Ver lo invisible: nuevos sensores ópticos próximos para la viticultura de precisión

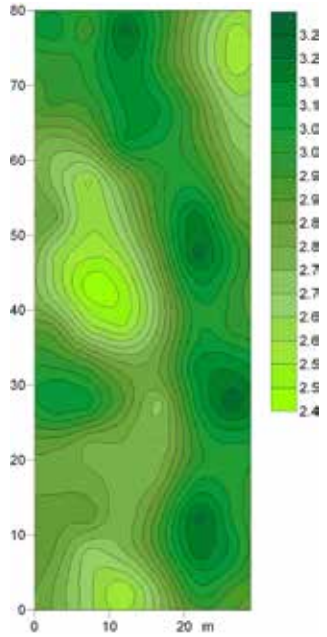
Voir l'invisible: nouveaux capteurs optiques proximaux pour la viticulture de précision

Seeing the invisible: new proximal optical sensors for precision viticulture

Zoran G. Cerovic

CNRS, Univ. Paris-Sud, Orsay, France

zoran.cerovic@u-psud.fr



Remote & proximal sensing of vegetation **in the field**

ACTIVE

artificial light source

Reflectance or **Fluorescence**

Type of functioning

PASSIVE

the Sun as light source

Reflectance or (Fluorescence)

Proximal sensing

Working distance

Remote sensing

contact — small — medium — large

Dualex **Multiplex** LIDAR aircraft satellite

CASI MERIS

Spectral Domain

UV — visible — NIR — SWIR — thermal — radio

Phen Car Anth Chl LMA Prot H_2O

Layout of the presentation

Acquiring information on the status of the vines

- with WHAT: Dualex & Multiplex
- HOW: Hand-held vs. vehicle mounted
- WHAT: Pigments in leaves and fruits
- WHY: Vigour & quality
- what ELSE: Diseases & research

Optical decision support tools

leaf-clip

Dualex:

Chlorophylls

Flavonols

proximal sensor : leaves and grapes

Multiplex:

Chlorophylls

Flavonols

Anthocyanins

(Stilbenes)

Type of measurement

Dualex

hand-held

leaves

GPS
inside

Multiplex

hand-held

leaves

grapes on vine

harvested grapes

vehicle-mounted

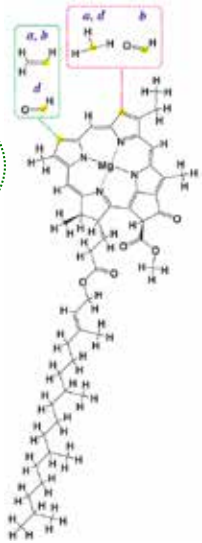
leaves

grapes on vines

harvested grapes

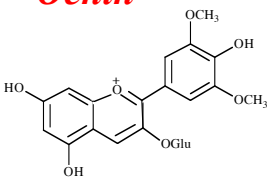
Pigments in viticulture and oenology - Optical indices

Chlorophyll a & b



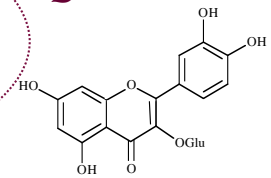
Chlorophylls in **leaves** & (grapes)
≈ Nitrogen

Oenin



Anthocyanins (leaves) & **grape skin**
≈ Colour ≈ Phen

Quercitrin



Flavonols **leaves** & **grapes**
≈ Phen **≈ Light** **≈ Nitrogen**

Vine N-status, leaf nitrogen, nitrogen balance index (NBI)

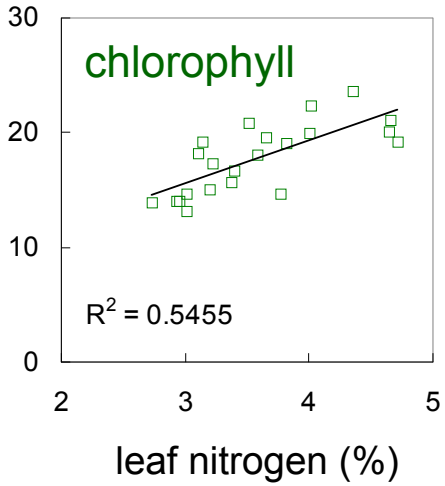
leaf N → grape N → must N → ***fermentation***

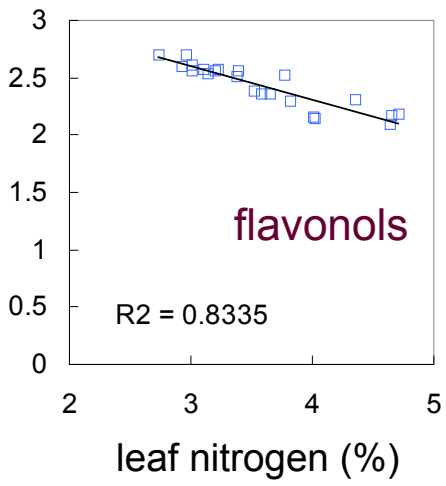
reserves → *next-year's N*

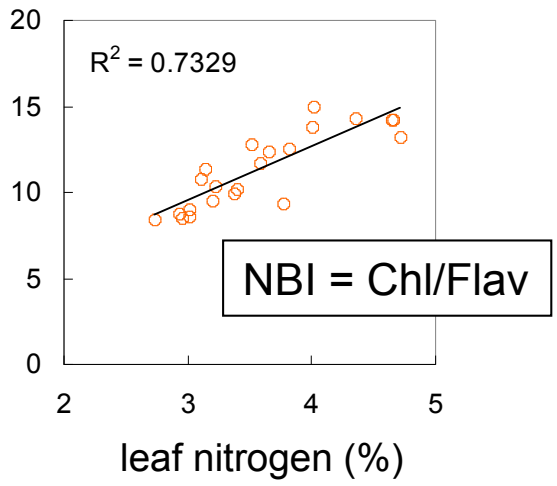
soil N

N-absorption influences:
- cover crops
- rainfall
- temperature

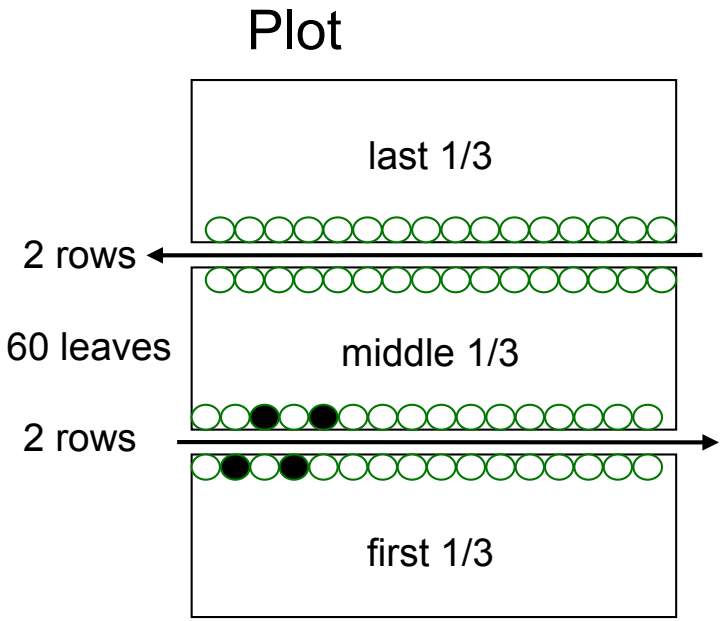
plot level action:
- nitrogen deficiency diagnosis
  fertilisation & next-year's vigour
- forecast of must nitrogen
  fermentation potential



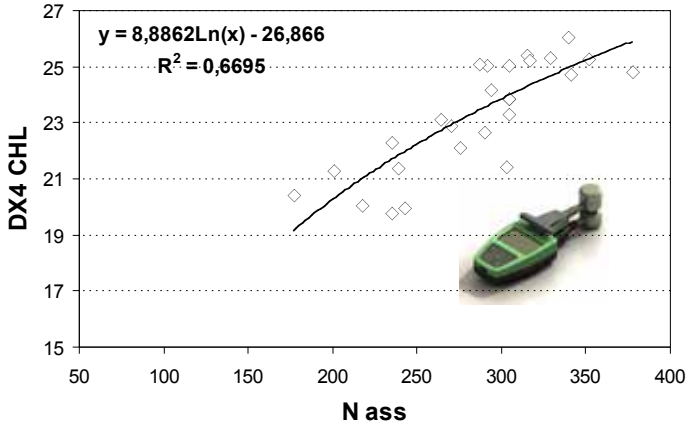




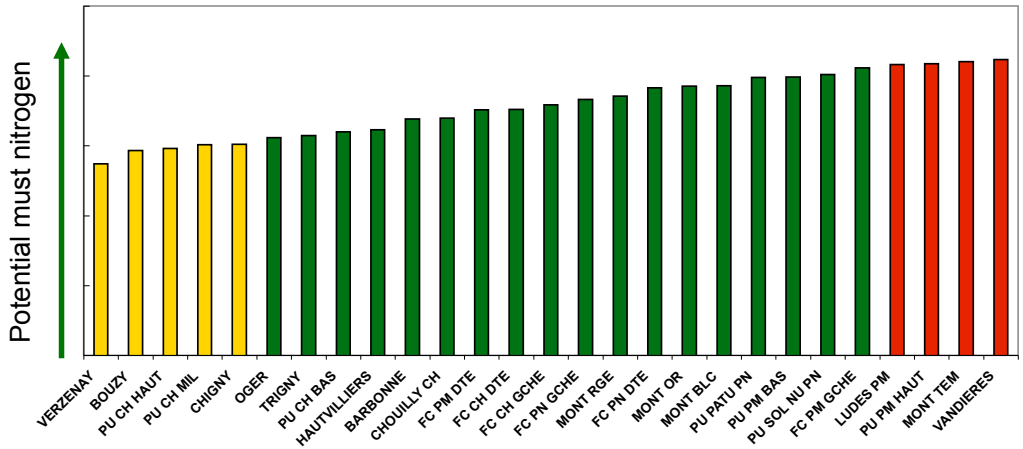
Forecast of must nitrogen



leaf chlorophyll @ flowering

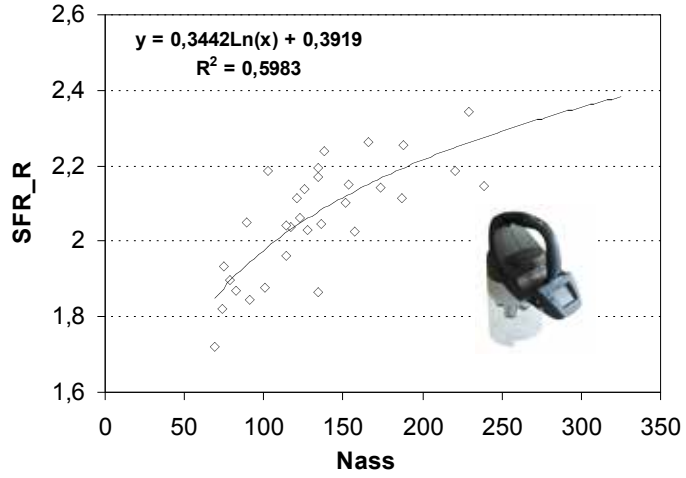


must nitrogen @ harvest



fertilisation & plot selection

leaf chlorophyll @ bunch closure



must nitrogen @ harvest

Vine management - zone definition & delineation

Vehicle-mounted canopy-level measurements

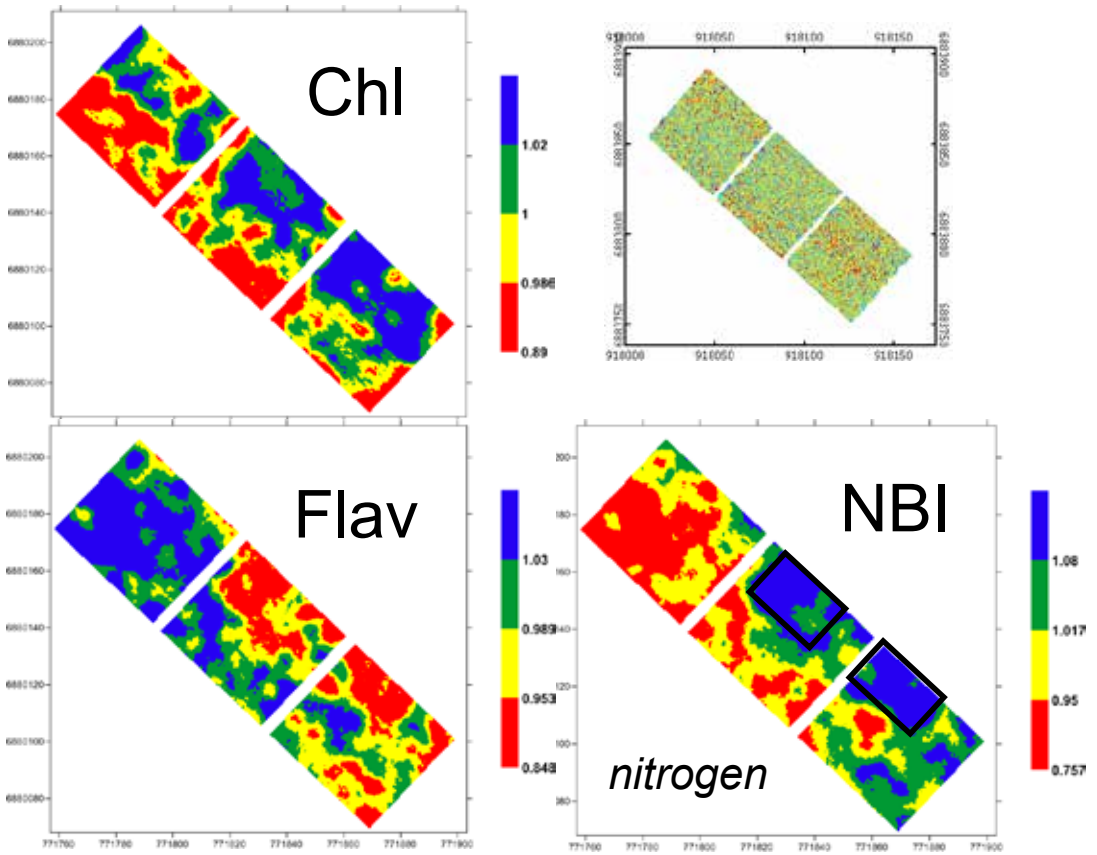
vigour
(porosity)

plot level action:
- fertilisation
- vigour estimation

intra-plot action:
- missing vines
- plot homogenisation
- plot fractioning
- soil sampling & analysis
- fertilisation

viticultural practice & zone delineation

MAP *generation*



susceptibility
(disease control)

In-season in-situ grape analysis (1) maturation kinetics

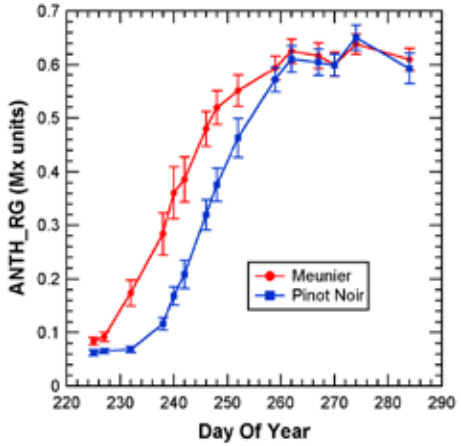
Hand-held single-grape Multiplex measurements

red - phenolic maturity

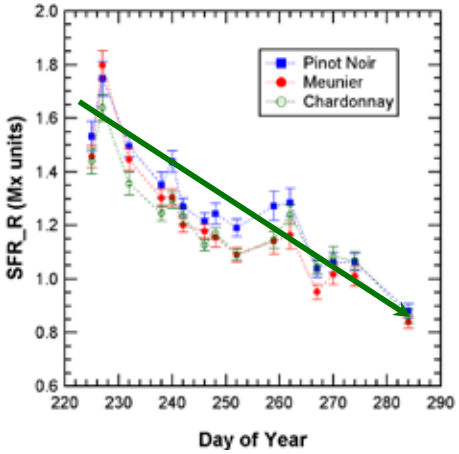
anthocyanins

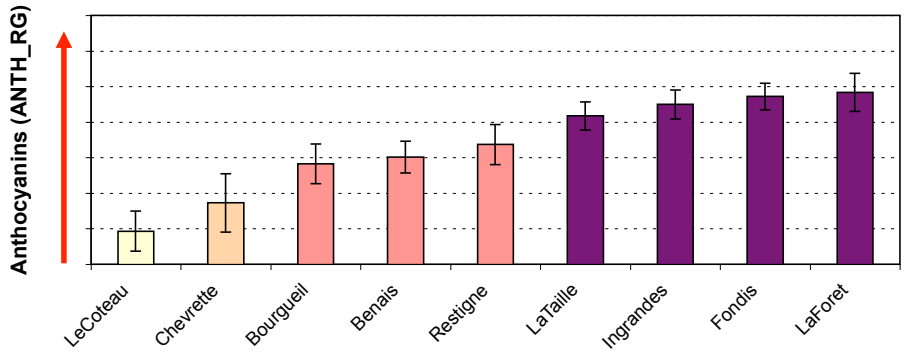
(colour)

Anth



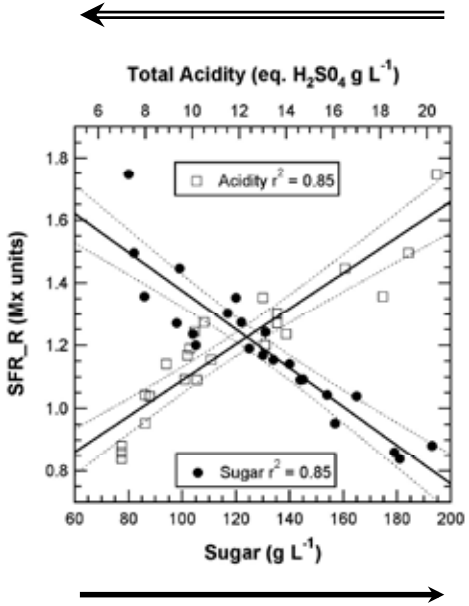
Chl





white - technological maturity

sugar & acidity



plot level action:

- harvest date
- plot selection
- plot allocation

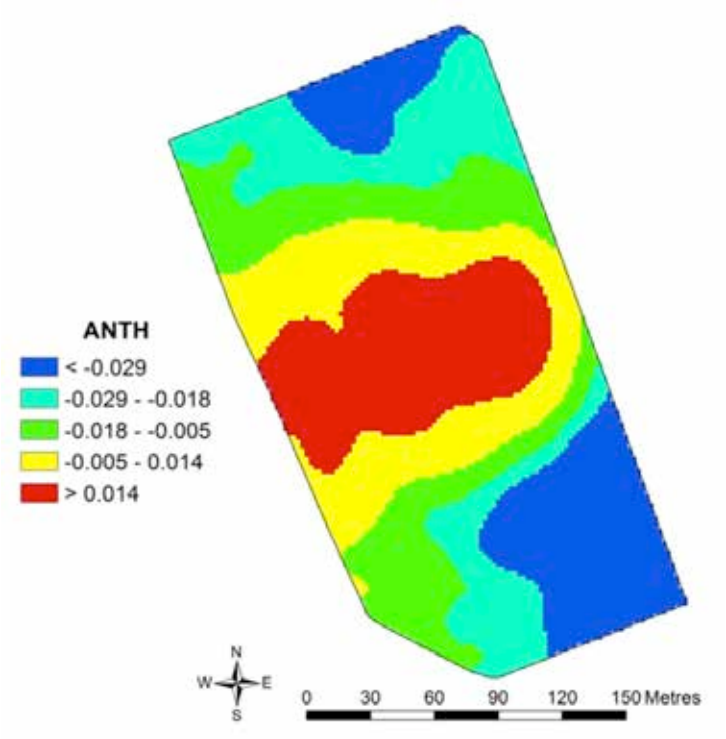
Replaces laboratory analysis on 200-berries samples & avoids berry sampling problems

In-situ grape analysis (2) quality zone delineation

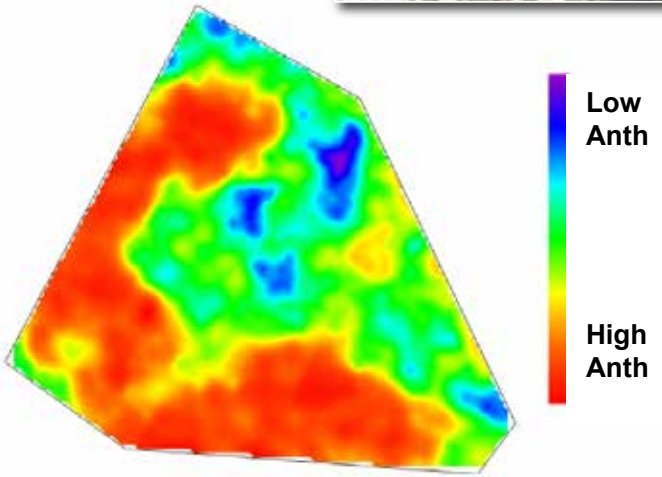
Hand-held measurement

Map
generation

Vehicle-mounted Multiplex
leaves removed



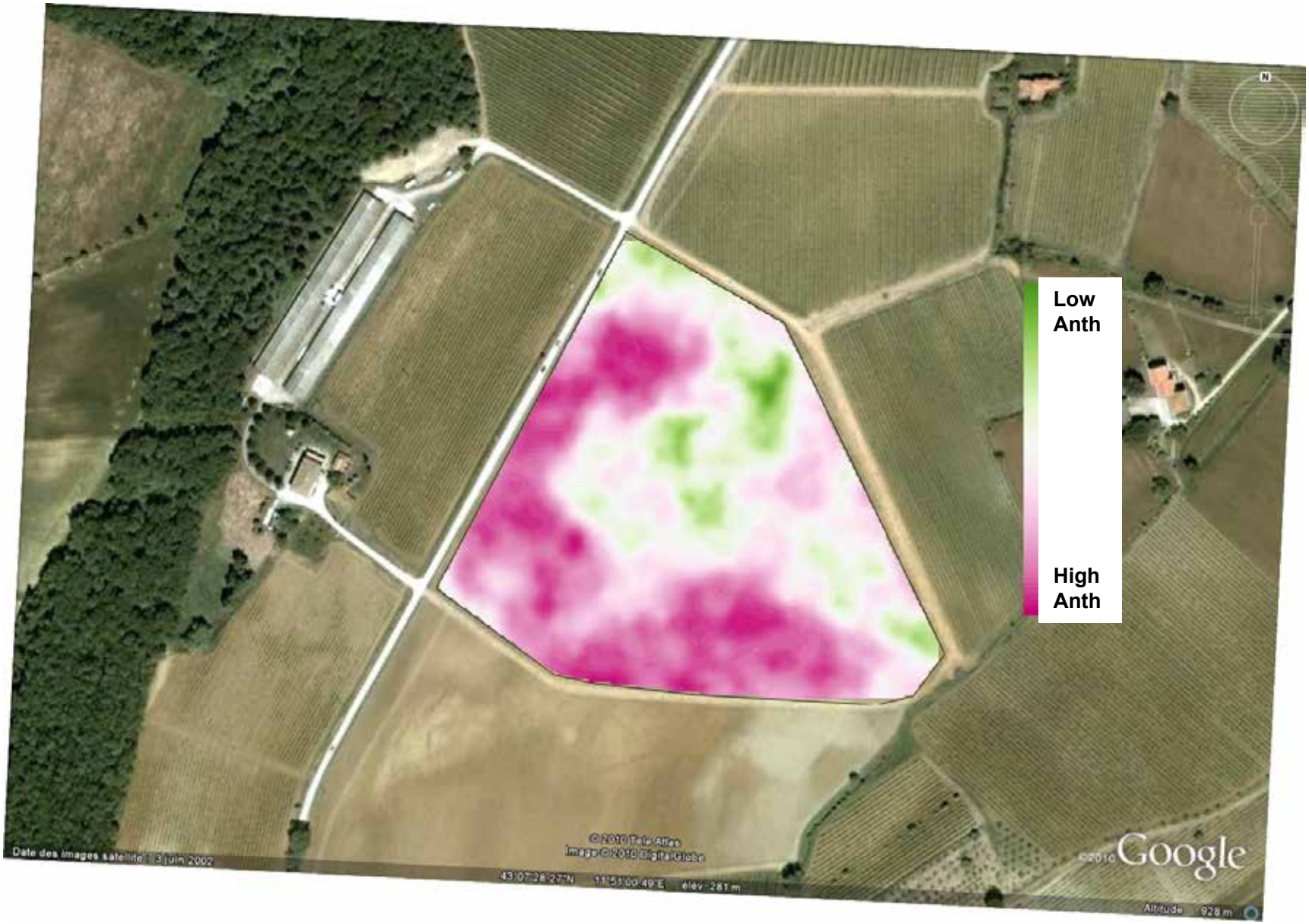
ANTH



intra-plot action:
- zones delineation
- plot fractioning
- subplot allocation
- selective harvesting

quality forecast & selective harvesting forecast

Seeing is believing



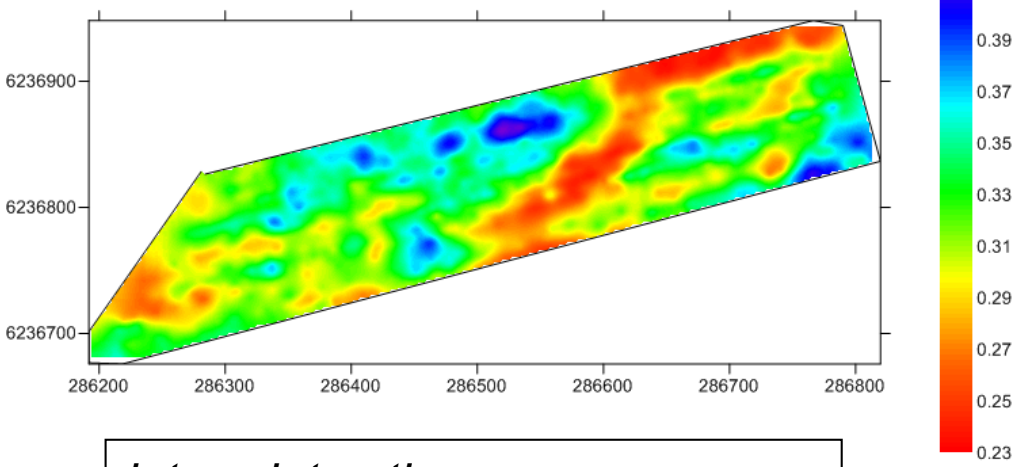
Harvested grape analysis - diagnosis & control

Hand-held at reception
single-grape measurement

Mounted on harvester
continuous measurement

plot level action:
- differential payment
- practice verification
- forecast verification
- selection & allocation

harvest map generation



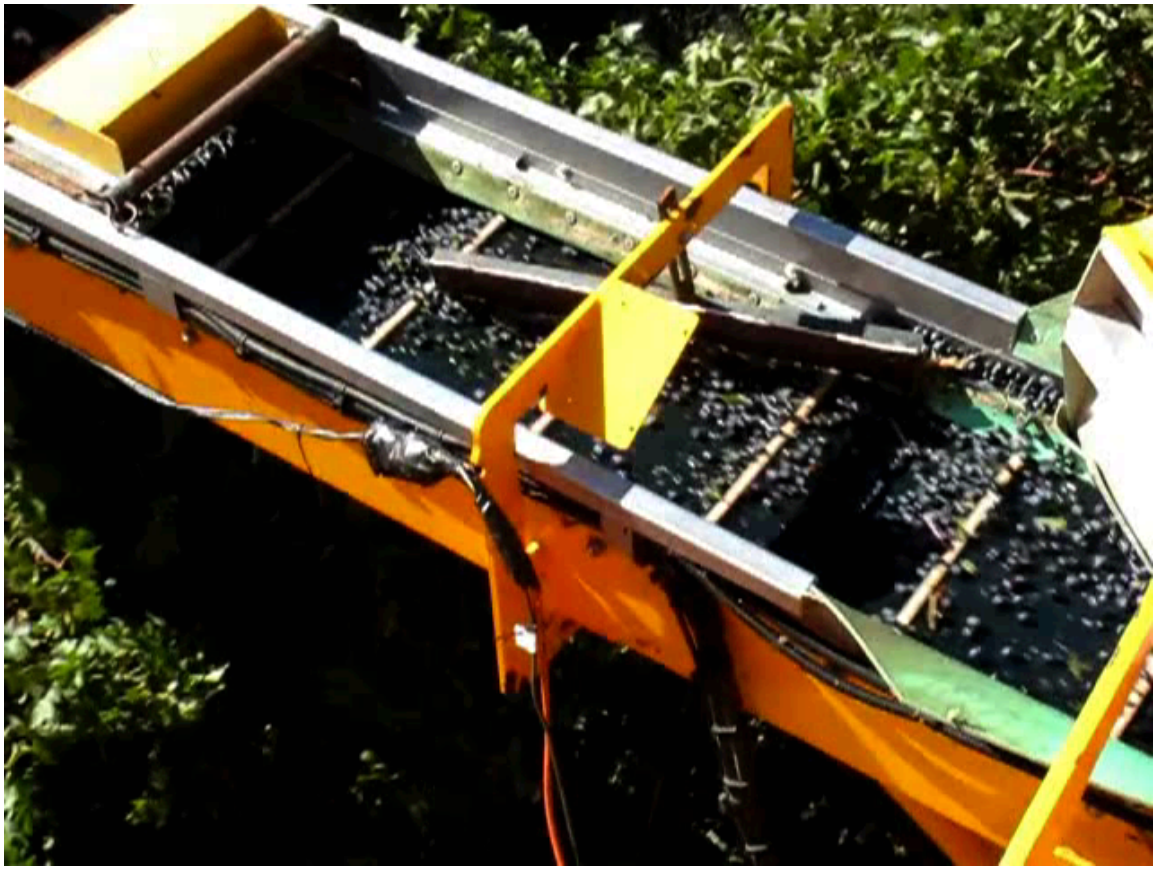
quality diagnosis & selective harvesting

intra-plot action:
- non-grape matter estimation
- on-the-go selective harvesting

Harvested grape analysis - diagnosis & control

Mounted on harvester

continuous measurement

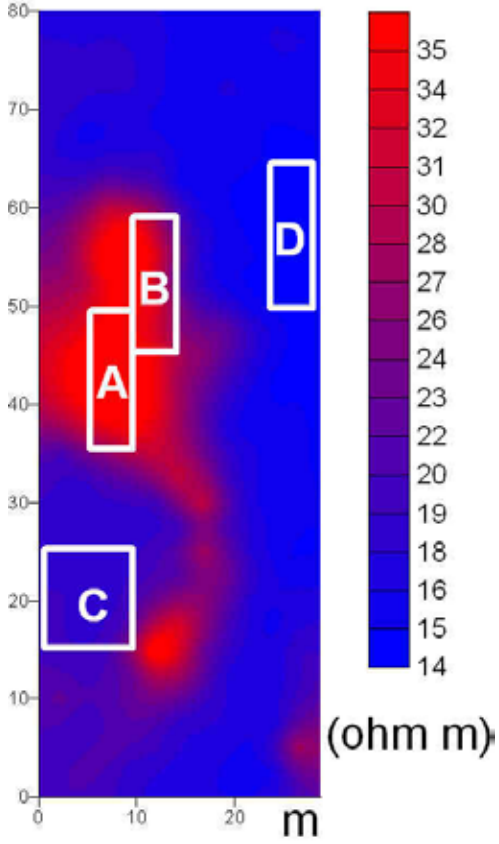


Map use summary: zoning and harvest allocation

Merlot @ Château Couhins, Bordeaux

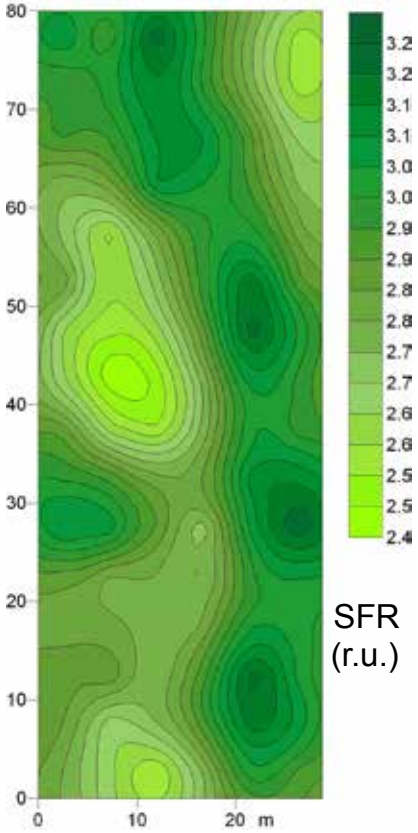
Soil

Apparent resistivity



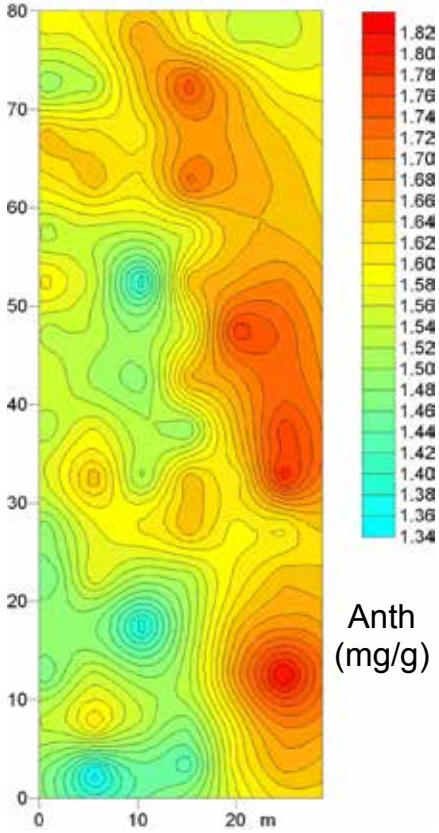
vine

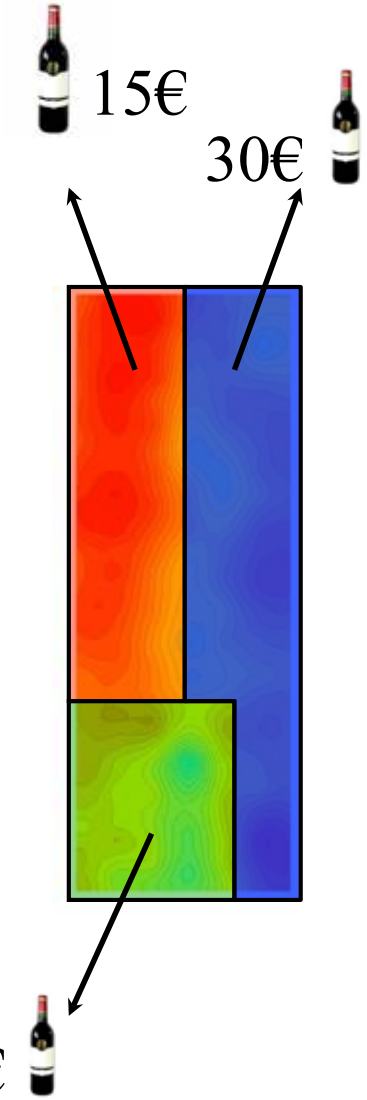
Chlorophyll



grape

Anthocyanins





FORCE-A's decision support optical tools for viticulture

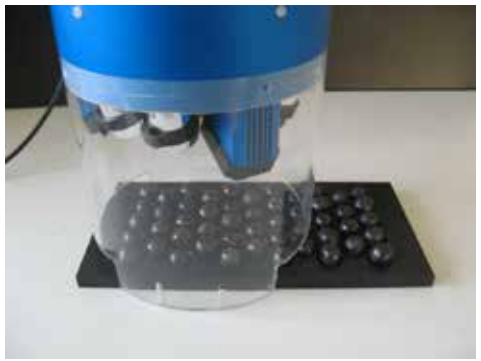
	Tool	Sample	Measurement	Result	Information	Practice
vegetative phase				mean plot value	**nitrogen - vigour**	***fertilisation must N forecast***
		leaves			**missing vines**	***plot management***
				map	**wood disease disease outbreak**	***vine health suceptibility***
		in situ			**zone definition**	***fertilisation soil sampling***
reproductive phase		grapes		mean plot value	**maturation kinetics**	***plot selection & allocation***
				map	**zone definition**	***grape-quality forecast selective harvesting***
		in situ		map		
		harvest		mean plot value	**harvest diagnosis**	***plot selection grape pricing***
				map	**diagnosis & selection**	***diagnostic map harvest selection***

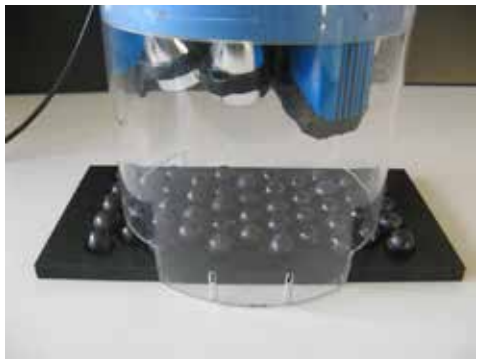
Dualex *Multiplex* *Hand-held* *Vehicle-mounted*

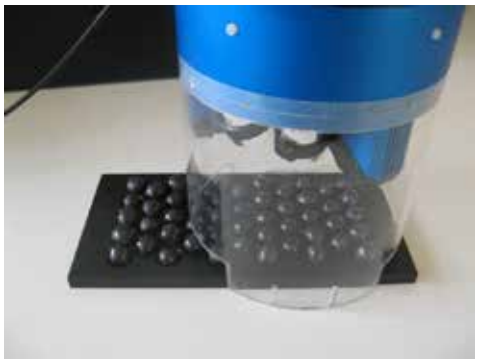
http://www.force-a.eu/fr/qualite_raisin.html

Multiplex measurements on berries in the laboratory

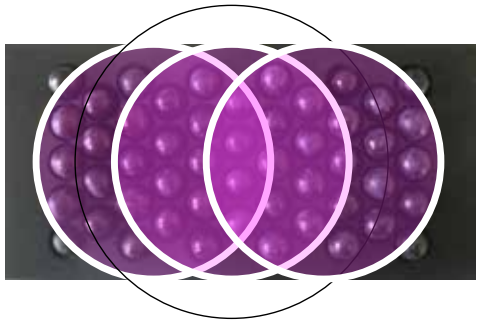
NO extraction needed





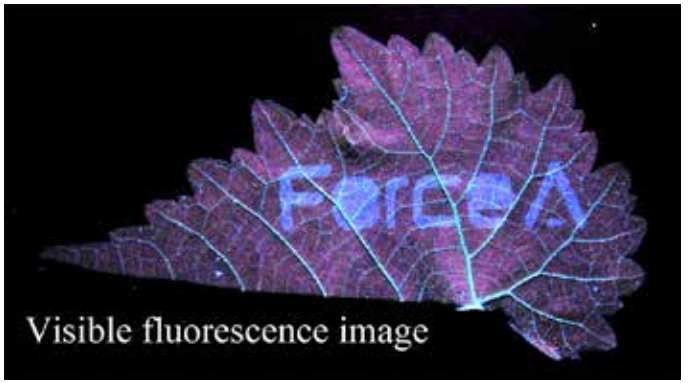


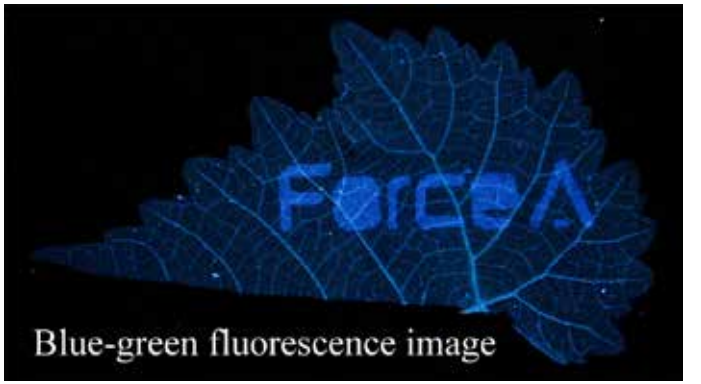
30 or 100 or 200-berries samples



Tools for research and new developments

Force A
SEE TO ACT





UV-exited
"blue"
fluorescence

HCA **stilbenes**

Fungi

Layout of the presentation n°2

Acquiring information on the status of grapevines

- Proximal sensors other than Multiplex
- The vine “vigour”
- All-year-around monitoring
- Examples
- Decision support systems

The role of proximal optical sensing

The decision of how to grow the **vine** is the choice of the winegrower - *"chef de culture"*.

The decision of how to make the **wine** is the choice of the winemaker - *"chef de cave"*.

The decision which **type of wine** to make is the choice of the vineyard owner - *"le patron"*.

The role of *optical sensing* is **only** to provide to all three of them the **information to make the right choice**.

Proximal sensors overview

SPAD 502

Dualex

Greenseeker

Crop Circle

N-sensor

UV-A-PAM

Luminar

Spectron

Multiplex

Research set-ups with no names

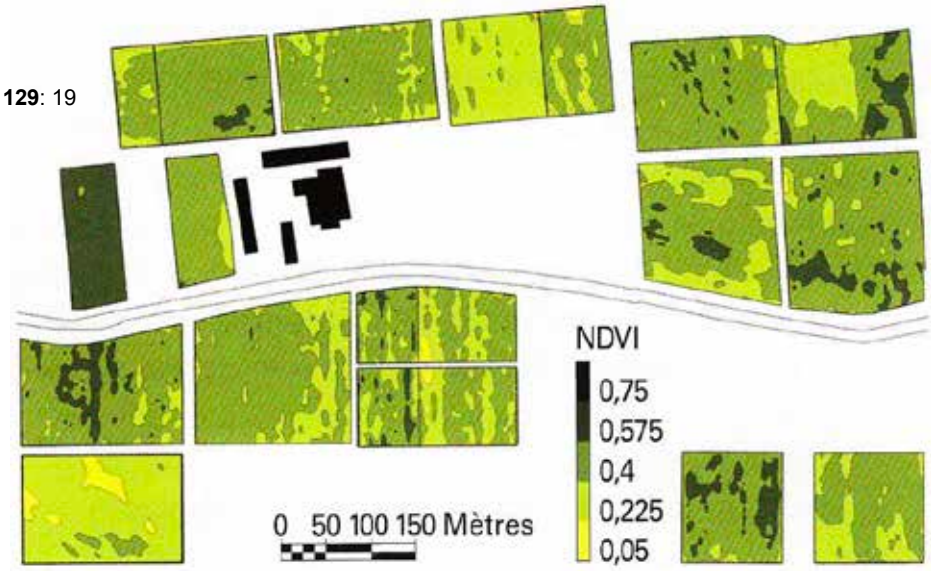
Proximal active reflectance sensors: NDVI and PCD

NDVI: Normalised Difference Vegetation Index

$$\frac{NIR-R}{NIR+R}$$

GreenSeeker
Trimble
Previously N-Tech

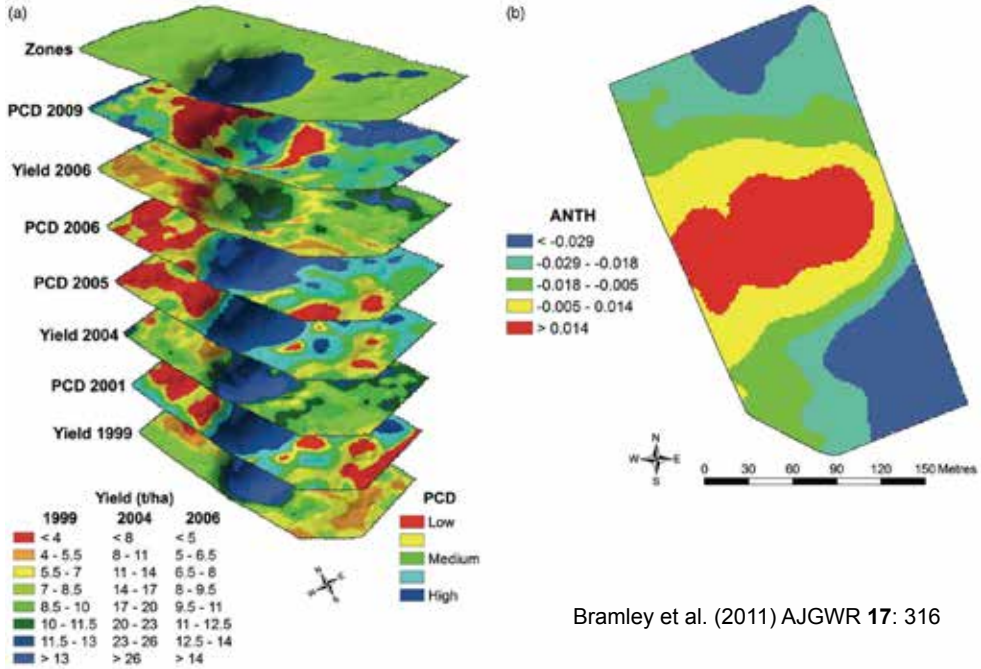
Goutouly (2008) Rev. Oenol. **129**: 19



Crop Circle
Holland Scientific

$$\frac{NIR}{R}$$

PCD: Plant Cell Density Index



Bramley et al. (2011) AJGWR **17**: 316

Proximal laser sensor for wood: Physiocap®

Weighing pruning wood

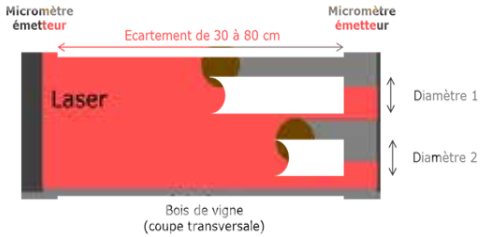
Estimation of
Vine balance
Vine capacity
(Ravaz index)

Winter in-field scanning

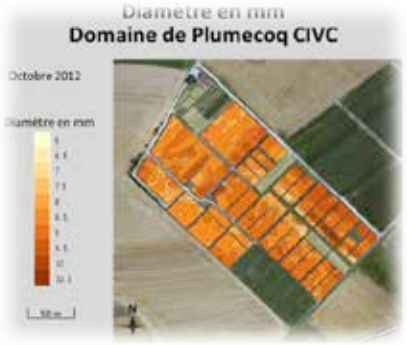
On straddle tractor

On tractor

Laser micrometre



Production of maps



Physiocap®
Design: **CIVC**
Production: e.re.c.a
Data treatment: FORCE-A

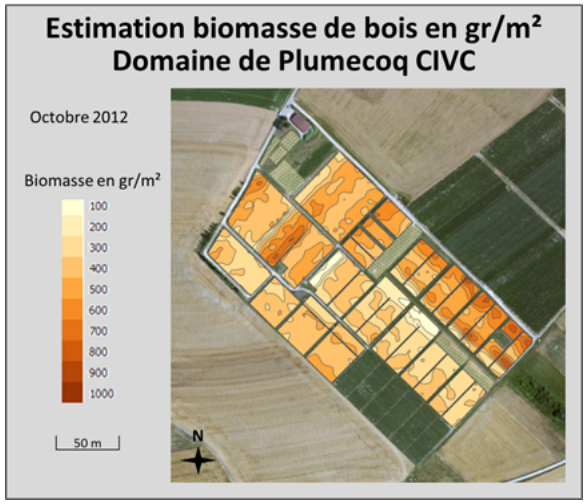
COMITÉ CHAMPAGNE CIVC
Force A VOIR POUR AGIR
e.re.c.a Bureau d'études en Electronique et Informatique Embarquée

Physiocap® measurements

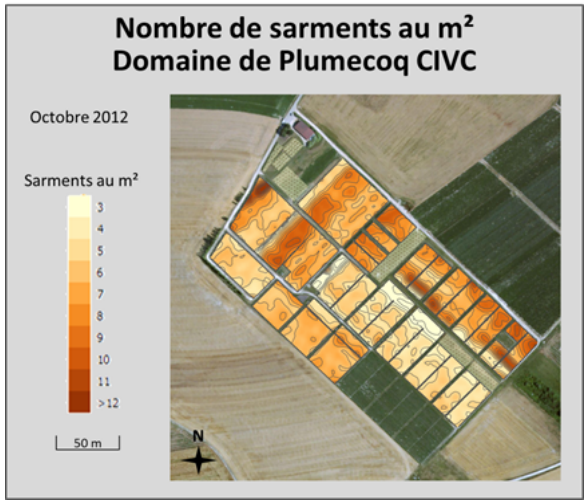
Vine Capacity

Vegetative expression

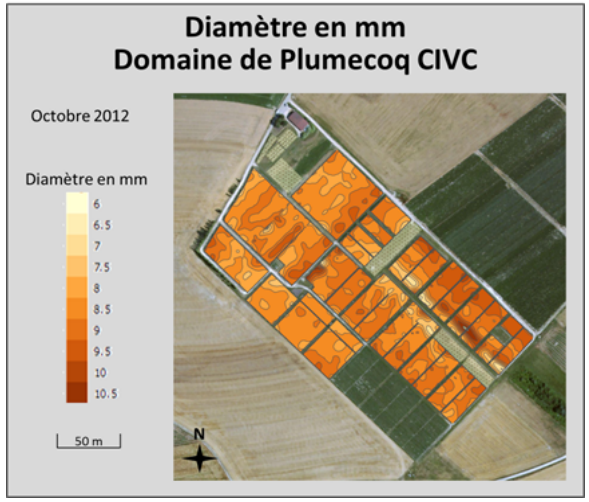
Pruning wood



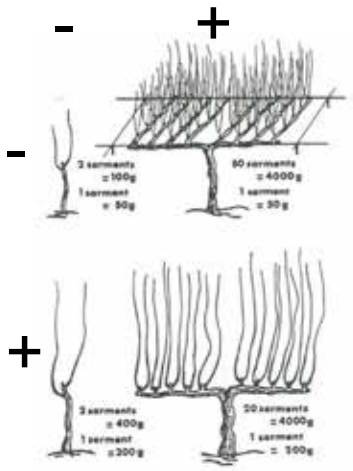
Number of shoots



Shoot diameter



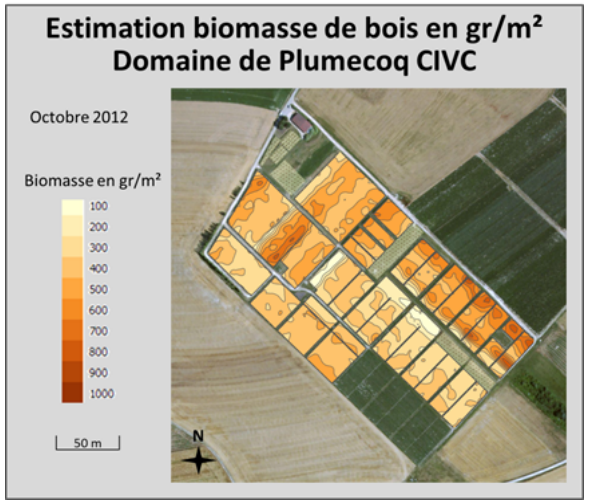
Shoot vigour



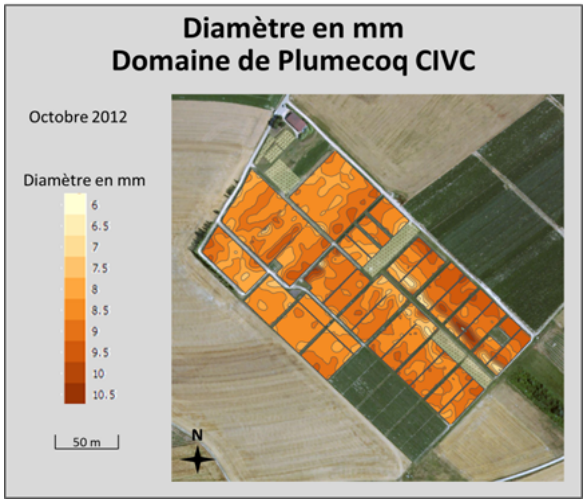
Champagnol, 1984

CIVC advices based on Physiocap® measurements

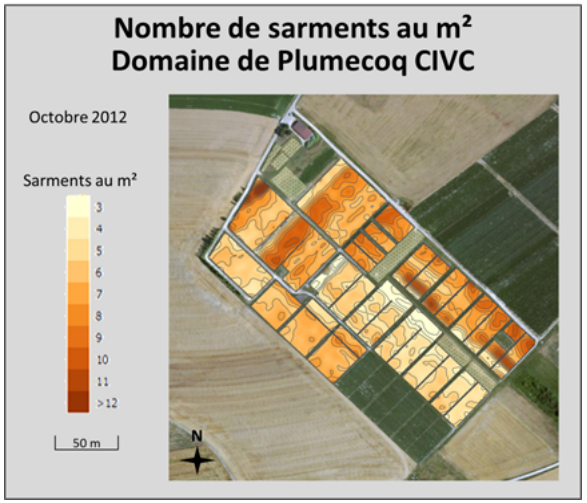
Pruning wood



Shoot diameter

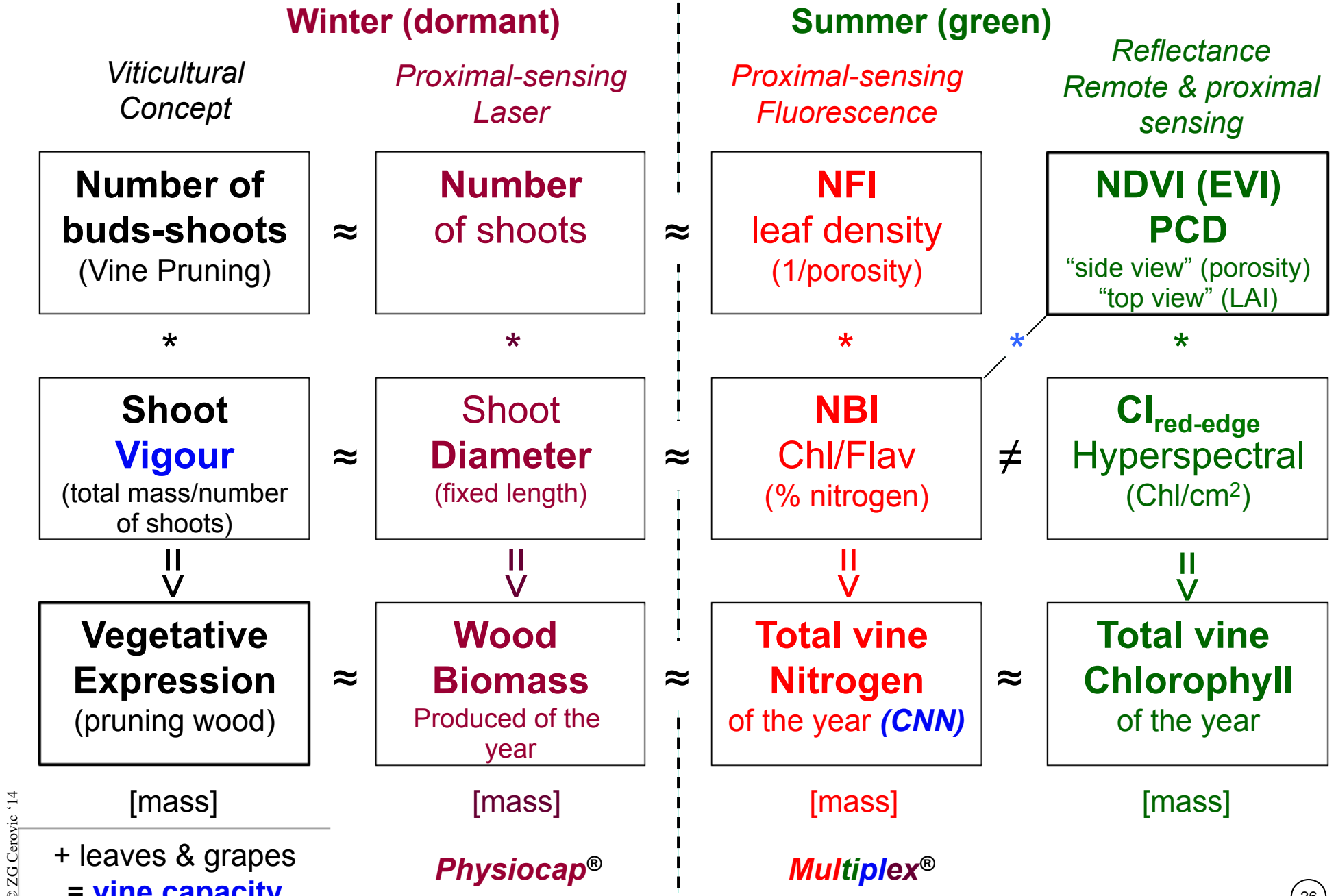


Number of shoots



	Low	Medium	Large
Low	**Decrease cover crop Increase fertiliser**		**Longer pruning Retain more buds**
Medium		Balanced	
Large	**Shorter pruning Larger bud removal**		**Add cover crop Exclude fertilisation**

Vine capacity and "Vigour" of the vine – single year



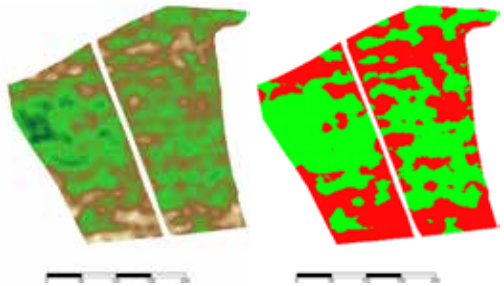
All-year-around vineyard monitoring – summer

N
May
July

Zones validation at two growth stages

Canopy mapping – mounted Multiplex®

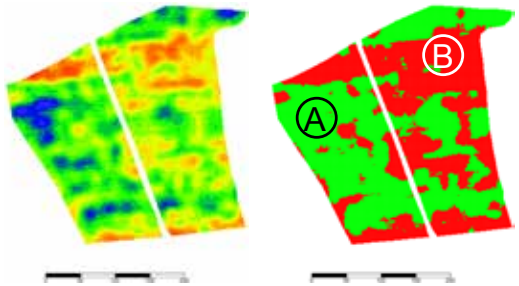
Flowering



mapping *zoning*

*Up to **five** info maps per date*

Bunch closure or veraison



mapping *zoning*

*Per zone Quantification by **Dualex***

S
November
December

Leaf

NFI
Chl
Flav
NBI
N-uptake

- In-season fertilisation
- Forecast of grape & must nitrogen
- Need for inter-row cover-crop (next year)
- Disease pressure estimation

All-year-around vineyard monitoring – summer

N
August
September

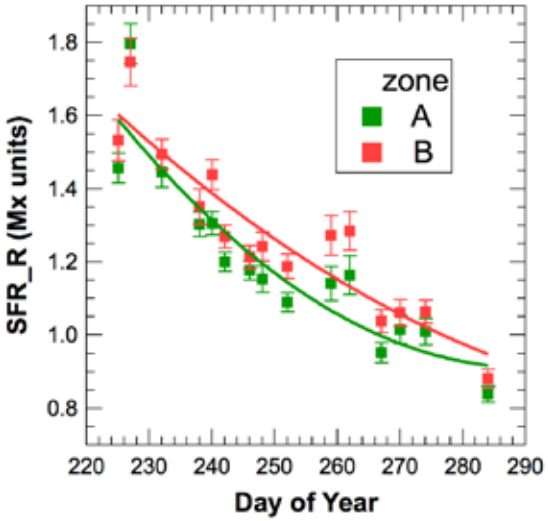
Grapes maturation monitoring – hand-held Multiplex®

S
February
March

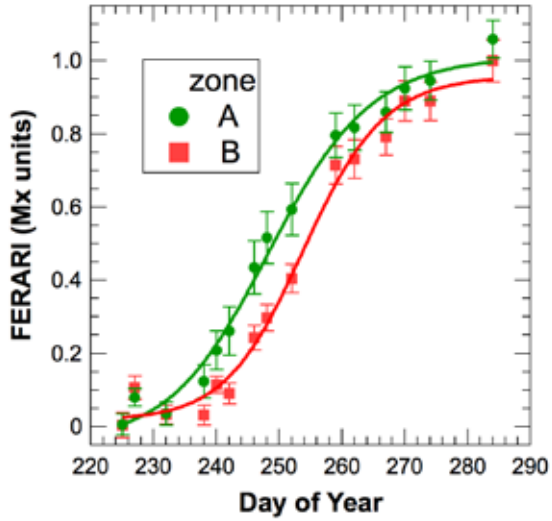
Phenolic and technological maturation kinetics

From veraison to close to maturity

Chlorophyll



Anthocyanins



August September October

grapes

Chl
Anth

- Precocity zone confirmation
- Harvest date forecast
- Type of wine forecast

(rosé vs. red) (premium vs. super-premium)

All-year-around vineyard monitoring – autumn

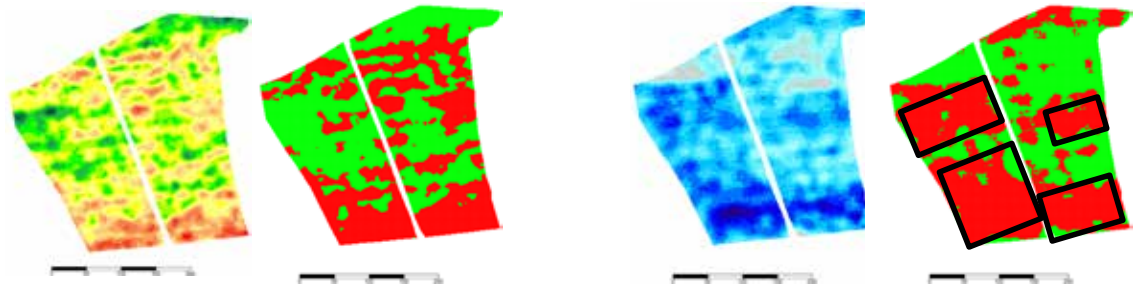
N
September
October

Harvest zones validation

Grapes mapping – hand-held Multiplex®

Berry softening (veraison) to maturity

Chlorophyll *Anthocyanins*



mapping *zoning* *mapping* *zoning*

S
March
April

grapes

Chl
Anth

- Selective harvesting - same date
- Selective harvesting - time delay

All-year-around vineyard monitoring – winter

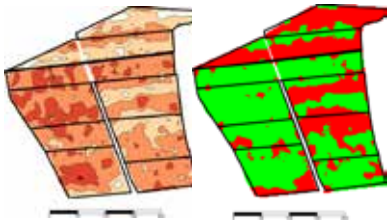
N
December
January

Vegetative expression and vigour zones validation

Wood mapping – Physiocap®

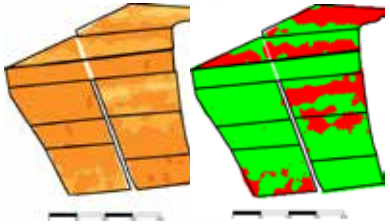
Winter dormancy

Number of shoots



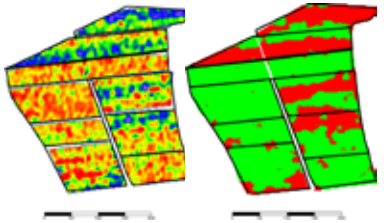
mapping & zoning

Shoot diameter



mapping & zoning

Pruning wood weight



mapping & zoning

S
June
July

Wood (canes)

Diameter
Number
Weight

- Pruning planning (Ravaz index)
- Vintage evaluation
- Fertilisation or inter-row cropping
- N reserve estimation

1) Multi-parametric data acquisition with fluorescence-based Multiplex®

Multiplex®

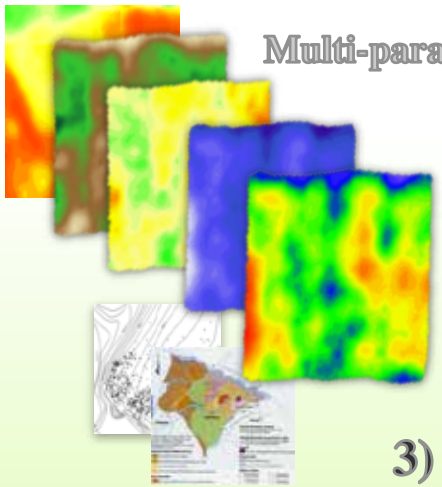
GPS

FA-BOX

Transfer :
SD card
USB key
Wireless

2) Map processing

FA-SERVER



Multi-parametric Maps

3) Characterisation of spatial variability for global management

Other data inputs

Plot zoning

Viticultural applications for sustainable management

Reports

4) In-field map display

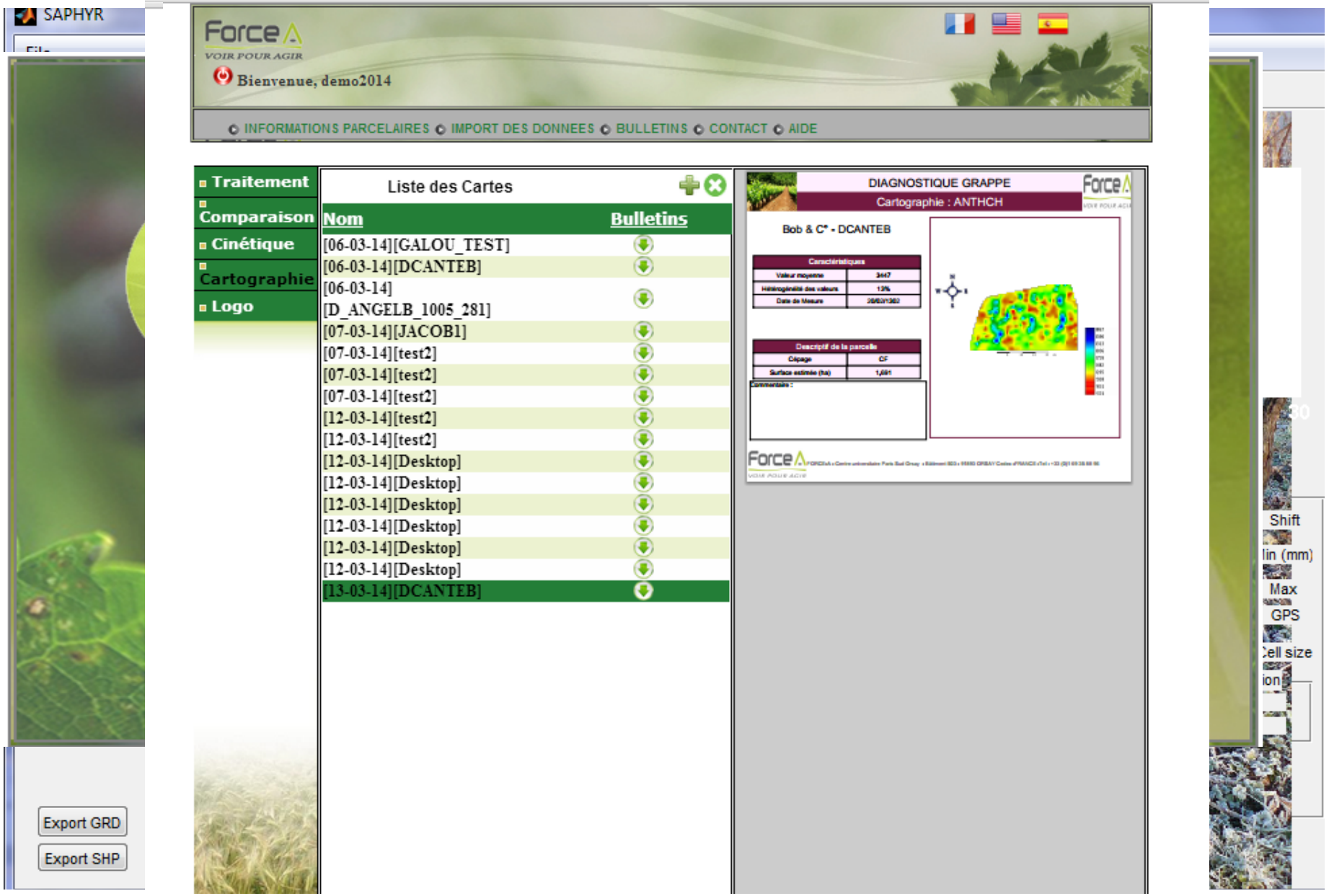
Smartphone

Support for optimizing viticultural practices and selective harvesting

N+1 year management & traceability

Real-time support solution for global vineyard precision management

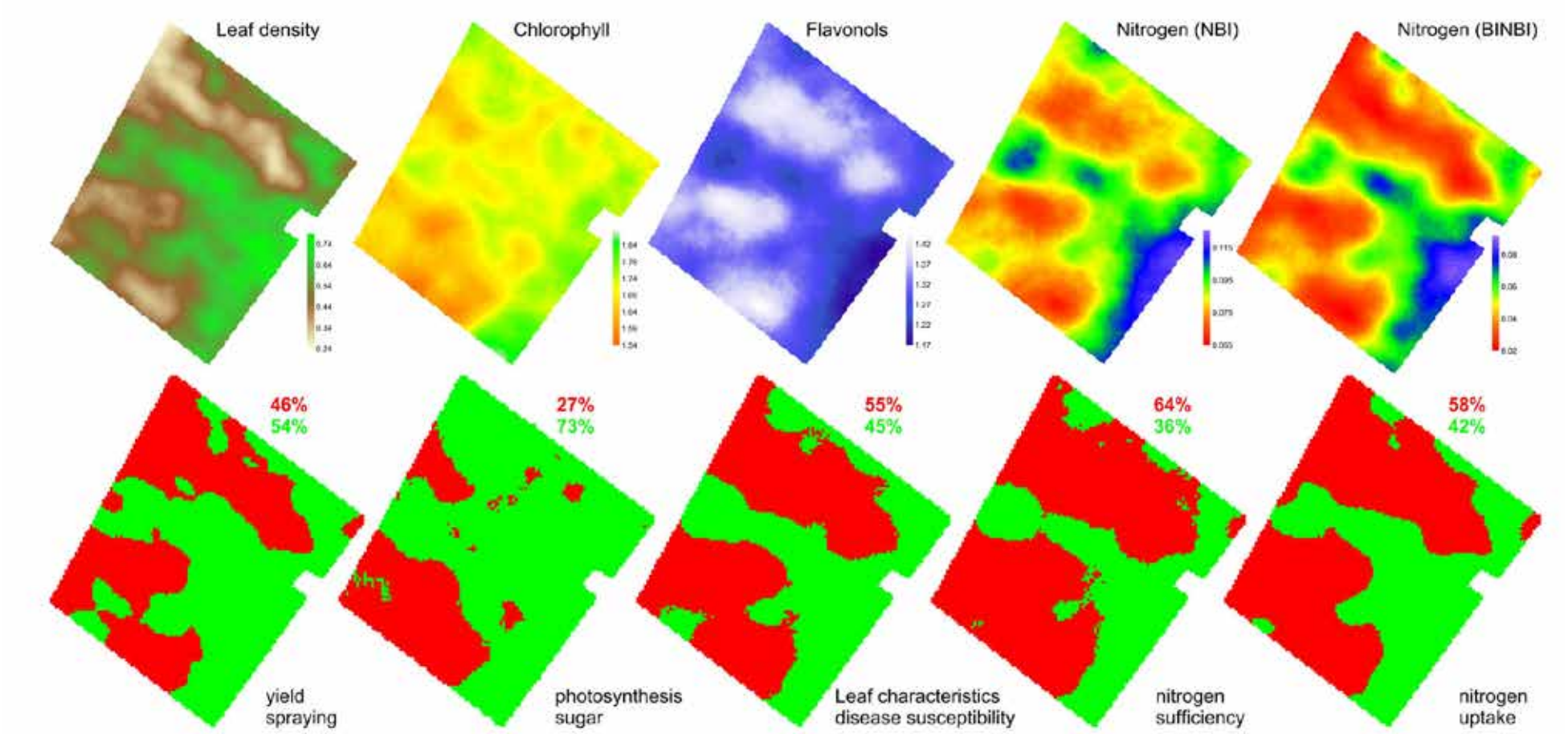
Web platform and software for data treatment



Spatial heterogeneity – Plot Zoning – Five-info maps

Shoot number *Shoot vigour* Vegetative expression

NFI (Chl / Flav) = NBI NFI*NBI



Gap fraction
LAD
LAIsv

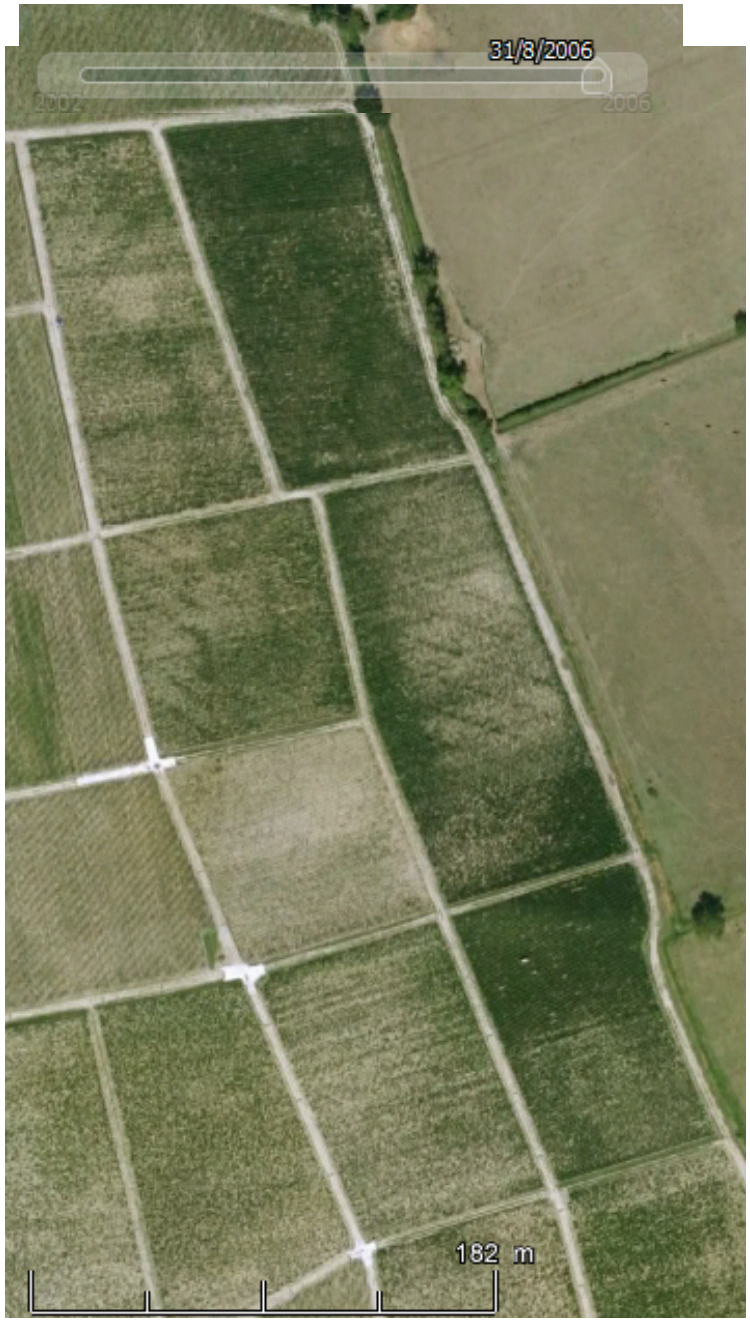
Nitrogen
Surface-
based

Light
Exposure

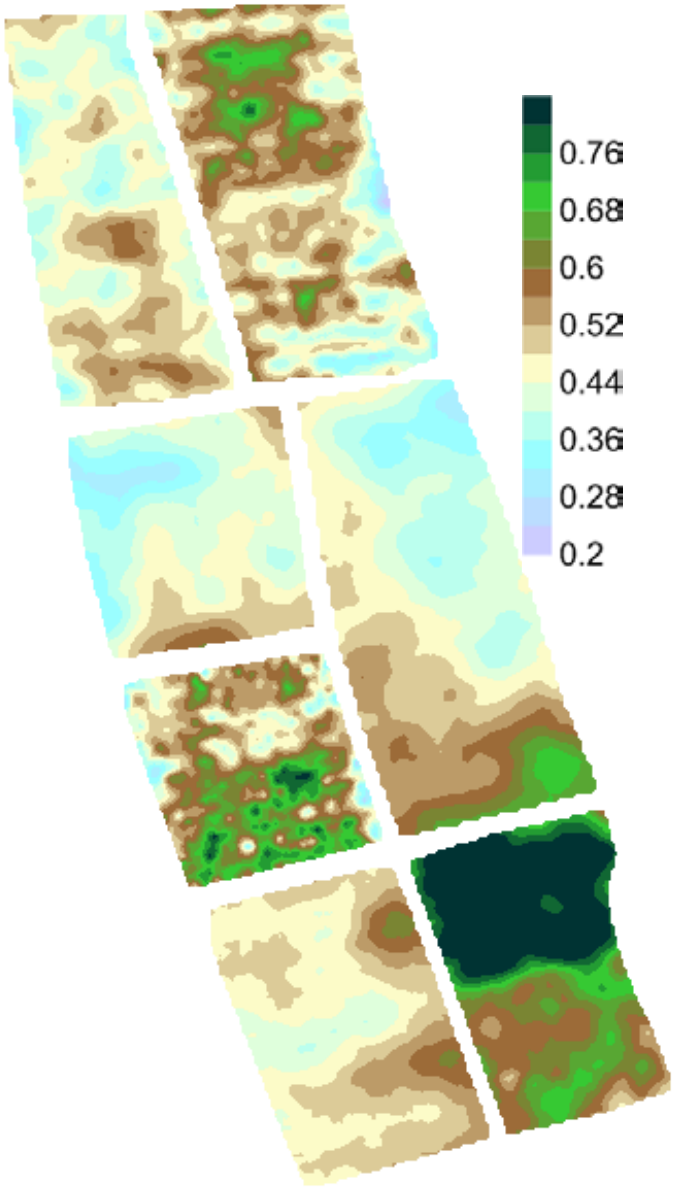
Nitrogen
Mass-
based

Total
Nitrogen
per vine

Leaf density



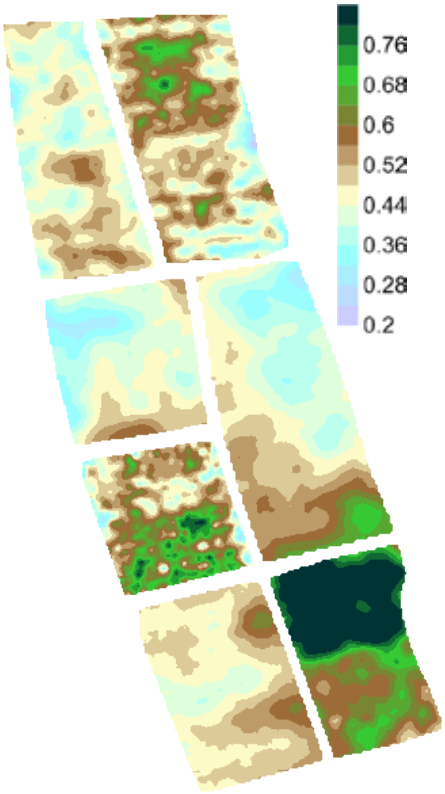
NFI



Assessing Nitrogen

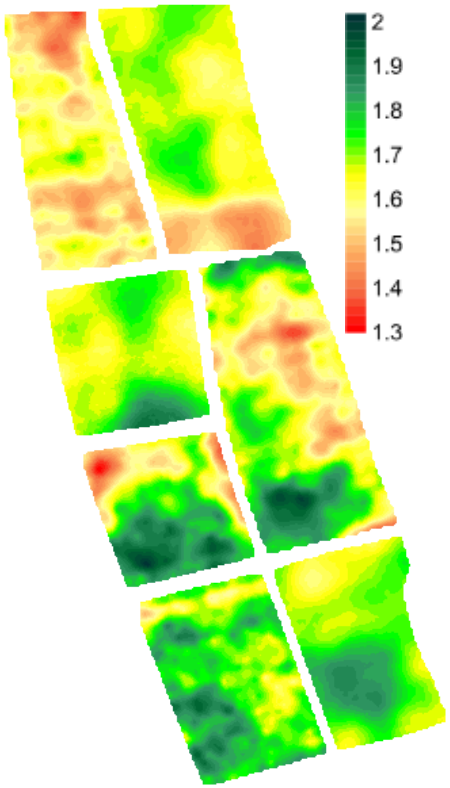
NDVI
Alternative

NFI



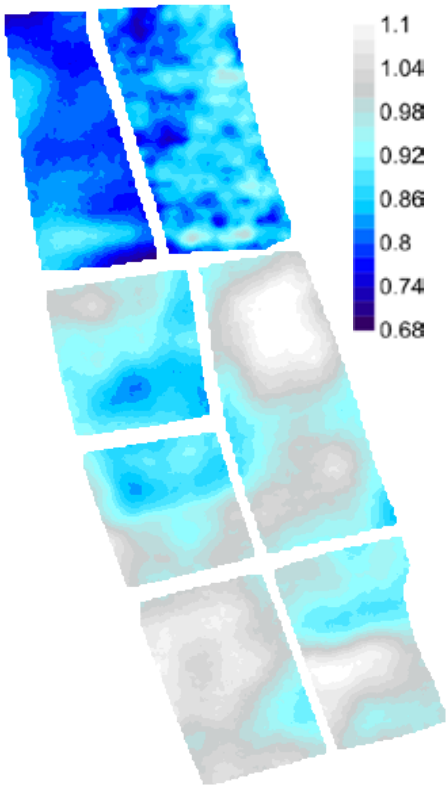
CI red-edge
Alternative

CHL



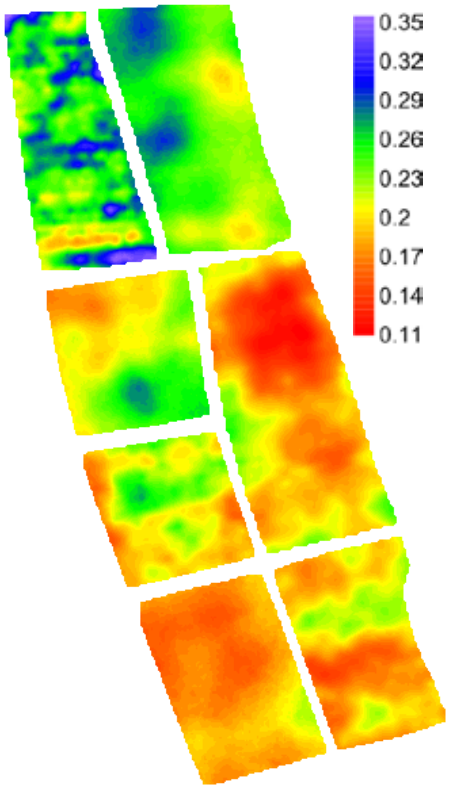
Mx
Only

FLAV



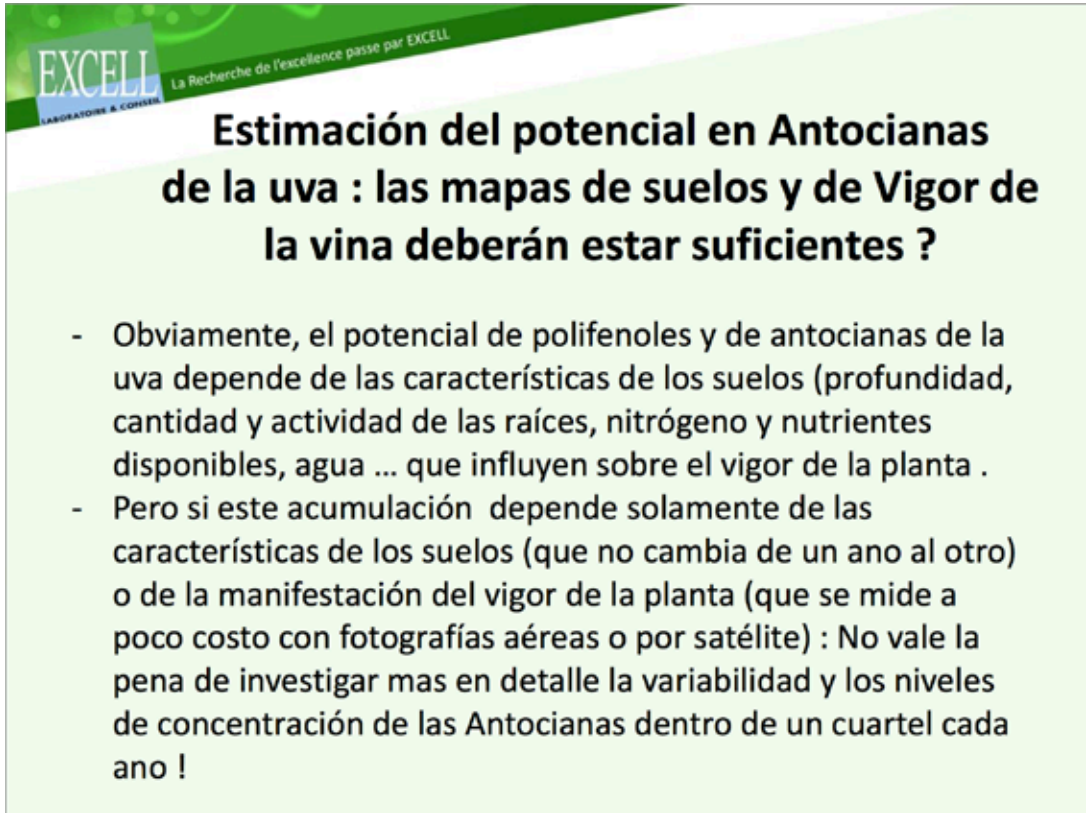
Mx
Only

NBI

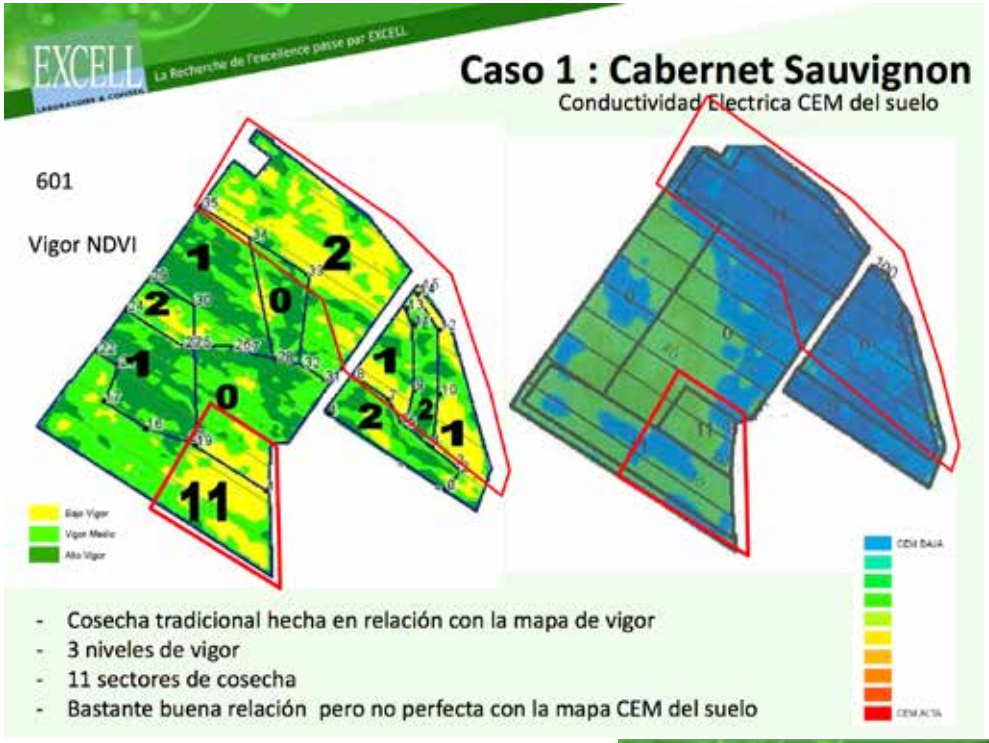


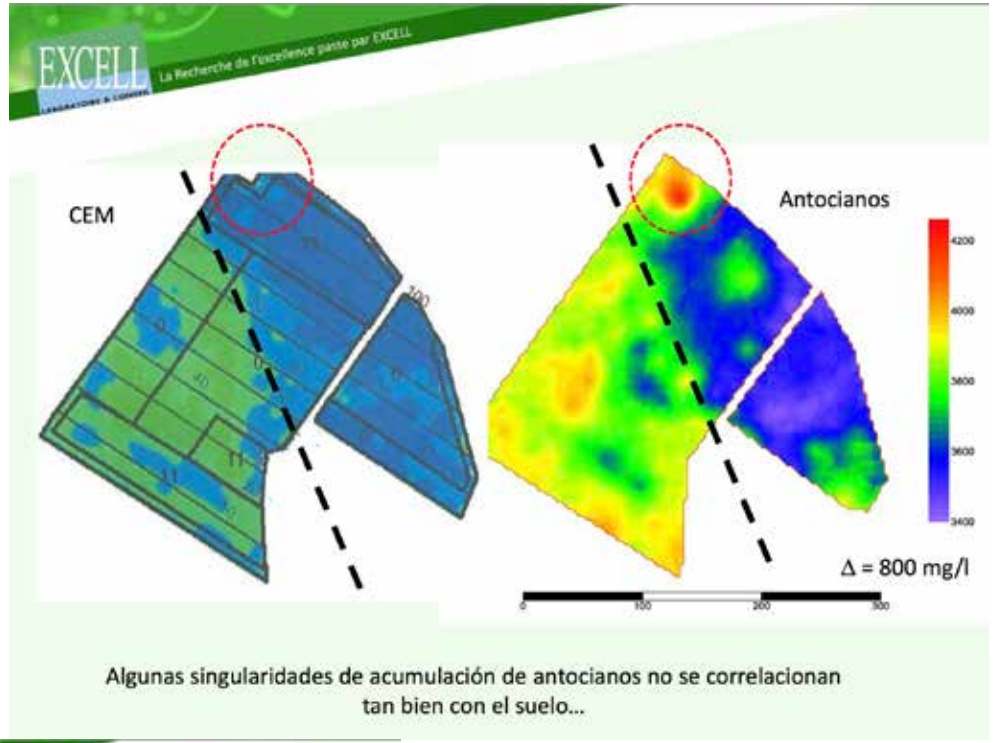
Assessing anthocyanins - maps for selective harvesting

Chilean experience 2013
Pascal Chatonnet - Excell

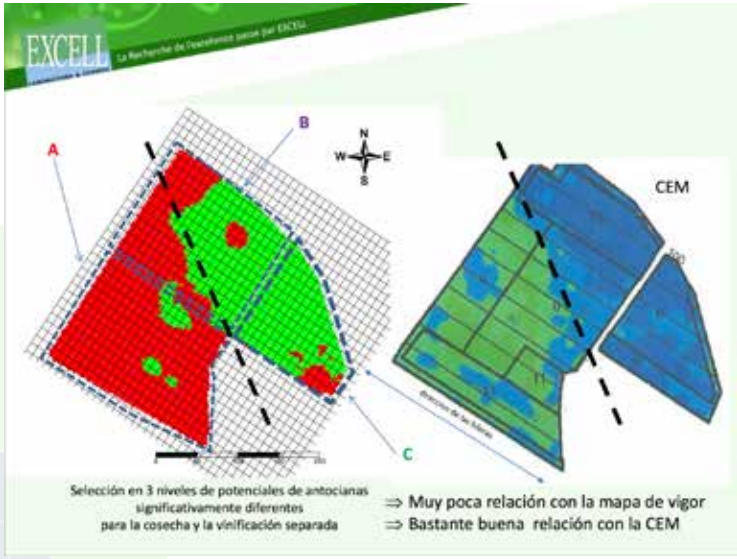


Assessing anthocyanins - maps for selective harvesting





Assessing anthocyanins - maps for selective harvesting



EXCELL LABORATOIRE & CONSEIL — La Recherche de l'excellence passe par EXCELL

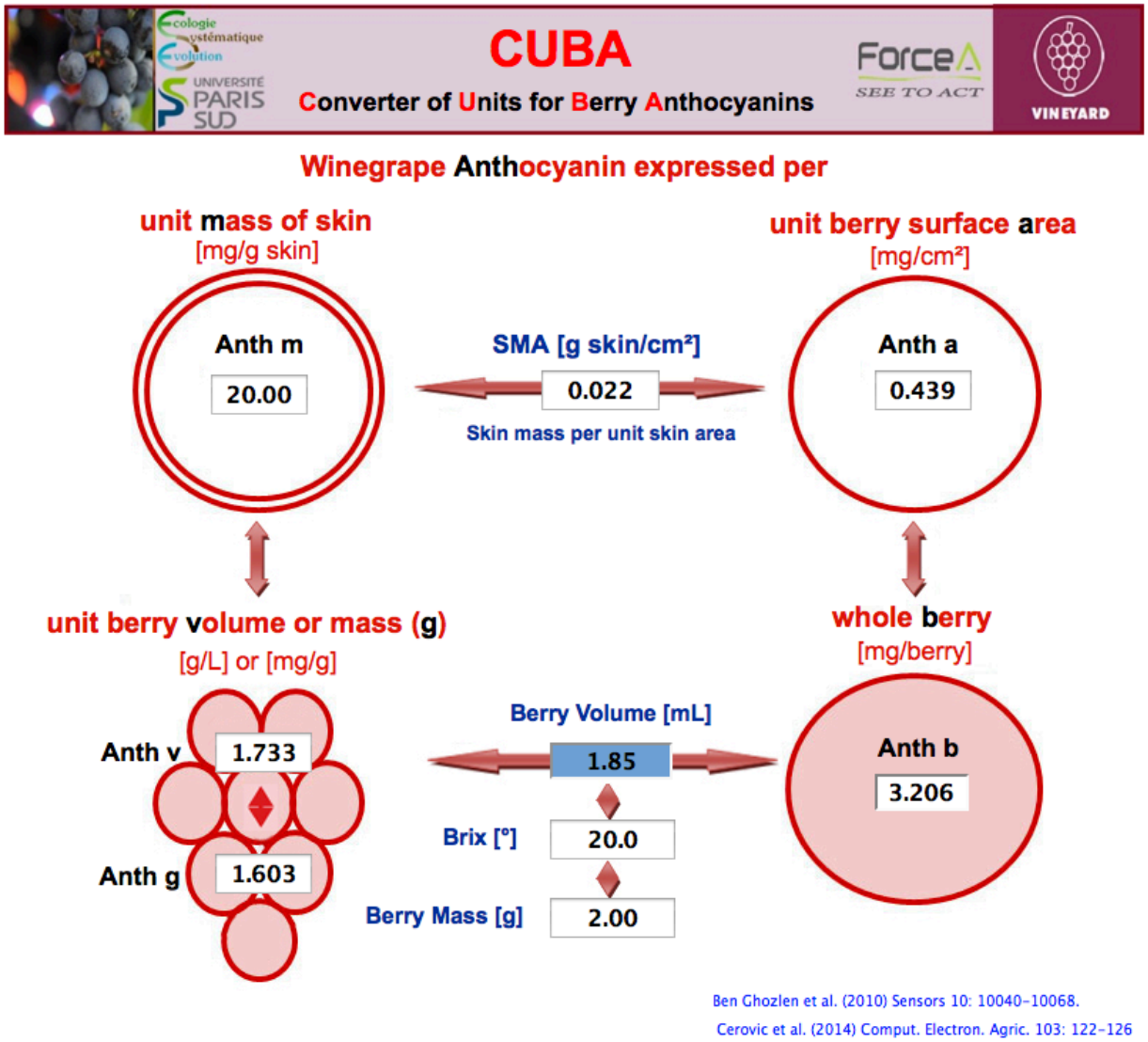
Potencial historico del cuartel

Block	Identificación	IPT	Antocianos tot	DMACH	I de ionización	Taninos totales g/L	DMACH/ LA	Vino	Litros	
B	**Potencial A**	99	676	119	26,4	1,2	96	A	2925	27%
	Potencial B	92	678	108	23,4	1,3	83	B	2925	
	Potencial C	93	595	81	19,8	1,4	58	B(-)	4950	

Potencial de antocianos en el cuartel **antes de la cosecha**

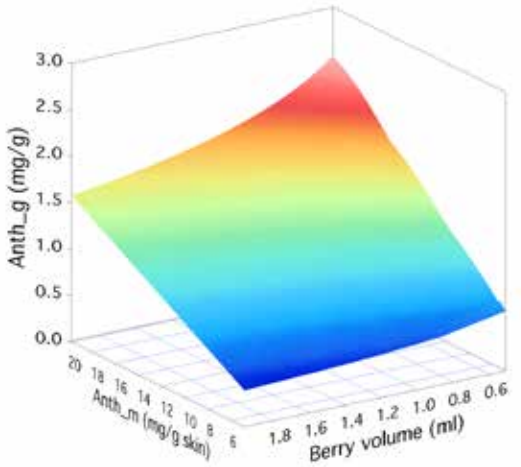
- Pequeñas diferencias en los fenoles totales;
- Pequeñas diferencias de antocianas entre el potencial A y B en los vinos mucho pero mas significativa con el potencial C;
- No hay diferencias de taninos/flavanoles al nivel cuantitativo entre A y B Y mucho mas al nivel cualitativo (DMACH/LA);
- Coloración menor de los antocianos en el potencial C (menos ionización)
- Finalmente el nivel C no produce vino C porque las diferencias de potenciales de antocianos no estaban muy altas (800 mg/l);
- **Pero con el mapeo de los antocianos, fue posible de sacar 27% de vino A en un cuartel clasificado como B!**

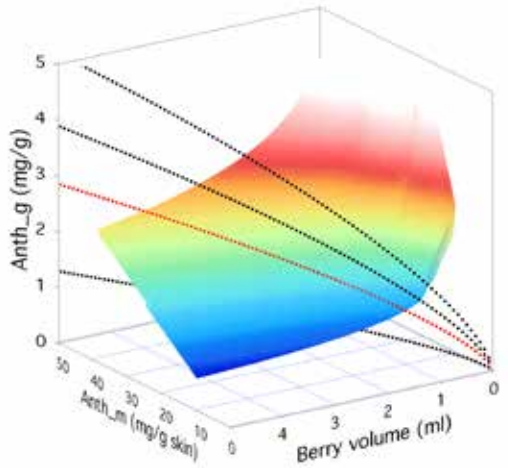
Anthocyanin units conversion - CUBA



Ben Ghozlen et al. (2010) Sensors 10: 10040-10068.

Cerovic et al. (2014) Comput. Electron. Agric. 103: 122-126





http://max2.ese.u-psud.fr/cuba/

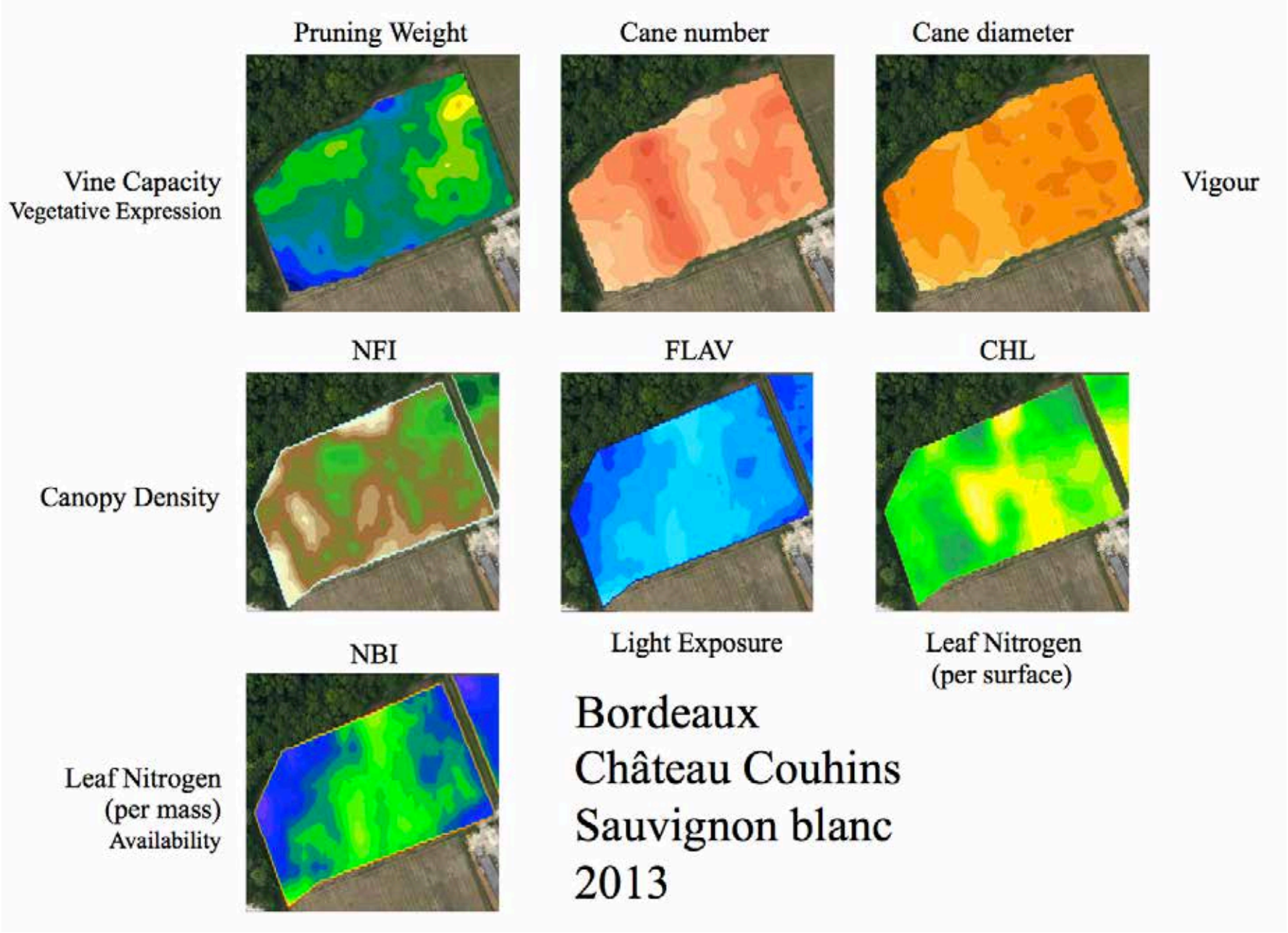
Anthocyanin maps for selective harvesting - Bordeaux

Year	Analysed Surface (ha)	Cost of Analysis (€)	Number of Tanks Shifted	Number of Bottles	Price Difference per Bottle (€)	Net Profit (€)
1	**15**	5 063	**1**	8 533	**69**	583 714
2	**27.5**	8 863	**2**	17 066	**42.4**	714 735

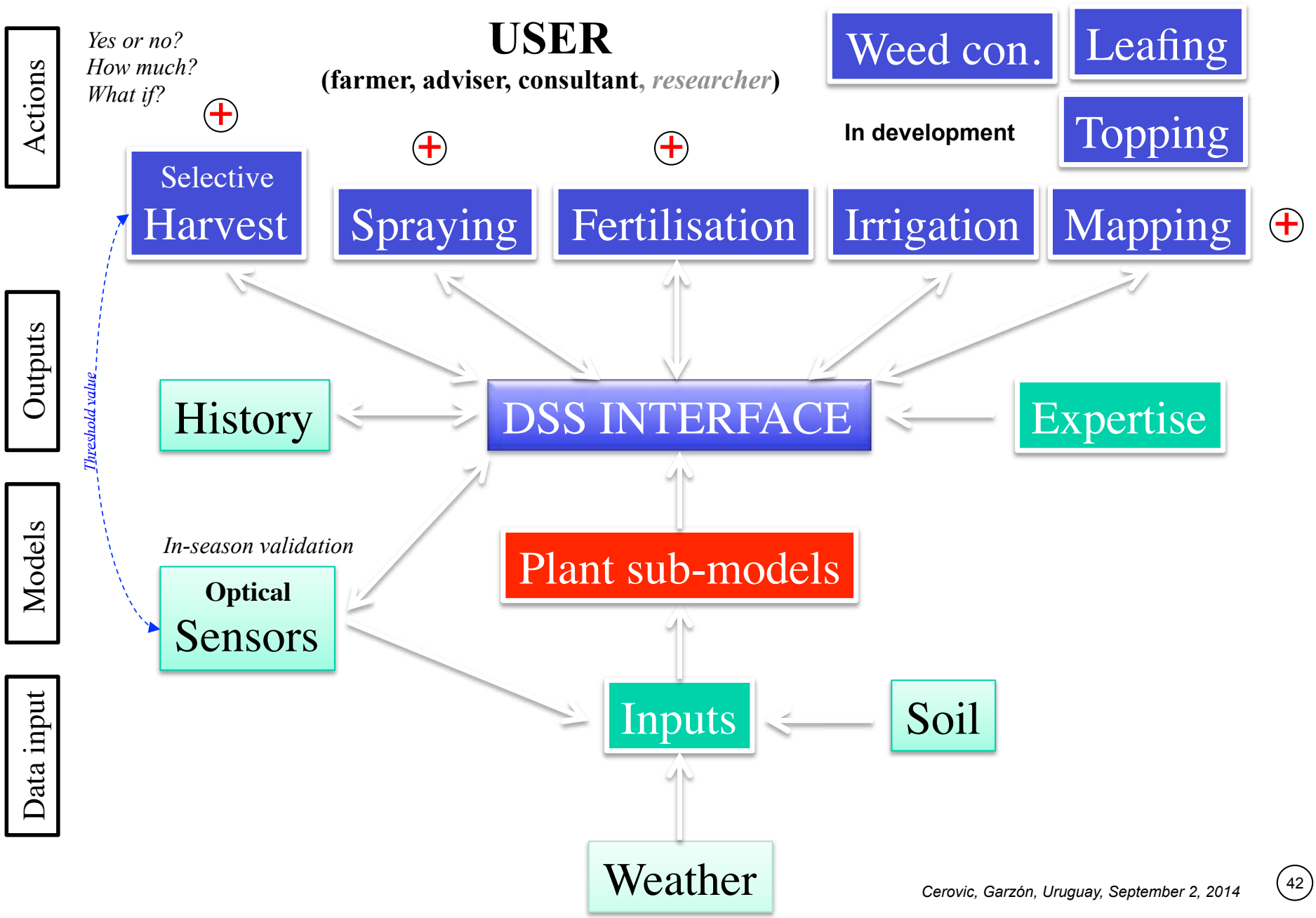
Details of the business case

- Bordeaux “Château”.
- Merlot Noir, Cabernet Sauvignon.
- 30% of total surface are intermediate plots used for the 1St or 2nd wine.
- Fermentation tanks of 64 hl (for approximately 2 ha of 3.7 T ha^{-1}).
- Price per bottle: **1St wine 73 to 192 €**, 2nd wine **26 to 41 €**, depending on year.
- Cost for Multiplex anthocyanin mapping: **300 to 350 € ha^{-1}**, depending on surface.
- Analysis every year before harvest.
- Average cost of analysis: 1% of net profit.
- Increase in turnover for the Château thanks to the analysis: 3 to 4%.

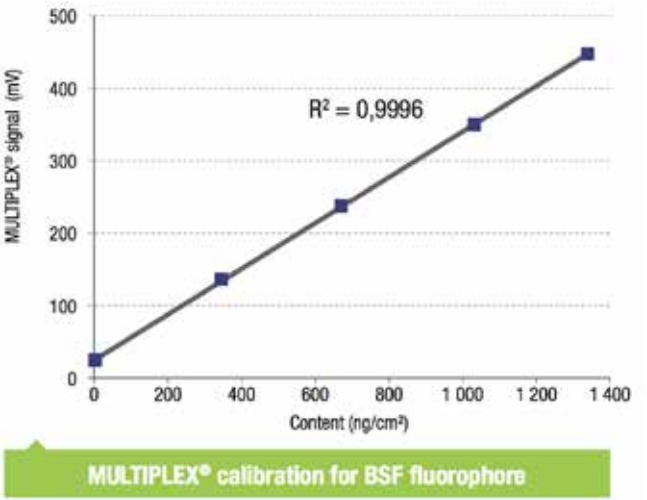
Plot heterogeneity



Action oriented Farm Management Information System & DSS



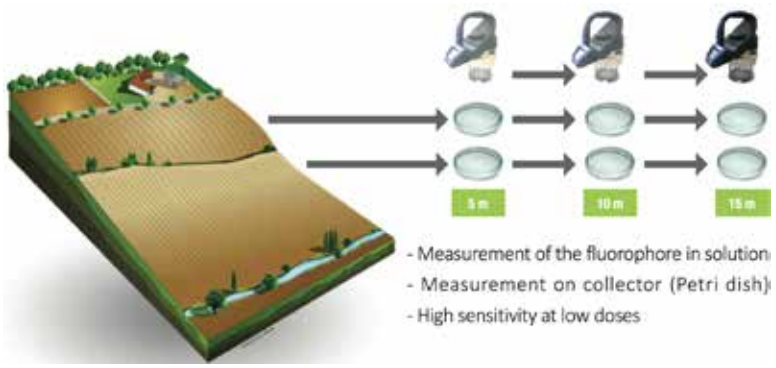
Sprayer Calibration – Spray Coverage and Drift



MULTIPLEX® calibration for BSF fluorophore

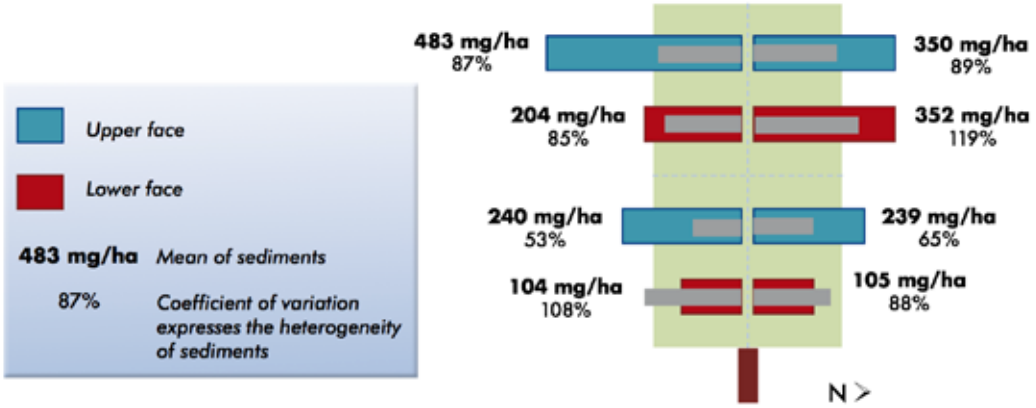
Spraying on the crop of a mixture containing a fluorophore

Deposits quantification on leaves with the MULTIPLEX® sensor



- Measurement of the fluorophore in solution
- Measurement on collector (Petri dish)
- High sensitivity at low doses

Sediments distribution on a vine row: mean in mg/ha and coefficient of variation in %



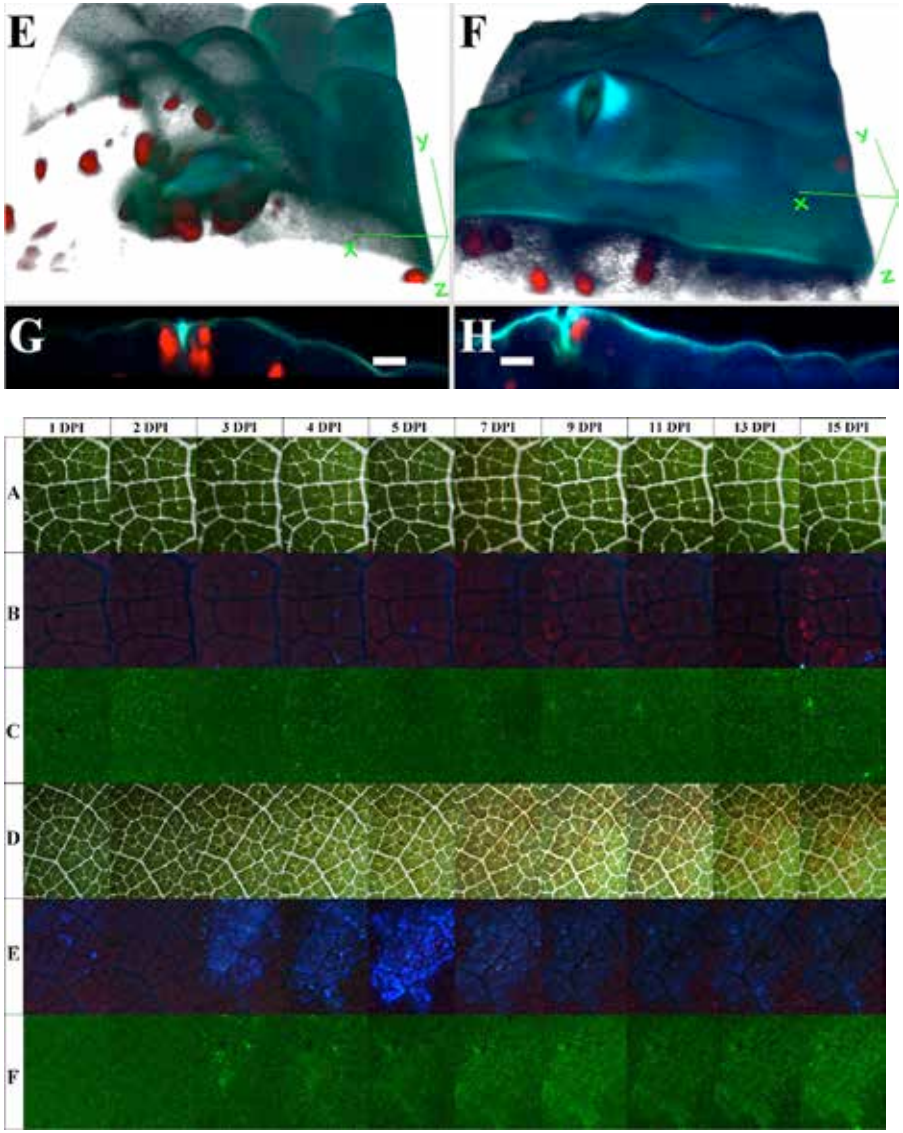
FORCE-A
Centre Universitaire Paris Sud, Bât. 503
Rue du Belvédère
91893 ORSAY CEDEX - France

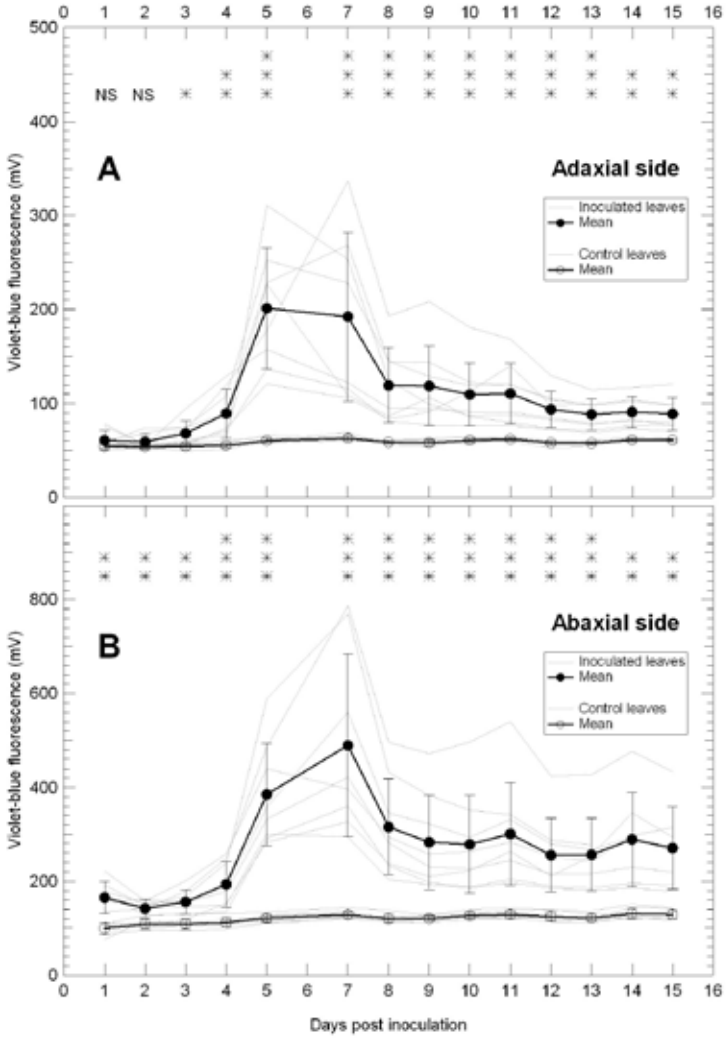
Tél. +33 (0)1 69 35 88 62
Fax +33 (0)1 69 35 88 97
www.force-a.com
e-mail : info@force-a.fr

Force A
SEE TO ACT

Diseases diagnostics: downy mildew in grapevine

Bellow et al. (2012) J. Exp Bot., in press





Bellow et al. (2012) submitted to RSE

Dr Zoran G. Cerovic
CNRS, Univ. Paris-Sud
Orsay, France
zoran.cerovic@u-psud.fr
Tel : +33 (0)1 69 15 72 24
Fax : +33 (0)1 69 15 73 53

FORCE-A
Centre Universitaire Paris Sud
Bât. 503
91893 ORSAY Cedex
France
Tel : +33 (0)1 69 35 88 62
Fax : +33 (0)1 69 35 88 97
www.force-a.com
info@force-a.fr