



# Precision Viticulture

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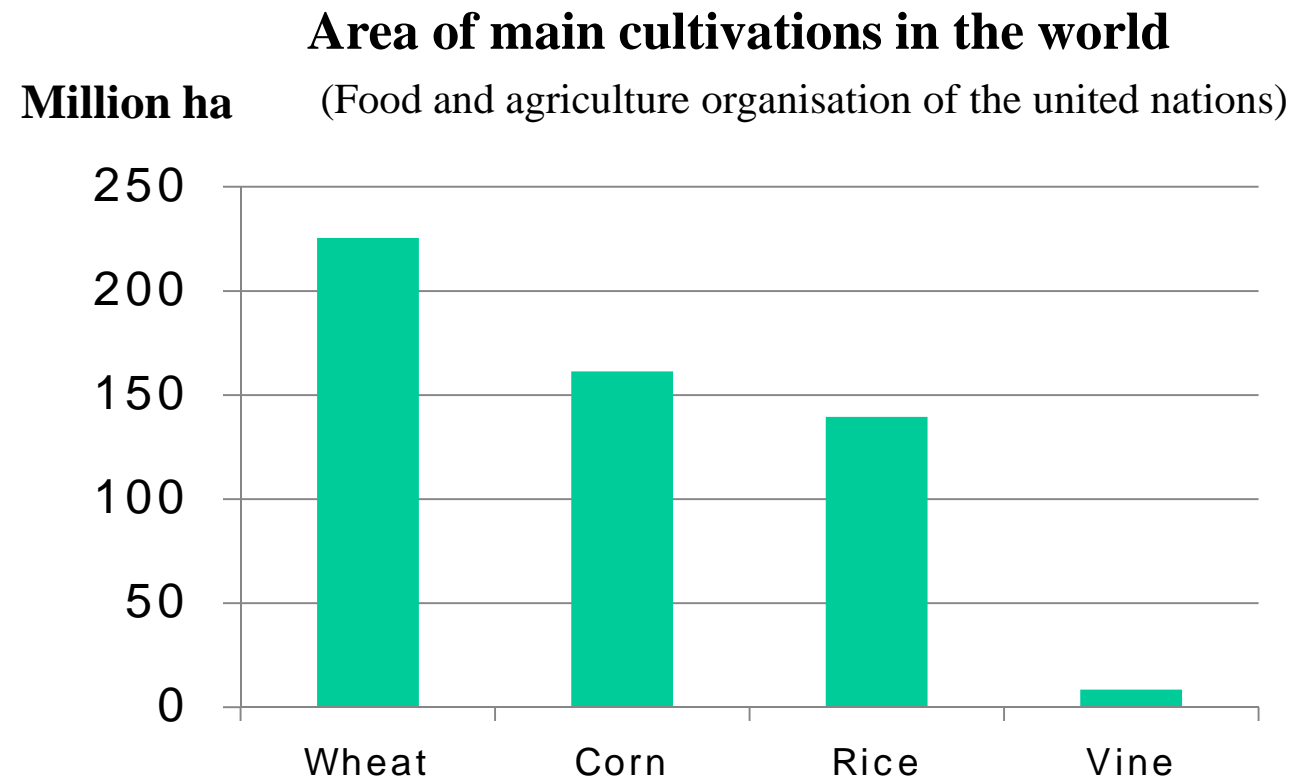
# Summary



- 1. Some figures about viticulture**
- 2. Some unique features (expectation about PV)**
- 3. Specificities of the vine cultivation**
- 4. Scientific and technical questions raised by PV**
- 5. Questions addressed during the last years**
- 6. Consideration on PV adoption**
- 7. New questions raised by PV**

# 1. Some figures about viticulture

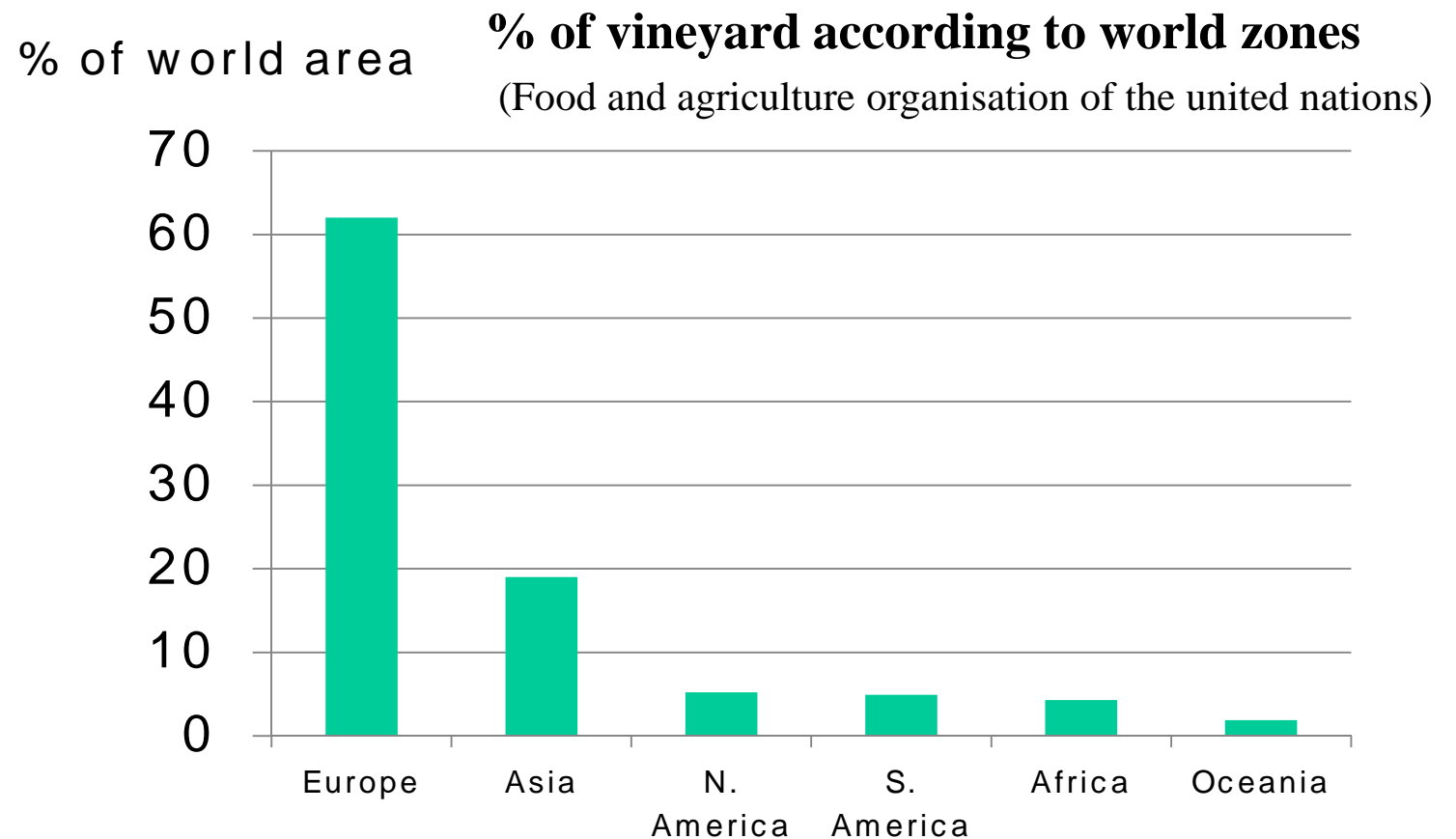
**Viticulture : 8 millions of ha in the world.**  
**Marginal cultivation worldwide**



# 1. Some figures about viticulture

**Strong disparity**

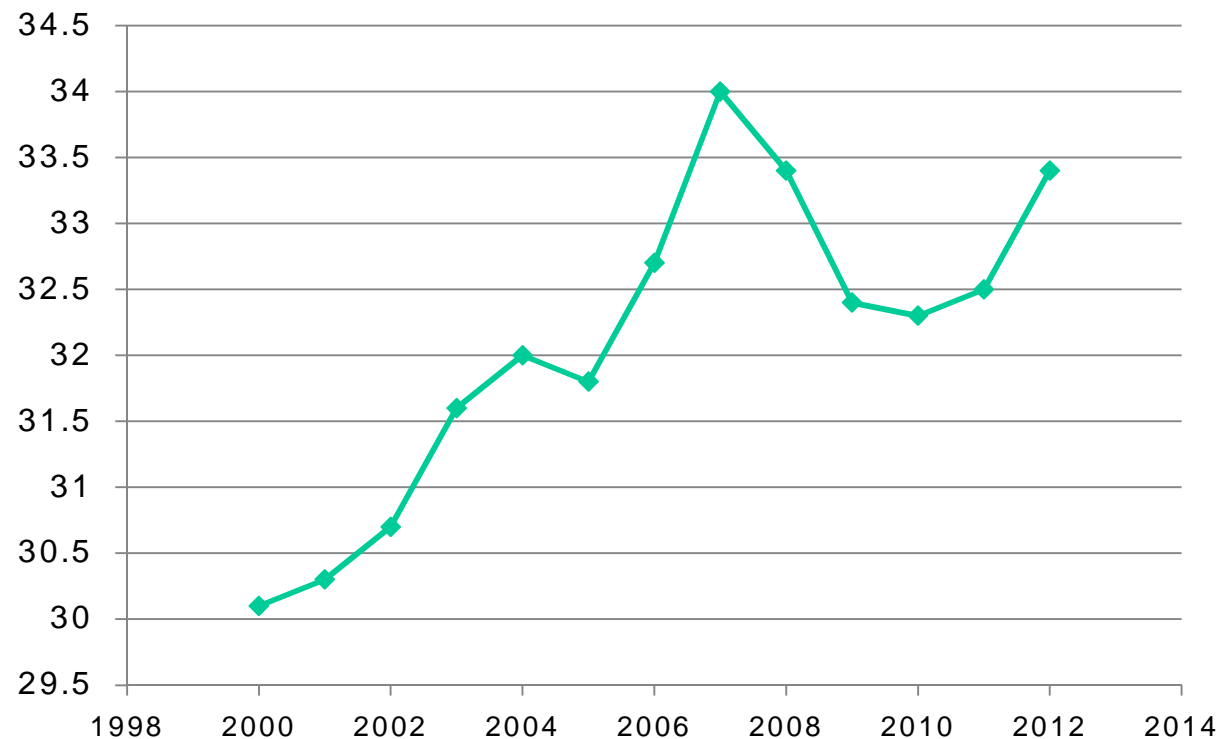
**The largest producers are also the largest consumers**



# 1. Some figures about viticulture

**Growing market since 2000,  
Viticulture will remain a cash crop for the years to come.**

**World wine consumption**  
**Billions of bottles**



(International Office of Wine)

1. Some figures about viticulture
2. Some unique features (expectation about PV)
  1. Quality management
  2. Environnemental issues
3. Specificities of the vine cultivation
4. Scientific and technical questions raised by PV
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## 2. Some unique features



Ultra premium  
> 50 €/bottle



Super premium  
> 30 €/bottle



Premium  
> 10 €/bottle



Popular premium  
> 5 €/bottle

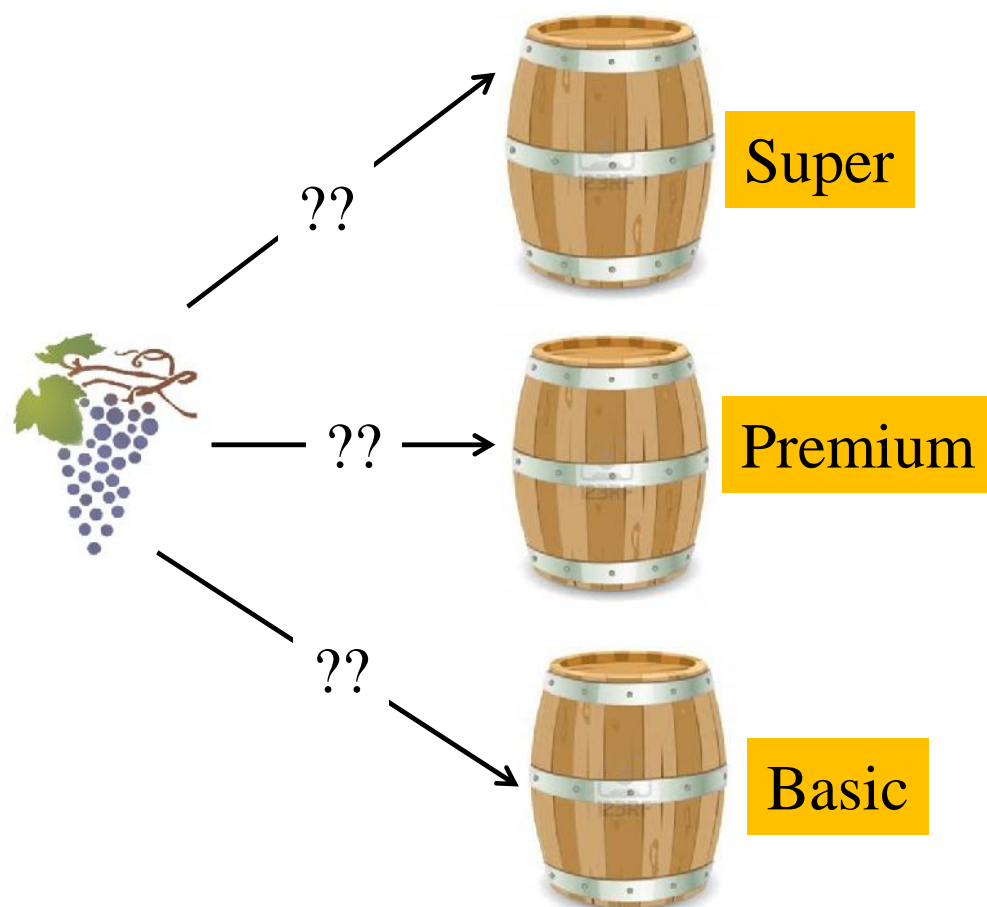


Basic  
< 5 €/bottle

**One of agricultural product with the  
widest range of price.  
(even in the same winery)**

## 2. Some unique features

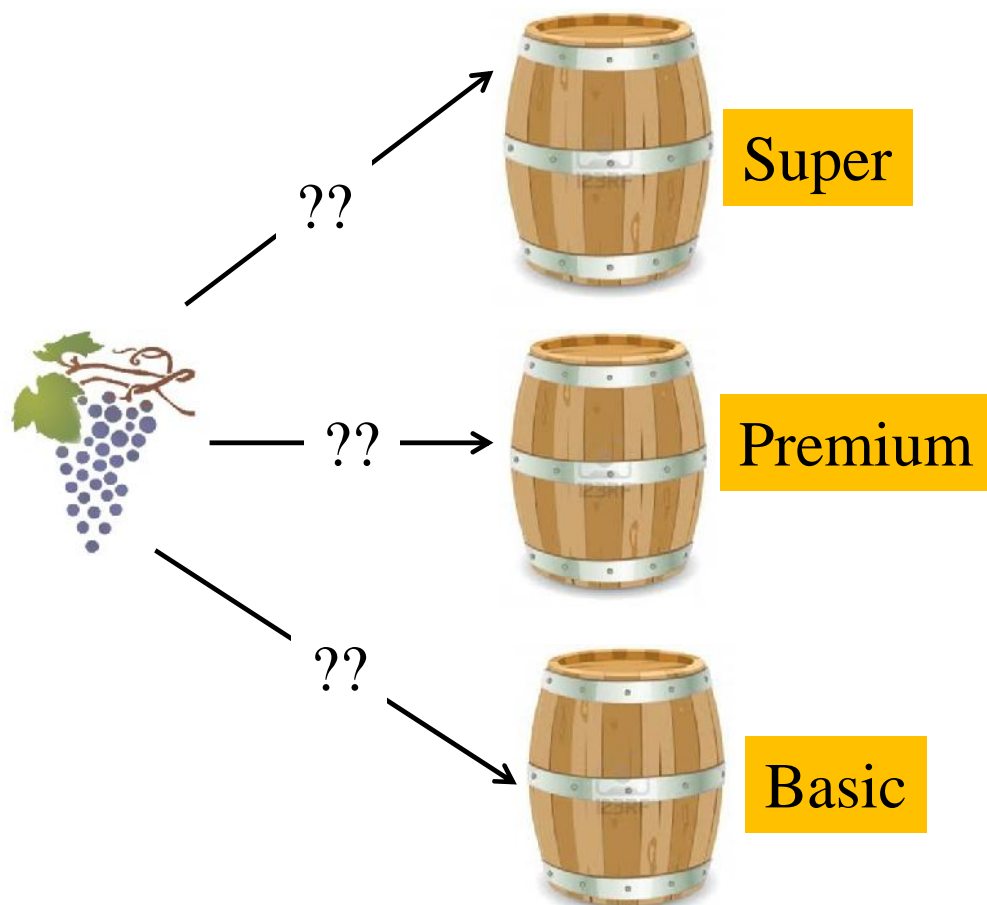
### a. Harvest the right quality to process the right quality





## 2. Some unique features

### a. Harvest the right quality to process the right quality



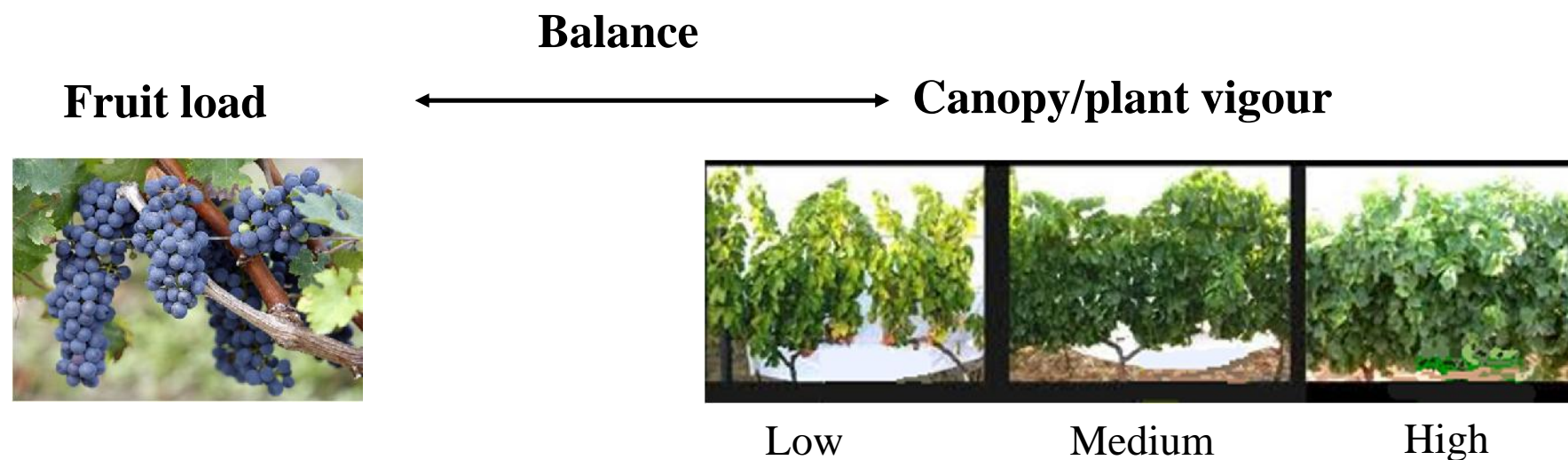
### Opportunity for PV

- Define quality zones,
- Differential harvest,
- On the go sensors



## 2. Some unique features

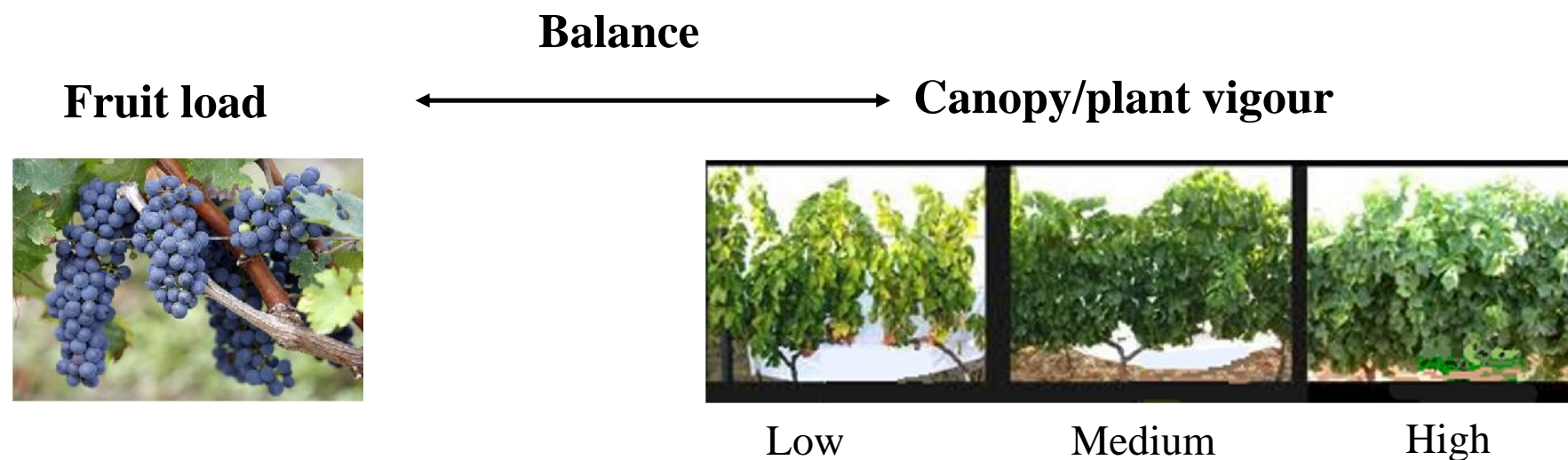
### b. Produce the right quantity at the right quality



- **Pruning,**
- **Fertilisation (Nitrogen)**
- **Water restriction (Irrigation, crop cover),**
- **Canopy management (leaf removal)**

## 2. Some unique features

### b. Produce the right quantity at the right quality



- Pruning,
- Fertilisation (Nitrogen)
- Water restriction (Irrigation, weeding),
- Canopy management (leaf removal)

### Opportunity for PV

- Site specific management,

## 2. Some unique features

### c. Pesticide application



Source : Irstea

**Two times more pesticides than for arable crops like wheat or corn**

(International Office of Wine)

### **Opportunity for PV**

- **Variable rate application of pesticides according to canopy size and shape**

1. Some figures about viticulture
2. Some unique features (expectation about PV)
3. **Specificities of the vine cultivation**
  1. **Opportunities for PV**
  2. **Weakness for PV**
4. Scientific and technical questions raised by PV
5. Questions addressed during the last years
6. Consideration on PV adoption
7. New questions raised by PV



### 3. Specificities of the vine cultivation

- Small fields (~1 ha - 20 ha)
- Manual operations (winter pruning)
- Perennial cultivation
- Sparse canopy (soil and vines)
- Expert knowledge



Photo : M. Heywang

Is there significant spatial variability that justifies PV ?

### 3. Specificities of the vine cultivation

- Small fields (~1 ha - 20 ha)
- Manual operations (winter pruning)
- Perennial cultivation
- Sparse canopy (soil and vines)
- Manual operations (expertise)



Photo : M. Heywang

**Is there a significant spatial variability that justifies PV ?**

**Is there a temporal stability of spatial variability ?**



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Photo : M. Heywang

**Is there a significant spatial variability that justifies PV ?**

**Is there a temporal stability of spatial variability ?**

**Is remote sensing information relevant to detect vigour zones ?**

**How to characterize variability in shape/size of the canopy ?**

### 3. Specificities of the vine cultivation

**Difficulties related with sparse canopy as well as the diversity of training systems.**



Vertical shoot positioning



Pergola



Bush systems

### 3. Specificities of the vine cultivation

**Difficulties related with sparse canopy as well as the diversity of training systems.**



Bare soil



Cover crop between the rows



### 3. Specificities of the vine cultivation

- Small fields (~1 ha - 20 ha)
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- Perennial cultivation
- Sparse canopy (soil and vines)
- Manual operations (expertise)



Photo : M. Heywang

**Is there a significant spatial variability that justifies PV ?**

**Is there a temporal stability of spatial variability ?**

**Is remote sensing information relevant to detect vigour zones ?**

**How to characterize variability in shape/size of the canopy ?**

**Possibility to consider hand held sensors.**

# Summary



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## **4. Scientific and technical questions raised by PV**



- **Is there a significant spatial variability that justifies PV ?**
- **Is it temporal stable ?**

## 4. Scientific and technical questions raised by PV



- Is there a significant spatial variability that justifies PV ?
  - Is it temporal stable ?
  - How to define within-field vigour zones ?
    - soil fertility ?
    - plant growth ?
    - water status ?
    - biomass, plant geometry ?
- Quality management

## 4. Scientific and technical questions raised by PV



- Is there a significant spatial variability that justifies PV ?
  - Is it temporal stable ?
  - How to define within-field vigour zones ?
    - soil fertility ?
    - plant growth ?
    - water status ?
    - biomass, plant geometry ?
- Quality management
  - Pesticides application



## 4. Scientific and technical questions raised by PV



- Is there a significant spatial variability that justifies PV ?
  - Is it temporal stable ?
  - **How to define within-field vigour zones ?**
    - soil fertility ?
    - plant growth ?
    - water status ?
    - biomass, plant geometry ?
  - **How to define within-field quality zones ?**
    - data processing,
    - specific sensors,
- **Quality management**
  - **Pesticides application**
  - **Differential harvest**

# Summary



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## **5. Questions addressed during the last years**

### **Is there a within-field spatial variability in viticulture ?**

**Since 2000, many investigations focused on main parameters in vine**

**Production parameters (yield, vigour),**

**Harvest quality parameters (sugar, acidity, etc.),**

**Decision information (nitrogen, water status, etc.)**

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Decision information (nitrogen, water status, etc.)

**Australia :** *Bramley R.G.V., 2005*

**Spain :** *Arno et al., 2005, Baluja et al., 2012*

**France :** *Tisseyre et al., 2008.*

**Chili :** *Ortega et al. 2003,*

**California :** *Johnson L., 2003*

**New Zealand :** *Trought et al., 2011*

**France, Australia, Spain :** An International data base on yield at the within field level in viticulture France-Spain-Australia over 142 fields (*Taylor et al. 2005*).

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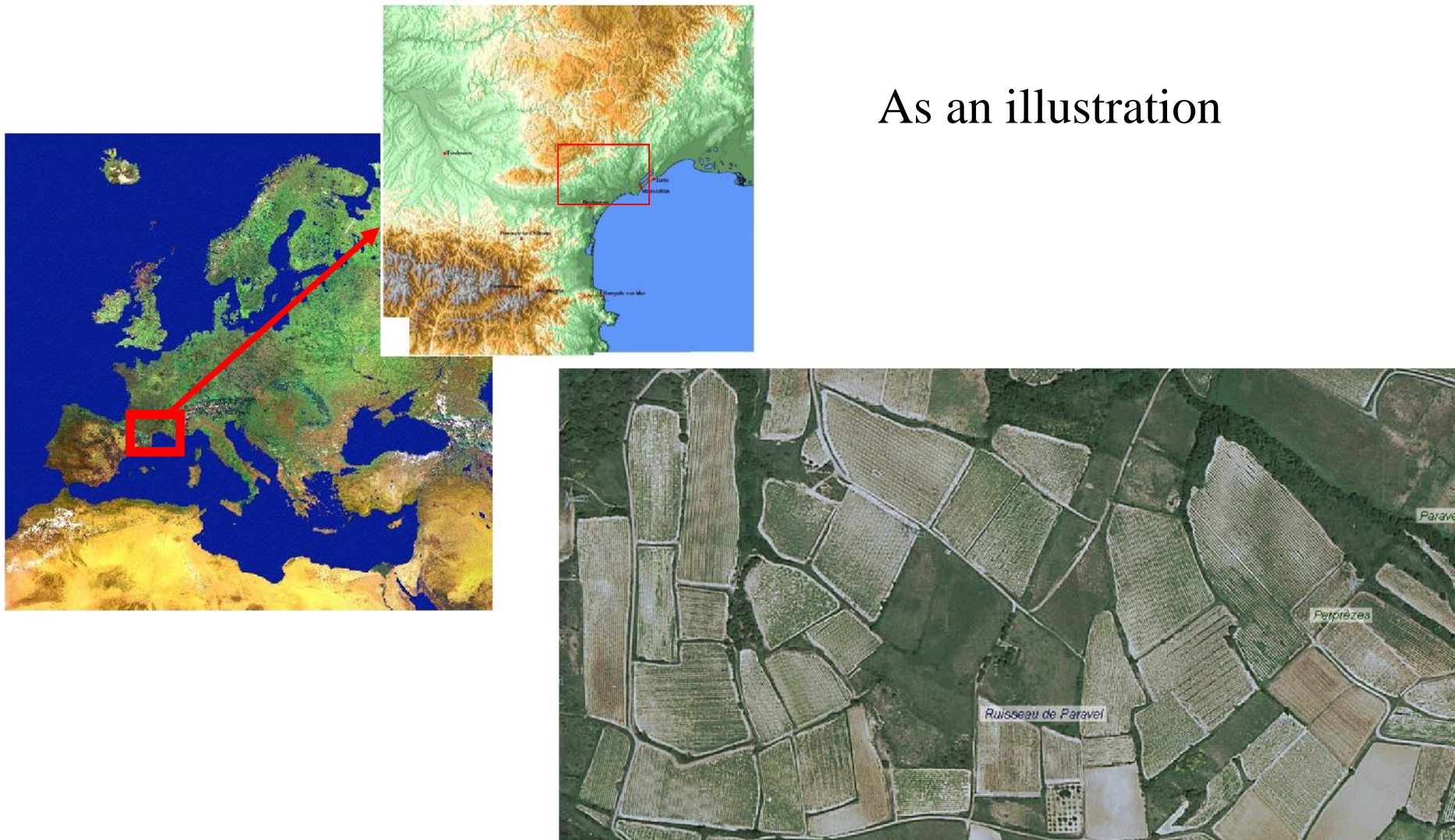
**France, Australia, Spain :** An International data base on yield at the within field level in viticulture France-Spain-Australia over 142 fields (*Taylor et al. 2005*).

There is a significant spatial variability in viticulture

## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**

As an illustration





## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**



1.1 ha

Coordinates RGF 93 : X, 742874; Y, 6275236

Sources : IGN Coordinates RGF 93 : X, 742874; Y, 6275236

## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**



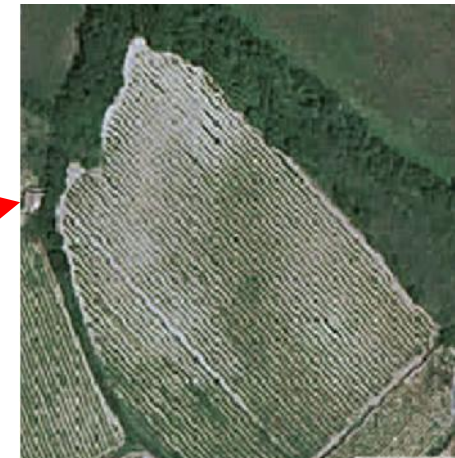
Trends/gradients





## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**



Spatial patterns



Spatial patterns

## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**

Why this variability within small fields ?

## 5. Questions addressed during the last years

**Is there a within field spatial variability in viticulture ?**

Why this variability within small fields ?



Vines are usually planted on hilly landscape with significant spatial variability in soil, climate, etc.

## 5. Questions addressed during the last years

**Is the spatial variability temporal stable over the years ?**

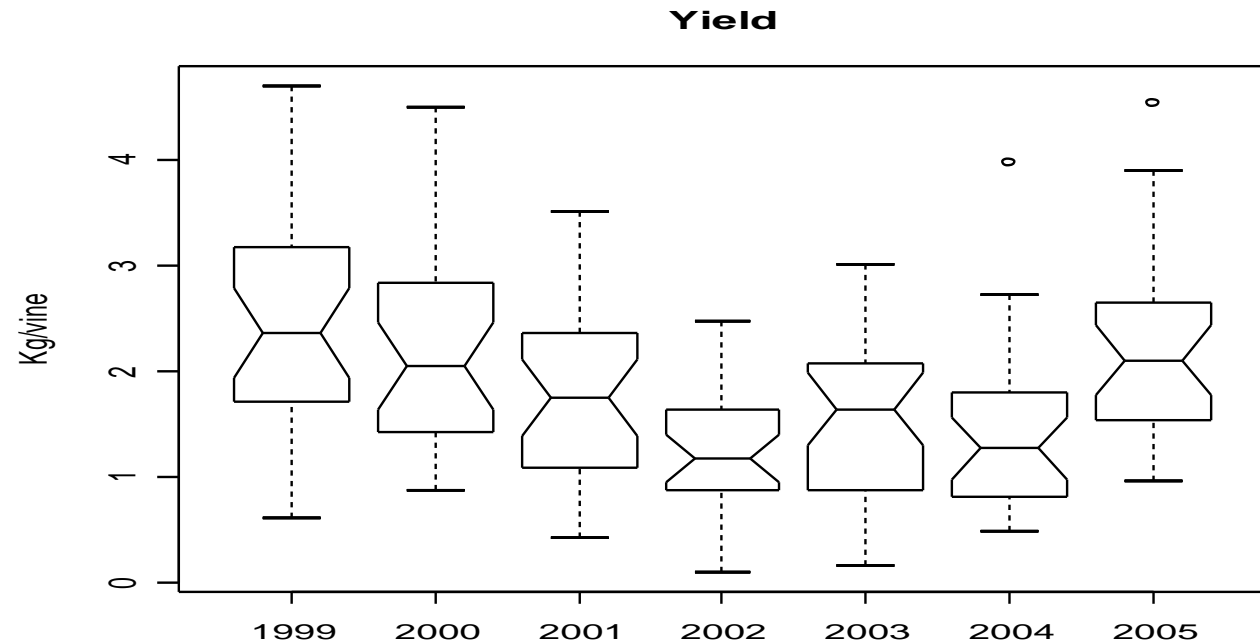
A significant question for the management of the quality.

## 5. Questions addressed during the last years

**Is the spatial variability temporal stable ?**

**How to characterize the temporal stability ?**

The year effect is particularly significant in non irrigated conditions





## 5. Questions addressed during the last years

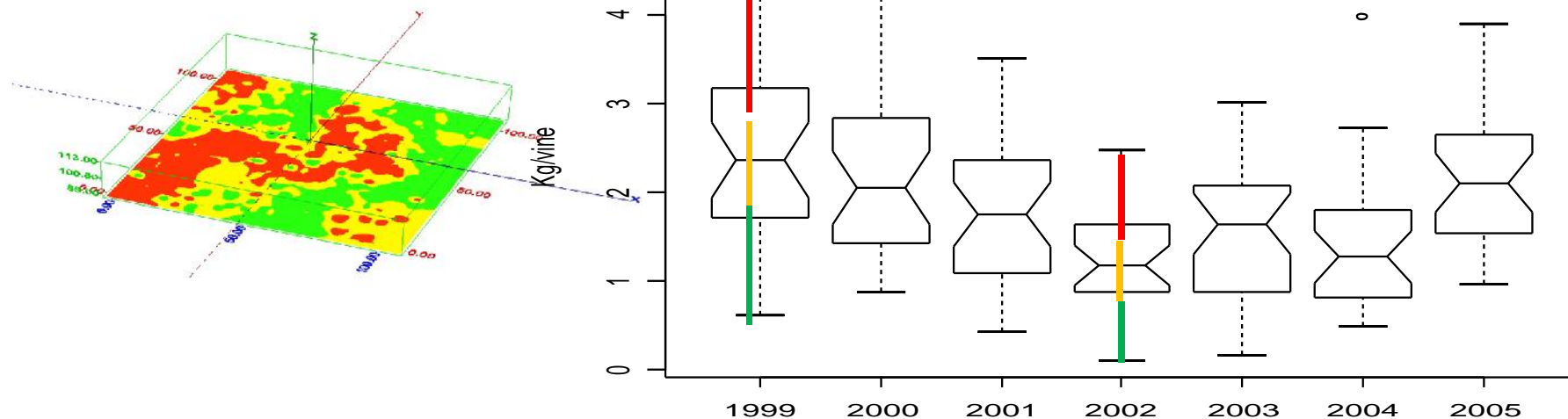
**Is the spatial variability temporal stable ?**

**How to characterize the temporal stability ?**

Adaptation of a rank test (Kendall)

(*Tisseyre et al., 2008*)

— high  
— Medium  
— Low



## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

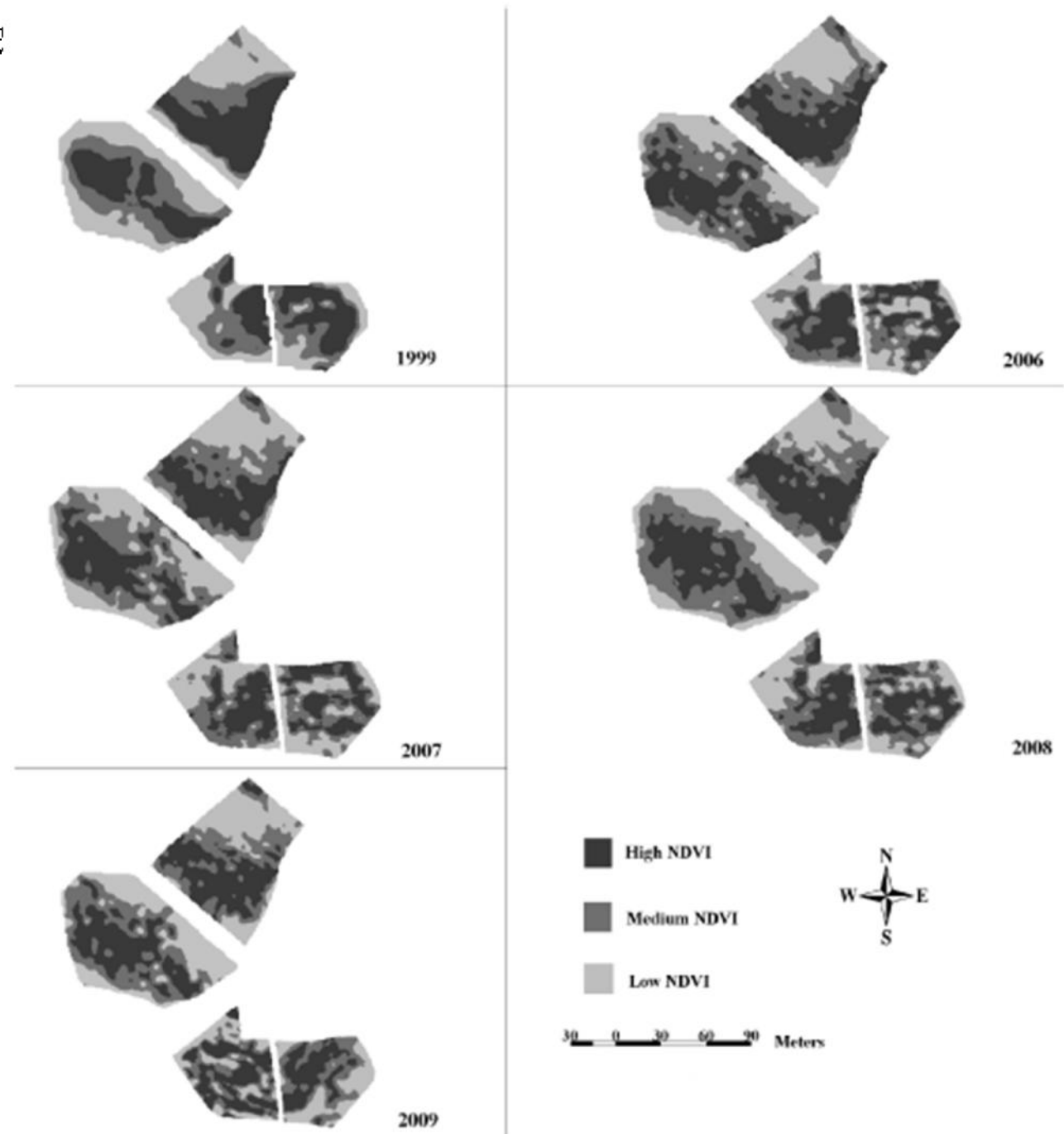
Kendall's coefficient of concordance computed over seven years (\*12 dates and 2 years)

	Kendall W	Significance (p<0.01)	
Temporal stable	Water status (PLWP)*	0.87	***
	Vigour	0.76	***
	Yield	0.59	***
Not stable over the time	pH	0.37	Ns
	Sugar content	0.35	Ns
	Acidity	0.29	Ns

(Tisseyre *et al.*, 2008)

## 5. Questions addressed

**Is the variability  
temporal stable ?**

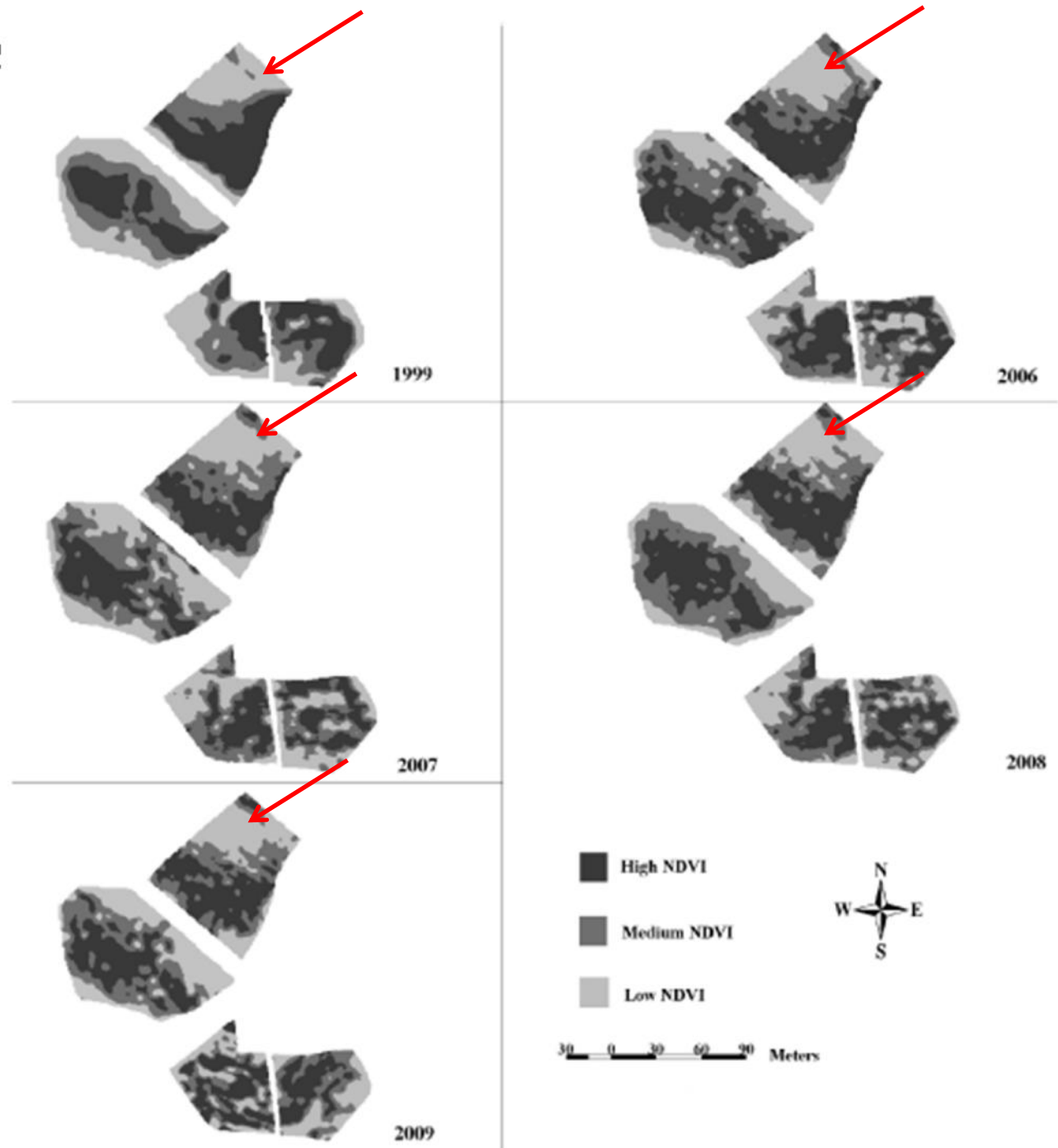


Kazmiersky et al., 2011



## 5. Questions addressed

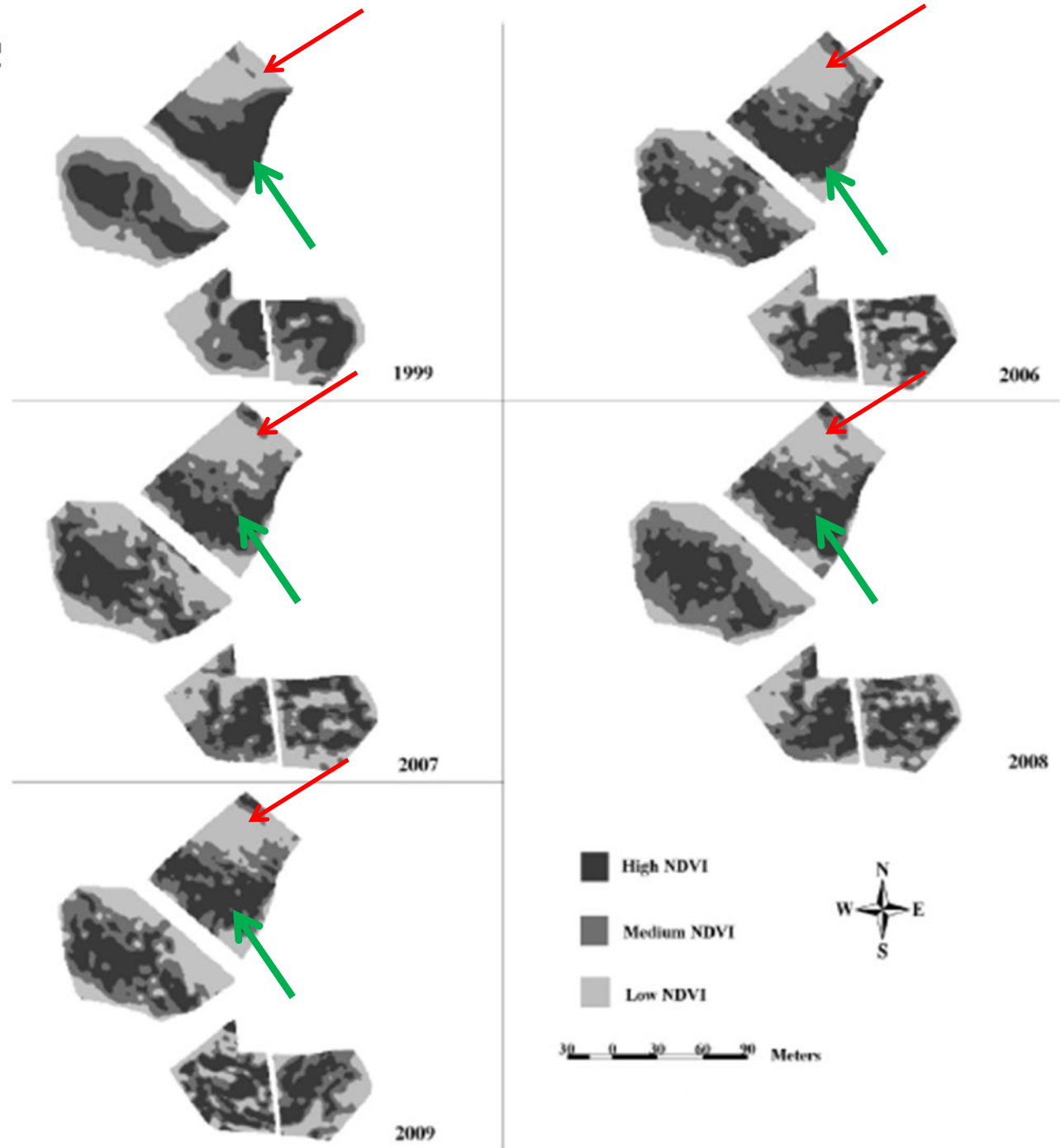
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Kazmiersky et al., 2011

## 5. Questions addressed

Is the variability  
temporal stable ?



Kazmiersky et al., 2011

## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

### **Interesting case of the plant water status (PLWP)**

- significant information to manage the quality
- very stable spatial organisation
- highly variable over the time and cumbersome to measure

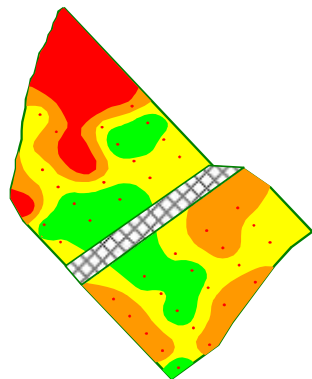
## 5. Questions addressed during the last years

### Is the variability temporal stable ?

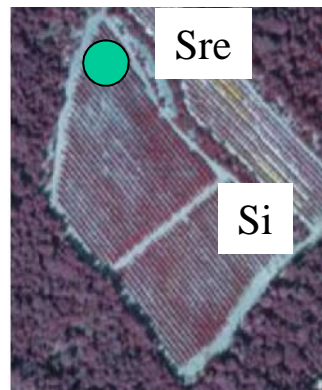
#### Interesting case of the plant water status (PLWP)

- significant information to manage the quality
- very stable spatial organisation
- highly variable over the time and cumbersome to measure

#### Towards an extrapolation model of the plant water status



$a_{s_i}$



D : domain under consideration

Sre : site of reference

Si : site of the domain

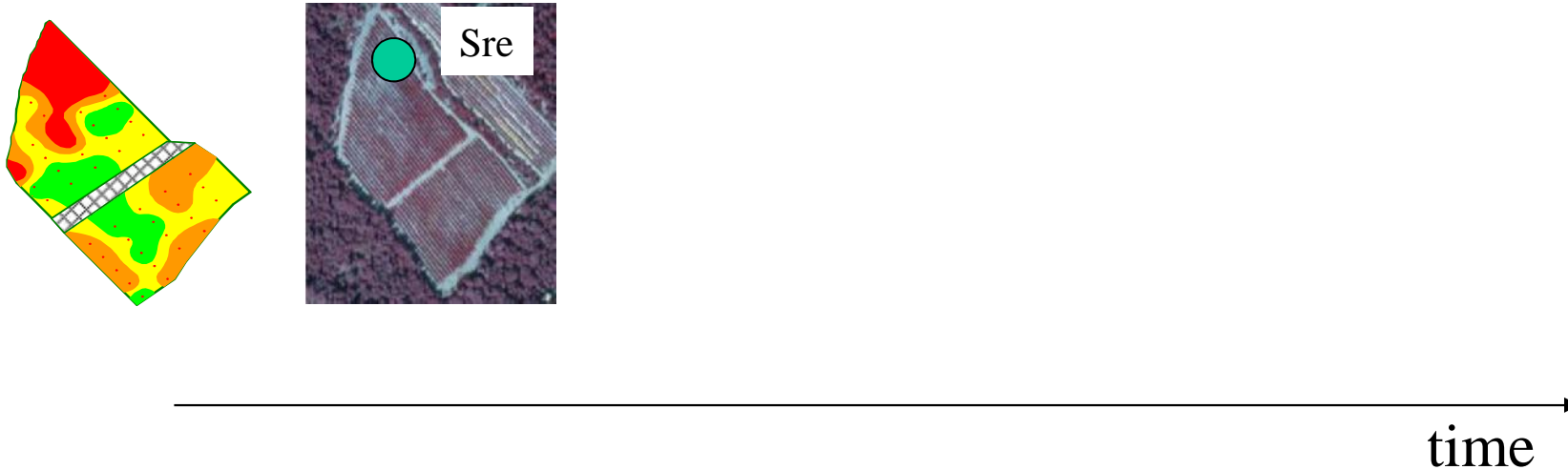
$$\hat{z}(s_i, t_j) = a_{s_i}(z_{re}(s_{re}, t_j))$$

*Acevedo et al., 2010*

## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

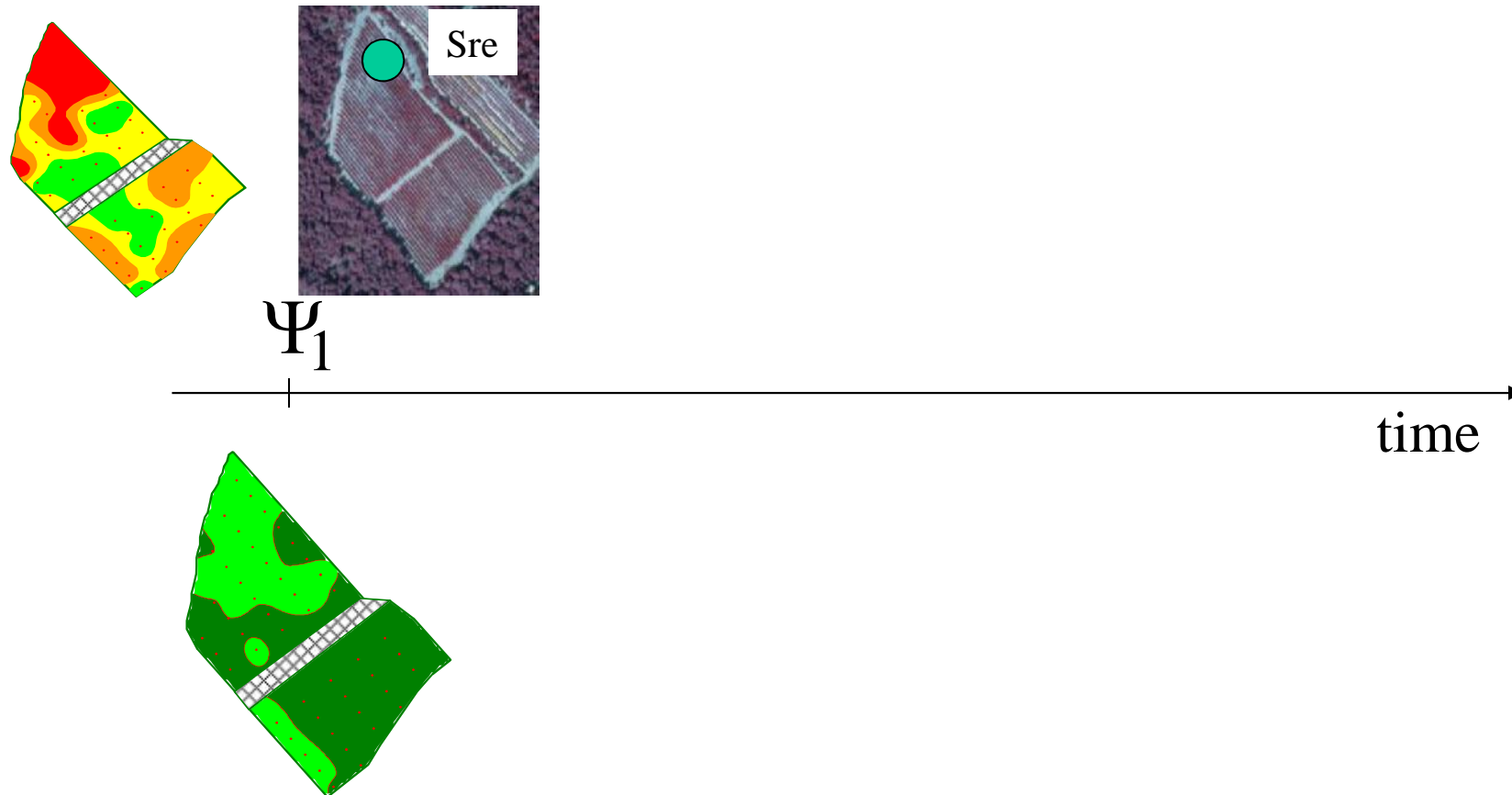
**Towards an extrapolation model of the plant water status**



## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

**Towards an extrapolation model of the plant water status**

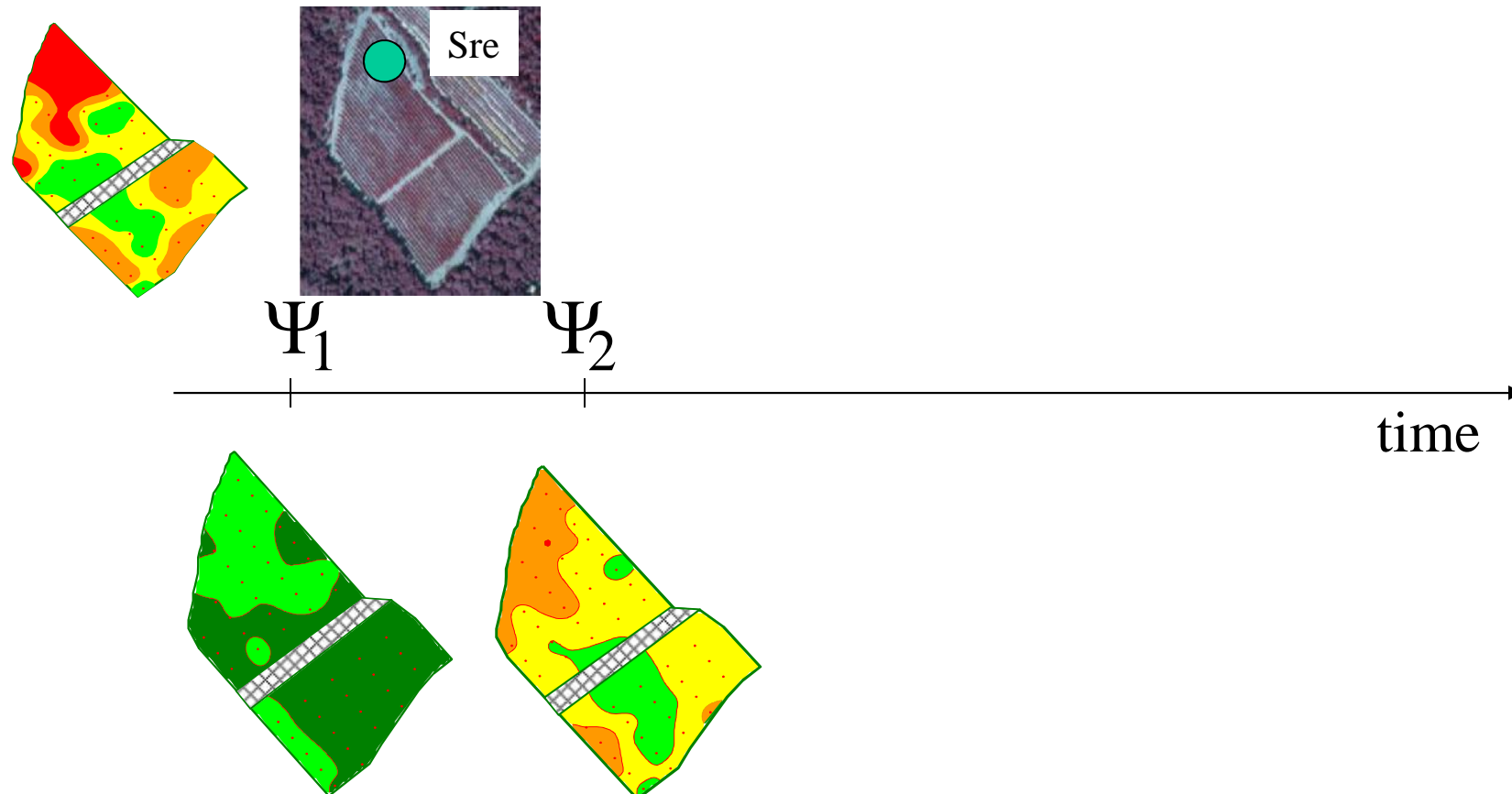




## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

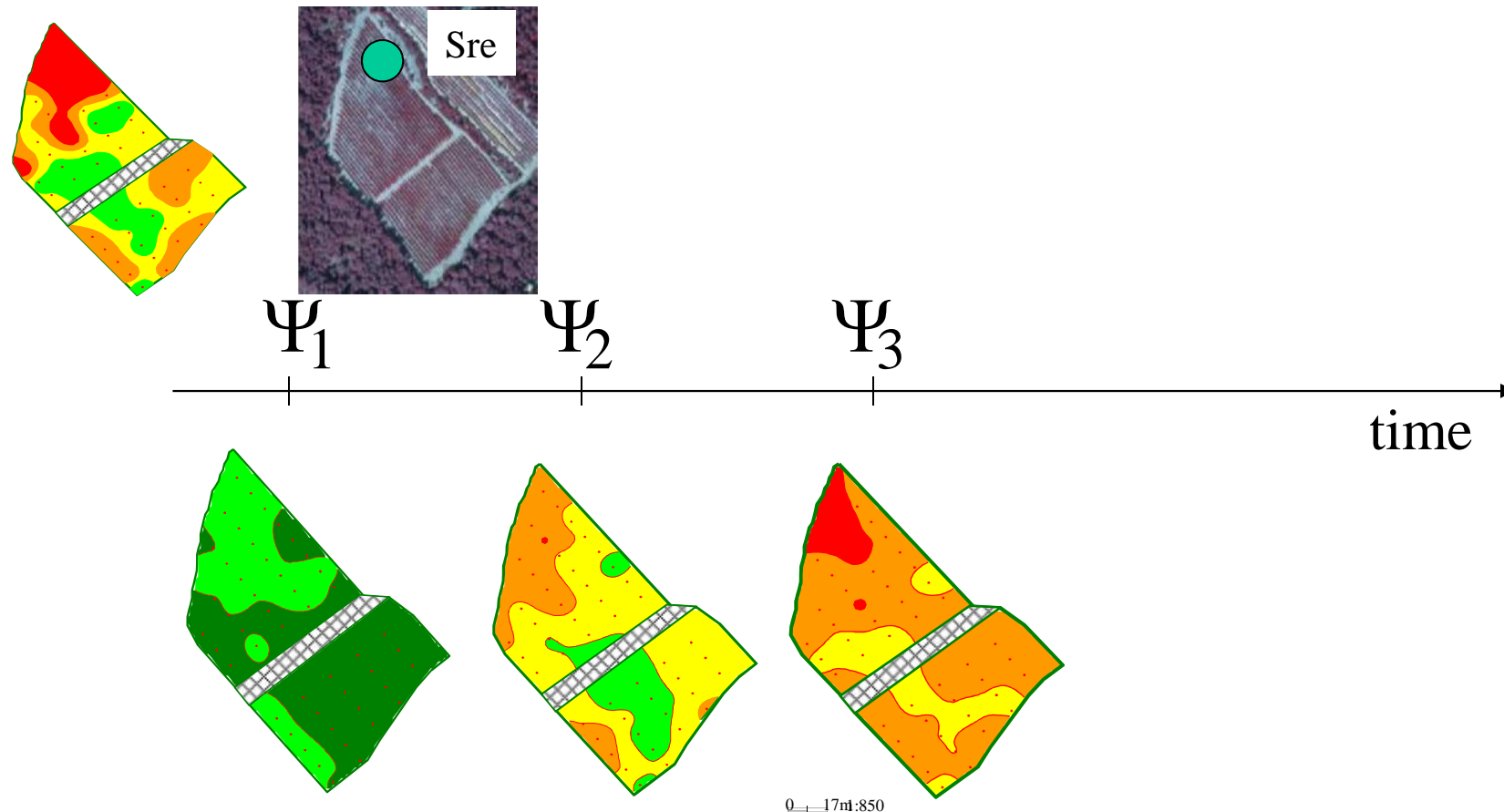
**Towards an extrapolation model of the plant water status**



## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

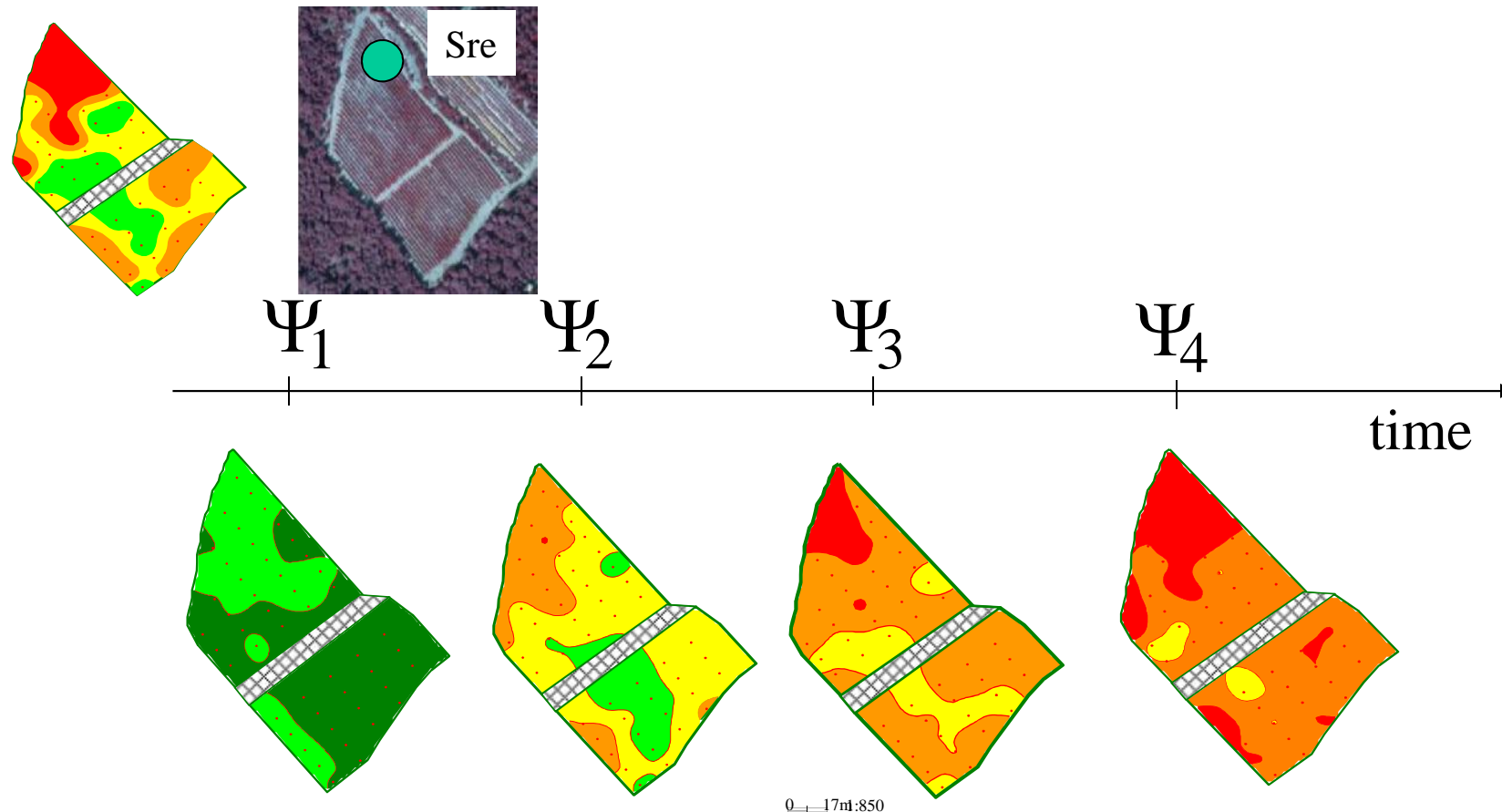
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## 5. Questions addressed during the last years

**Is the variability temporal stable ?**

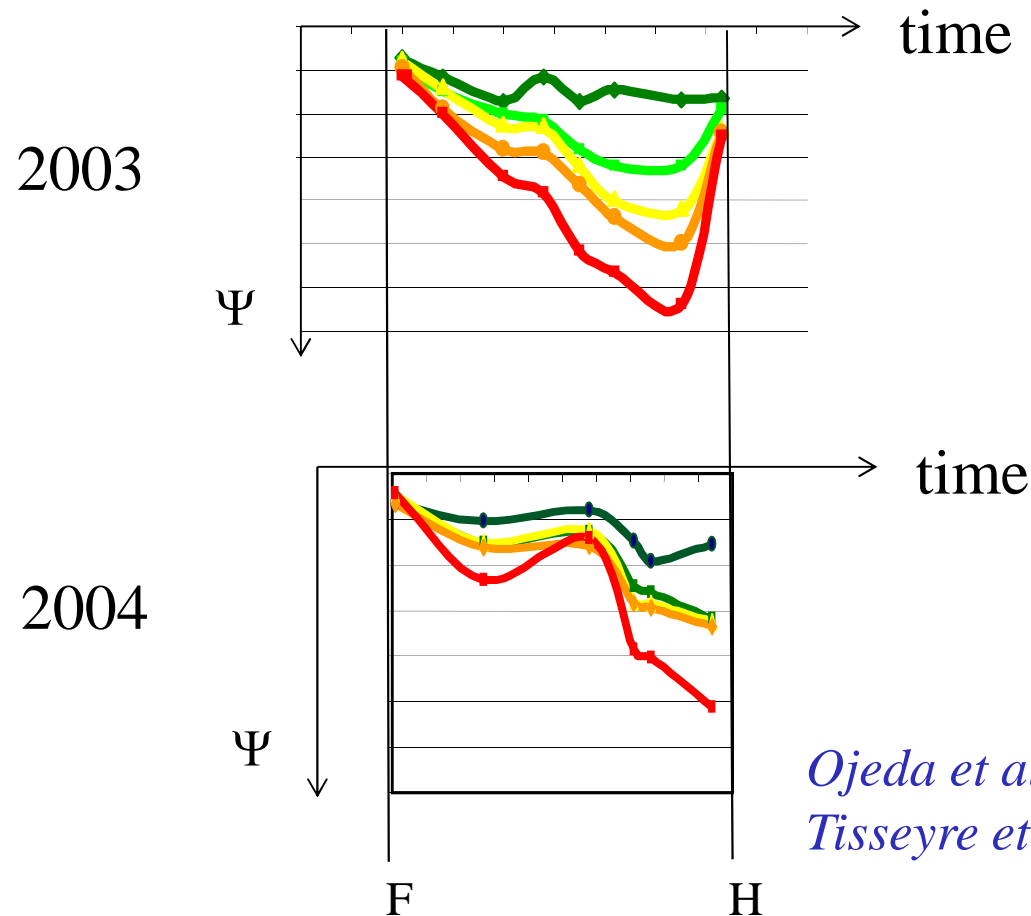
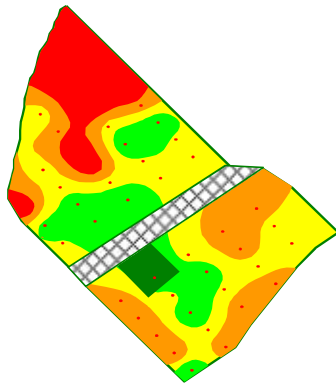
**Towards an extrapolation model of the plant water status**



## 5. Questions addressed during the last years

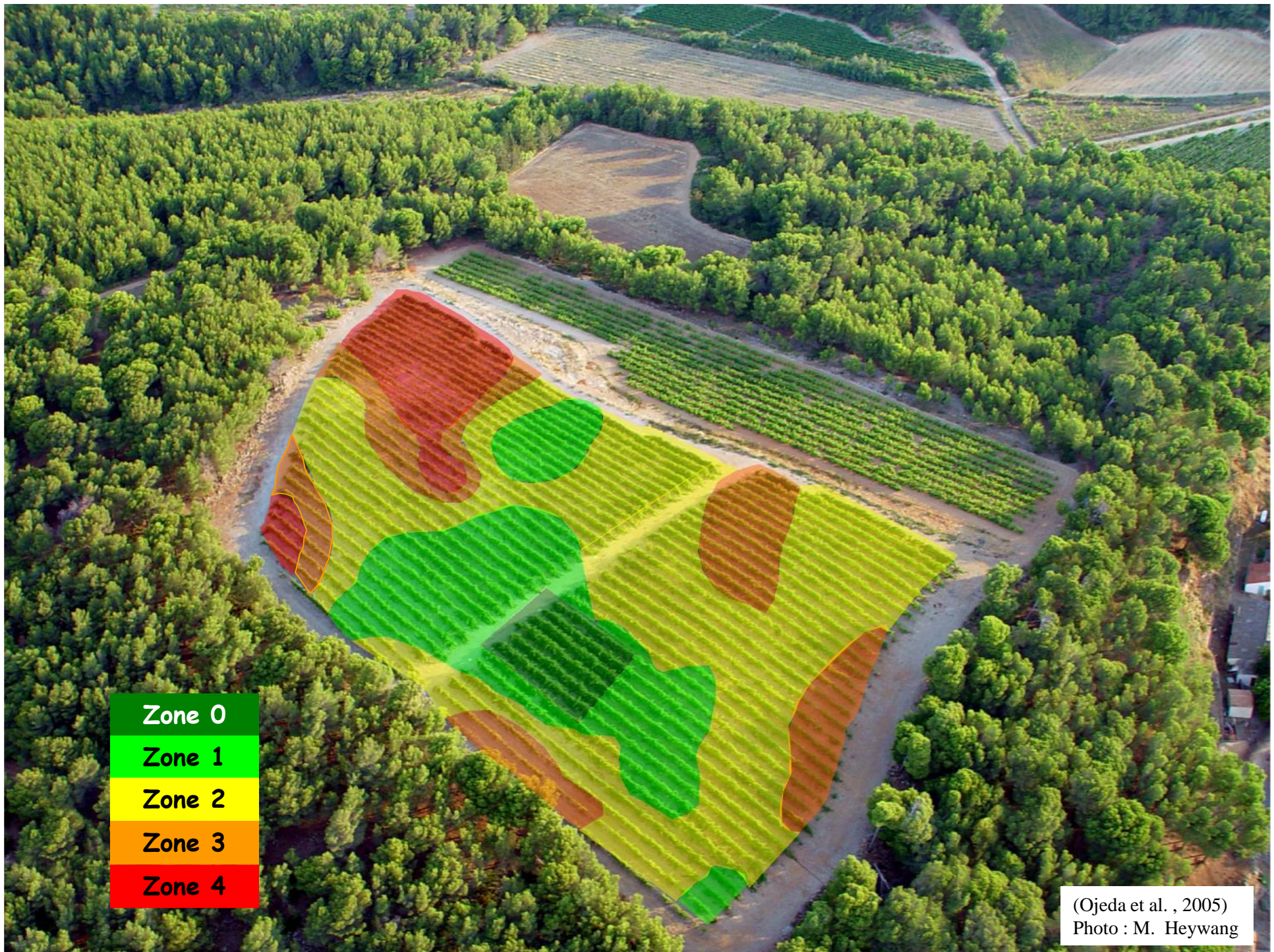
**Is the variability temporal stable ?**

**Interest to identify the spatial structure of the plant water status**



*Ojeda et al., 2005*  
*Tisseyre et al., 2005*





(Ojeda et al. , 2005)  
Photo : M. Heywang



An aerial photograph of a vineyard with a color-coded stress map overlay. The vineyard is surrounded by dense green forest. The map overlay shows a large area of high stress (red) in the upper left, with a smaller area of high stress (red) in the lower left. The rest of the vineyard is mostly green, indicating low stress. The map is divided into five zones, each with a different color: Zone 0 (green), Zone 1 (light green), Zone 2 (yellow), Zone 3 (orange), and Zone 4 (red).

WET SUMMER  
2004

Zone 0

Zone 1

Zone 2

Zone 3

Zone 4

(Ojeda et al., 2005)  
Photo : M. Heywang





DRY and HOT SUMMER  
2003

Zone 0

Zone 1

Zone 2

Zone 3

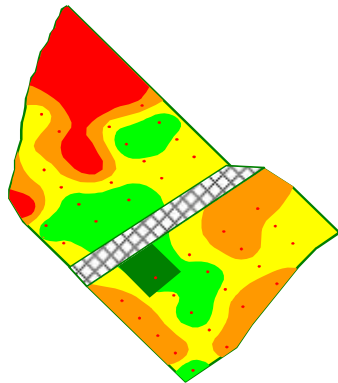
Zone 4

(Ojeda et al., 2005)  
Photo : M. Heywang



## 5. Questions addressed during the last years

### Summary on basic Assumptions for PV adoptions



- > **Significant and organised spatial variability in viticulture,**
- > **Temporal stability of the plant water status within field variability,**
  - > **Temporal stability of production parameters**
  - > **Instability of harvest quality (flip-flop effect),**

**Vigour zones/plant water status zones are relevant management zones for quality purposes.**

## 5. Questions addressed during the last years

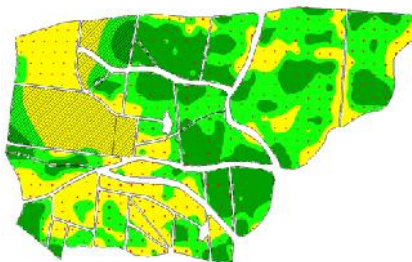
### How to define quality zones ?

Like for other crops two main information may be considered,

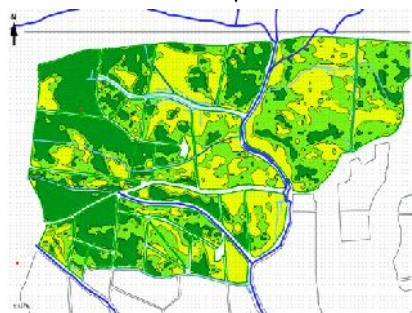
Soil (ERa, ECa) *Barbeau et al.*, 2005,  
Taylor, 2004,  
*Best et al.*, 2005,  
*Lamb et al.*, 2005,  
*Couloma et al.*, 2009,



Sources : [www.geocarta.net](http://www.geocarta.net)



ECa/ERa soil maps



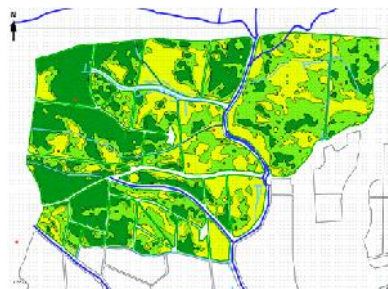
*Montero et al.*, 1999,  
*Lamb et al.*, 2001,  
*Hall et al.*, 2003,  
*Bramley*, 2001,  
*Johnson et al.*, 2003,  
*Dobrowski et al.*, 2003,  
*Best et al.*, 2005,  
*Bramley et al.* 2005,  
*Arno et al.* 2005,  
*Acevedo et al.*, 2008,  
*Santesteban et al.*, 2013,

Multispectral images  
Vegetative indexes

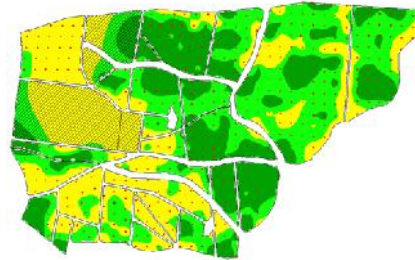
## 5. Questions addressed during the last years

### The general Idea :

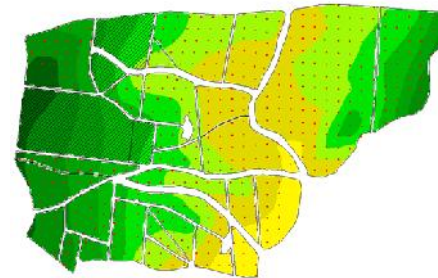
1. Define temporal stable vigour zones based on High resolution information,



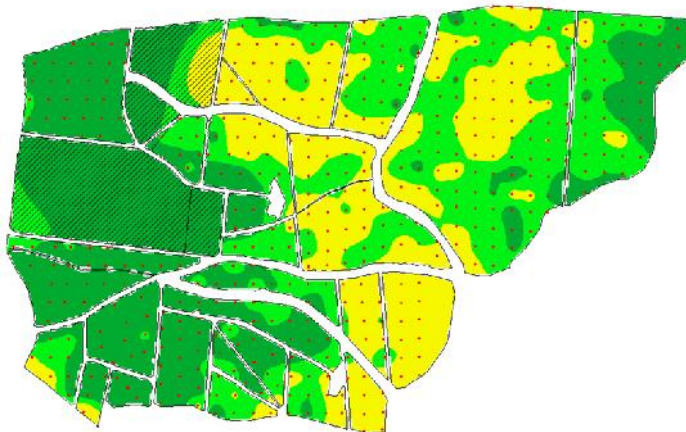
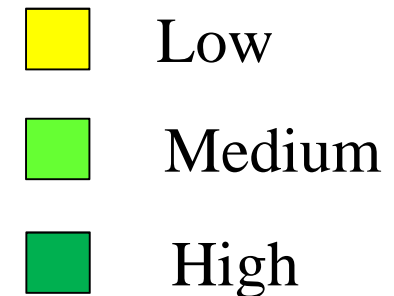
NDVI



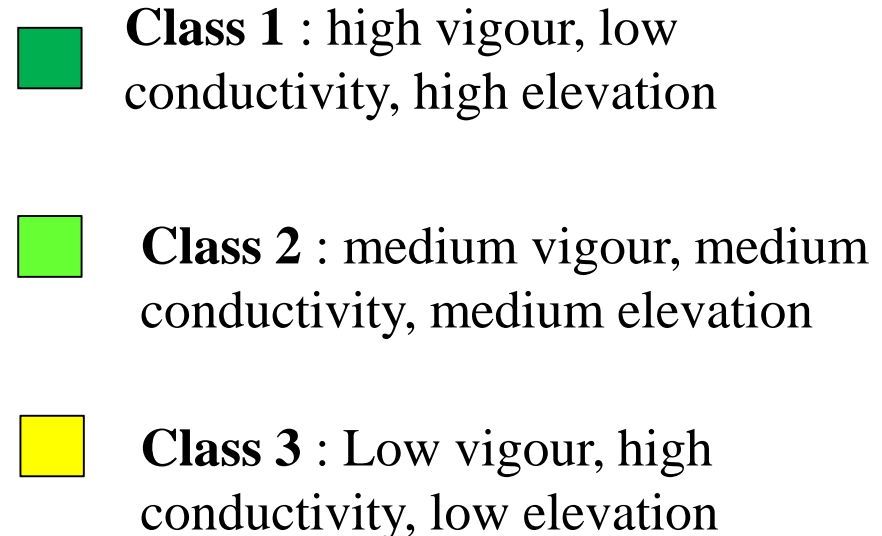
Conductivity



Elevation



Classification

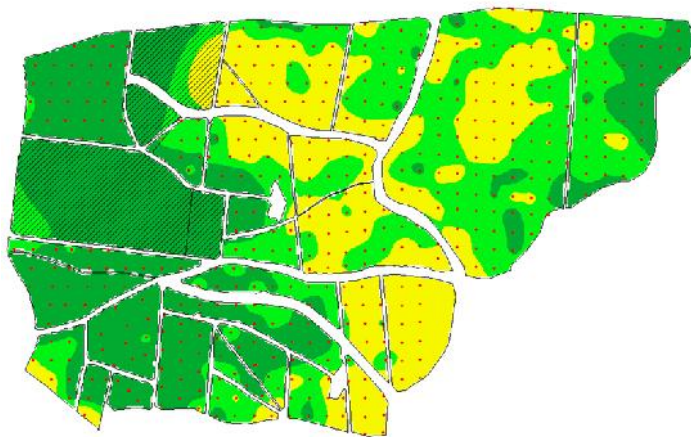




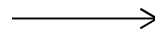
## 5. Questions addressed during the last years

### The general idea :

1. Define temporal stable vigour zones based on high resolution information,
2. Additional sampling
  1. Validation,
  2. Agronomical information about possible management,
  3. Quality parameters -> differential harvest



Classification



Ground truth sampling



## 5. Questions addressed during the last years

### Some specific issues in viticulture



Metallic trellising and resulting magnetic field on ECa

*Lamb et al., 2005*

ERa should be preferred for narrow vineyard ?

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### Some specific issues in viticulture



Metallic trellising and resulting magnetic field on ECa

*Lamb et al., 2005*

ERa should be preferred for narrow vineyard ?



Example of a specific traddle designed for narrow vineyards

## 5. Questions addressed during the last years

### Some specific issues in viticulture

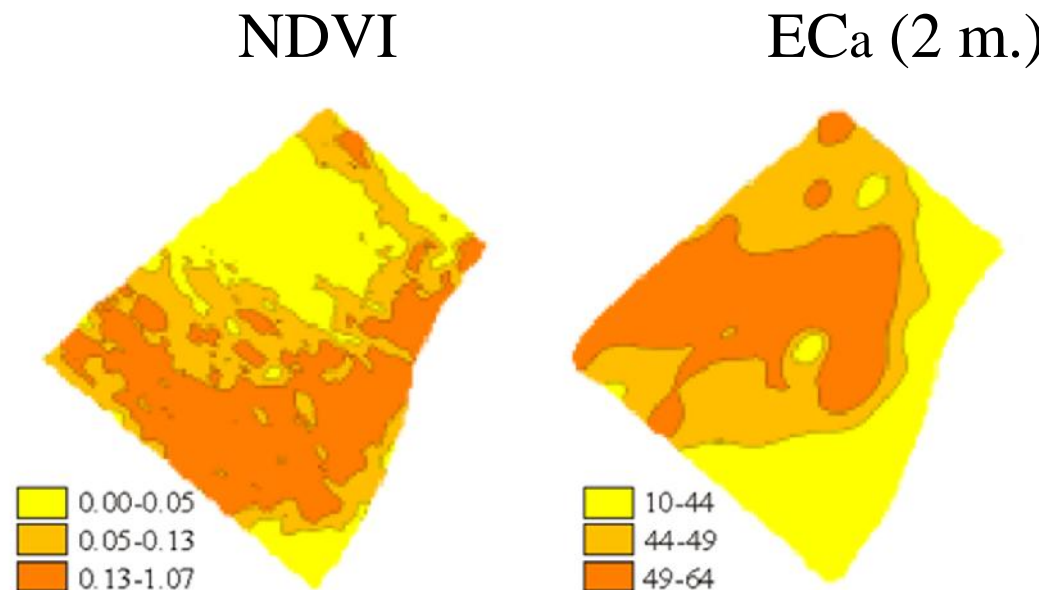


Roots can be deeper than 5 m. in dry vineyards

## 5. Questions addressed during the last years

### Some specific issues in viticulture

Vigour spatial patterns may not corresponds to soil conductivity spatial patterns at 2 m.



Couloma et al., 2009



## 5. Questions addressed during the last years

### Some specific issues in viticulture



Cover crop between the rows

Incidence of training systems and cover crop on vegetative index

Kazmiersky et al., 2011.

Tisseyre et al., 2011.

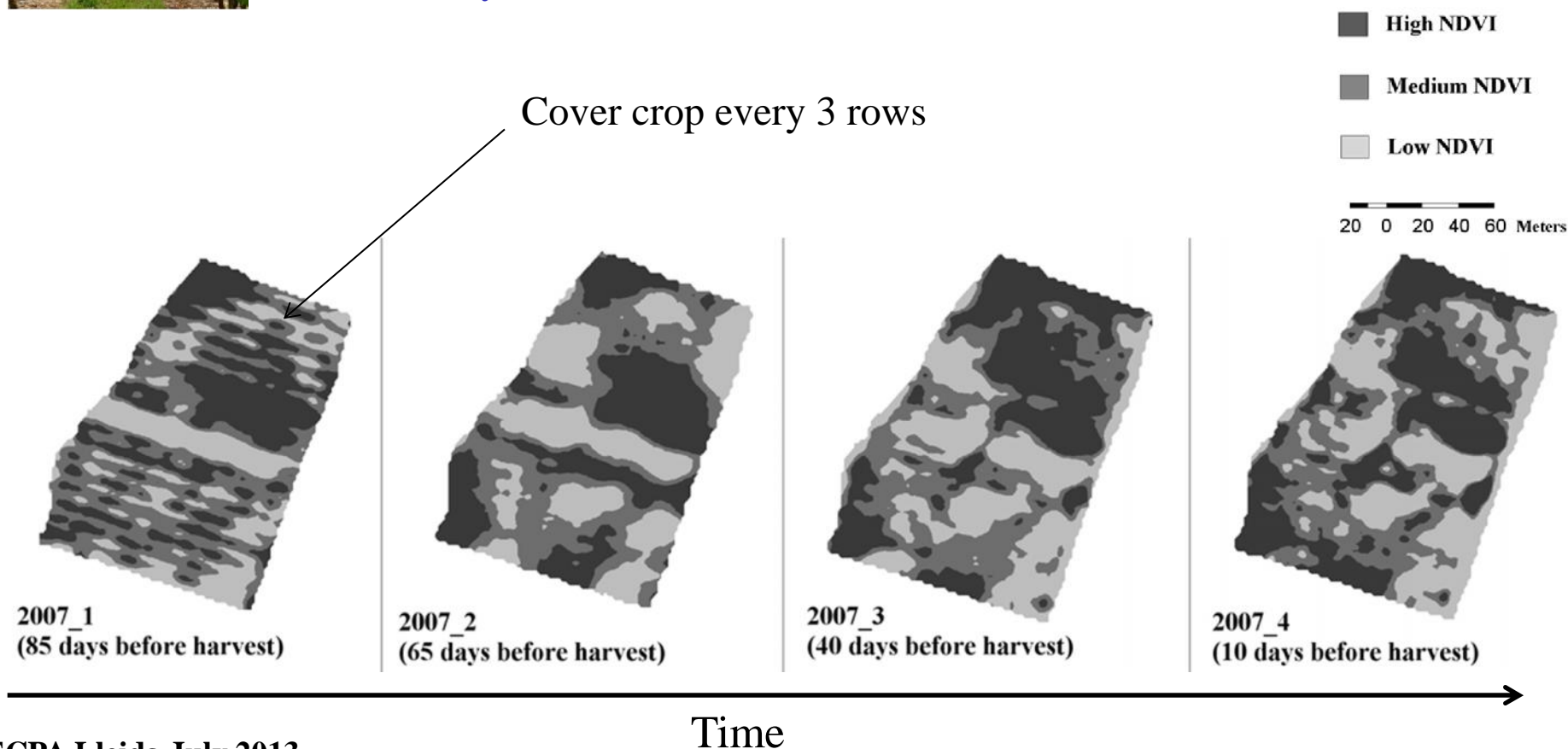
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Incidence of training systems and cover crop on vegetative index

[Kazmiersky et al., 2011.](#)



## 5. Questions addressed during the last years

### Some specific issues in viticulture



Incidence of training systems and cover crop on vegetative index

[Kazmiersky et al., 2011.](#)

Possible strategies to overcome cover crop incidence

- Wait for the crop to dry (but delay of image acquisition),

## 5. Questions addressed during the last years

### Some specific issues in viticulture

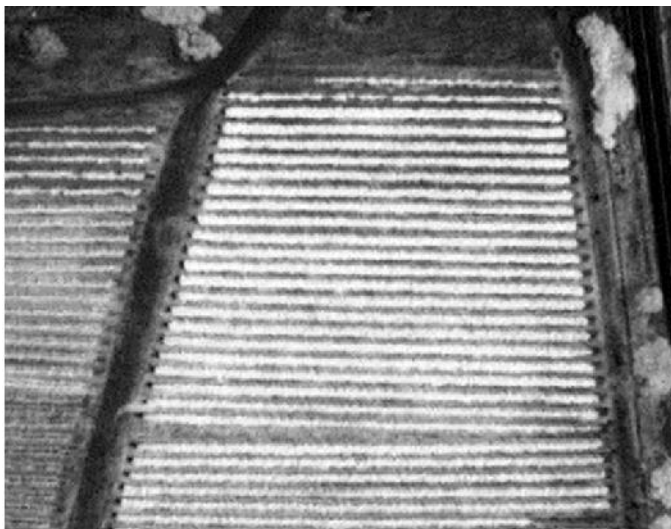


Incidence of training systems and cover crop on vegetative index

[Kazmiersky et al., 2011.](#)

Possible strategies to overcome cover crop incidence

- high resolution images



Very high resolution images  
Vine rows segmentation

→ New opportunities with  
Unmanned Aerial Vehicles

[Matese et al., 2013](#)

## 5. Questions addressed during the last years

### Some specific issues in viticulture



Incidence of training systems and cover crop on vegetative index

[Kazmiersky et al., 2011.](#)

Possible strategies to overcome cover crop incidence

- On board sensors



Use of on board sensors

- Greenseeker [Drissi et al., 2009.](#)
- Crop circle [Stamatiatis et al., 2010.](#)
- Multiplex [Debuisson et al., 2010.](#)



## 5. Questions addressed during the last years

### Some specific issues in viticulture



Incidence of training systems and cover crop on vegetative index

Possible strategies to overcome cover crop incidence

- On board sensors some specific strategies like in Champagne (Physiocap®)



Morlet, 2013



## 5. Questions addressed during the last years

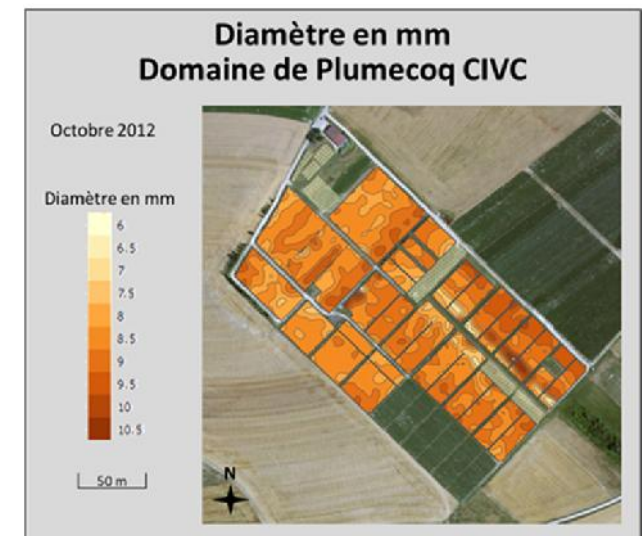
### Some specific issues in viticulture



Incidence of training systems and cover crop on vegetative index

Possible strategies to overcome cover crop incidence

- On board sensors some specific strategies like in Champagne (Physiocap®)



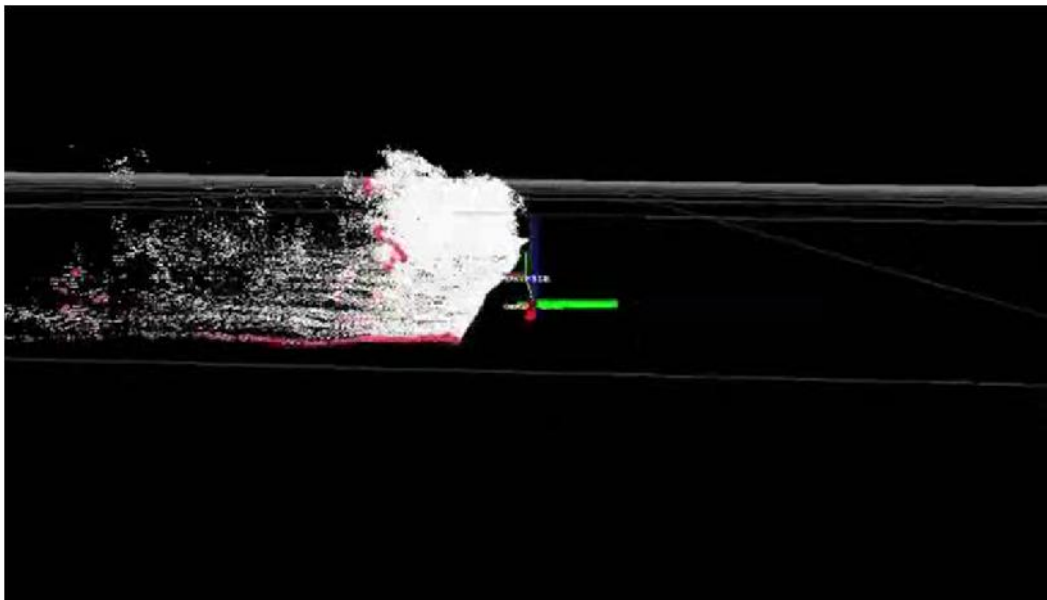
## 5. Questions addressed during the last years

### Some specific issues in viticulture

Investigations on board lidar to characterize the vine canopy

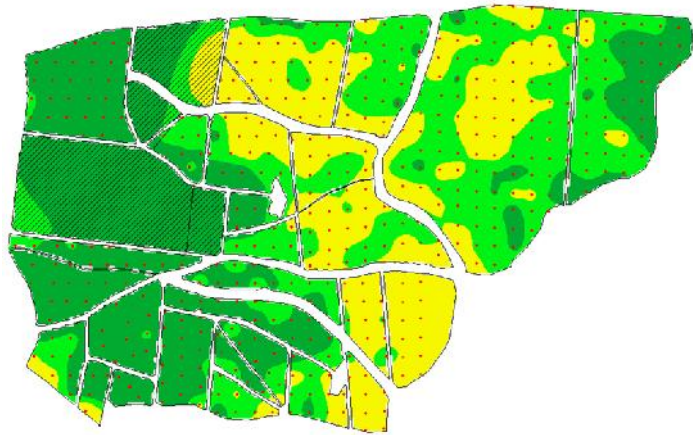
Sanz et al., 2013

Rosell et al., 2009



## 5. Questions addressed during the last years

### How to define within-field quality zones ?



Classification



Ground truth sampling

[Santesteban et al., 2013,](#)



## 5. Questions addressed during the last years

### How to define within-field quality zones ?

#### Hand-held sensors (spectrometry, fluorescence, machine vision)

*SPECTRON™*  
Pellenc, IRSTEA, IFV



[www.pellenc.com](http://www.pellenc.com)  
Geraudie et al., 2010

*Qualiris grappe™*



[www.sodimel.fr](http://www.sodimel.fr)  
Serrano et al., 2005

*Multiplex™*  
Force-A



[www.force-a.eu](http://www.force-a.eu)  
Baluja et al., 2012.

*Premivm™*  
Psl, KIT



[www.premivm.eu](http://www.premivm.eu)  
Navratil et al., 2012.

# Summary



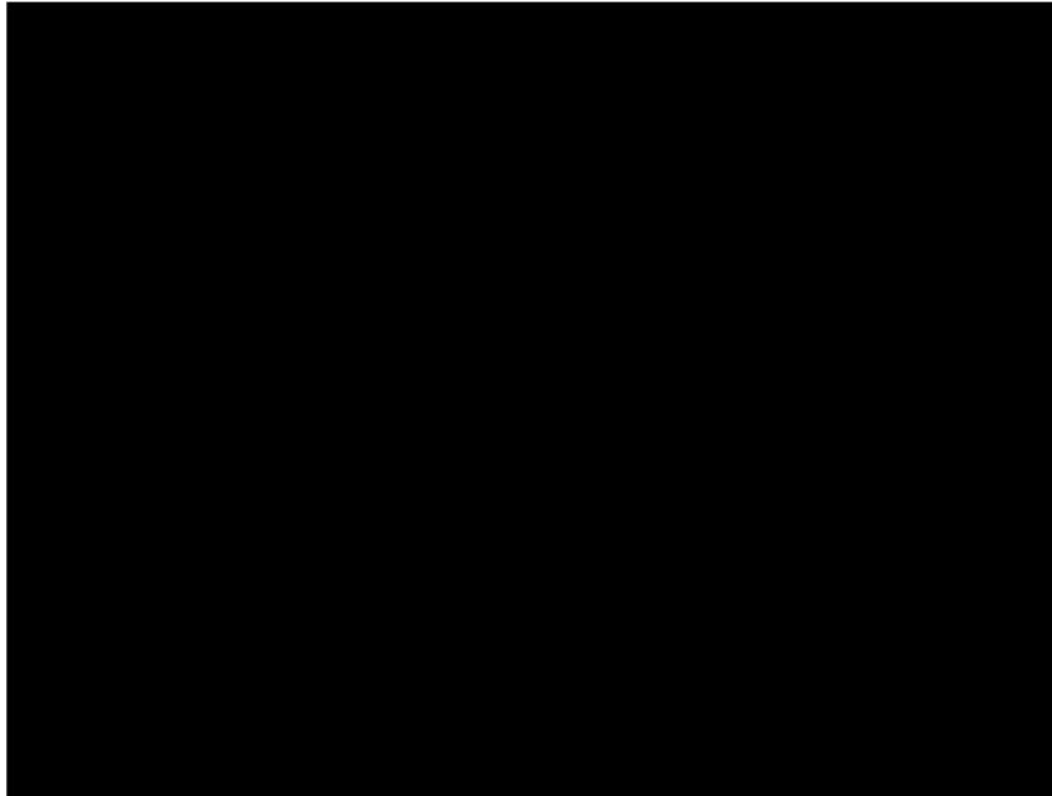
- 1. Some figures about viticulture**
- 2. Some unique features (expectation about PV)**
- 3. Specificities of the vine cultivation**
- 4. Scientific and technical questions raised by PV**
- 5. Questions addressed during the last years**
- 6. Consideration on PV adoption**
- 7. New questions raised by PV**



## 6 Consideration on PV adoption

### Guidance

High adoption of RTK GPS machine position for planting.



Source : Duvineau

## 6 Consideration on PV adoption

### Yield monitoring

#### Low adoption rate

Adoption by a few large companies (Australia, San Pedro-Chili, Raïmat/Torres-Spain, united states),

Only one manufacturer (ATV, australia),

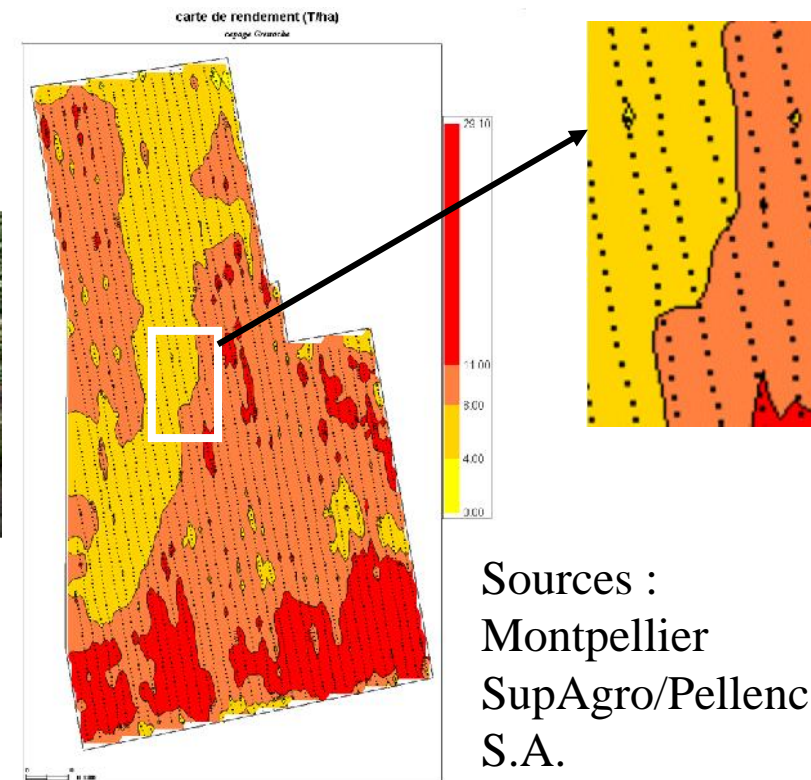
Problem of grape harvesting machines,

Problem of data consolidation



Sources : ATV

#### Yield map

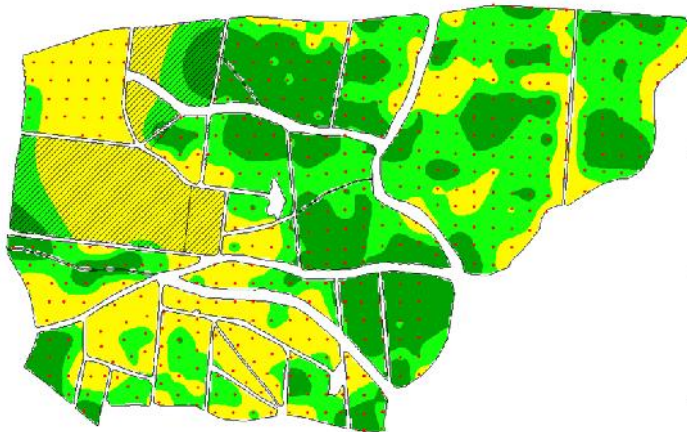


Sources :  
Montpellier  
SupAgro/Pellenc  
S.A.

## 6 Consideration on PV adoption

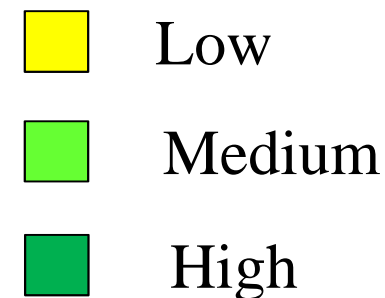
### Soil Survey (ERa, ECa)

- On very high quality vineyards,
- Drawbacks : price of the survey,
- Some interesting economical model
  - Sensor rent and mapping service -> 4000 ha in a cooperatives



Conductivity (ECa)

Santesteban et al., 2013,



## 6 Consideration on PV adoption



### Vigor mapping

- Satellite imagery (Oenoview®, Geosys®) : env. 7000 ha/year,
- Airborne images
  - hard to find reliable figures,
  - many companies world wide (specterra®, avion jaune®, agrosat®, etc.) ,
  - adoption in high quality vineyard and/or within research collaborations.
- Unmanned aerial vehicle
  - Many studies and new services during the last years
  - but economical model is still not clear.
- On board sensors
  - Start of adoption in some specific vineyards (Champagne).

## 6 Consideration on PV adoption

### Differential harvest

- Only two prototypes of grape harvesters
  - New Holland (Coex, France)
  - Gruppo Italiano Vini (Italy),
- Possible strategy when grape harvesting machines without tanks.

*Bramley and Hamilton, 2004*

*Taylor, 2004*

*Sethuramasamyraja et al., 2010*

*Bramley et al., 2011*

*Odair Santos et al. , 2012*



Source : GIV - Lonardi



## 6 Consideration on PV adoption

### Variable rate fertilisation for viticulture

- Released commercial Machines specially dedicated to vineyards (Casella ®/Terradat ® , Tecnovict ® Italy)



Source : Lonardi, Casella

### Variable rate leaf removal

- Released commercial Machines (Tecnovict ® Italy)



Source : Tecnovict/Deutz)

### Variable rate sanitary products application for viticulture

- Start of adoption : exemple greenseeker (Avidorhightech ®)

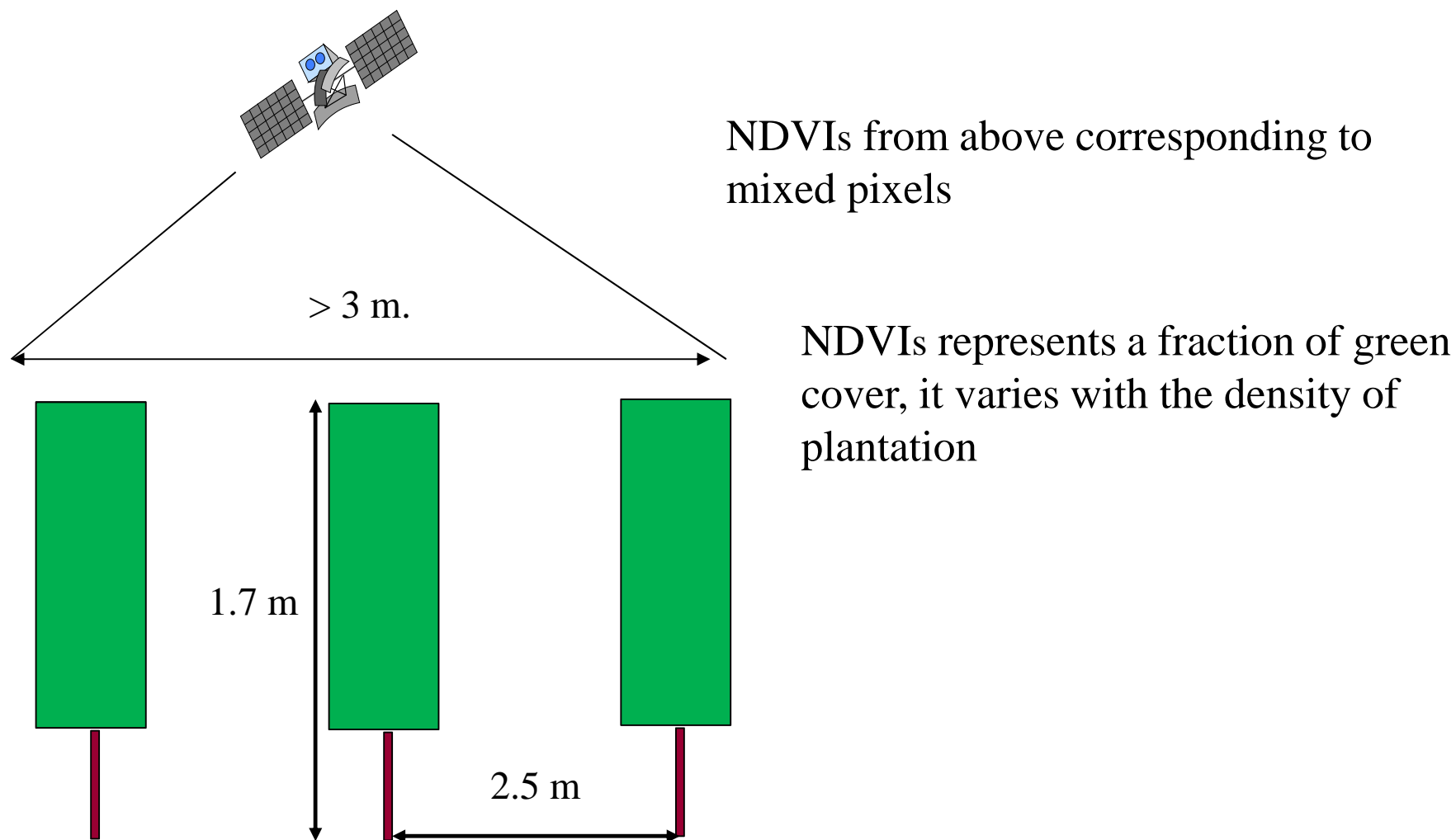
# Summary



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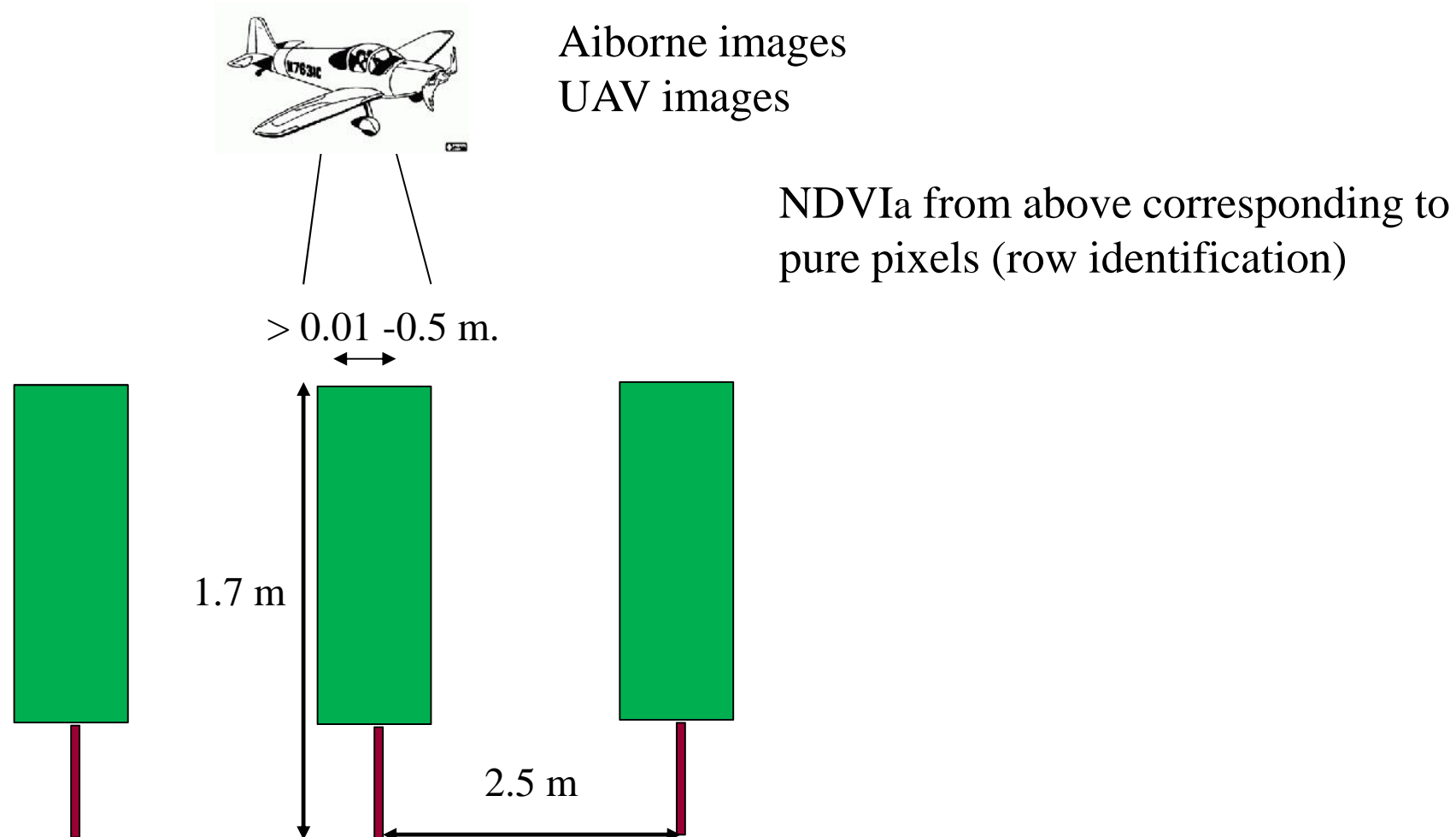
## 6. New questions

Clarification about the meaning of vegetative indices in viticulture



## 6. New questions

Clarification about the meaning of vegetative indices in viticulture



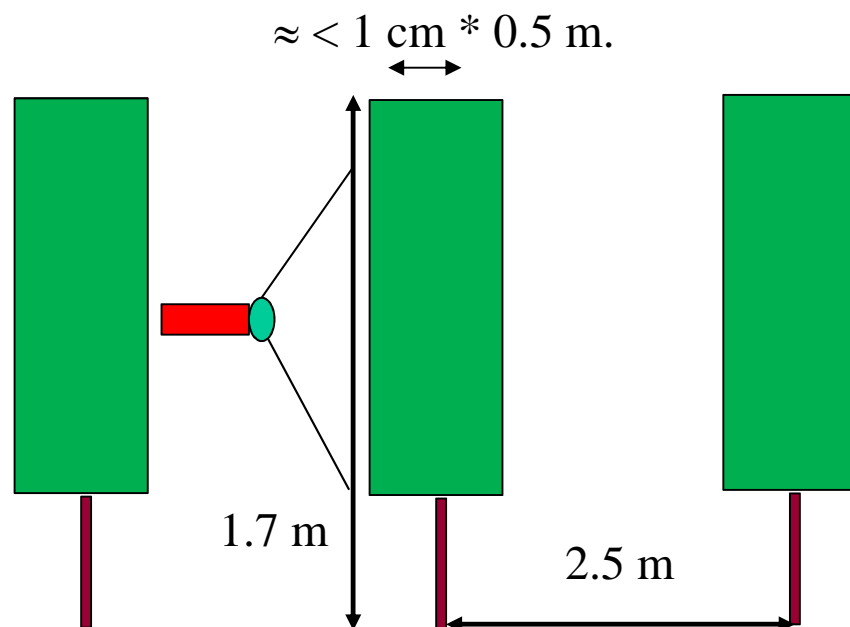


## 6. New questions

Clarification about the meaning of vegetative indices in viticulture

Proxi detection

NDVI<sub>p</sub> from the row corresponding to the porosity of the canopy.



## 6. New questions



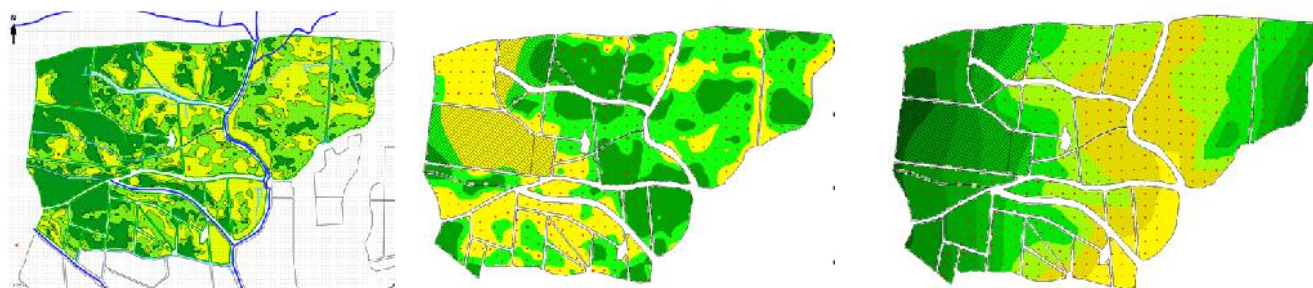
Clarification about the meaning of vegetative indices in viticulture

### **NDVIs, NDVIa and NDVIp**

- Often called with the same term, NDVI (even in scientific papers),
- Provide relevant indirect information about within field variability of canopy size and shape to estimate vigour variability,
- Corresponds in reality to very different measurements.
- Improve the knowledge with each NDVI and the relationship with agronomical information taking into account the diversity of the training systems, modelisation of training system and row effect (under development with oenoview®)

## 6. New questions

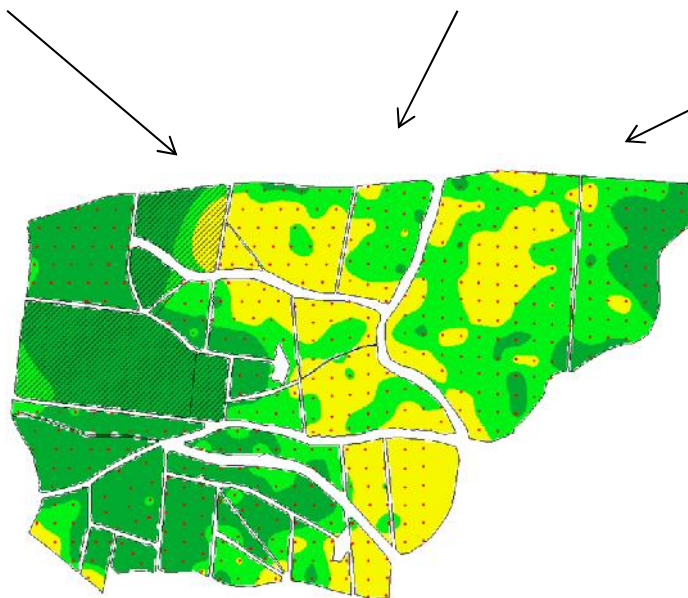
Data processing : need real segmentation algorithm



NDVI

Conductivity

Elevation



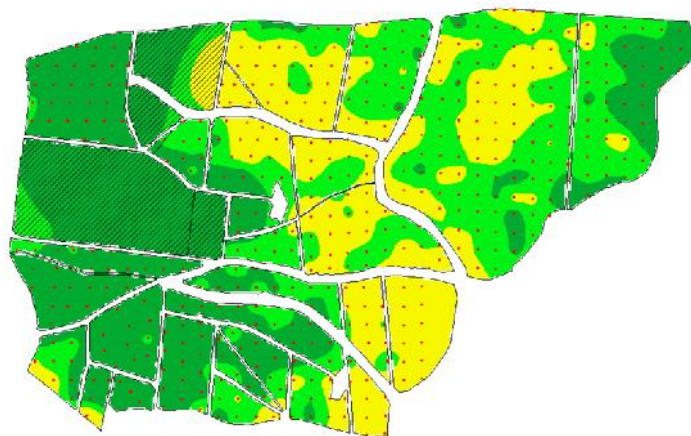
Classification

Common classification methods are not perfect

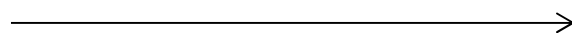
- Classes  $\neq$  zones
- Complicated pre\_processing steps when data resolution is different and or data are not colocated

## 6. New questions

Tools and methods for non destructive measurements and sampling



Classification



Ground truth sampling

Ground truth will always be a necessity :

- Development/improvement of hand held sensors (spectrometry, machine vision, etc.),
- Development of on the go method for sampling optimisation,



## 6. New questions

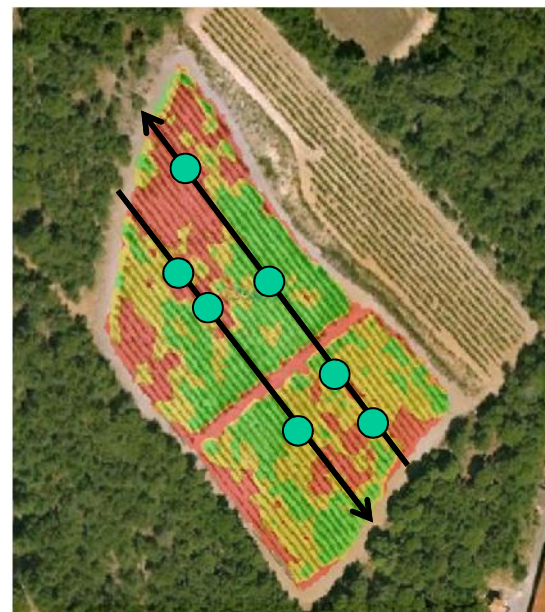
Tools and methods for non destructive measurements and sampling

Optimize sampling taking into account operational constraints :

- 30 fields surveyed /day (over 4000 fields),
- Use of high resolution vigor information on Smartphone with GPS chip,
- Which row to sample ? Which distance between the samples ?



Smartphone, Pocket-PC



Real-time sampling  
optimisation

## 6. New questions



Great expectations on

- Thermal imagery (water status and irrigation management)
- Hyperspectral images (specific estimation of agronomical information),
  - Nitrogen,
  - Disease infestations,

## 6. Conclusion



PV is a necessary step to improve :

- Quality management,
- Sustainability of the production (economical, environmental, and social)

In more than 10 years, researchers provided significant knowledge on :

- Spatial variability and its specificities in all the regions of the world,
- How to use high resolution information (advantages and limitations in most of viticulture regions),
- New and specific sensing systems,

Many research projects are currently trying to answer issues in PV :

- Quality measurement,
- Disease infestation,
- Variable rate application,
- Water management (irrigation),
- Data processing,

## 6. Conclusion



Low adoption

Adoption seems obvious for large wineries,

It is less obvious for cooperatives with small growers (large proportion of the production),

Many research projects are developped in collaboration with large companies.

Very few (none ?) with small holders and cooperatives.

- social diversities,
- many companies/contractors,

Are the needs of large wineries and small holders the same ?



**Thank you**