# Precision Viticulture

B. Tisseyre

*UMR ITAP, Montpellier SupAgro/IRSTEA, France*

**ECPA Lleida July 2013**

# 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**

**Area of main cultivations in the world**

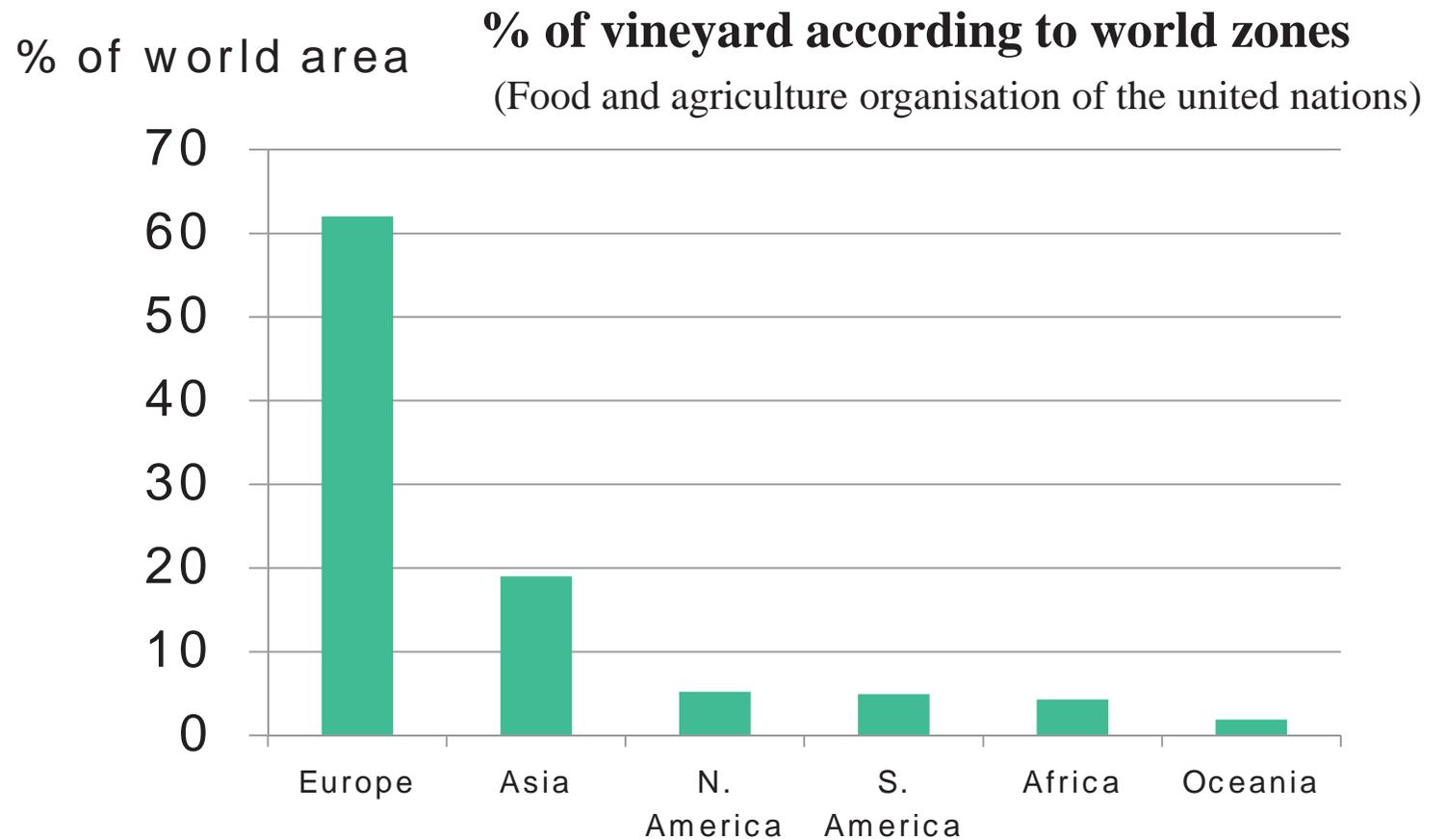**Million ha**   (Food and agriculture organisation of the united nations)

# 1. Some figures about viticulture

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

% of world area

**% of vineyard according to world zones**
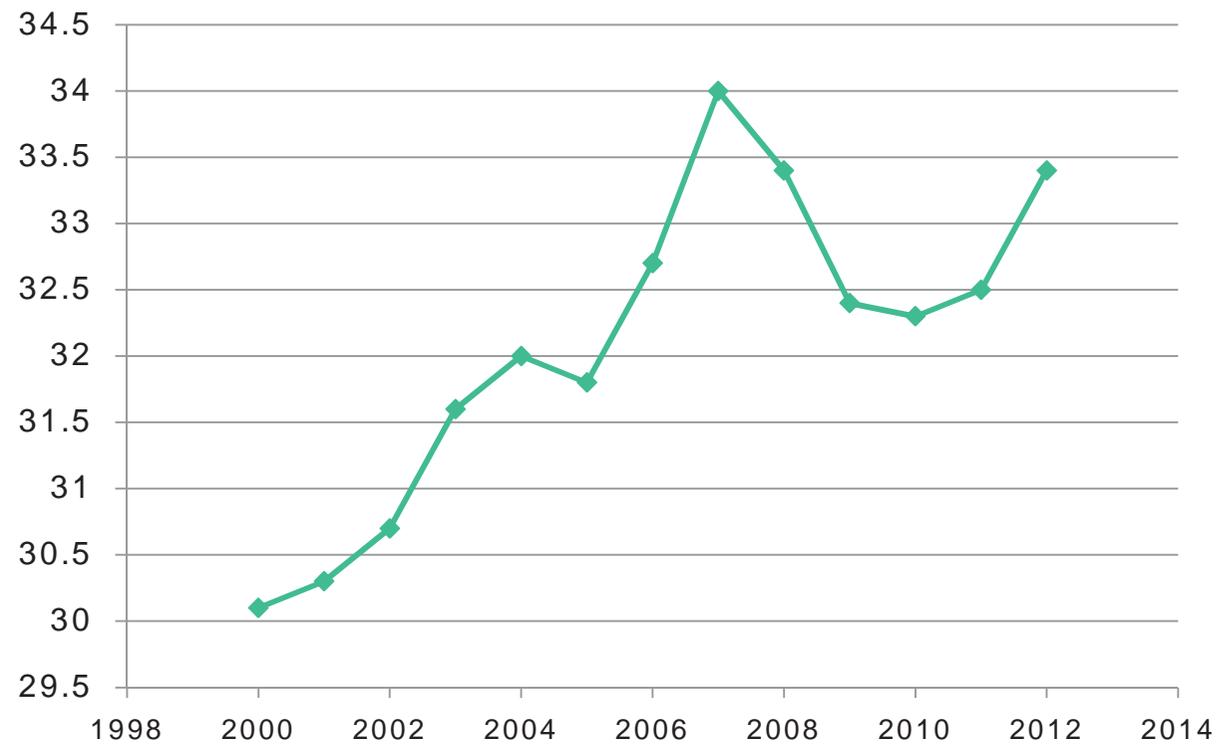(Food and agriculture organisation of the united nations)

# 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)

# Summary

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
5. Questions addressed during the last years
6. Consideration on PV adoption
7. New questions raised by PV

# 2. Some unique features

Ultra premium
> 50 €/bottle

Super premium
> 30 €/bottle

Premium
> 10 €/bottle

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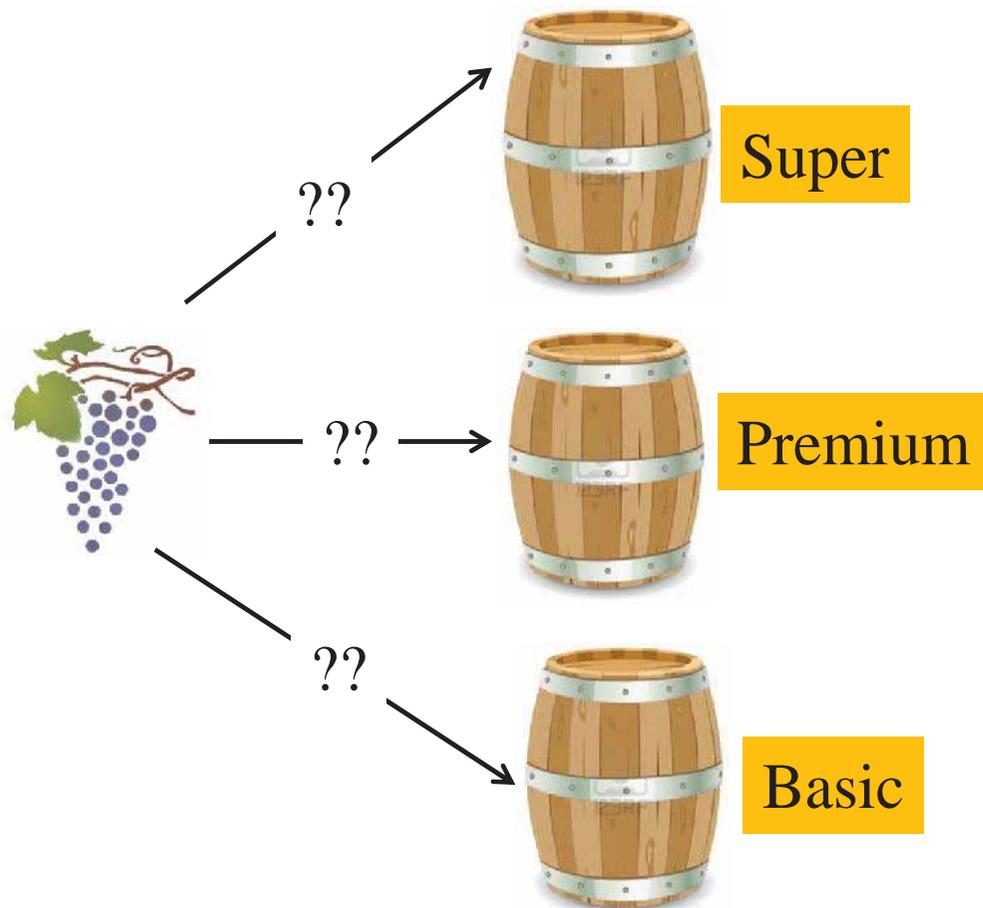**(even in the same winery)**

Popular premium
> 5 €/bottle

Basic
< 5 €/bottle

# 2. Some unique features

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

?? → Super

?? → Premium

?? → Basic

# 2. Some unique features

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

?? → Super

?? → Premium

?? → Basic
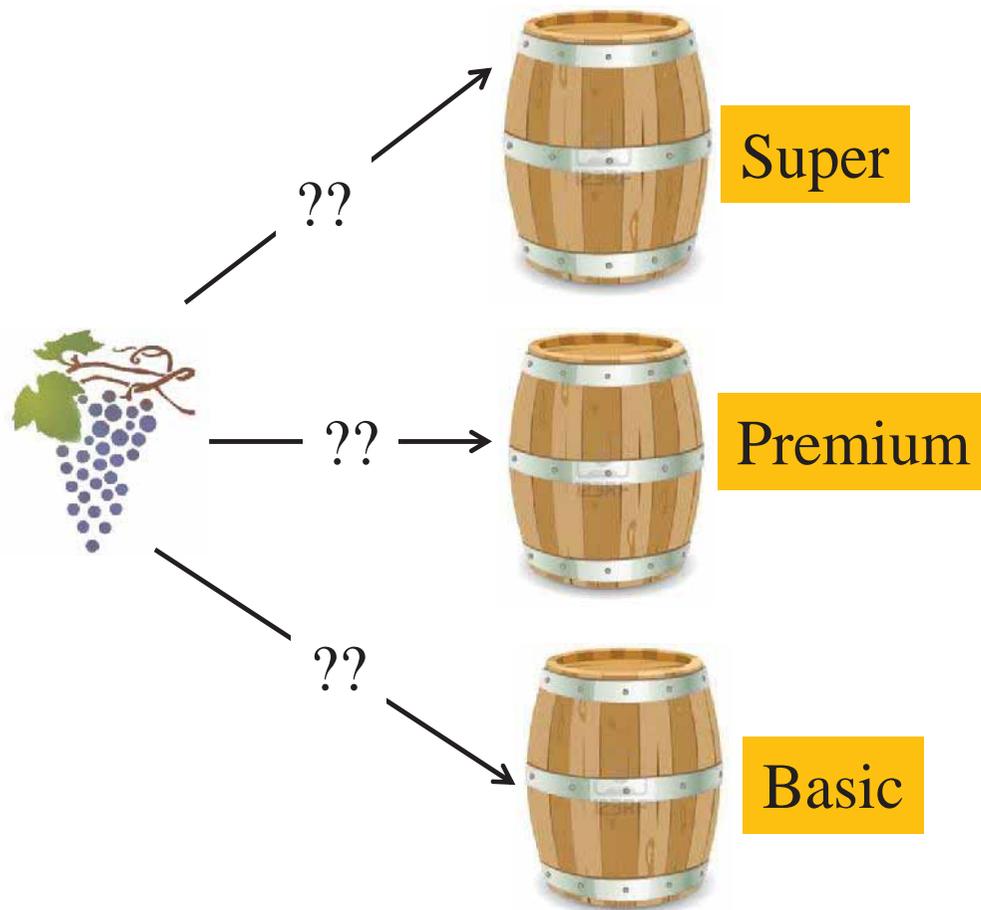
## Opportunity for PV

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

# 2. Some unique features

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

Balance

**Fruit load** ←——————————→ **Canopy/plant vigour**



Low        Medium        High

# 2. Some unique features

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

**Balance**

**Fruit load** ⟷ **Canopy/plant vigour**



Low      Medium      High

- **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**

**Balance**

**Fruit load** ⟵————————⟶ **Canopy/plant vigour**



Low       Medium       High

- **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**

# Summary

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)

-Perenial 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)

-Perenial 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 positionning



Pergola



Bush systems

**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)

-Manual operations (winter pruning)

-Perenial cultivation

-Sparse canopy (soil and vines)

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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 ?**

**Possibility to consider hand held sensors.**

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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 ?**
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- **How to define within-field vigour zones ?**
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    - biomass, plant geometry ?

- **Quality management**

- **Pesticides application**

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- **How to define within-field vigour zones ?**
    - soil fertility ?
    - plant growth ?
    - water status ?
    - biomass, plant geometry ?

    - **Quality management**

    - **Pesticides application**

- **How to define within-field quality zones ?**
    - data processing,
    - specific sensors,

    - **Differential harvest**

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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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There is a significant spatial variability in viticulture

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



As an illustration
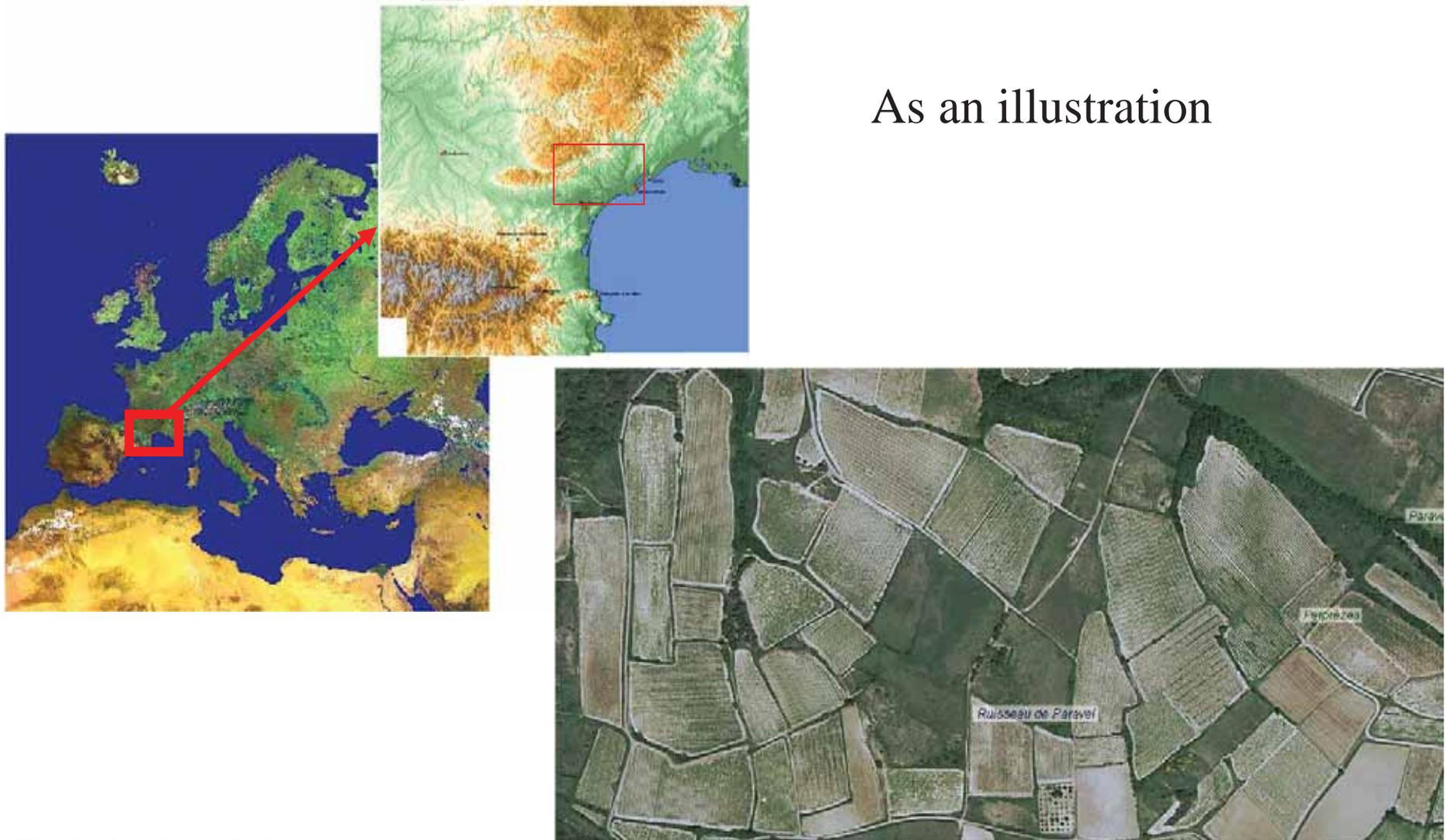
**Is there a within field spatial variability in viticulture ?**



1.1 ha

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

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



Trends/gradients

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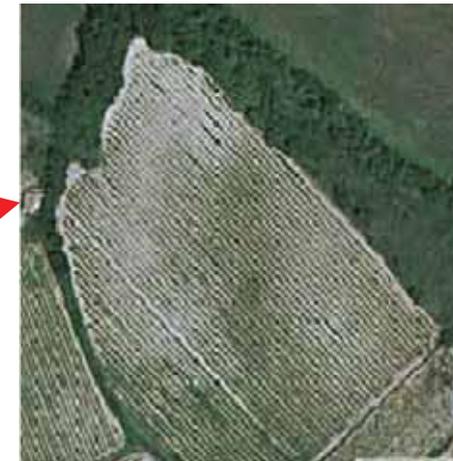


Spatial patterns



Spatial patterns

# 5. Questions addressed during the last years

**<span style="color:red">Is there a within field spatial variability in viticulture ?</span>**

Why this variability within small fields ?

# 5. Questions addressed during the last years

**<span style="color:red">Is there a within field spatial variability in viticulture ?</span>**

Why this variability within small fields ?



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

**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



Yield

**Is the spatial variability temporal stable ?**

**How to characterize the temporal stability ?**
Adaptation of a rank test (Kendall)
(*Tisseyre et al., 2008*)



Yield

high
Medium
Low

Kg/vine

1999   2000   2001   2002   2003   2004   2005
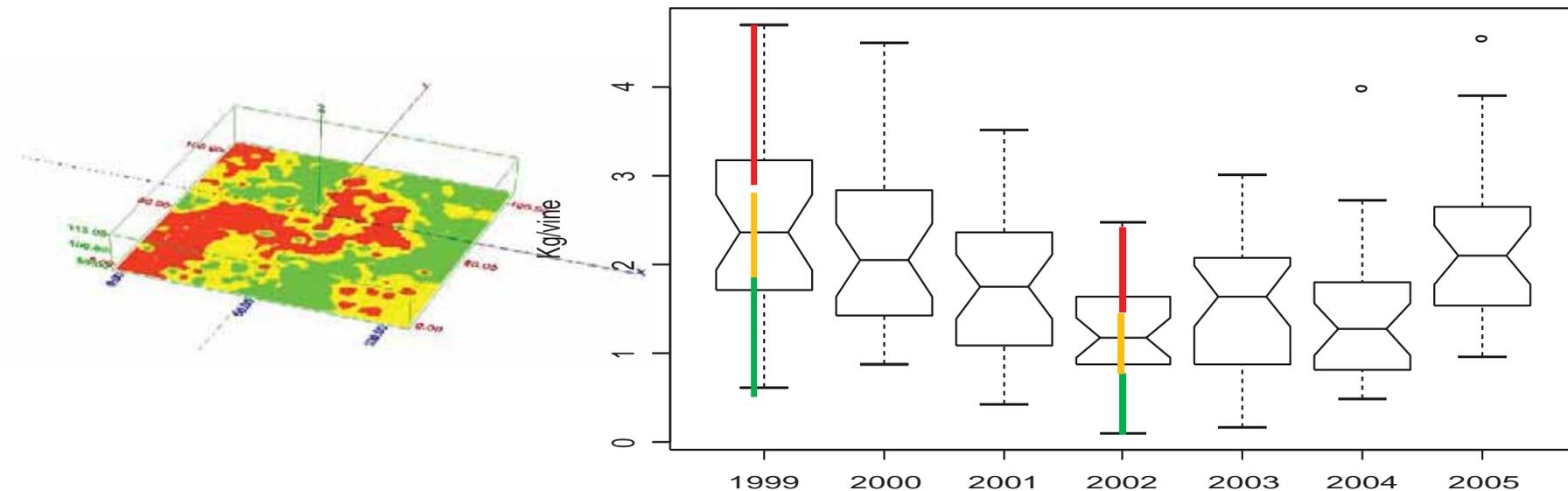
# 5. Questions addressed during the last years

**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) |
| Water status (PLWP)* | 0.87 | *** |
| Vigour | 0.76 | *** |
| Yield | 0.59 | *** |
| pH | 0.37 | Ns |
| Sugar content | 0.35 | Ns |
| Acidity | 0.29 | Ns |

Temporal stable

Not stable over the time

*(Tisseyre et al., 2008)*

# 5. Questions addresse
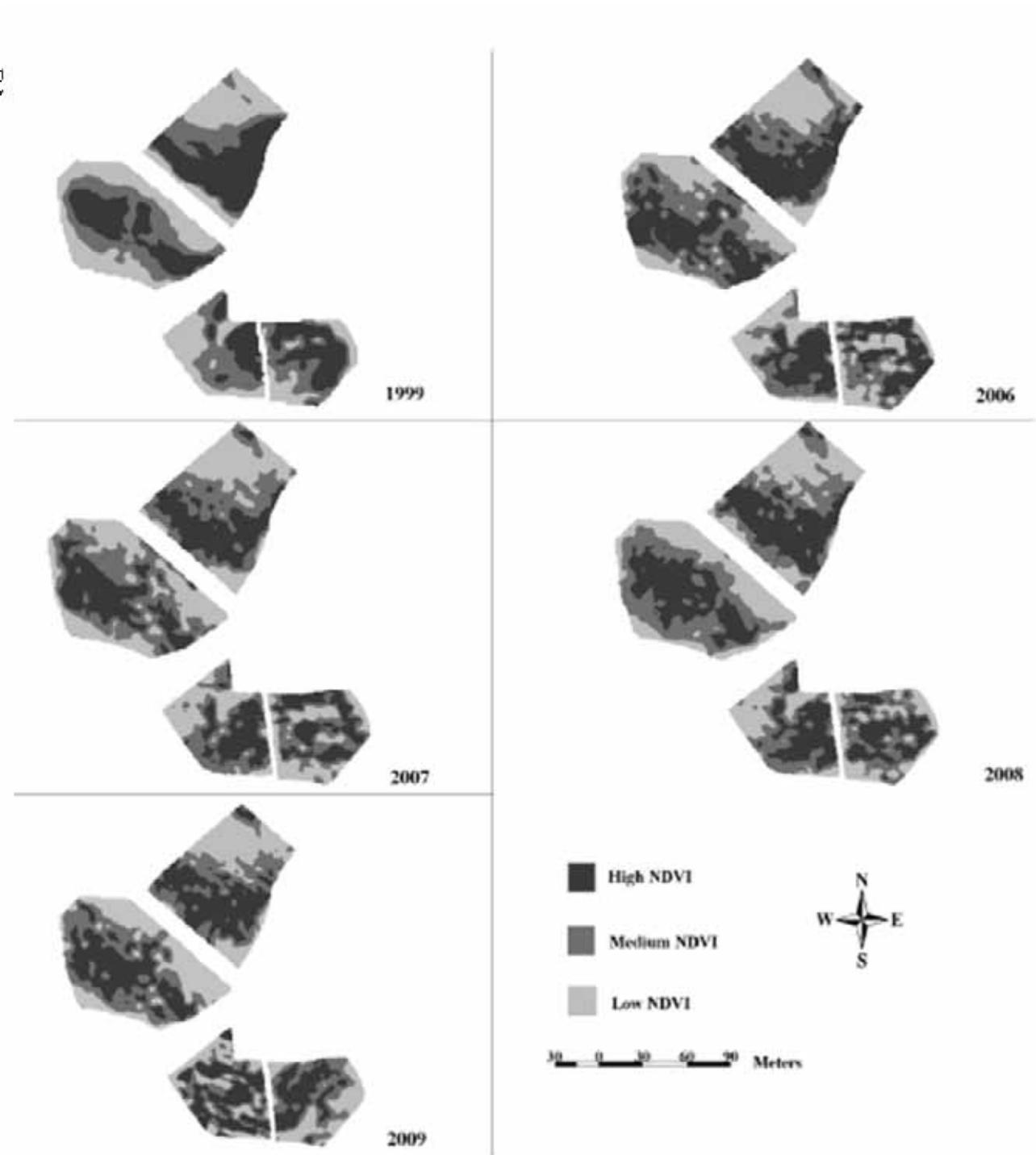
**Is the variability
temporal stable ?**



Kazmiersky et al., 2011

# 5. Questions addresse

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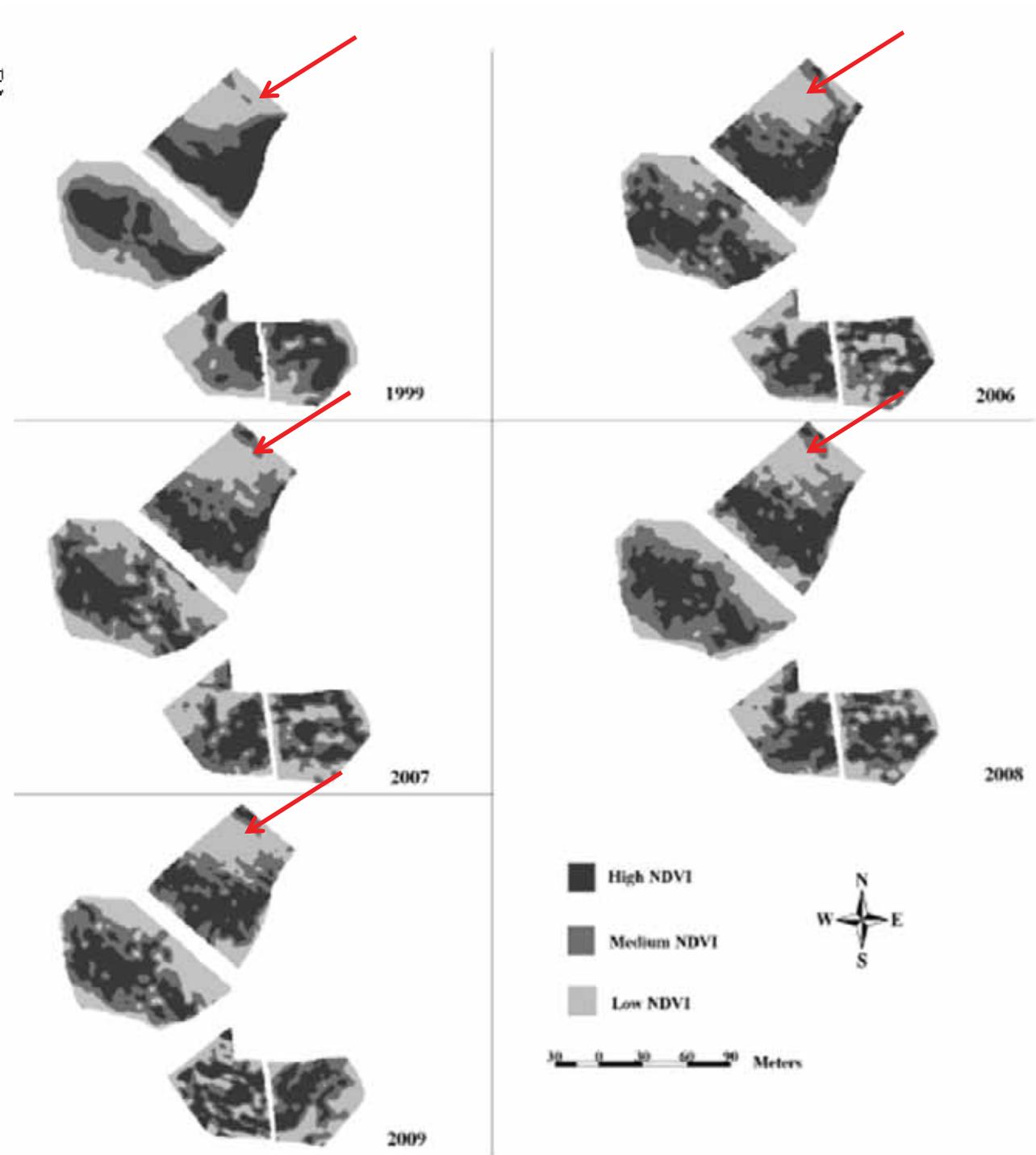


Kazmiersky et al., 2011

# 5. Questions addresse

**Is the variability temporal stable ?**
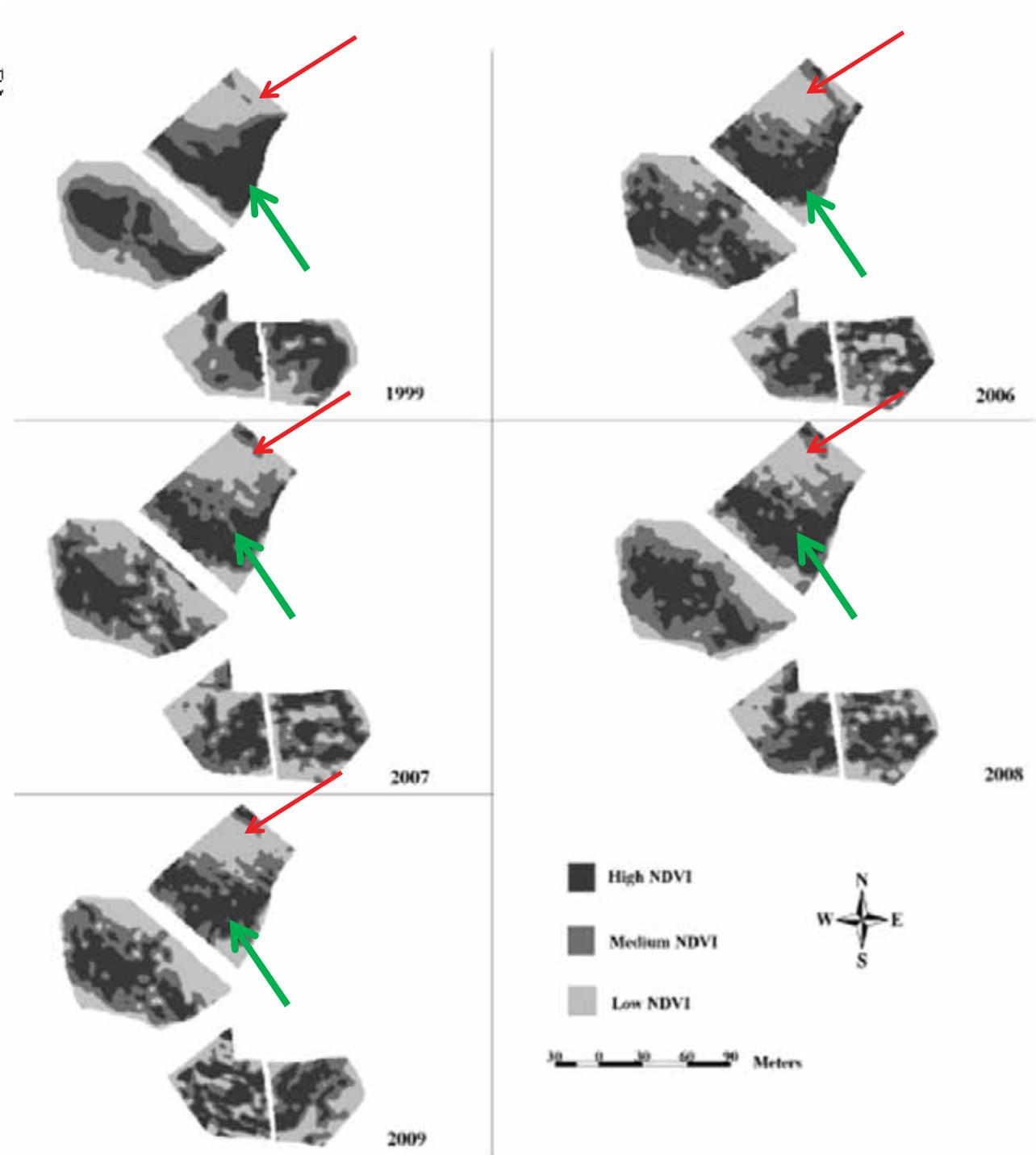


Kazmiersky et al., 2011

# 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**

$as_i$

Sre
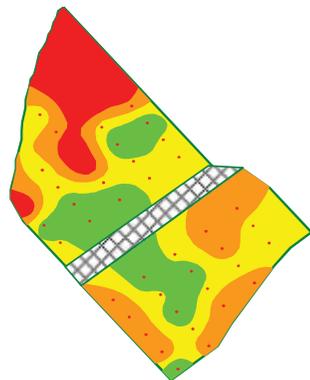
Si
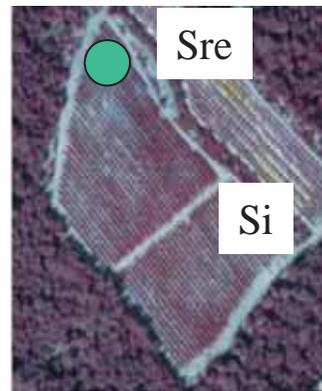
D : domain under consideration

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*

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**Is the variability temporal stable ?**

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



time

**Is the variability temporal stable ?**

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



$\Psi_1$

time

Sre

**Is the variability temporal stable ?**

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



$\Psi_1$      $\Psi_2$

time

**Is the variability temporal stable ?**

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



$\Psi_1$ $\Psi_2$ $\Psi_3$

time

**Is the variability temporal stable ?**

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



$\Psi_1$      $\Psi_2$      $\Psi_3$      $\Psi_4$

time

**Is the variability temporal stable ?**

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



2003

2004

time

$\Psi$

time

$\Psi$

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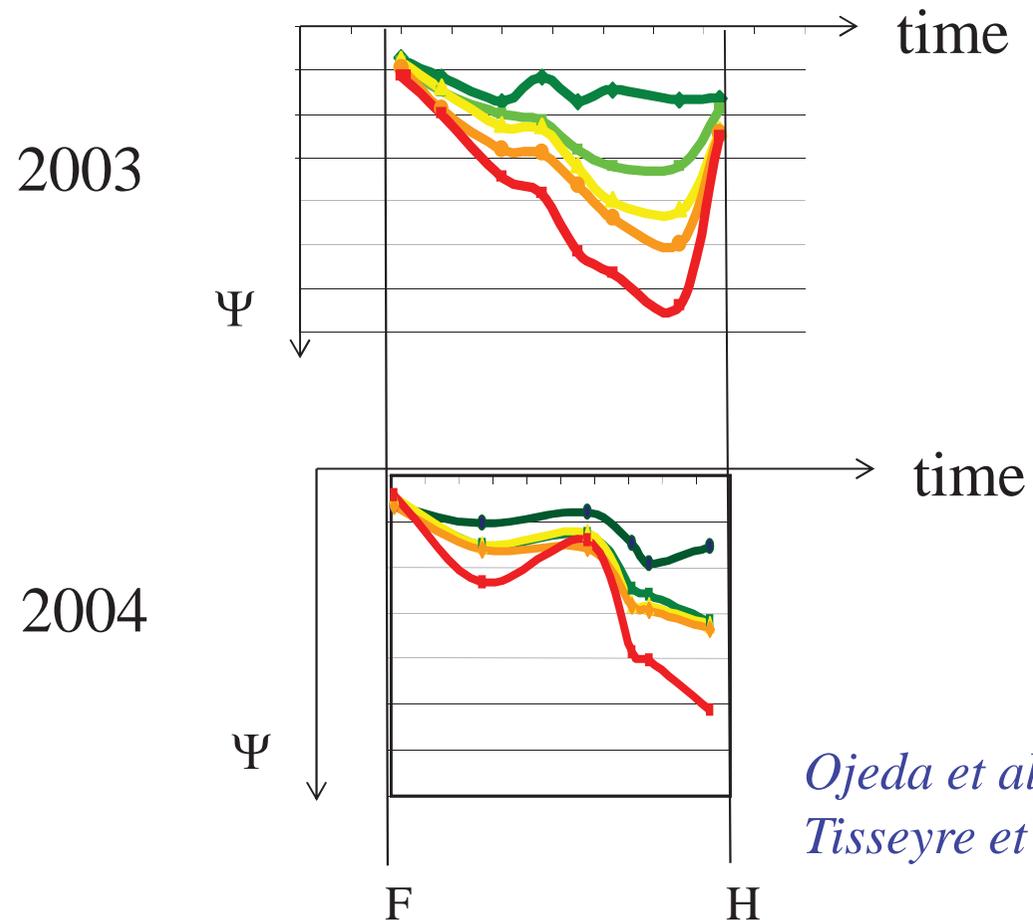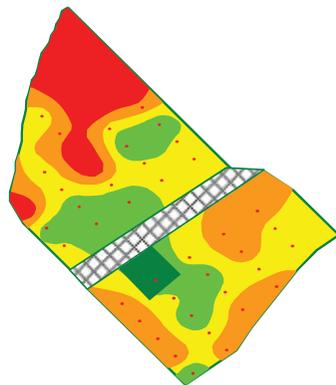
*Ojeda et al., 2005*
*Tisseyre et al., 2005*

Zone 0
Zone 1
Zone 2
Zone 3
Zone 4
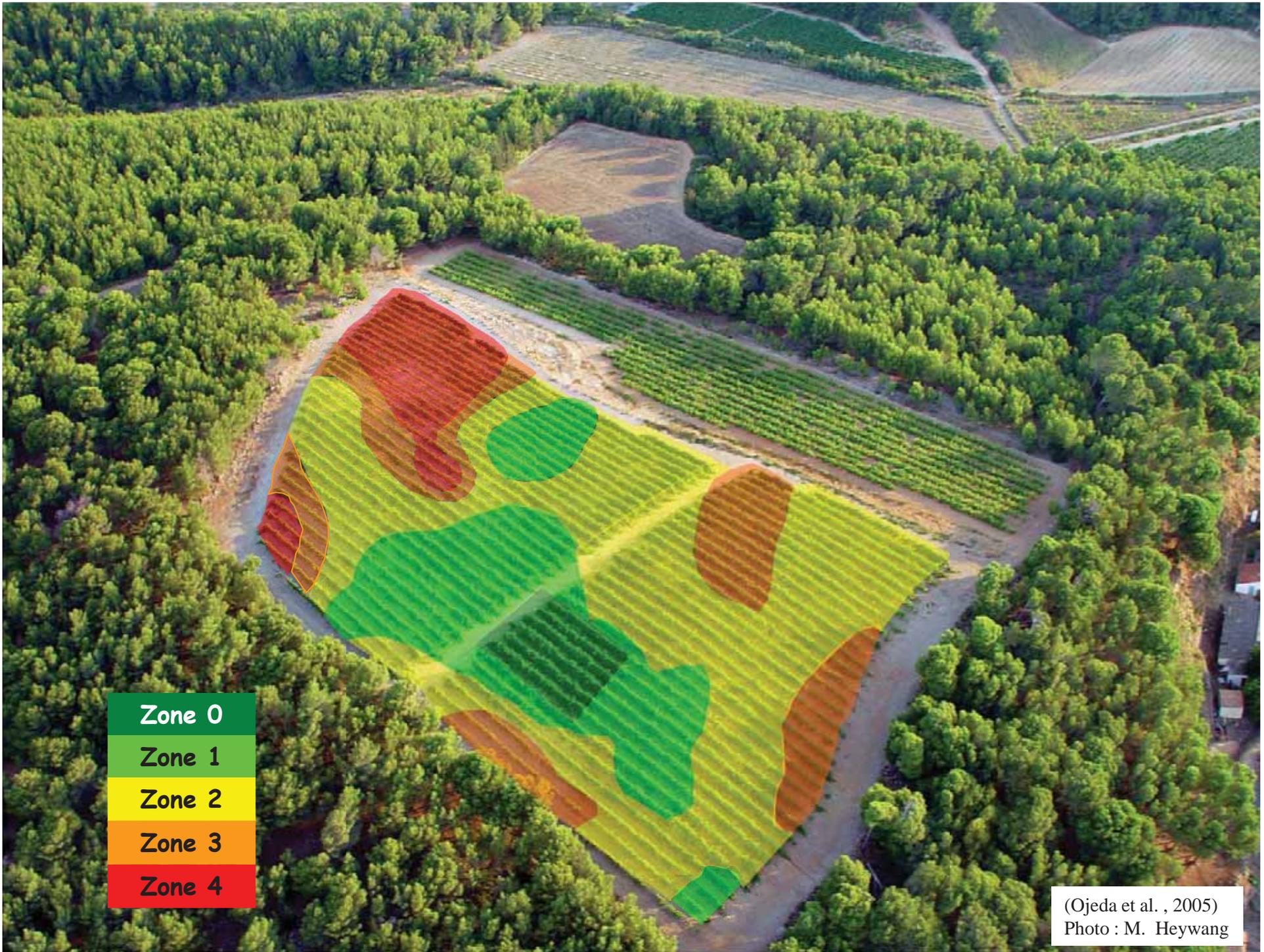
(Ojeda et al. , 2005)
Photo : M. Heywang
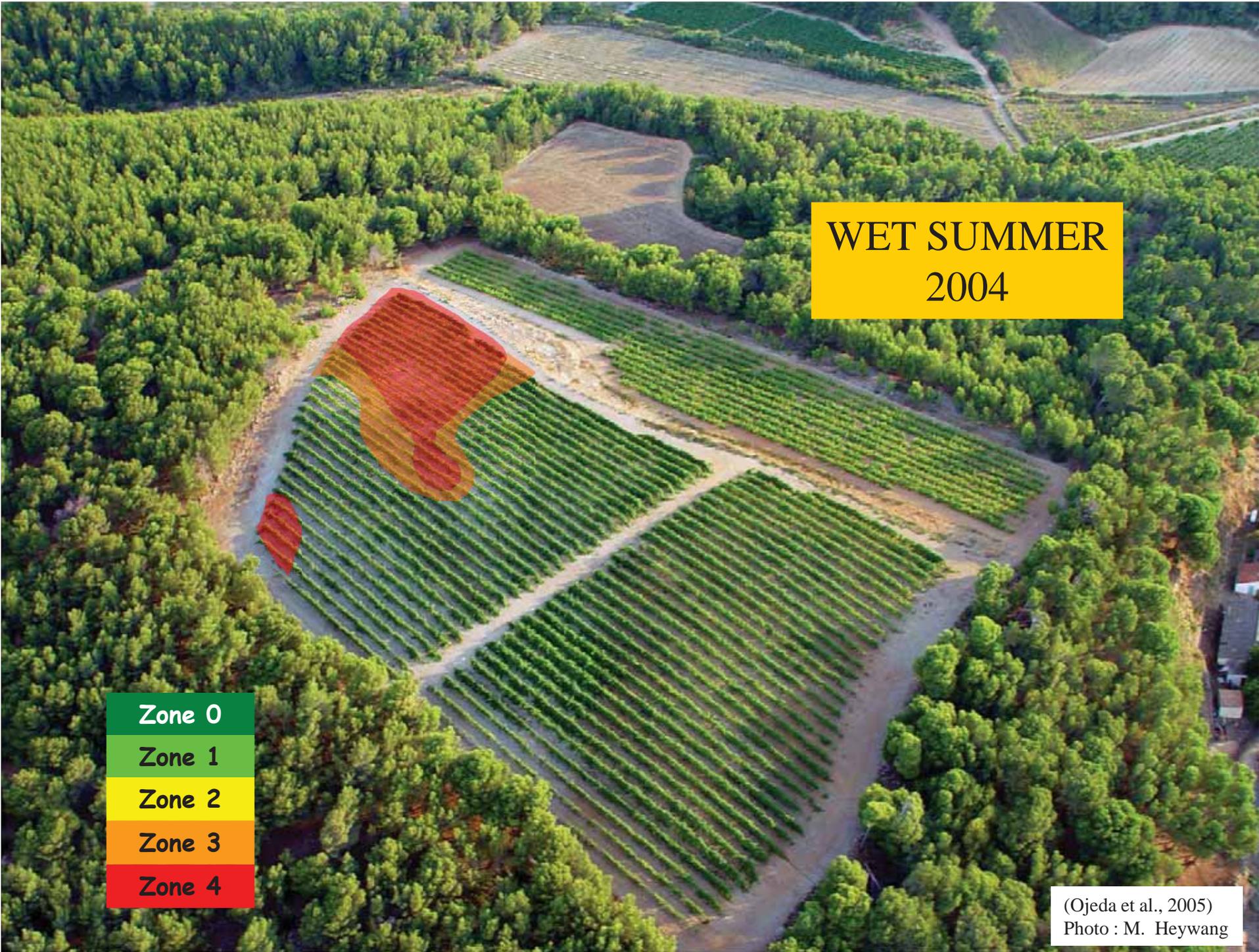
WET SUMMER
2004

Zone 0
Zone 1
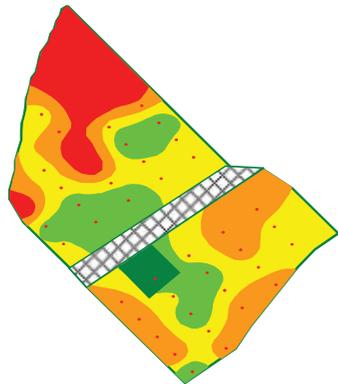Zone 2
Zone 3
Zone 4

(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.**

**How to define quality zones ?**

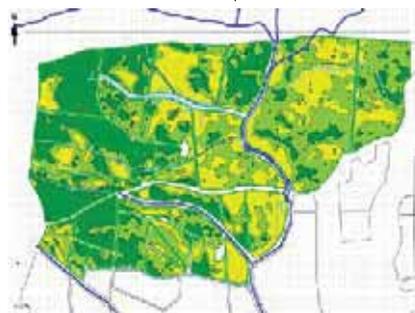Like for other crops two main information may be considered,

Soil (ERa, ECa)

Barbeau *et al.,* 2005,
Taylor, 2004,
Best *et al.,* 2005,
Lamb *et al.,* 2005,
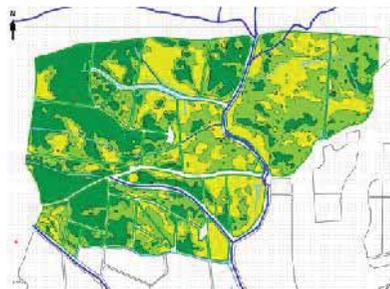Couloma *et al.,* 2009,

Sources : www.geocarta.net

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 etal., 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,
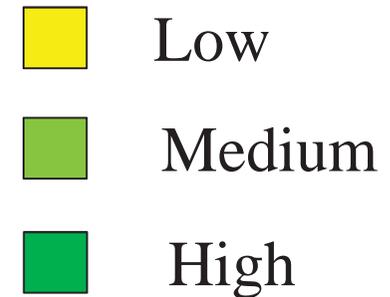


NDVI     Conductivity     Elevation

Low

Medium

High

Classification

**Class 1** : high vigour, low conductivity, high elevation

**Class 2** : medium vigour, medium conductivity, medium elevation

**Class 3** : Low vigour, high conductivity, low elevation

ECPA Lleida July 2013     Santesteban et al., 2013,

# 5. Questions addressed during the last years

**The general idea :**

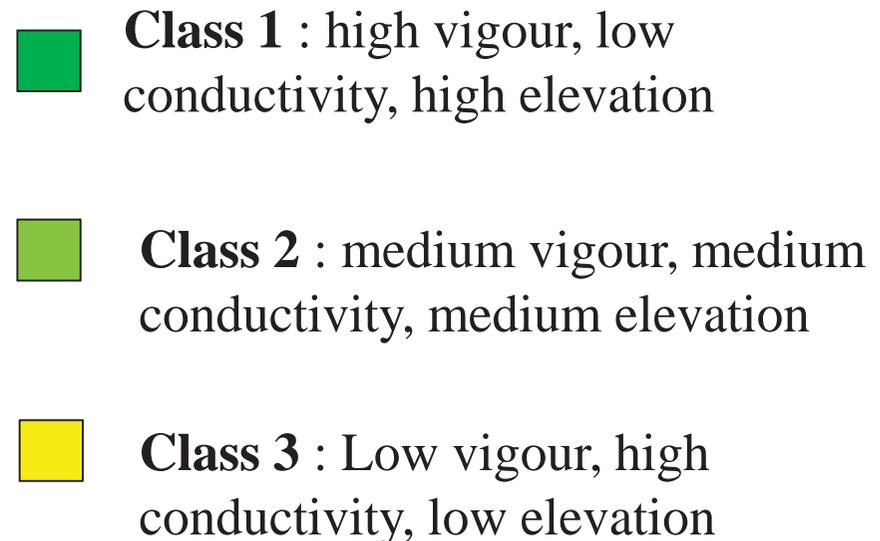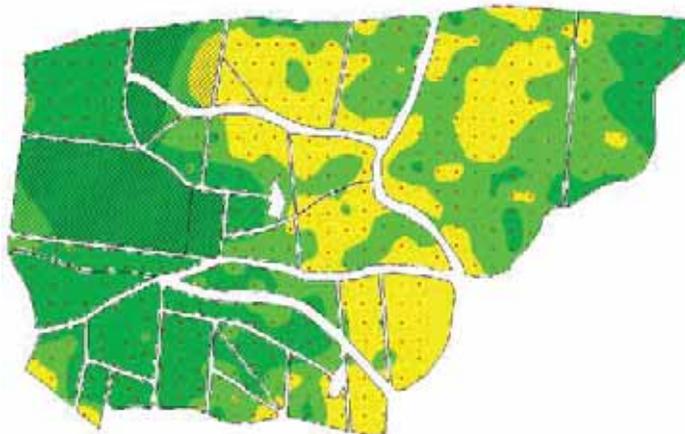1. Define temporal stable vigour zones based on high resolution information,
2. Additional sampling
   1. Validation,
   2. Agronomical information about possible management,
   3. Quality parameters -> differential harvest



Classification

Ground truth sampling

Santesteban et al., 2013,

**Some specific issues in viticulture**



Metallic trellising and resulting magnetic field on ECa

Lamb *et al., 2005*

ERa should be prefered for narrow vineyard ?

# 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 prefered for narrow vineyard ?

Example of a specific traddle designed for narrow vineyards

Source : geocarta

**Some specific issues in viticulture**



Roots can be deeper than 5 m. in dry vineyards

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# 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.

NDVI                    ECa (2 m.)
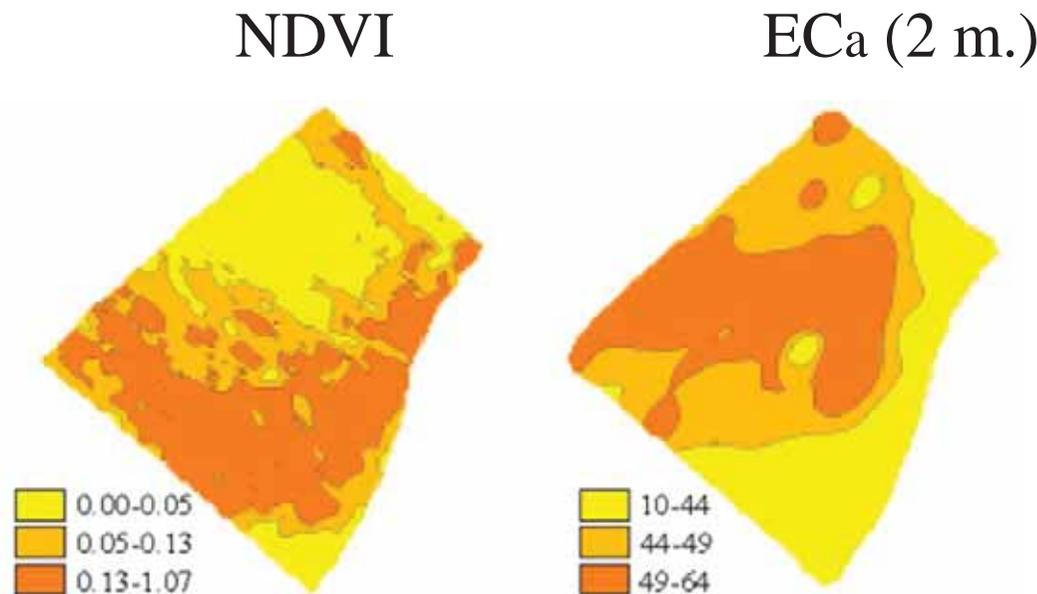


Couloma et al., 2009

# 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.
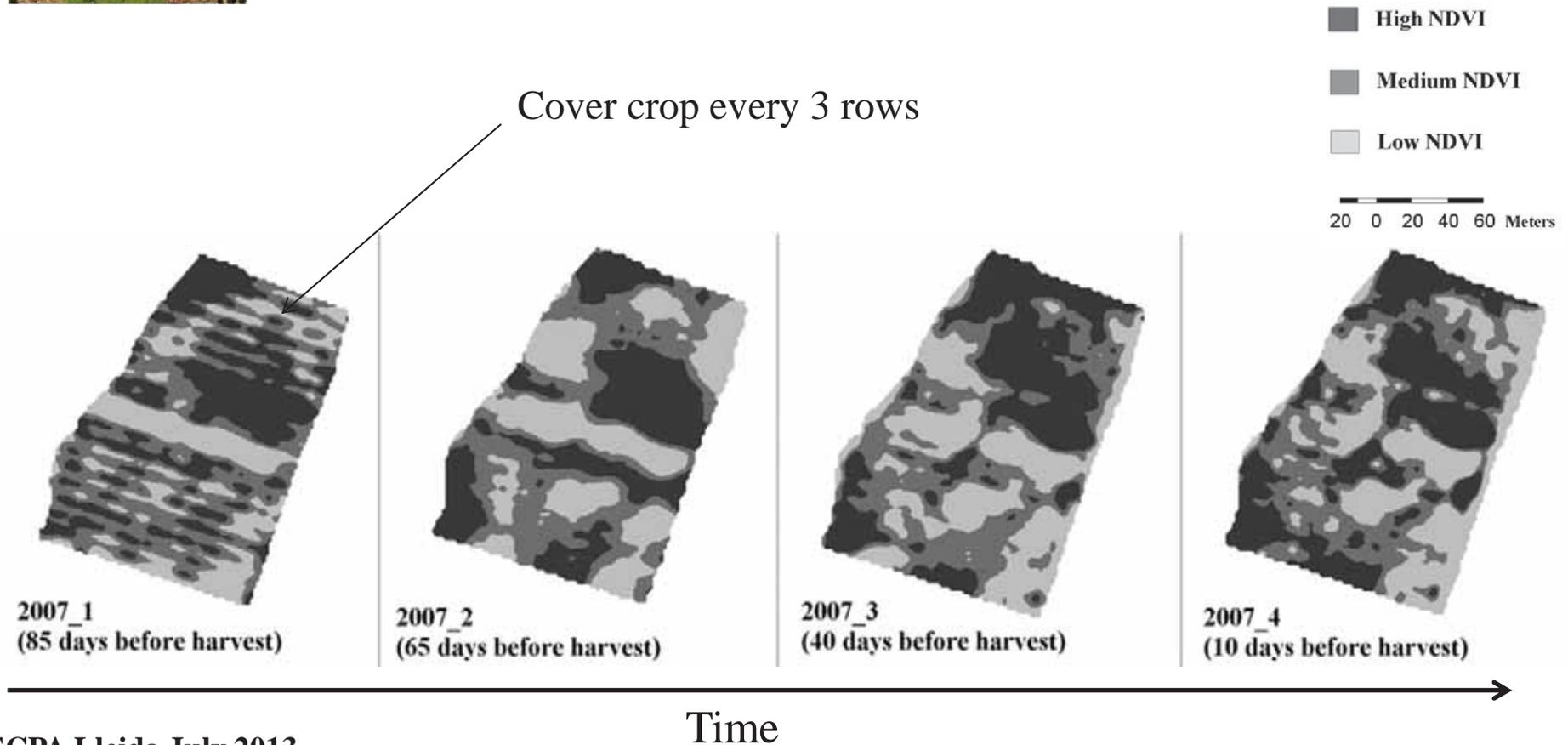Tisseyre et al., 2011.

**Some specific issues in viticulture**

Incidence of training systems and cover crop on vegetative index

Kazmiersky et al., 2011.



Cover crop every 3 rows

High NDVI

Medium NDVI

Low NDVI

20  0  20  40  60  Meters

2007_1 (85 days before harvest)

2007_2 (65 days before harvest)

2007_3 (40 days before harvest)

2007_4 (10 days before harvest)

Time

# 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

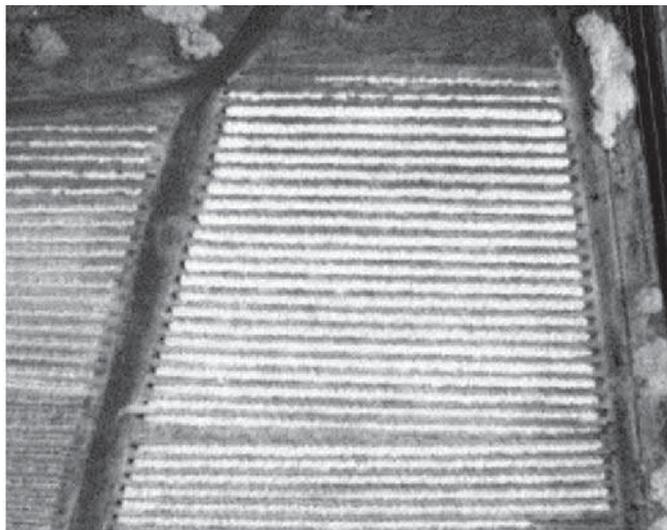**Some specific issues in viticulture**



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.
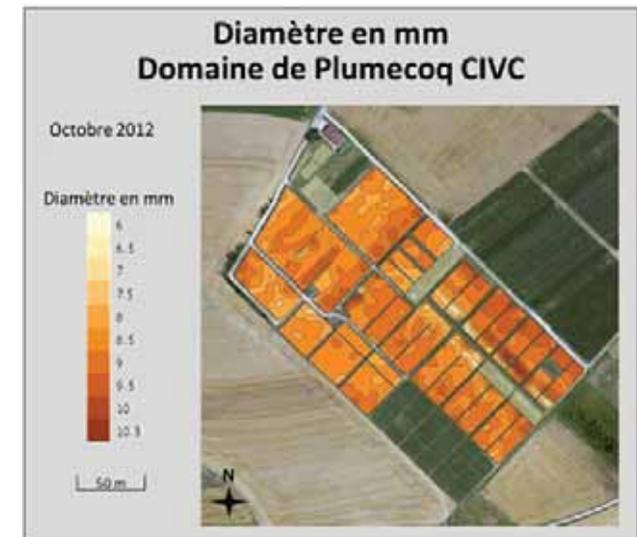
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**Some specific issues in viticulture**



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®)



Ligne de scan
Dénombrement
Mesure du diamètre



Morlet, 2013

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# 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®)
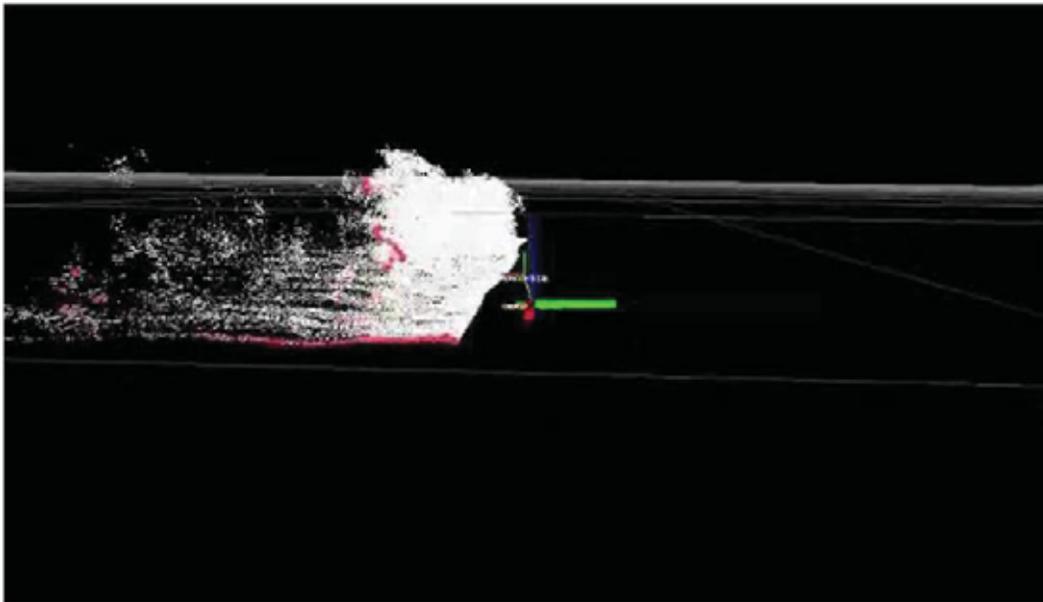






Morlet, 2013

# 5. Questions addressed during the last years

**Some specific issues in viticulture**

Investigations on board lidar to characterize the vine canopy

Sanz et al., 2013

Rosell et al., 2009

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



Classification  $\longrightarrow$  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*

*Qualiris grappe* ™

*Multiplex* ™
*Force-A*

*Premivm* ™
*PsI, KIT*



www.pellenc.com
Geraudie et al., 2010

www.sodimel.fr
Serrano et al., 2005

www.force-a.eu
Baluja et al., 2012.

www.premivm.eu
Navratil et al., 2012.

# Summary
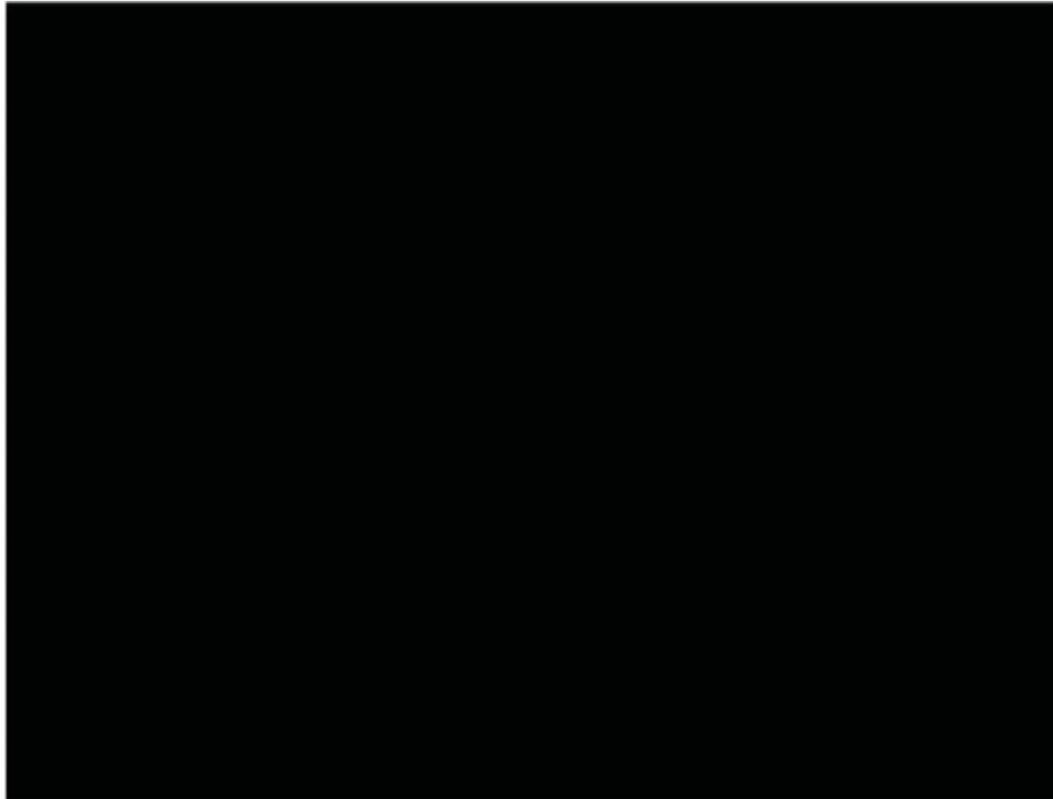
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**Guidance**

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),
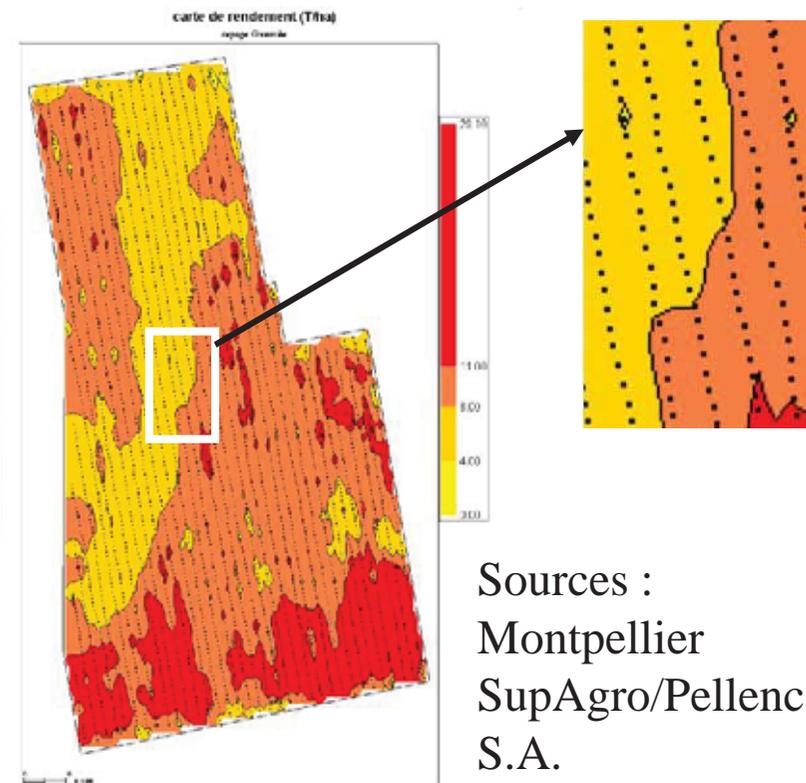
Only one manufacturer (ATV, australia),

Problem of grape harvesting machines,

Problem of data consolidation

Yield map





Sources : ATV



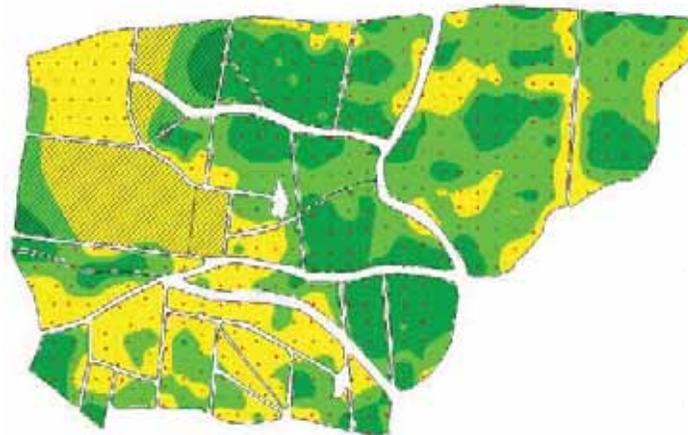carte de rendement (T/ha)

Sources :
Montpellier
SupAgro/Pellenc
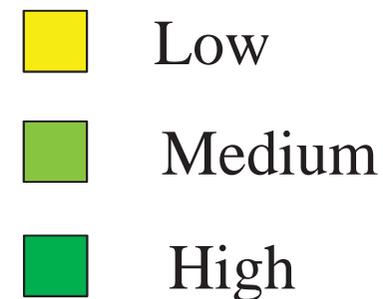S.A.

# 6 Consideration on PV adoption

**Soil Survey (ERa, ECa)**

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



Conductivity (ECa)

Santesteban et al., 2013,

☐ Low

☐ Medium

☐ High

# 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)



**Variable rate sanitary products application for viticulture**

- Start of adoption : exemple greenseeker
  (Avidorhightech ®)

Source : Tecnovict/Deutz)

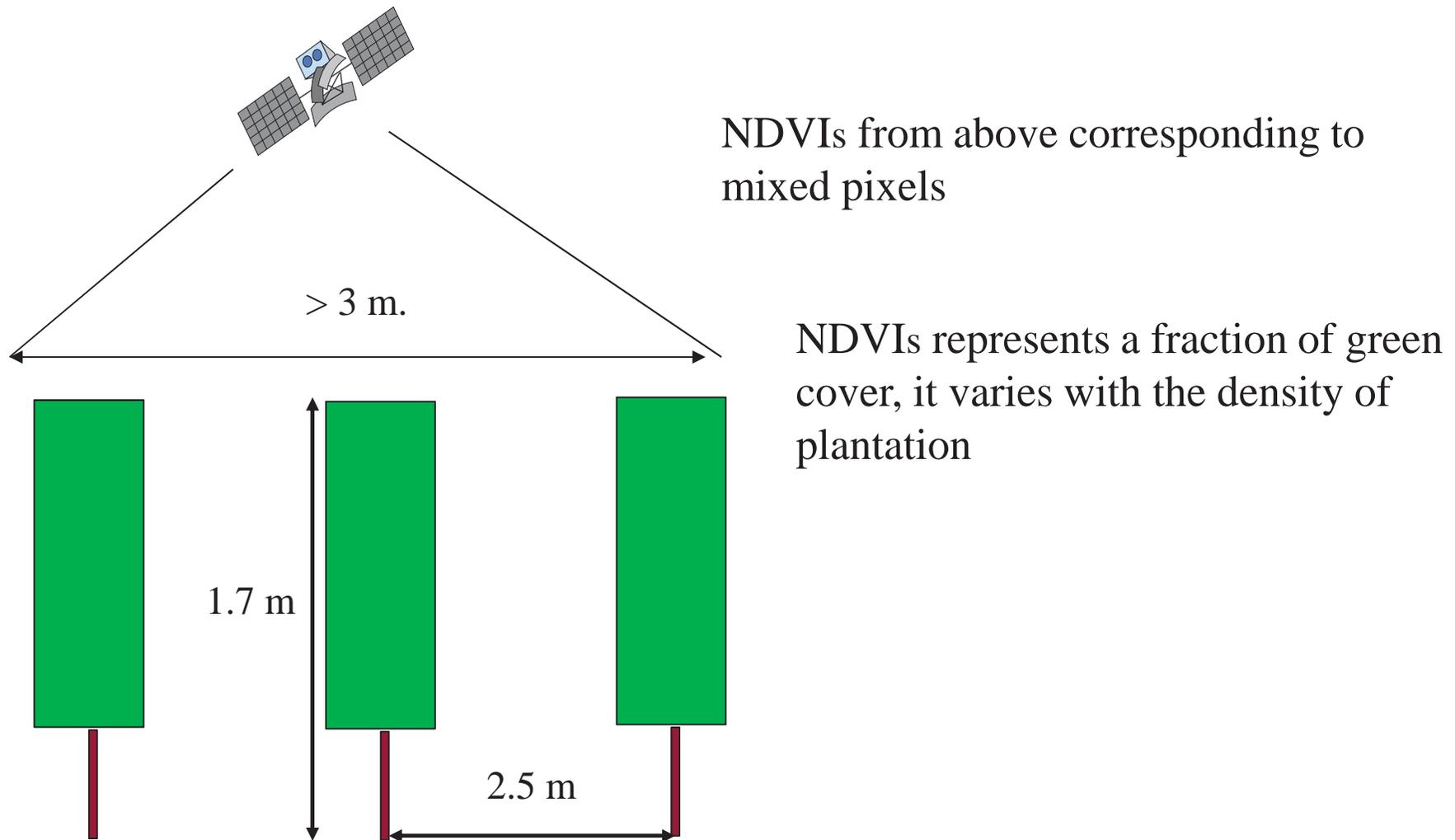# Summary

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. New questions

Clarification about the meaning of vegetative indices in viticulture



NDVIs from above corresponding to mixed pixels

NDVIs represents a fraction of green cover, it varies with the density of plantation
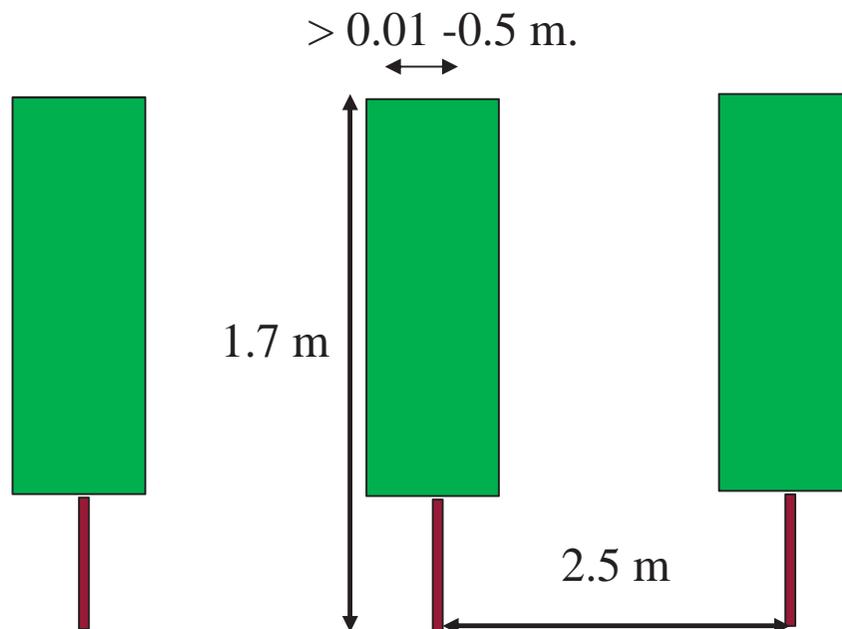
> 3 m.

1.7 m

2.5 m

# 6. New questions

Clarification about the meaning of vegetative indices in viticulture



Aiborne images
UAV images

NDVIa from above corresponding to
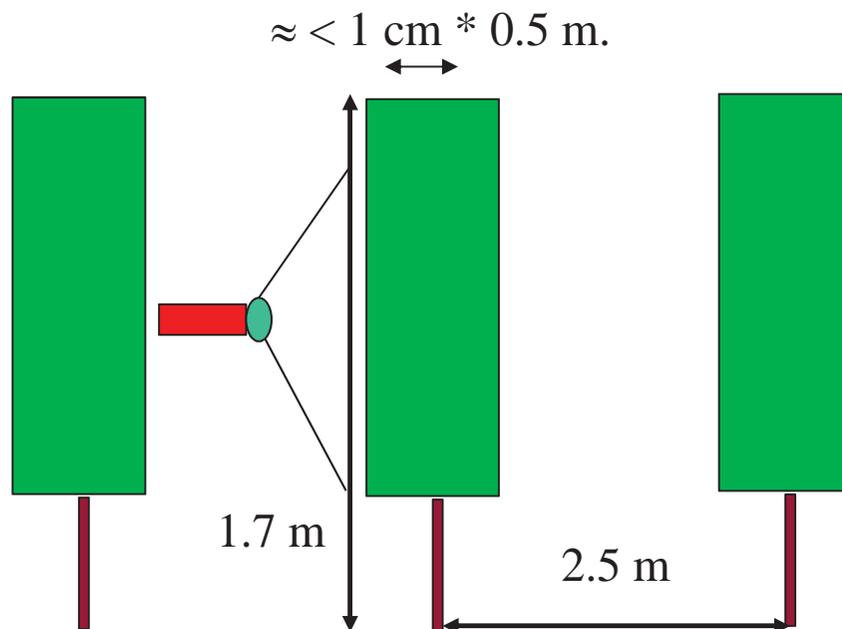pure pixels (row identification)

> 0.01 -0.5 m.

1.7 m

2.5 m

# 6. New questions

Clarification about the meaning of vegetative indices in viticulture

Proxi detection

NDVIp from the row corresponding to the porosity of the canopy.

$\approx < 1$ cm $* 0.5$ m.

1.7 m

2.5 m

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# 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

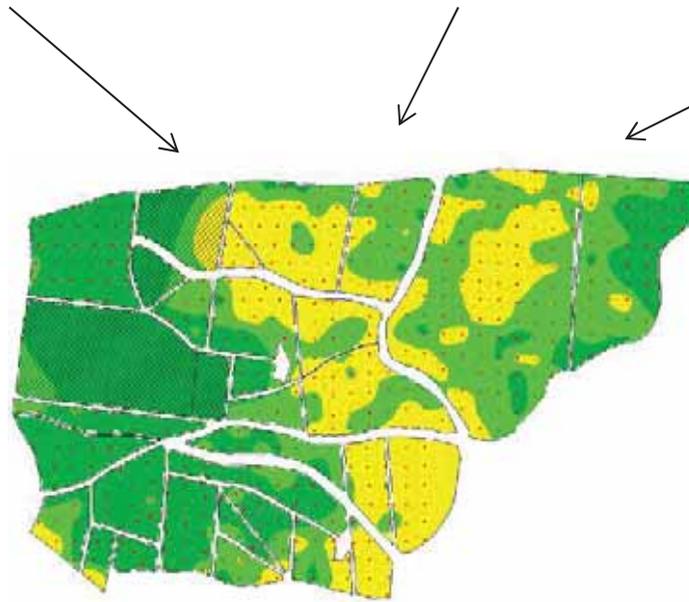Data processing : need real segmentation algorithm
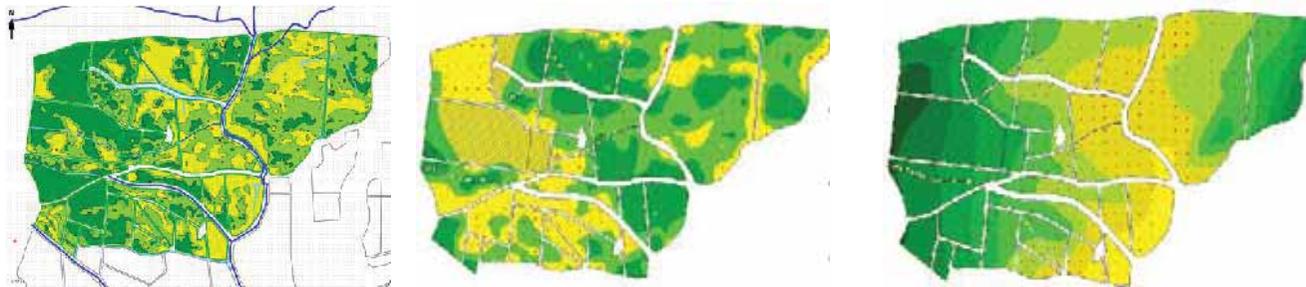


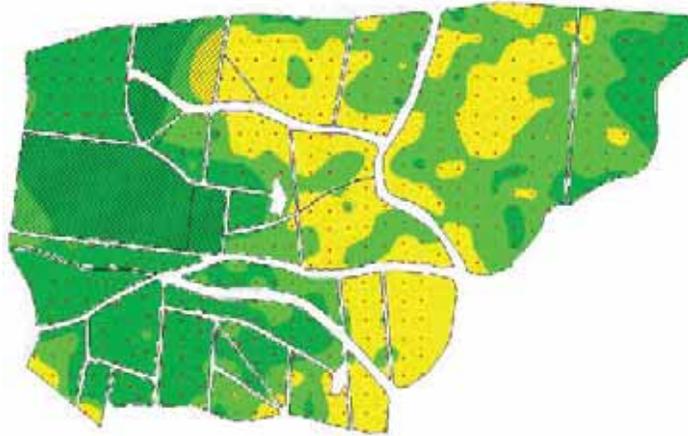NDVI               Conductivity               Elevation



Classification

Common classification methods are not perfect

- Classes ≠ 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 $\longrightarrow$ 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,

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
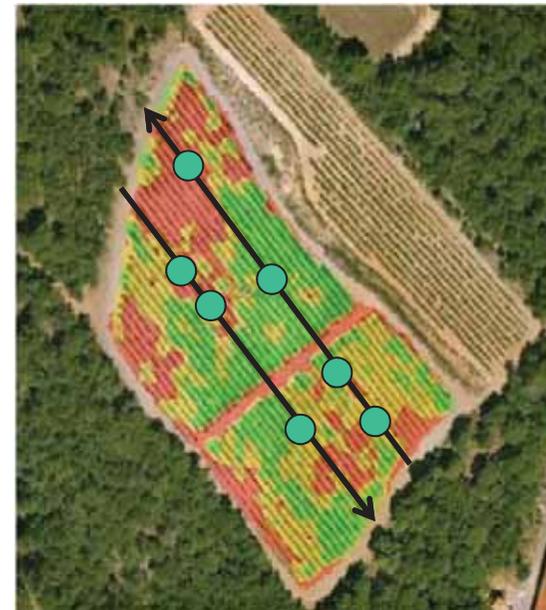


Real-time sampling optimisation

# 6. New questions

Great expectations on

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

# 6. Conclusion

PV is a necessary step to improve :
- Quality management,
- Sustainibility 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

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