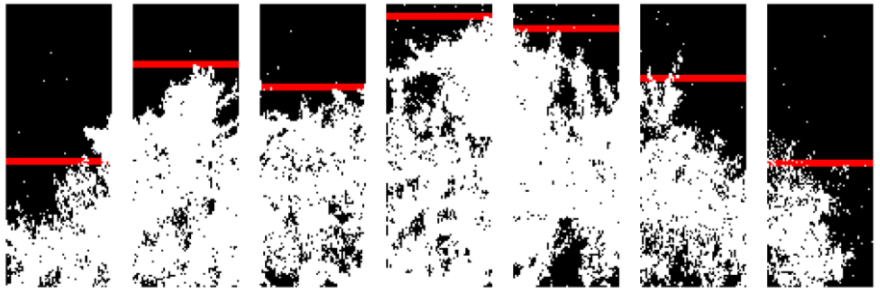
Google Play

Download on the
App Store

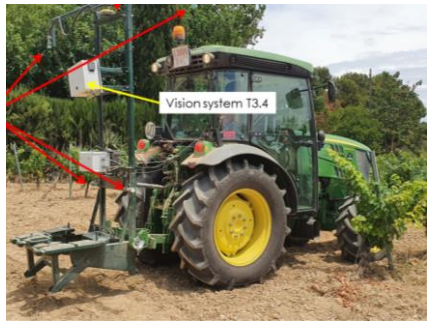
CitrusUGV

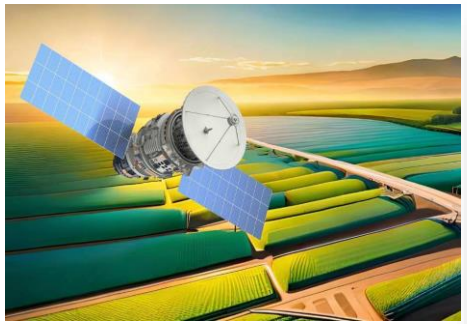
Hay que caracterizar la vegetación

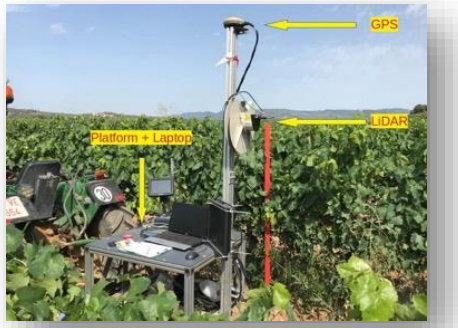


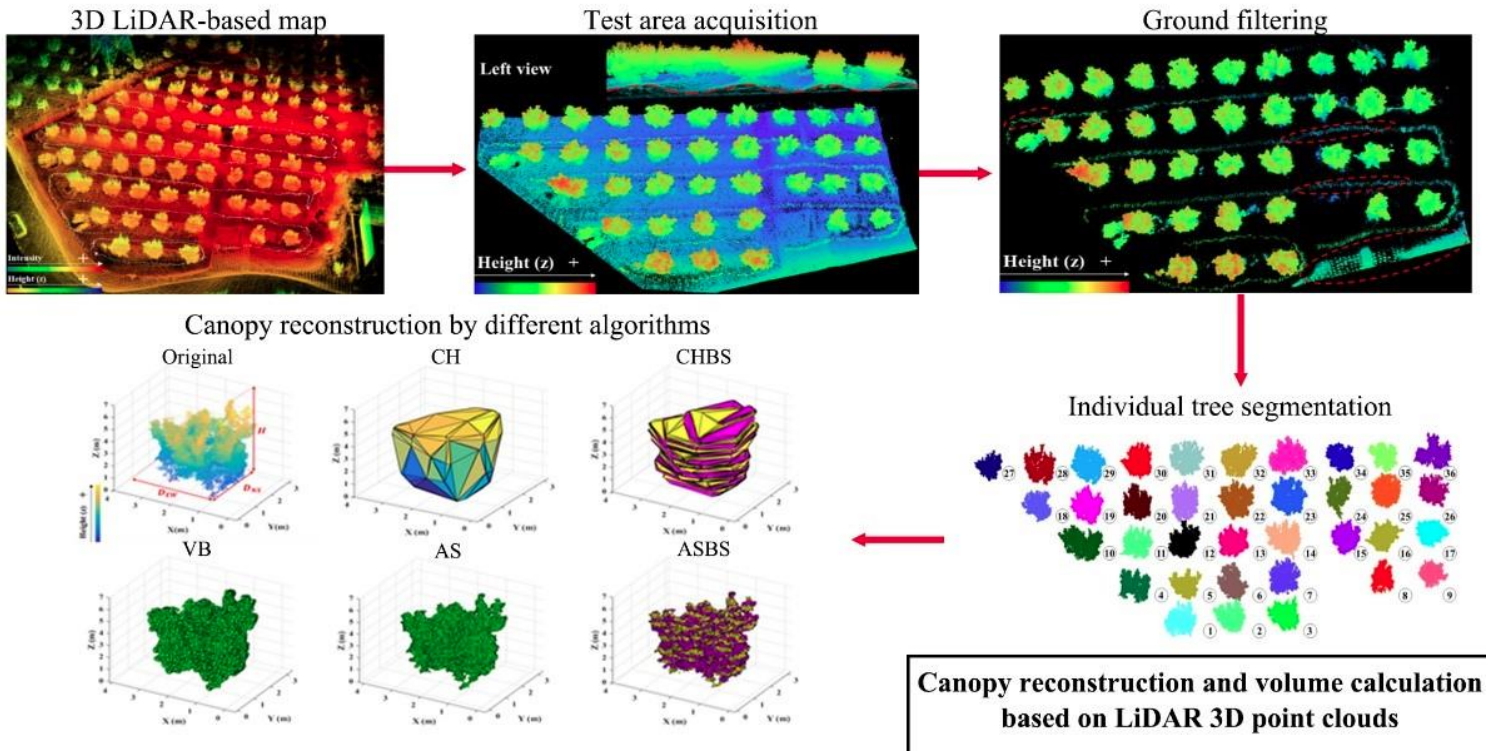


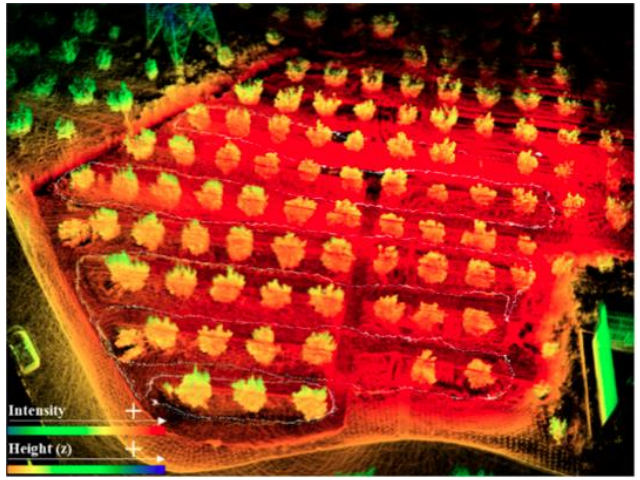
Canopy Height
Row Spacing

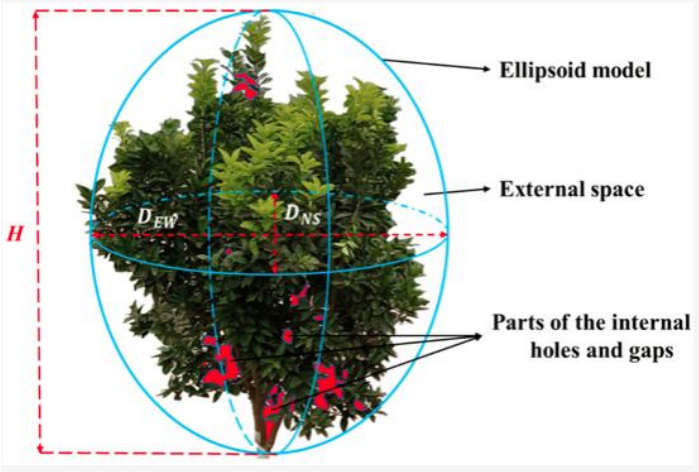

Vision system T3.4




GPS
LIDAR
Platform + Laptop







Liu, X.; Wang, Y.; Kang, F.; Yue, Y.; Zheng, Y. Canopy Parameter Estimation of *Citrus grandis* var. *Longanyou*Based on LiDAR 3D Point Clouds. *Remote Sens.* **2021**, *13*, 1859. https://doi.org/10.3390/rs13091859

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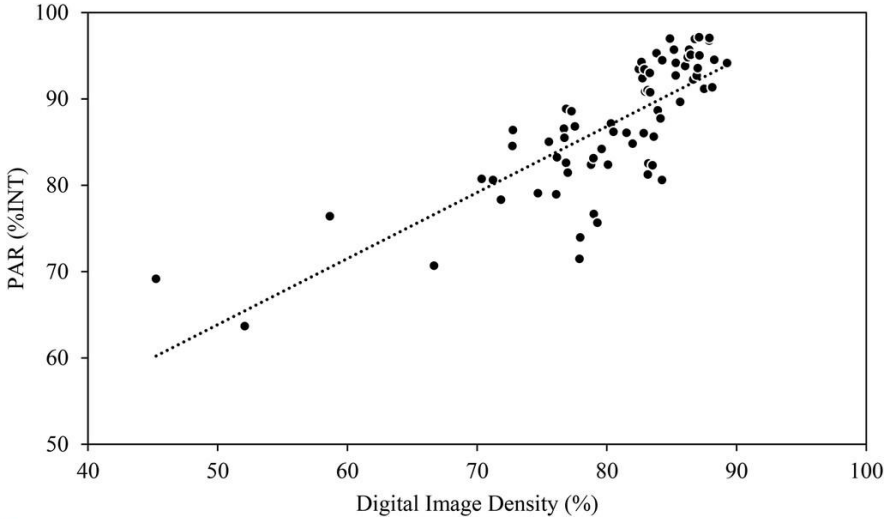
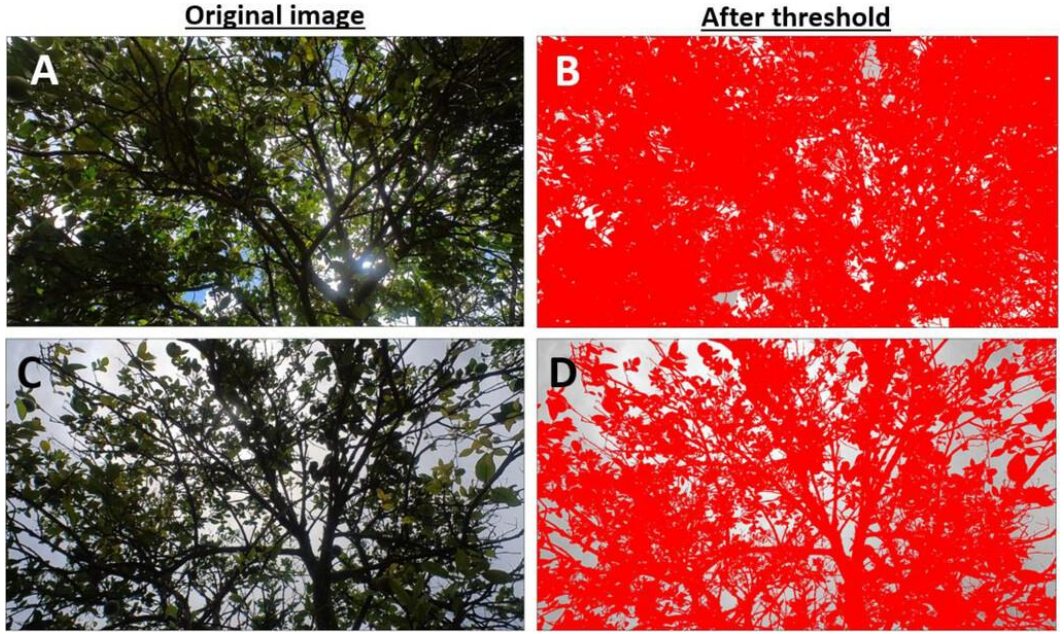
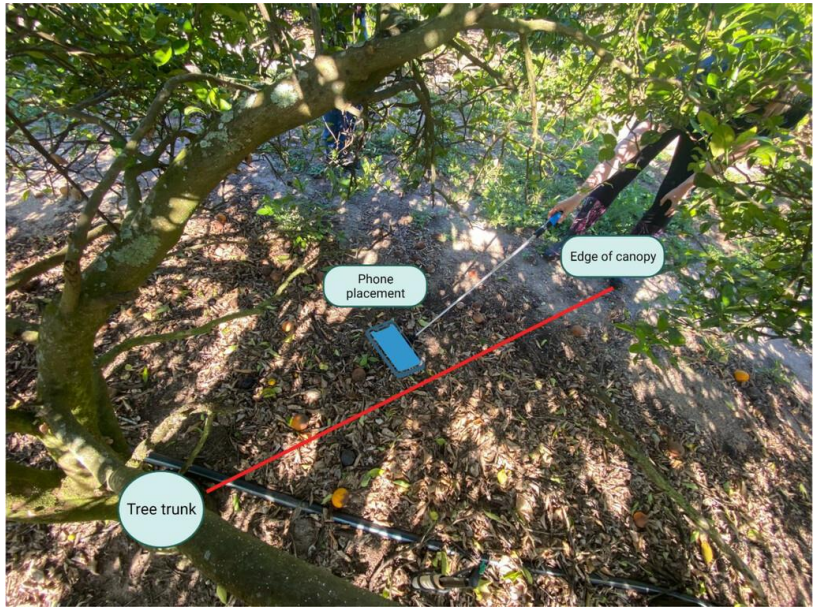
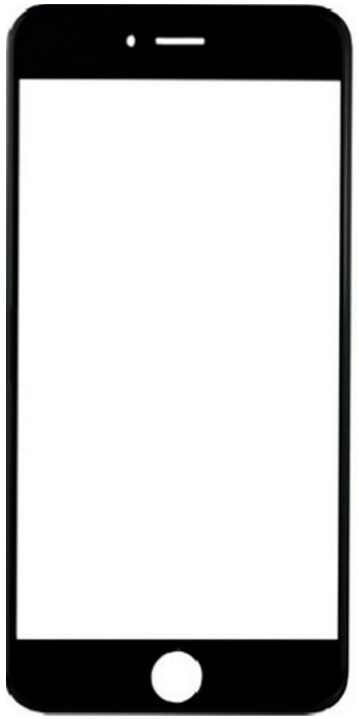








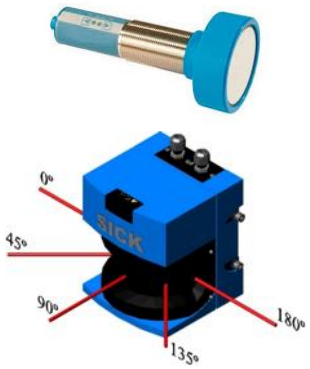
Livingston, T., Levy, A., & Vashisth, T. (2023). A Simple Low-cost Method for Accurate Canopy Density Evaluation of Citrus. *HortScience*, *58*(7), 747-749. Retrieved Nov 30, 2024, from https://doi.org/10.21273/HORTSCI17112-23

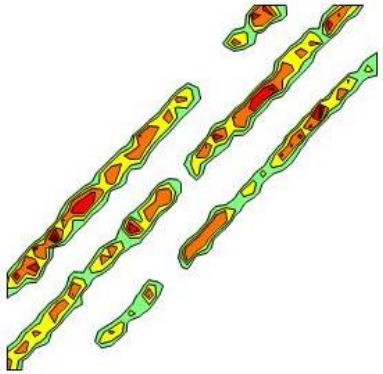
Canopy characterization

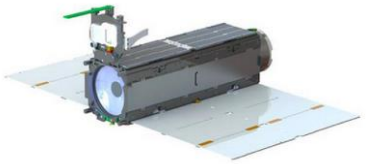
Principles of Variable Rate Application (VRA)

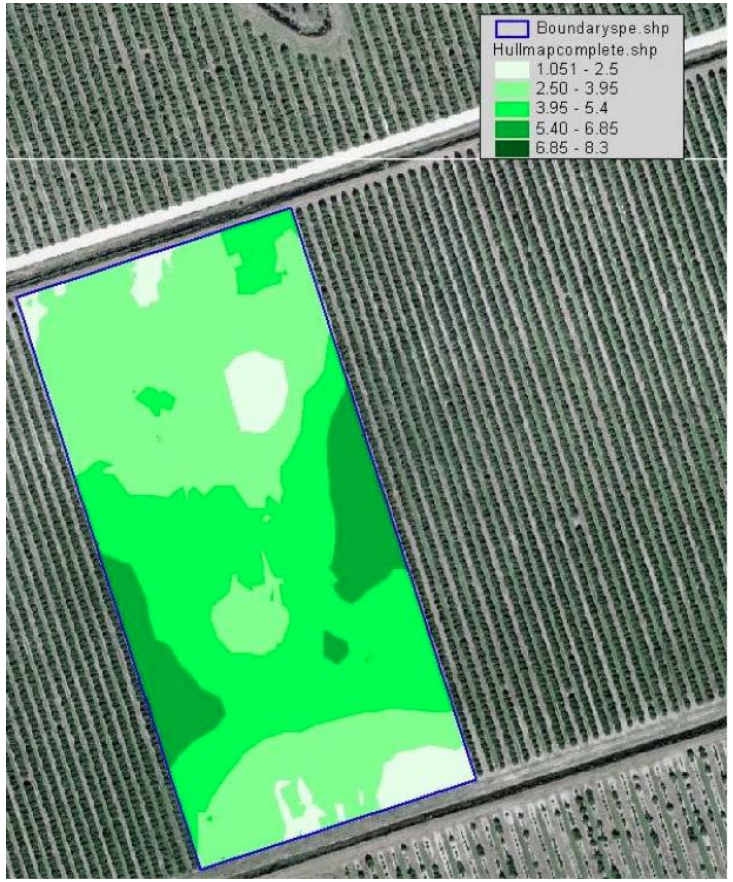
Canopy characterization using proximal sensors
"on-line"
Real time measurement

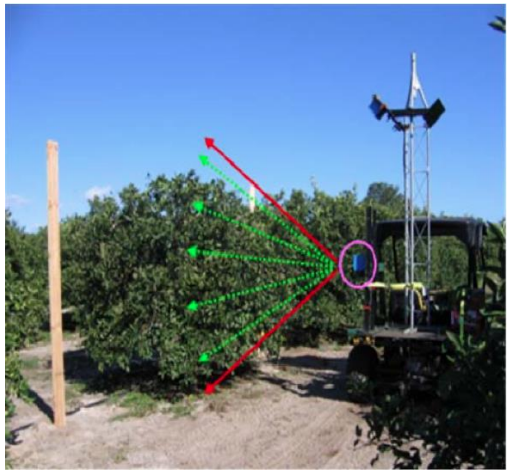
Automated remote sensing based models
"off-line"
Map-based measurement

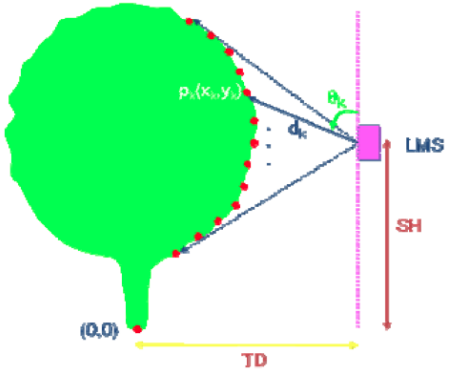


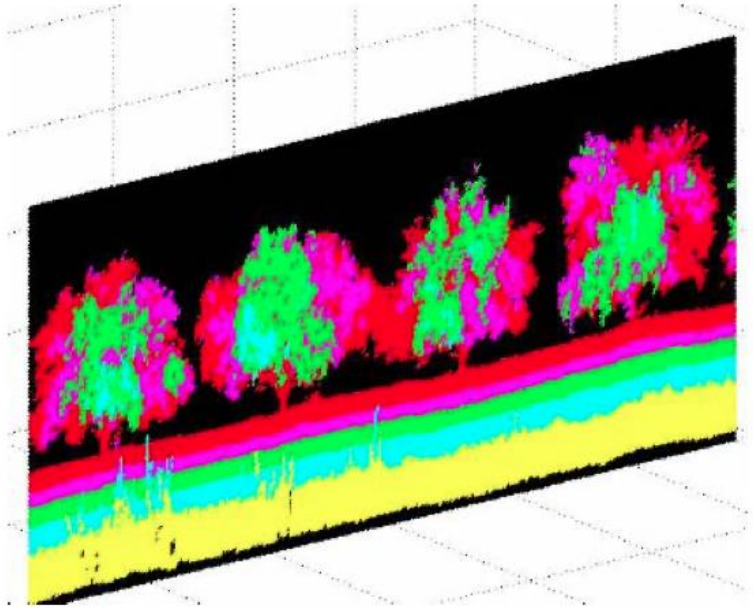




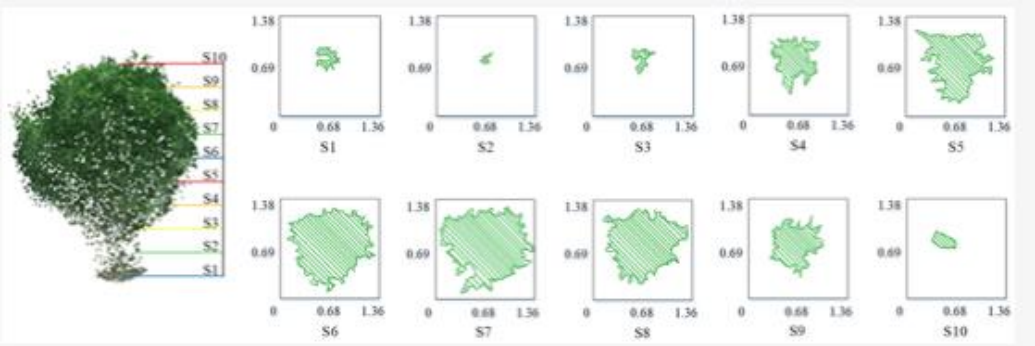


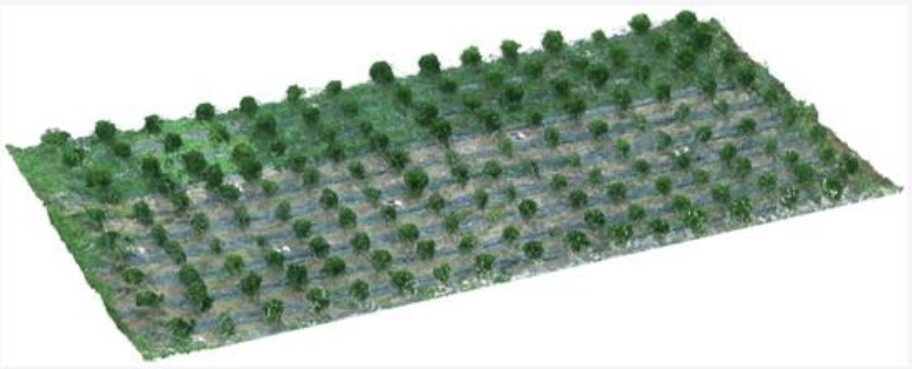


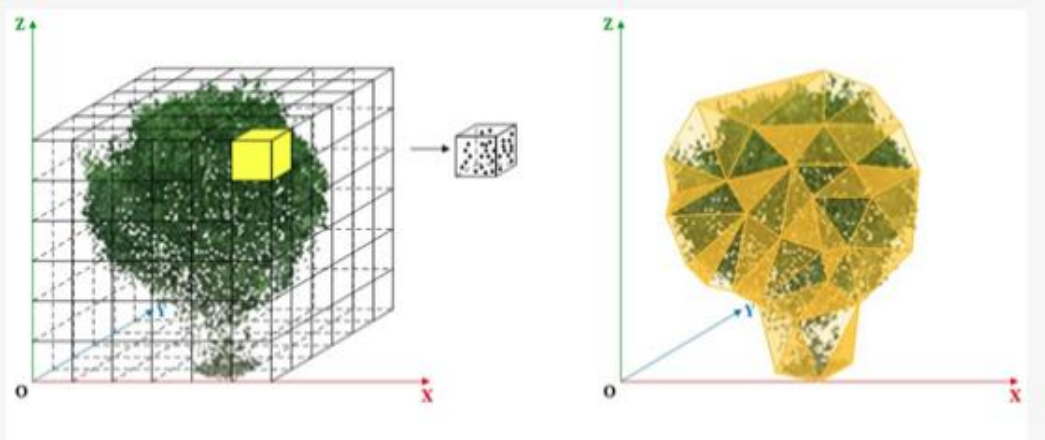




Ehsani, R.; Lee, K. 2008. A measurement system for quantifying citrus foliage volume and porosity. *Journal of Agricultural Machinery Science* 2008, 4 (4), 333-338

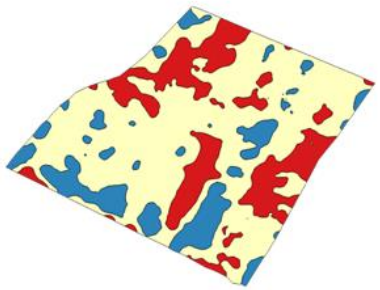


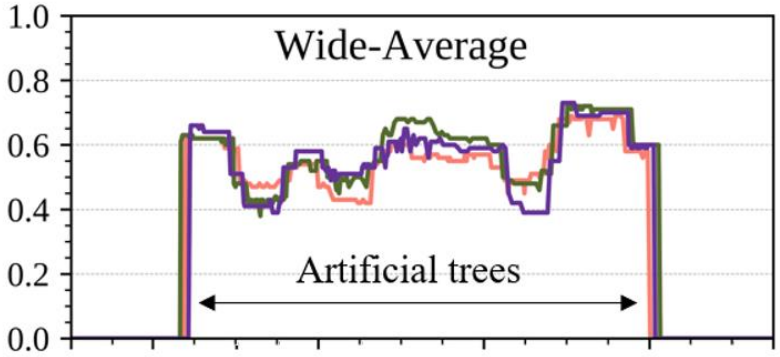




Qi, Y.; Dong, X.; Chen, P.; Lee, K.-H.; Lan, Y.; Lu, X.; Jia, R.; Deng, J.; Zhang, Y. Canopy Volume Extraction of Citrus reticulate Blanco cv. Shatangju Trees Using UAV Image-Based Point Cloud Deep Learning. Remote Sens. 2021, 13, 3437. https://doi.org/10.3390/rs13173437

- Los sistemas **VRA** tienen en cuenta la variabilidad de la vegetación dentro de una misma parcela
- Estas tecnologías recopilan datos sobre la variabilidad del cultivo, bien en tiempo real mediante **sensores embarcados**, bien mediante el procesamiento de los datos generando **mapas de prescripción**.
- Las características de la vegetación se procesan para calcular el **caudal de boquilla** deseado en un lugar determinado
- El caudal de boquilla deseado se ajusta automáticamente durante el proceso utilizando diferentes opciones





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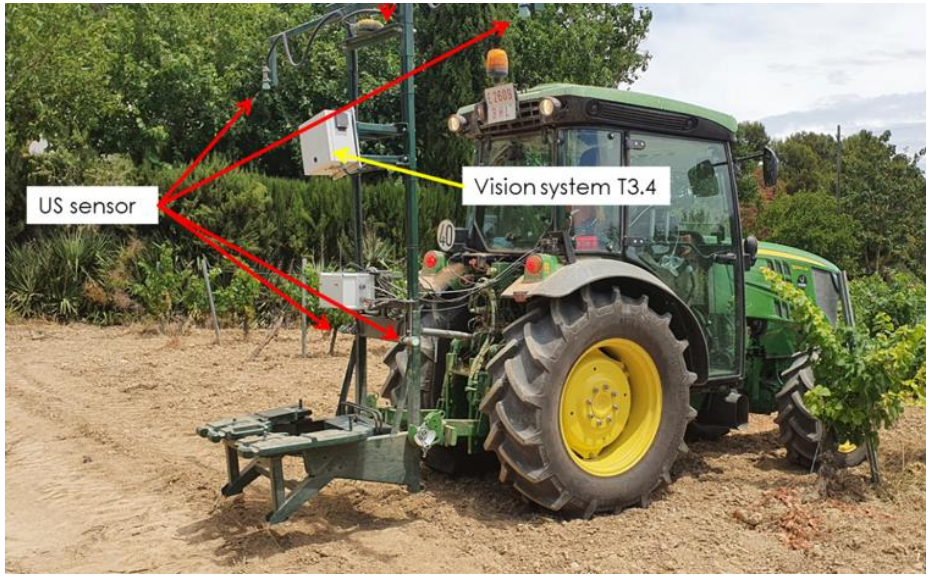
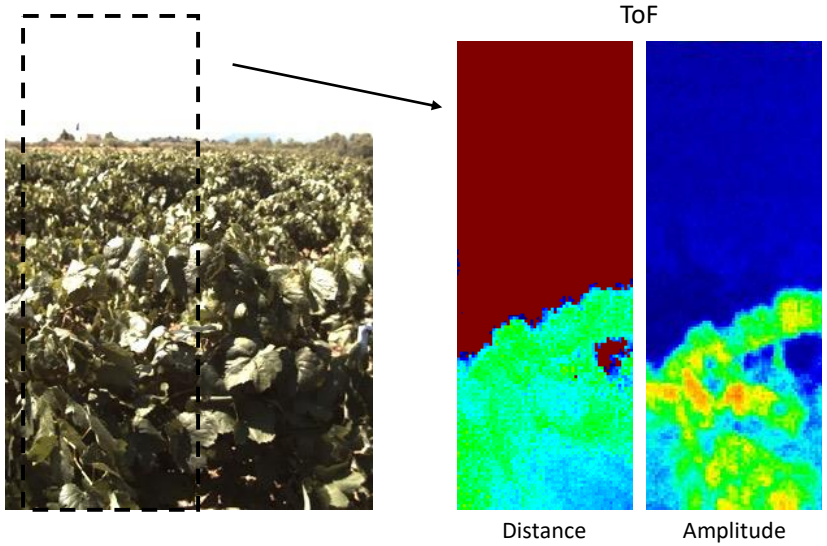
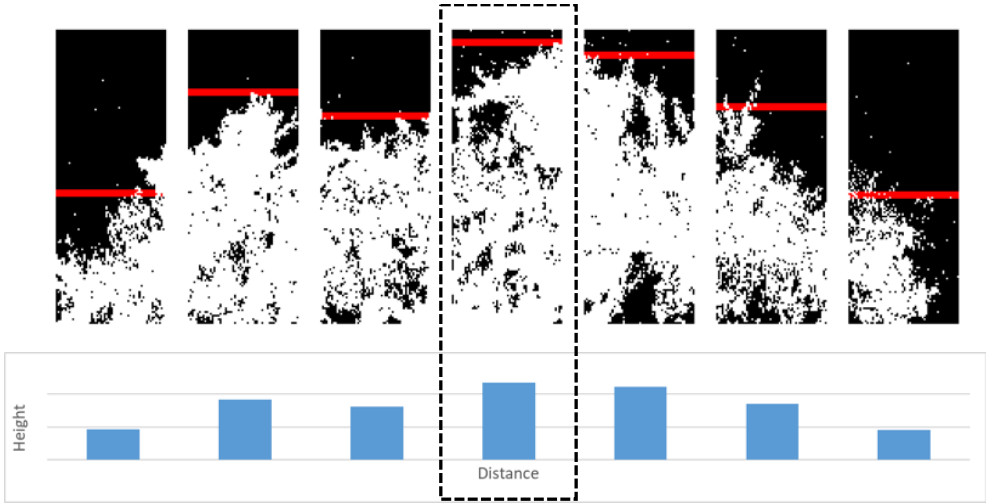
Experiences on canopy characterization







NOVATERRA

Integrated Novel Strategies for Reducing the Use and Impact of Pesticides, Towards Sustainable Mediterranean Vineyards and Olive Groves

The NOVATERRA project has received funding from the European Commission's Horizon 2020 grant agreement number 101000554.

https://www.novaterraproject.eu

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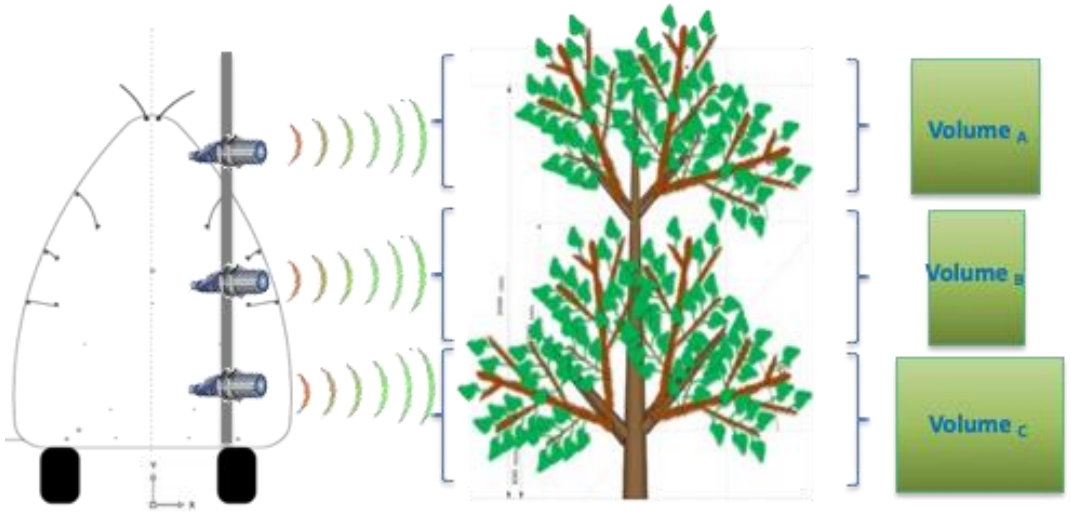
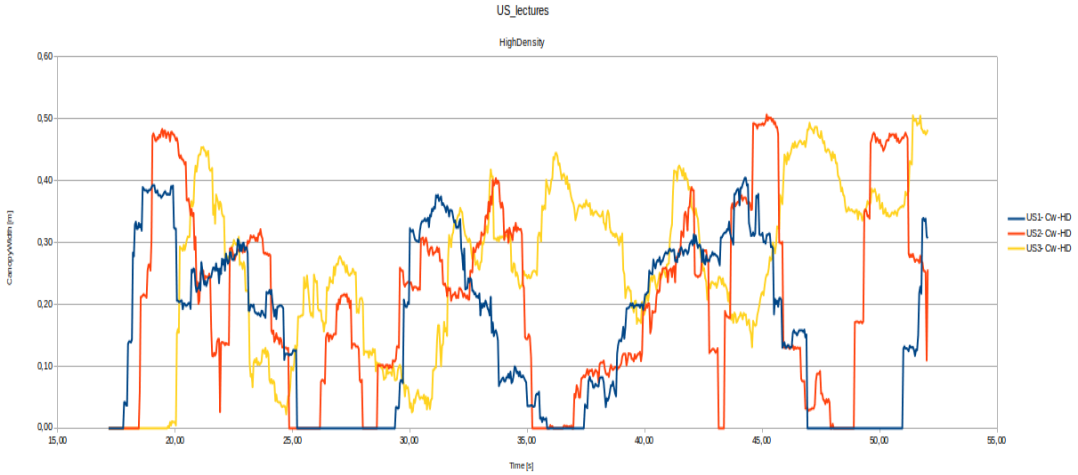
Experiences on canopy characterization



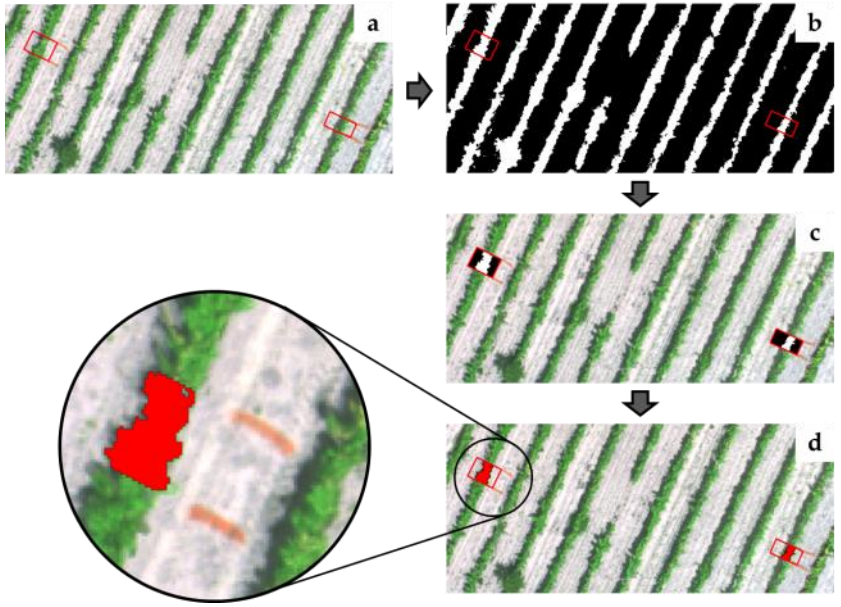


PTIMA

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT N. 773718

Salas, B.; Salcedo, R.; Garcia-Ruiz, F.; Gil, E. 2023. Design, implementation and validation of a sensor-based precise Airblast sprayer to improve pesticide applications in orchards. ***Precision Agriculture*** https://doi.org/10.1007/s11119-023-10097-7

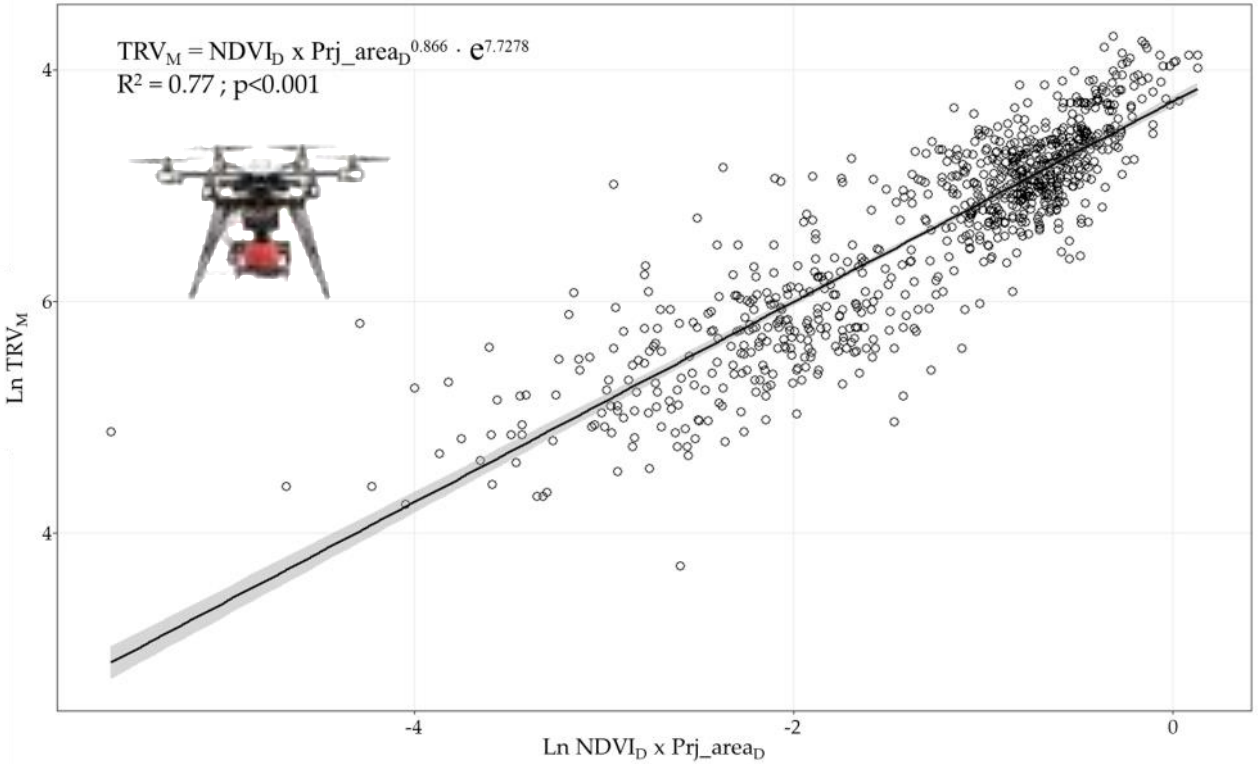
Experiences on canopy characterization



UAV based measures
B, G, B, RE and NIR
Projected area (m^2)
NDVI

Manual Mesures[2]
Canopy Height (m)
Canopy Width (m)
TRV (m^3/ha)
LWA (m^2/ha)

[2]EPPO (2021), PP 1/239 (3) Dose expression for plant protection products. EPPO Bull, 51. pp 10-33. doi: 10.1111/epp.12704

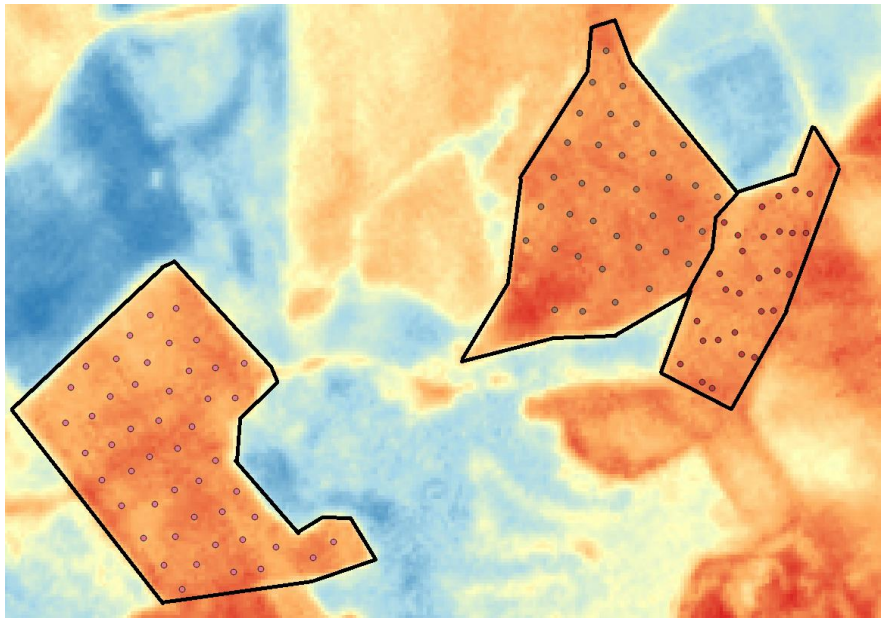


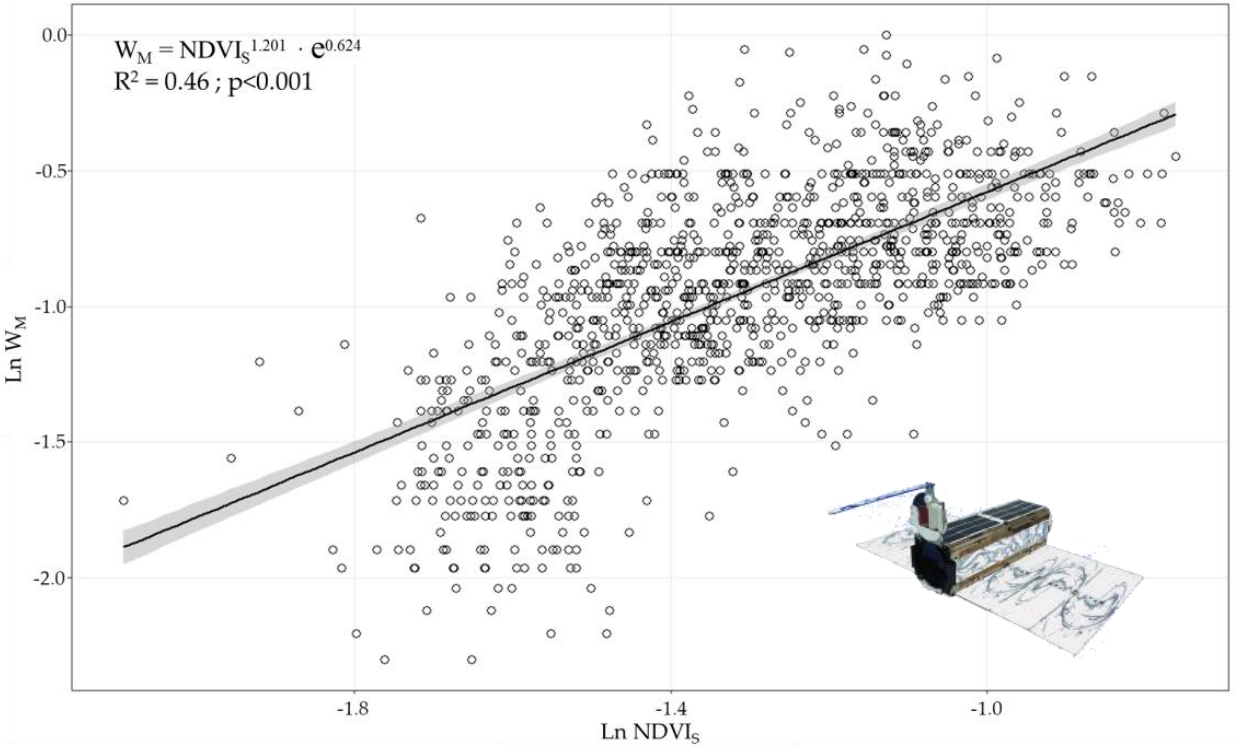
Campos, J.; García-Ruiz, F.; Gil, E. Assessment of Vineyard Canopy Characteristics from Vigour Maps Obtained Using UAV and Satellite Imagery. *Sensors* 2021, 21, 2363

Experiences on canopy characterization

Dove, Planet Labs

- CubeSat nano satellites
- 4 bands (2020): R, G, B and NIR
- Spatial resolution: 3 x 3 m
- Temporal resolution: 1 day





Campos, J.; García-Ruiz, F.; Gil, E. Assessment of Vineyard Canopy Characteristics from Vigour Maps Obtained Using UAV and Satellite Imagery. ***Sensors*** 2021, 21, 2363

Adaptar la dosis al objetivo

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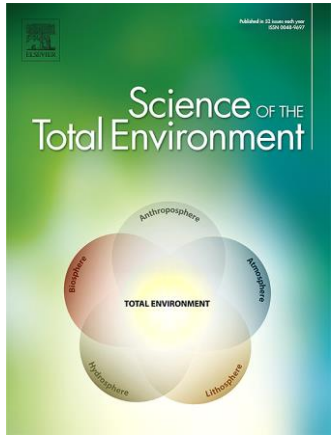
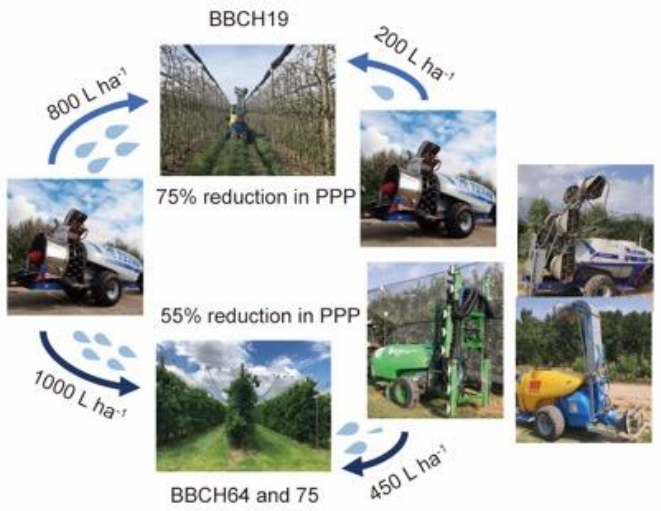
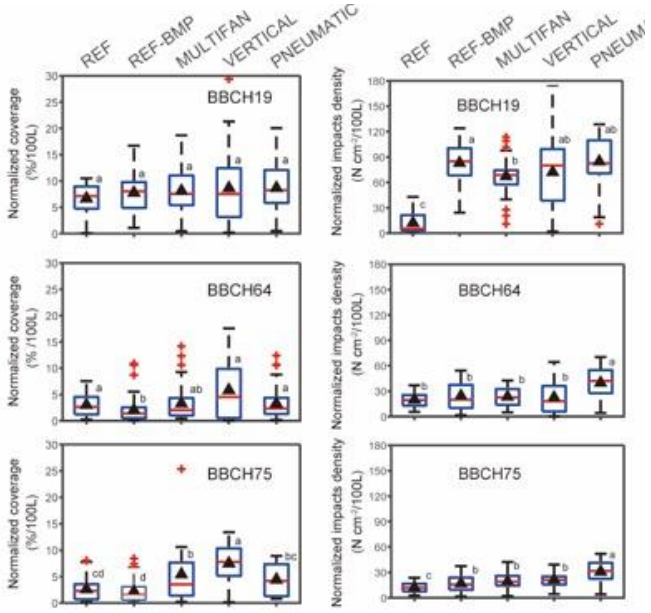
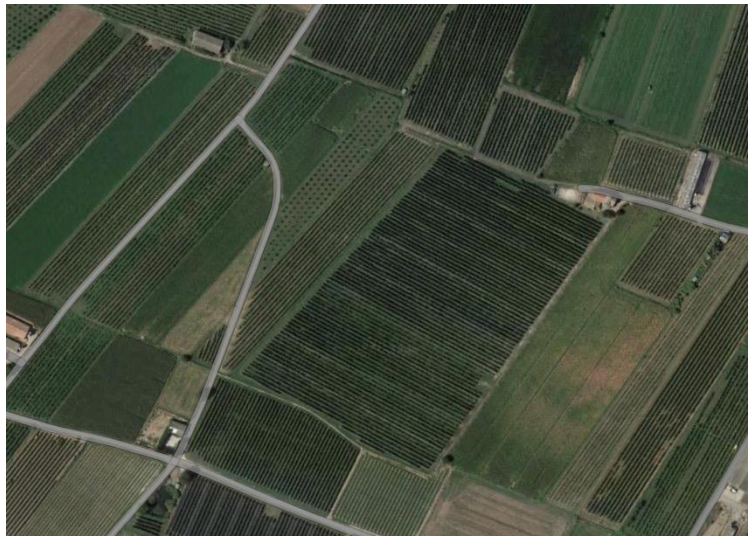






Only
Best Management Practices!!!

> 1000 Ha apple farm in Spain



PPP reduction: 35%
Same pest/disease control

Xun, L., Garcia-Ruiz, F., Fabregas, F. X., Gil, E. 2022. Pesticide dose based on canopy characteristics in apple trees: Reducing environmental risk by reducing the amount of pesticide while maintaining pest and disease control efficacy. Science of the Total Environment, 826, 154204. https://doi.org/10.1016/j.scitotenv.2022.154204

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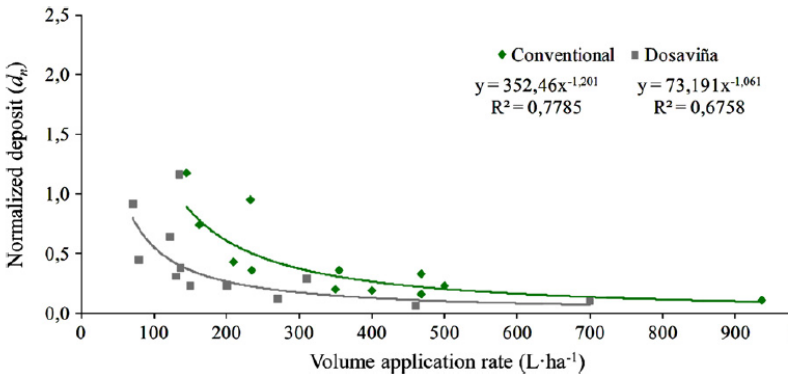
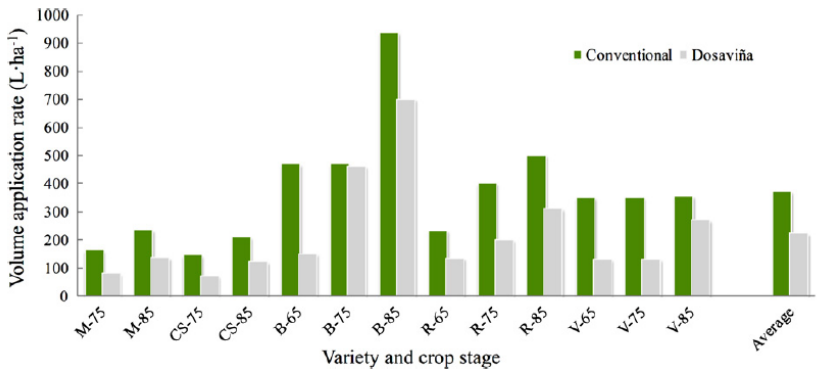
Algorithm
(2010-2020)

GOBIERNO DE ESPAÑA — MINISTERIO DE CIENCIA E INNOVACIÓN

OPTIDOSA Research project
(2007-2009)

53% PPP reduction

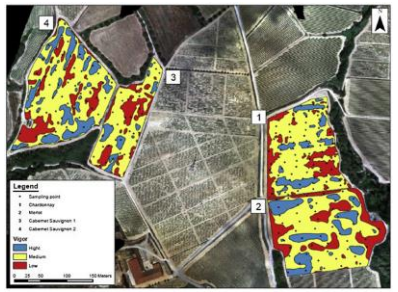




Gil, E., Llorens, J., Landers, A., Llop, J, Giralt, L. 2011. Field validation of DOSAVIÑA, a decision support system to determine the optimal volume rate for pesticide application in vineyards. ***European Journal of Agronomy***, 35(1): 33-46; doi:10.1016/j.eja.2011.03.005

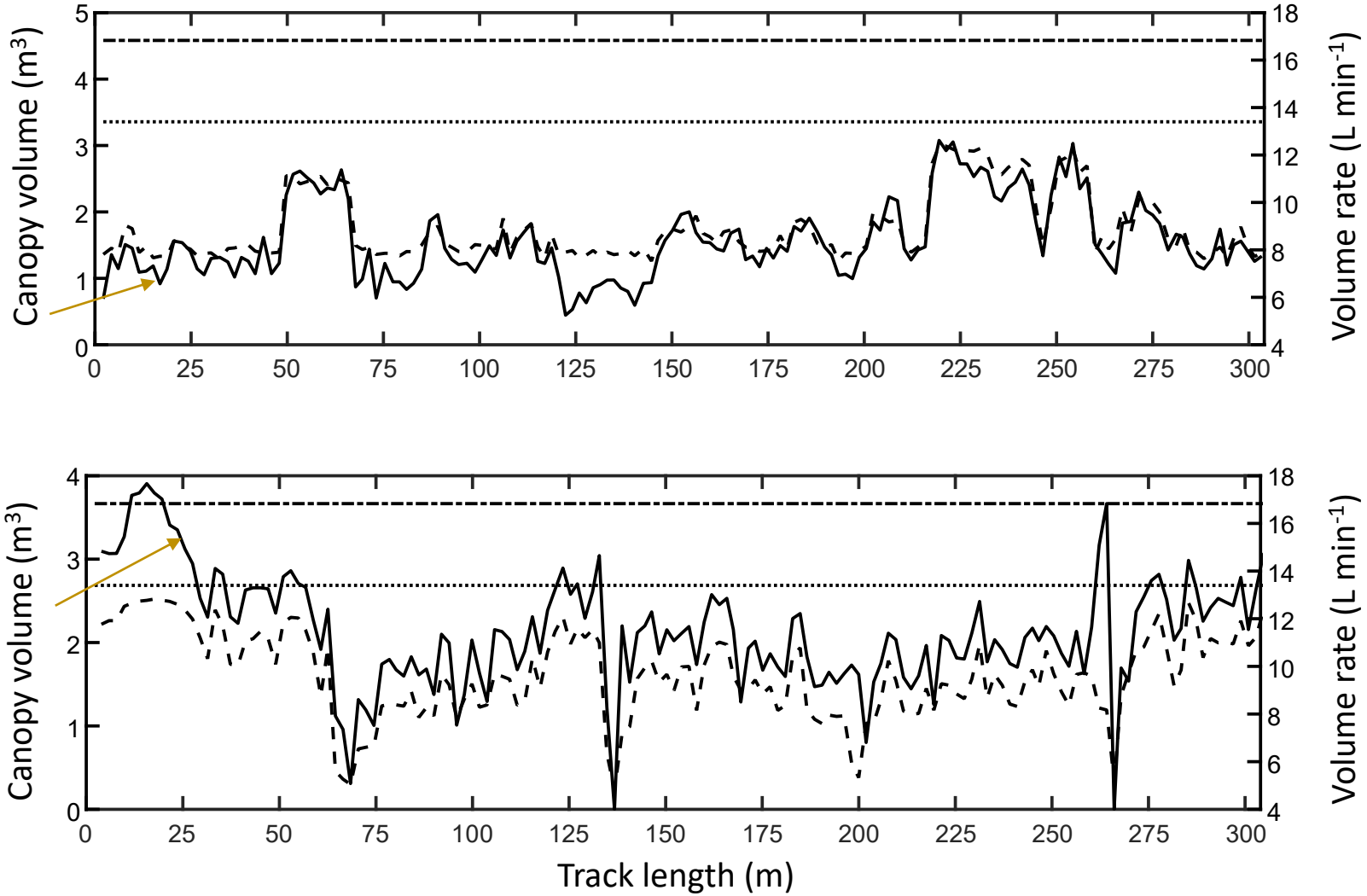
PERFECT project
(2018-2022)

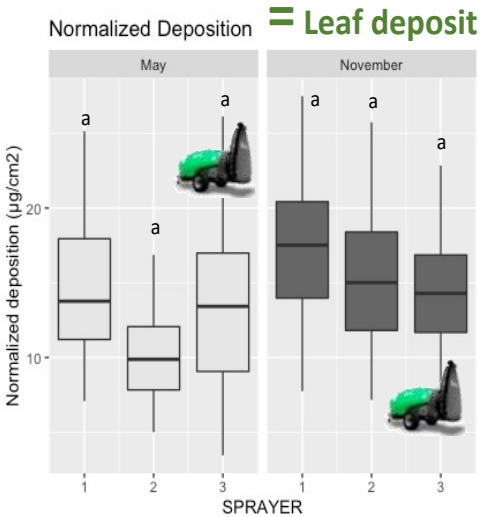
20-40 % PPP reduction

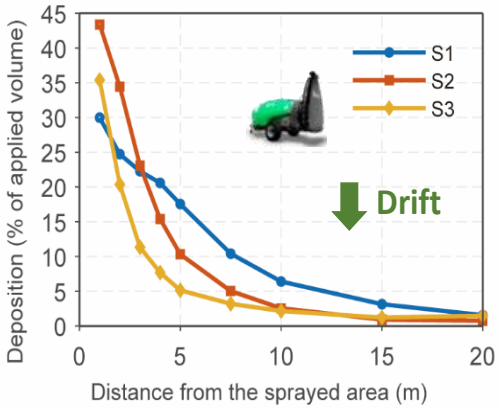


Gil E., Campos, J., Ortega, P., Llop J., Gras A., Armengol E., Salcedo R., Gallart M. 2019. DOSAVIÑA: Tool to calculate the optimal volume rate and pesticide amount in vineyard spray applications based on a modified leaf wall area method. ***Computers and Electronics in Agriculture***, Volume 160, May 2019, Pages 117-130

Canopy volume and corresponding spray output rate





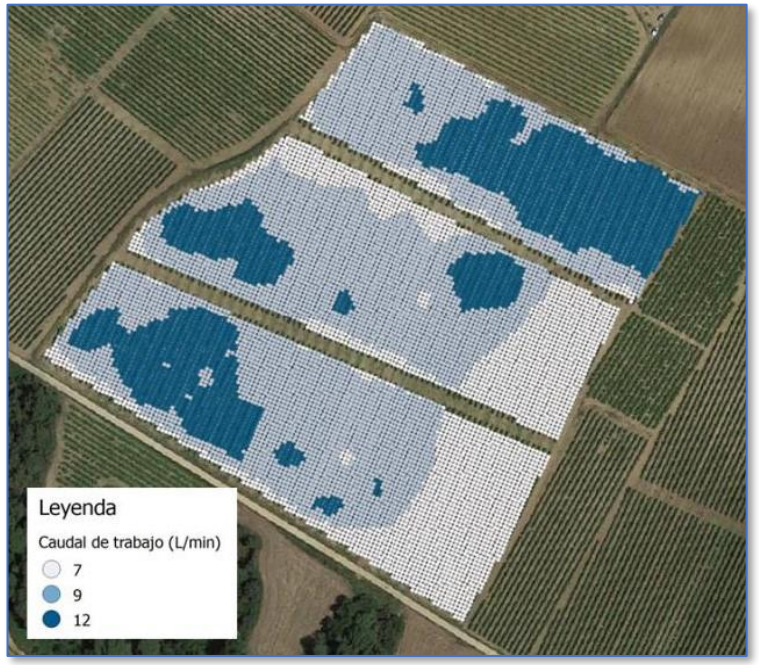


		Volume rate (L/ha)	% PPP savings
MAY	Ref 0	881	0%
	Ref 1	773	12%
	Prototype	475	46%
NOV	Ref 0	877	0%
	Ref 1	769	12%
	Prototype	462	47%

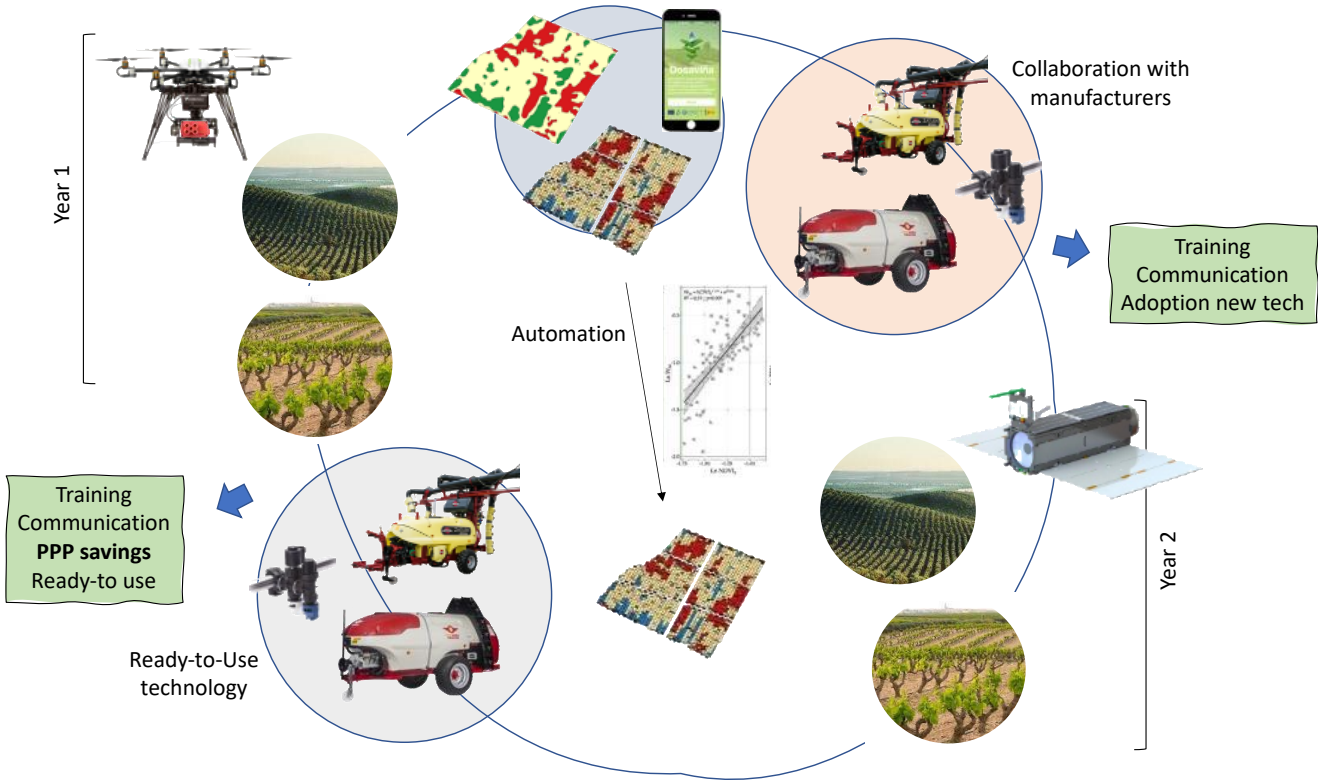
[PPP] constant
≈ 45% PPP reduction
Same pest control

Xun, L., Campos, J., Salas, B. *et al.* Advanced spraying systems to improve pesticide saving and reduce spray drift for apple orchards. *Precision Agric* **24**, 1526–1546 (2023). https://doi.org/10.1007/s11119-023-10007-x

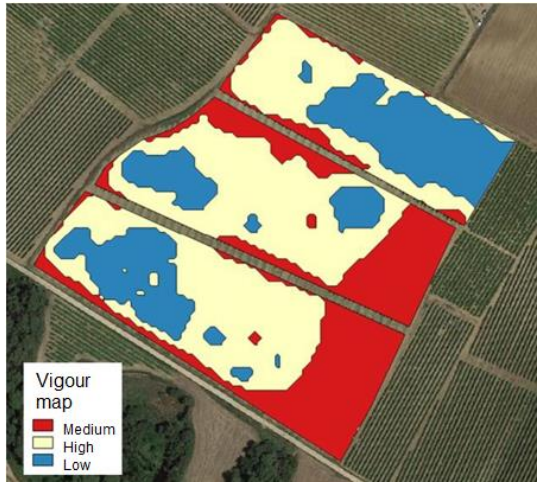
Conventional vs Variable Rate Application

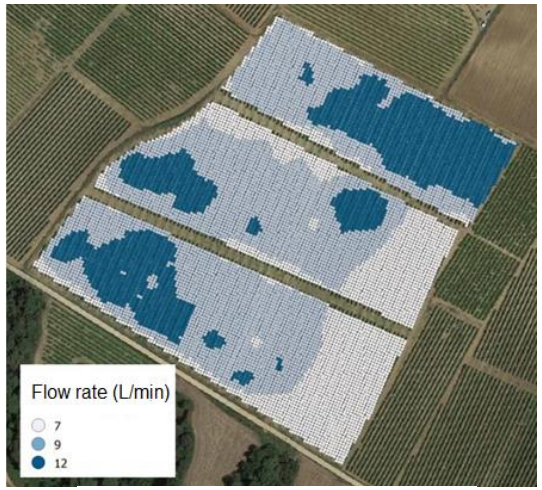


- What is the influence in spray quality? Biological efficacy? when spray volume and dose were adjusted
- To what extent the PPPs can be saved to maintain effective biological efficacy?



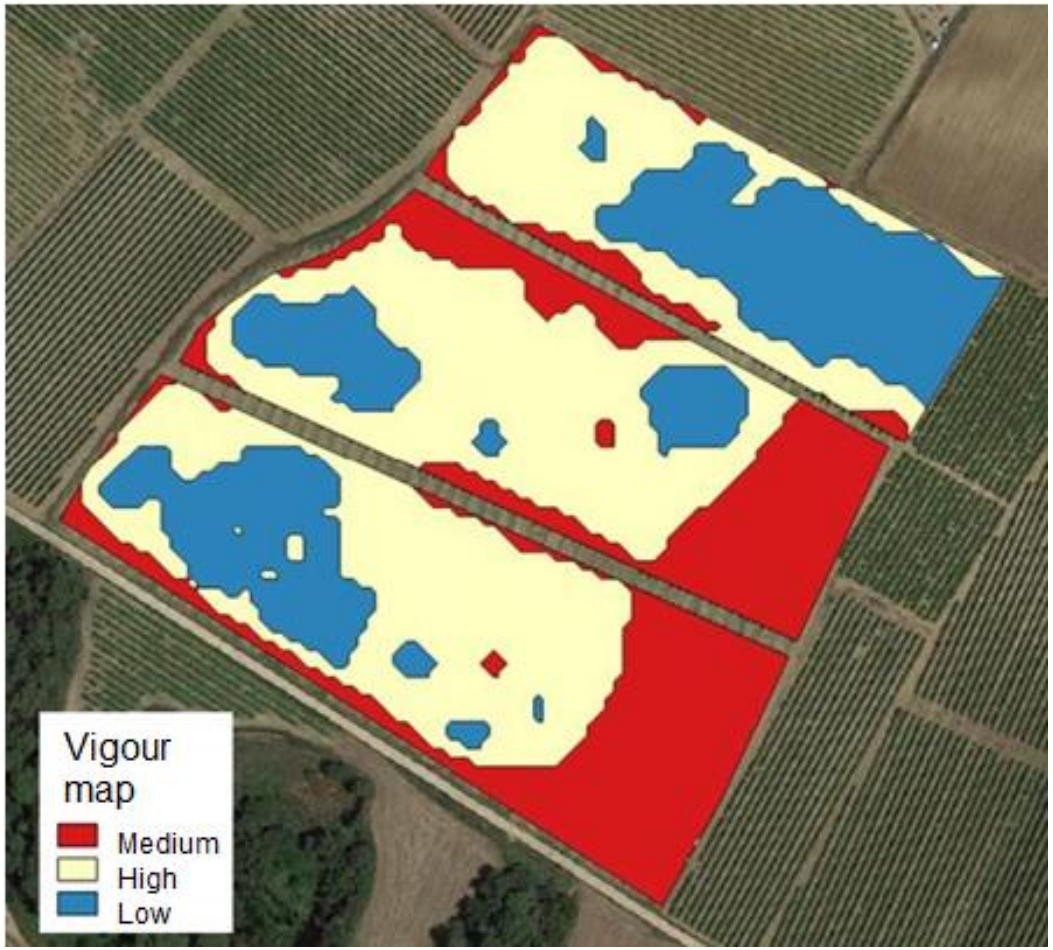
Vigour map (NDVI)

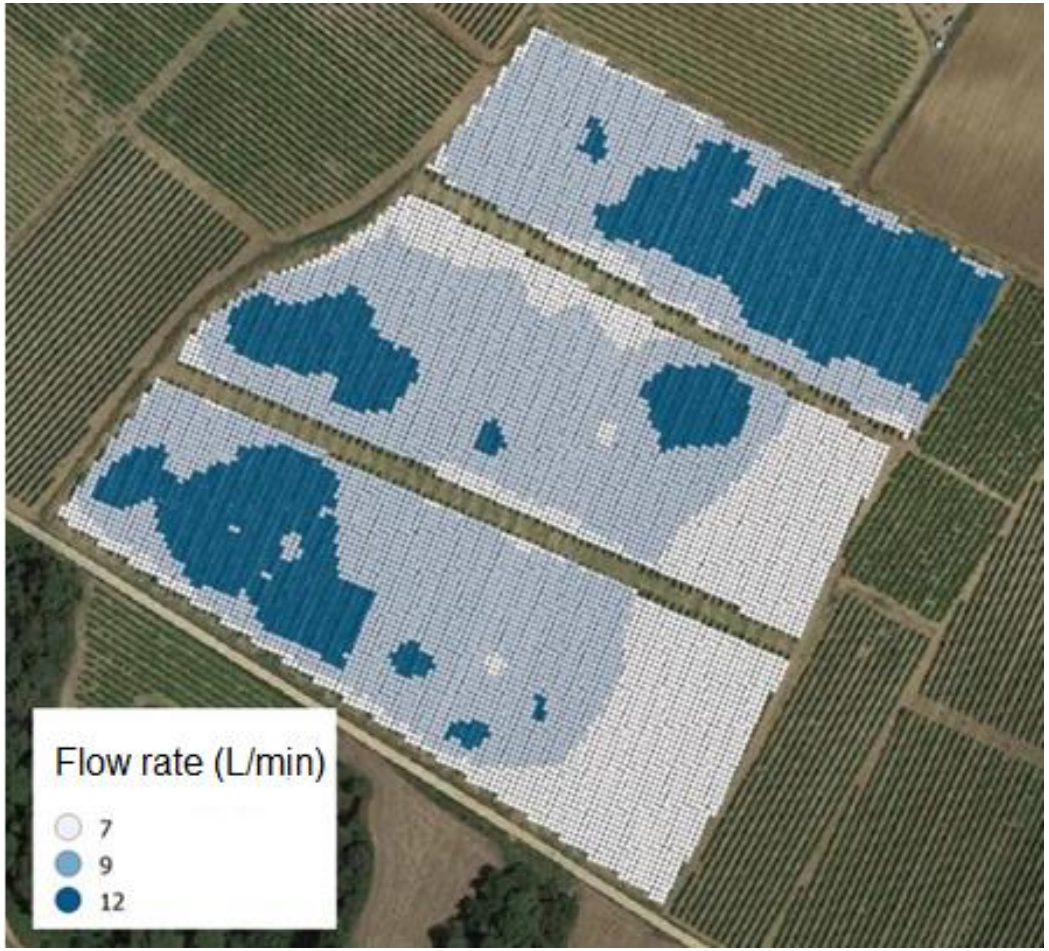




Prescription map (L/ha)

Campos, J., García-Ruíz, F., Gil, E. 2021. Assessment of vineyard canopy characteristics from vigour maps obtained Using UAV and satellite imagery. Sensors, 21(7), 2363. https://doi.org/10.3390/s21072363


Vigour map
Medium
High
Low


Flow rate (L/min)
7
9
12

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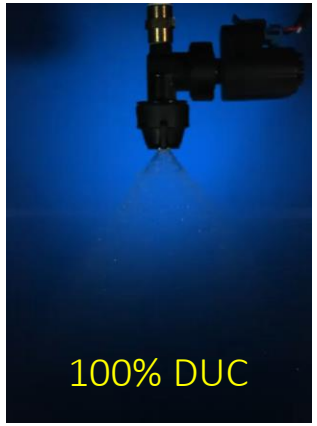

Images taken at the USDA/OSU laboratory in Wooster, Ohio (USA). Frequency: 10 Hz

Smart spraying for a sustainable vineyard and olive trees

PIVOS

https://en.pivos.upc.edu

PIVOS

UNITAT DE MECANITZACIÓ AGRÀRIA
www.uma.deab.upc.edu

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Aplicación de precision y autorización de productos

- Volumen de aplicación y dosis de producto
- Pérdidas de product en el suelo
- Deposición de product en la superficie foliar
- Deriva

Van de Zande, J. and Gil, E. 2024. Targeted application, Spray Technology and Authorisation. *Aspects of Applied Biology 148, 2024. International Advances in Pesticide Application*

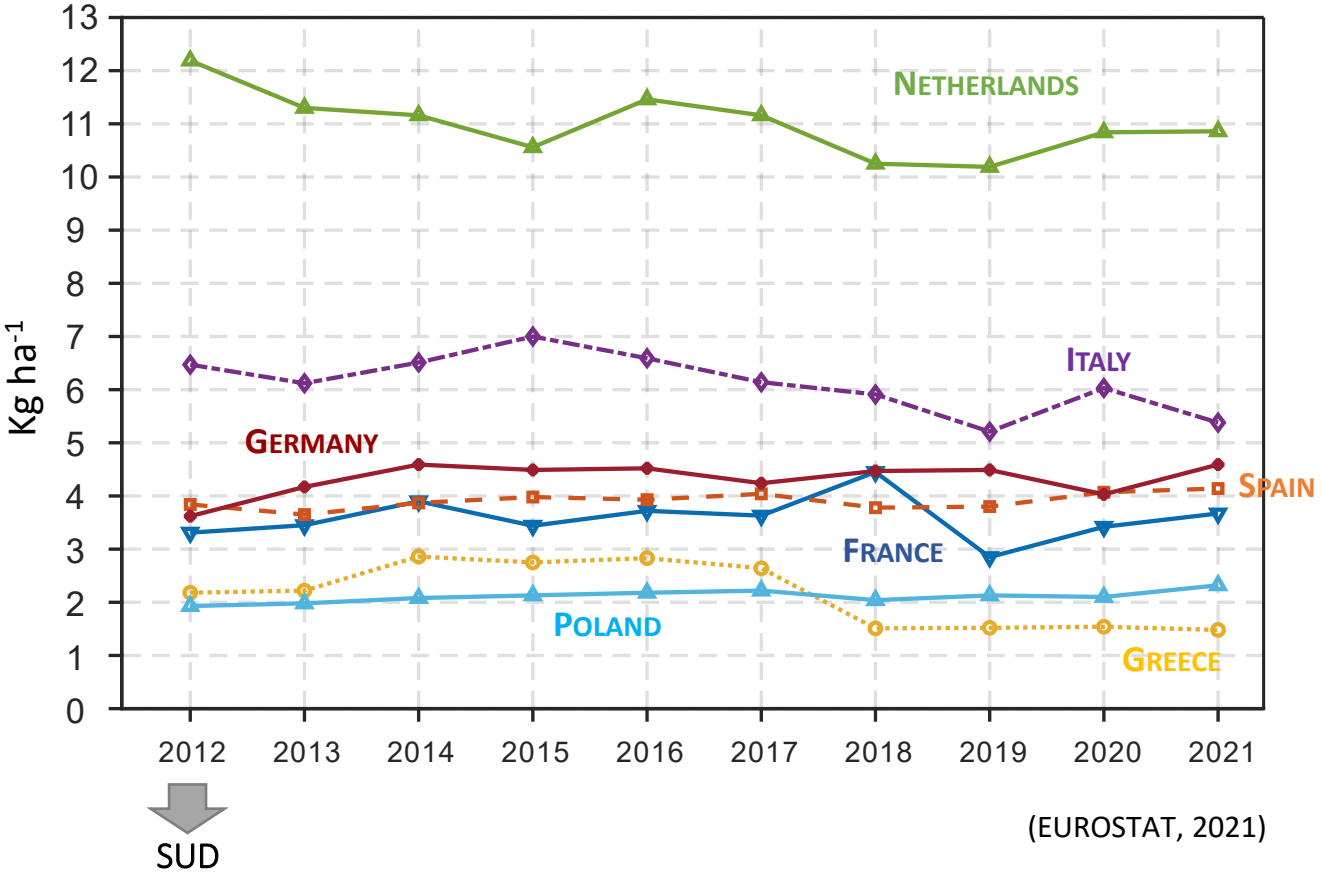
New efficient spray technology – Spray deposition

Depending on sprayer setting, more than **50% higher spray deposition** in tree is possible
Opens the potential to **reduce tank concentration** as effective dose on target remains the same

Van de Zande, J. and Gil, E. 2024. Targeted application, Spray Technology and Authorisation. *Aspects of Applied Biology 148, 2024. International Advances in Pesticide Application*

Escasa repercusión

PPP usage per area of cropland
in different EU countries (2012–2021)



(EUROSTAT, 2021)

Conclusiones y acciones propuestas

New efficient spray technology and regulatory aspects

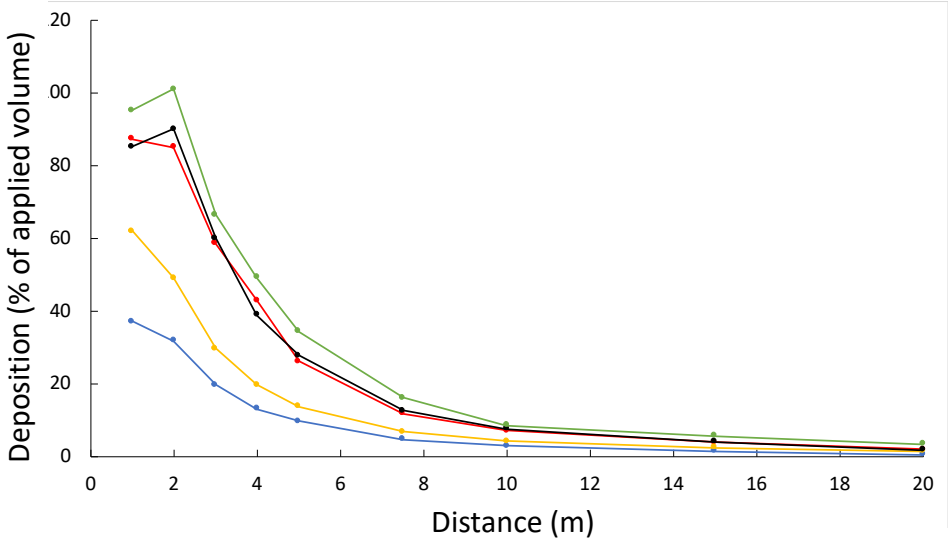
- Big differences between field crop and orchards. The highest quantity of PPP is applied on 3D crops. Increased efforts to promote and disseminate new technology are needed.
- We suggest agrochemical industry to register authorised PPP relevant for Precision Agriculture to widen the authorisation with higher number of applications during the growing season combined with reduced dose filling up the total authorised PPP amount of the original registration
- Precision application
  First improvement of efficiency of the spray process; increase deposit at the target -> use reduction/increased efficacy
  Only where needed
  If possible to adapt dose available info based on target?
- There is a need to merge technology with regulatory aspects. Topics as risk mitigation, dose expression, environmental requirements should be reviewed

Van de Zande, J. and Gil, E. 2024. Targeted application, Spray Technology and Authorisation. *Aspects of Applied Biology 148, 2024. International Advances in Pesticide Application*

Crop and/ or situation (a)	Zone	Product code	F G or I (b)	Pests or Group of pests controlled (c)	Formulation		Application				Application rate per treatment			PHI (days) (l)	Remarks: (m)
					Type (d-f)	Conc. of as (i)	method kind (f-h)	growth stage & season (j)	number min max (k)	interval between applications (min)	kg as/hL min max	water L/ha min max	kg as/ha min max		

- ❑ Can Pesticide Application Equipment (PAE) be used in regulation? How?
- ❑ Needs: classification of sprayers
  - *Functionality*
  - *Potential PPP reduction*
  - *Change in target deposition*
  - *Change in ground deposition*
- ❑ What information is needed?
- ❑ Harmonization; but of what?
- ❑ Exchangeability of DRT classified techniques

Sprayer's classification



www.performancepulve.fr

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Adjustment based on **pressure regulation**

Adjustment based on **nozzle's open frequency**

[redacted]

Smart spraying for a sustainable vineyard and olive trees (https://en.pivos.upc.edu)
Montpellier (France), September 2023

Drift

+

Reference sprayer

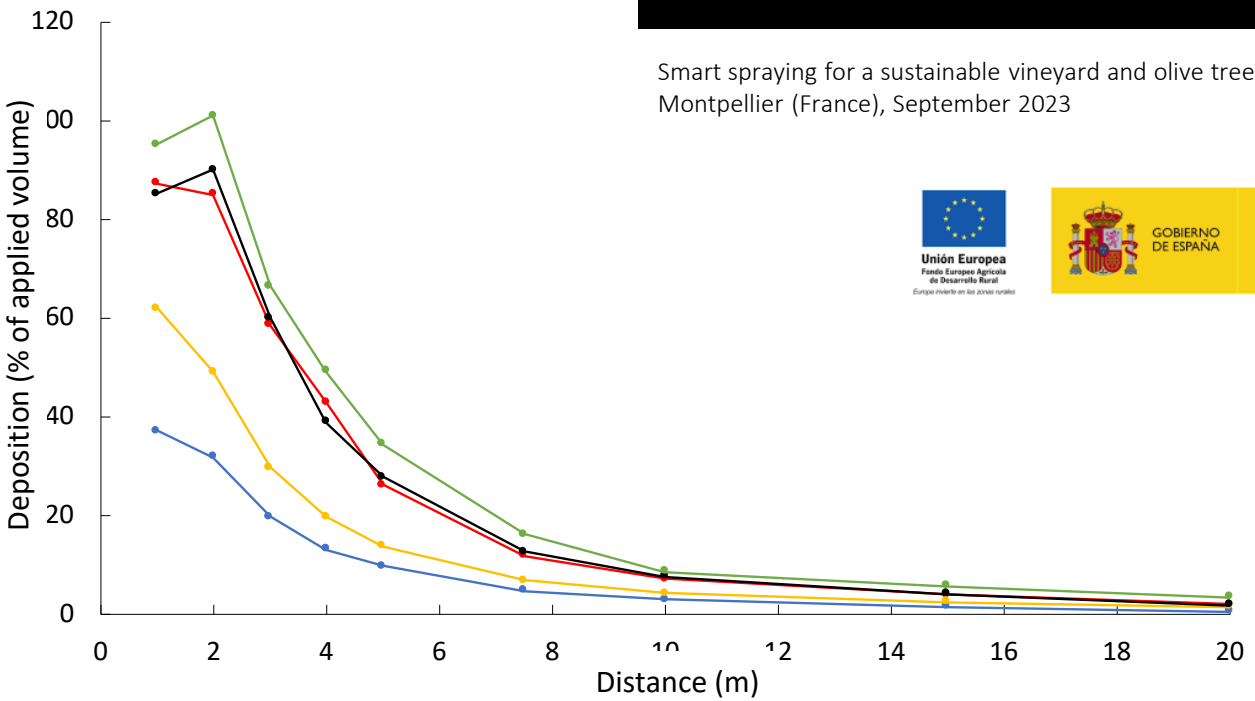
Low dense canopy VRA (pressure)

High dense canopy VRA (pressure)

Low dense canopy VRA (PWM)

High dense canopy VRA (PWM)

-



Based on ISO 22866:2005

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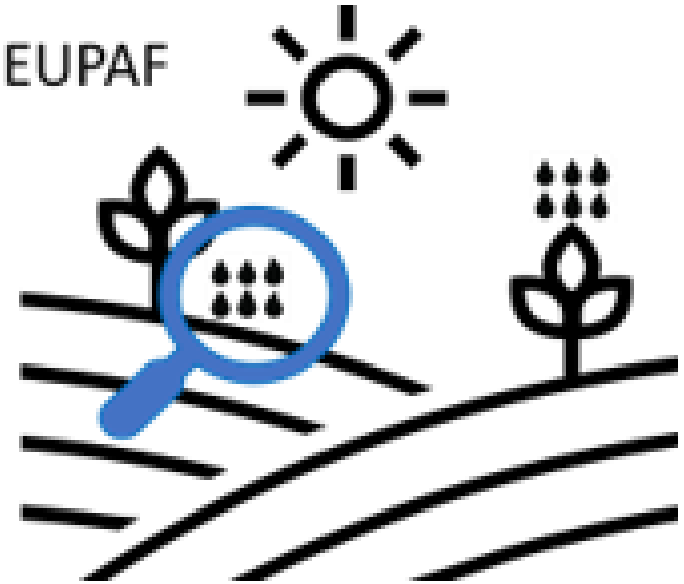
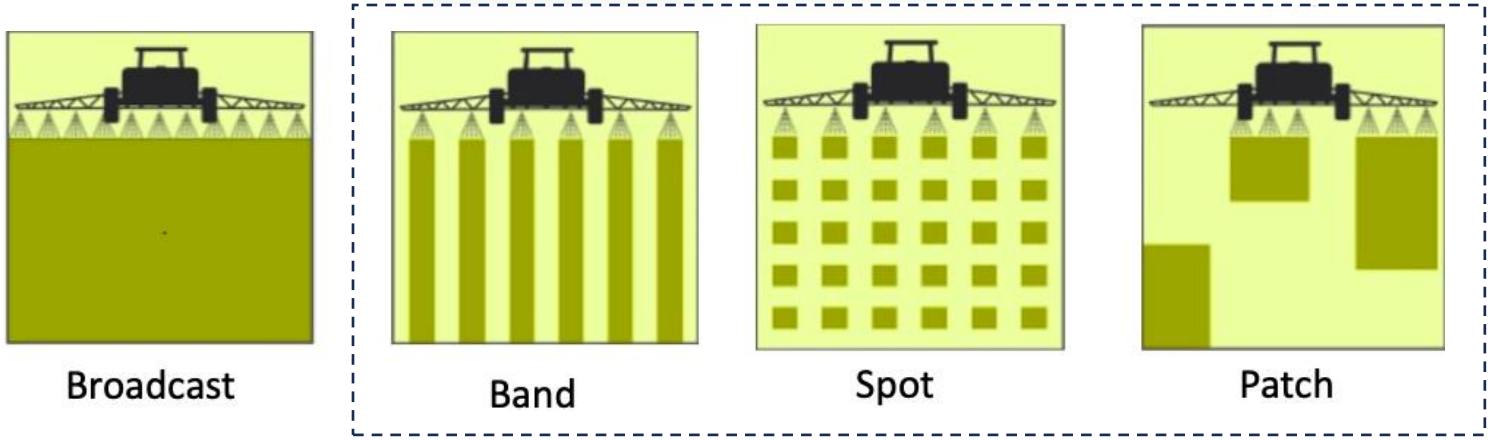
EUPAF

European Precision Application Task Force

EUPAF for orchard sprayers



European Precision Application Task Force (EUPAF)



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Task 1.2
Orchard sprayers

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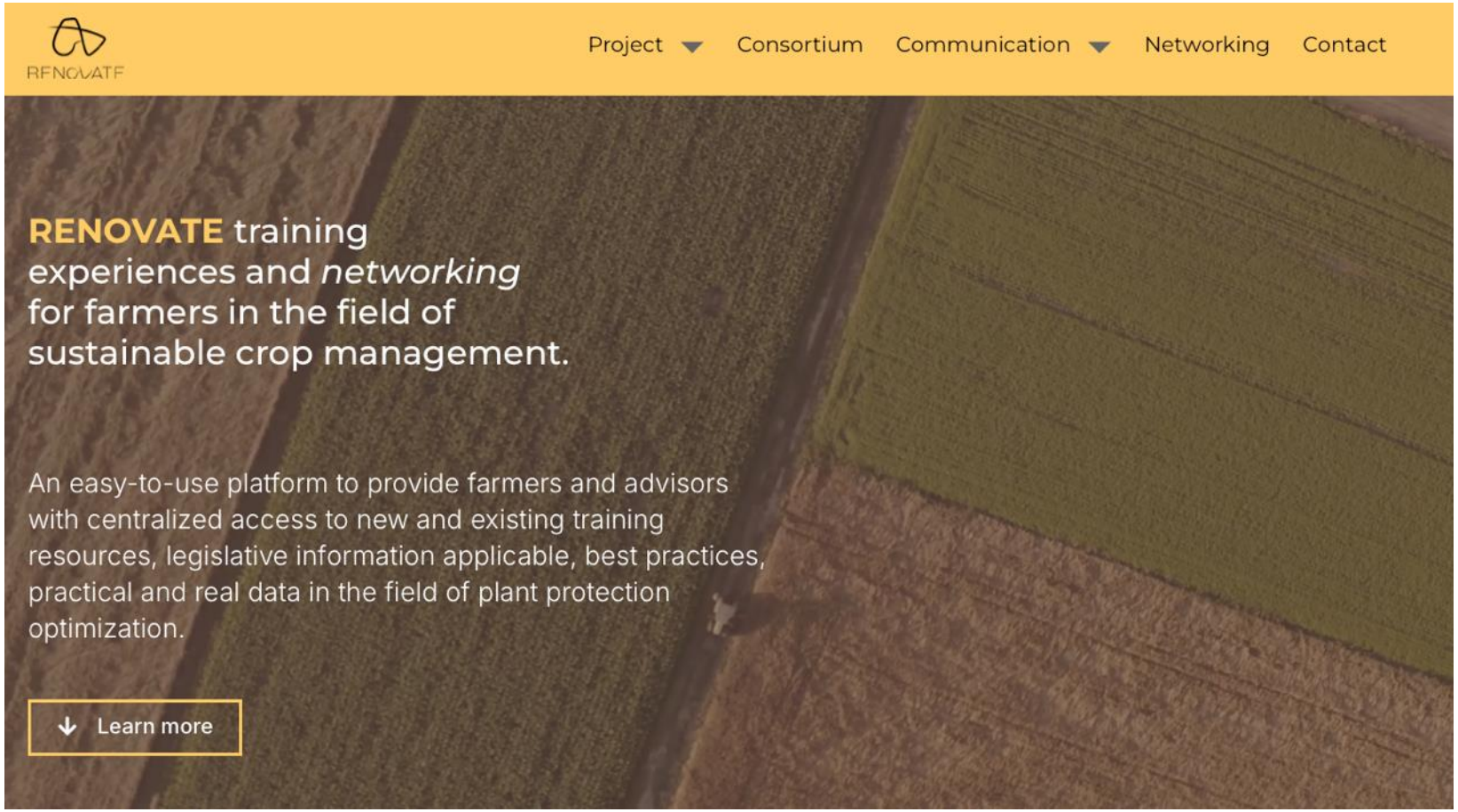

RENOVATE

https://renovateproject.eu

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